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Estimating Year-class Strength and Total Mortality for Greenland Halibut from Surveys in NAFO Subarea 2 and Divisions 3KLMNO

by

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Abstract

Recent assessments of Greenland halibut in NAFO Subarea 2 + Div. 3KLMNO have included multiplicative modeling of swept area abundance estimates from a variety of stratified random survey series. This paper reruns the model using the data files updated with the most recent survey information as well as presents a re-structured model using different survey series based on stratified mean catches pet set. Although the estimated strength of the various year-classes varies somewhat, the strong 1993-95 year-classes still dominate in all analyses. In addition, it appears that the 2000 and 2001 year-classes may be above average as well. Estimates of total mortality (Z) from survey data in Div. 2J+3K indicate an increasing trend in Z primarily for ages 4 to 11 peaking around the early-1990s. It declined again until about 1995 after which it has been increasing especially for ages 5-9. The 2002 values are near the highest in the series. Increasing mortality trends also were indicated for the most recent cohorts of the mid-1990s with higher Z values than any others in the series.

Analysis of Year-Class Strength using Abundance Indices

Recent assessments of this stock have included multiplicative modeling of swept area abundance estimates from a variety of stratified random survey series (Healey *et al*., 2002).

In the 2002 assessment of this stock, a measure of relative cohort strength for Greenland Halibut in SA2+3KLMNO was produced (Healey *et al*., 2002) using the following data sources: (i) the Canadian autumn 2G series (1996-1999), (ii) the Canadian autumn Div. 2H series (1996-1999, 2001), (iii) the Canadian autumn Div. 2J+3KLMNO series (1996-2001), (iv) the Canadian autumn 2J+3KL series (1981-1994), (v) the Canadian spring Div. 3L series (1977-82; 1984-95), (vi) the Canadian spring Div. 3LNO series (1996-2001), and (vii) the EU July Div. 3M series (1992-2001). Based on likelihood ratio testing, the most parsimonious model for this data was one which included eight variance parameters. This model contained six variance parameters for the six surveys which had no significant differences in survey*age variance, and for the Div. 3L spring series, a variance parameter for age 1, and a combined parameter for ages 2-4. Further details can be found in Table 2 of Healey *et al*. The final model used in the 2002 assessment is presented in Fig. 1. This result indicated that the 1993, 1994 and 1995 year-classes were all stronger than any other year-class over the period examined. Further, the most recent year-classes, the 1999 and 2000 cohorts were estimated to be above average. The 2000 estimate was imprecise owing to few observations on this year-class.

This analysis was reproduced to incorporate stock abundance information collected since the last assessment. New information was collected by the Canadian fall and spring research vessel surveys, and also during the European Union (EU) July survey of Div. 3M. From the results of fitting the various models, a series of likelihood ratio tests indicated that the most parsimonious model is one that fits a variance parameter for each survey, except the

Canadian 3L Spring Series, which had one variance parameter for age 1, and another variance parameter common to ages 2-4 in this survey. That is, the final model formulations for 2002 and for 2003 based upon survey abundance data are identical. The results of the updated model fit are given in Fig. 2. Estimated weights (not shown) are quite similar to those estimated in the previous assessment. The updated run estimates the relative strength of the 1999 and 2000 cohorts to be weaker than those in the 2002 run, although the previous estimates still lie within the error bars of the updated estimate. The additional data collected since the last assessment also permits estimation of the 2001 cohort. It too is estimated to be above average although with a large degree of error.

Analysis of Year-Class Strength using Mean No. per Set

Two particular concerns were raised in evaluating the above analyses with respect to potential bias:

1) Some survey series incorporated in the analyses were highly variable with respect to annual coverage. In particular, Canadian surveys since 1995 had been expanded to cover a wider area of distribution especially, but not restricted to, deeper water. Using estimates of abundance from areal expansion therefore incorporated a potential positive bias in recent years.
2) None of the above series were continuous over the entire time period suggesting that the estimates from the past may not be strongly linked enough to fully represent true relative strengths over the entire period examined.

In order to reduce these potential biases, only series with extensive survey coverage were used, and all indices were based on stratified mean numbers per set in order to remove the effect of varying annual survey coverage. In addition, the longest continuous time series (the converted Canadian Autumn 2J+3K (1978-2002)) replaced the independent Engel and Campelen trawl series in this area.

The mean number per set (MNPT) indices used in this analysis are tabled by cohort in Table 1, and plotted for each survey in Fig. 3. Surveys included are:

i) EU 3M (1992-2002) (Saborido and Vazquez, 2003),
ii) Canadian Autumn Div. 2J+3K (1978-2002),
iii) Canadian Autumn Div. 3L (1995-2002),
iv) Canadian Autumn Div. 3NO, and (1997-2002),
v) Canadian Spring Div. 3LNO (1996-2002).

Similar to the previous work on the abundance data, the initial model for the MNPT data is one having a separate variance parameter for each survey-age combination (20 variance parameters). The estimated year-class strength from this model is presented in Fig. 4. Using the MNPT data, we find that the 1993-1995 year-classes are estimated to be much stronger than any other cohorts over the time period considered. Further, since 1997, year-class strength has increased and the 2001 year-class is estimated to be above average (albeit with wide confidence). The estimated weights (Fig. 5) are highly variable, with the five highest weighted survey-age parameters taking almost 50% of the weight. The age 4 data from the EU Div. 3M series receives the highest weighting; also, the Div. 3NO Autumn series collectively receives a relatively low weight. Standardized residuals for this run (Fig. 6) indicate no serious problems; however some year effects are evident, particularly prior to 1992, during which only one survey existed.

Subsequent to fitting the "full" model with 20 variance parameters, a sequence of sub-models were fit to the data using fewer variance parameters. First, for each survey, the four survey-age variance parameters were collapsed into a single variance parameter (thus 17 total variance parameters) and the model was re-fit. Additional runs were conducted: one having a variance parameter for each survey (5 variance parameters), and a run having common variance parameter for all data. Likelihood ratio tests (Table 2) indicated that the simplest model which is not significantly different from the full model is one with a single, common variance parameter for all observations. The estimated year-class strength for this model (Fig. 7) is similar to that of the full run; again indicating that the 1993-1995 year-classes were exceptional and that recent year-classes are strong based on the information collected on these cohorts to date. Standardized residuals again indicate that there are no systematic problems, and that the bulk of the data fit quite well (Fig. 8).

A comparison of the estimated year-class strength as estimated from abundance data and the MNPT data (Fig. 9) shows that differences are minimal (well within the confidence limits of estimates). In fact, the 1976-2001 estimates of year-class strength from the 2003 abundance run (updated version of 2002 assessment model) and the final MNPT run have a correlation coefficient of 0.986 ($p << 0.0001$).

The estimated relative strength of early cohorts (pre-1992 for which there is just one survey) relies upon on correct conversion of Engel data to Campelen equivalents. However, the relative strength estimates produced using abundance data use the Engel data without conversion, and given that the agreement between these results is strong, this is not a point of concern.

Mortality

Total mortality (Z) was calculated from the Canadian autumn research vessel data in Div. 2J+3K from 1978-2002 for ages 2 to 13. The results are shown in Fig. 10. A Lowess smoother (tension=1) has been added to the plots to help visualize trends. There was an increasing trend in Z primarily for ages 4 to 11 peaking around the early-1990s. It declined again until about 1995 after which it has been increasing especially for ages 5-9. The 2002 values are about the highest in the series (Fig. 10).

Estimates of relative mortality by cohort were obtained from a multiplicative model using the same data. The following model was used:

$$\log(N_{ikt}) = \tau + \delta_k + (\alpha\delta)_{ik} + \varepsilon$$

where: N_{ikt} = number at age i for i= 5 to 14, belonging to cohort k in year t
τ = intercept
δ_k = cohort effect
$\alpha\delta_{ik}$ = combined age cohort effect
ε = residuals from the fitted model

The separate slopes parameter estimates ($\alpha\delta_k$) were plotted as estimates of average total mortality experienced by a cohort over ages 5-14. There was a significant fit of the model to the data.

Ages 5-14

R^2=0.92, n=219

Source	DF	Type III SS	F-Value	p-value
COHORT	31	31.63	1.84	0.0087
AGE*COHORT	32	818.63	25.58	0.0001

For the model using ages 5-14 there was an increase in mortality for cohorts from 1970 to 1981 followed by a slight decline, particularly for the cohorts of the mid-1980s. All subsequent cohorts experienced high mortality (Fig. 11).

Increasing mortality trends were indicated for the most recent cohorts of the mid-1990s with higher Z values than any others in the series.

References

Healey, B. P., N. G. Cadigan and W. B. Brodie. 2002. Analysis of pre-recruit data from surveys for Greenland halibut in NAFO Subarea 2 and Divisions 3KLMNO. NAFO SCR. Doc., No 21. Serial No. N4625.

Saborido, F. and A. Vazquez. 2003. Results from Bottom Trawl Surveys on Flemish Cap in July 2002. NAFO SCR. Doc., No. 42, Serial No. N4860, 41 p.

Table 1: Mean Numbers per set data used to model YC Strength of Greenland Halibut.

i) EU Div. 3M Survey (July; 1992-2002).

YC	1	2	3	4
1988				1.07
1989			0.36	0.708
1990		0.99	0.748	1.523
1991	1.15	1.164	1.34	1.55
1992	1.166	0.878	1.7	2.57
1993	1.032	1.74	1.9	6.41
1994	7.66	5.74	5.46	9.75
1995	3.57	2.63	6.4	8.93
1996	1.98	1.58	2.37	1.75
1997	1.79	0.53	0.39	0.85
1998	0.65	0.18	1.43	1.37
1999	1.99	1.04	2.01	
2000	5.17	2.04		
2001	2.44			

ii) Div. 2J+3K Canadian Autumn RV (Campelen or Equivalent; 1978-2002).

YC	1	2	3	4
1974				19.52
1975			33.37	7.154
1976		40.24	13.47	5.582
1977	9.605	18.07	6.2	6.013
1978	10.81	6.534	15.42	10.81
1979	6.775	22.99	12.78	11.41
1980	19.39	5.104	10.56	10.29
1981	4.746	4.453	9.563	6.871
1982	1.657	7.114	8.712	14.64
1983	4.465	14.67	16.62	12.17
1984	24.59	13.96	29.44	17.03
1985	17.21	11.21	15.04	25.22
1986	5.04	10.54	23.84	23.39
1987	8.817	12.54	9.953	13.32
1988	7.095	5.26	6.076	13.59
1989	1.341	5.589	20.4	19.28
1990	13.8	23.78	64	18.9
1991	5.693	43.64	22.61	6.031
1992	8.079	21.62	15.13	9.539
1993	29.79	51.1	32.01	21.13
1994	49.93	47.82	43.61	21.87
1995	98.68	58.62	31.19	28.28
1996	28.05	25.07	24.07	13.2
1997	23.35	34.42	16.43	14.07
1998	15.99	21.94	17	9.679
1999	38.57	22.72	12.5	
2000	43.9	24.08		
2001	40.67			

iii) Div. 3NO Canadian Autumn RV (Campelen; 1997-2002).

YC	1	2	3	4
1993				2.026
1994			3.517	2.435
1995		2.576	1.819	0.467
1996	0.591	0.783	0.5	0.19
1997	0.363	0.201	0.058	0.343
1998	0.035	0.055	0.333	0.472
1999	0.07	0.114	0.523	
2000	0.08	0.191		
2001	0.256			

iv) Div. 3L Canadian Autumn RV (Campelen; 1995-2002).

YC	1	2	3	4
1991				0.769
1992			1.331	2.478
1993		3.252	5.886	4.65
1994	4.489	4.569	4.777	5.153
1995	5.259	3.68	2.686	1.485
1996	1.856	2.141	0.659	1.309
1997	1.18	0.896	0.721	1.845
1998	0.108	1.853	1.159	1.545
1999	3.234	0.8	1.284	
2000	2.745	1.239		
2001	2.402			

v) Div. 3LNO Canadian Spring RV (Campelen; 1996-2002).

YC	1	2	3	4
1992				2.183
1993			4.599	3.227
1994		4.241	5.16	6.186
1995	1.621	3.924	3.847	1.982
1996	1.162	0.814	1.149	1.506
1997	0.22	0.552	1.068	0.676
1998	0.292	1.069	0.739	0.581
1999	0.793	0.714	0.603	
2000	0.565	0.572		
2001	0.642			

Table 2: Likelihood ratio tests.

Null Model*	**Test Statistic**	**df**	**p-value**
Common vp for 2J3K_F_MNPT only	2.9948	3	0.3924
Common vp for 3L_F_MNPT only	6.6300	3	0.0847
Common vp for 3NO_F_MNPT only	0.8567	3	0.8359
Common vp for 3LNO_S_MNPT only	0.2892	3	0.9620
Common vp for EU_3M_MNPT only	3.8842	3	0.2742
One vp for each survey	13.16571	15	0.5895
Common vp	29.52546	19	0.0582

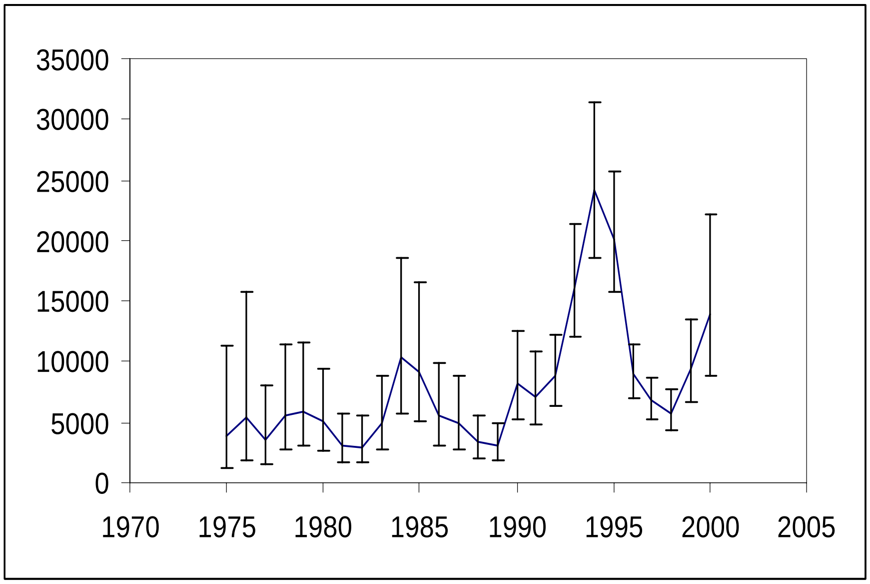


Fig. 1. Estimate of year-class strength (+/- 2 SE's) from the final 8 variance parameter model in the 2002 assessment, based on survey abundance data.

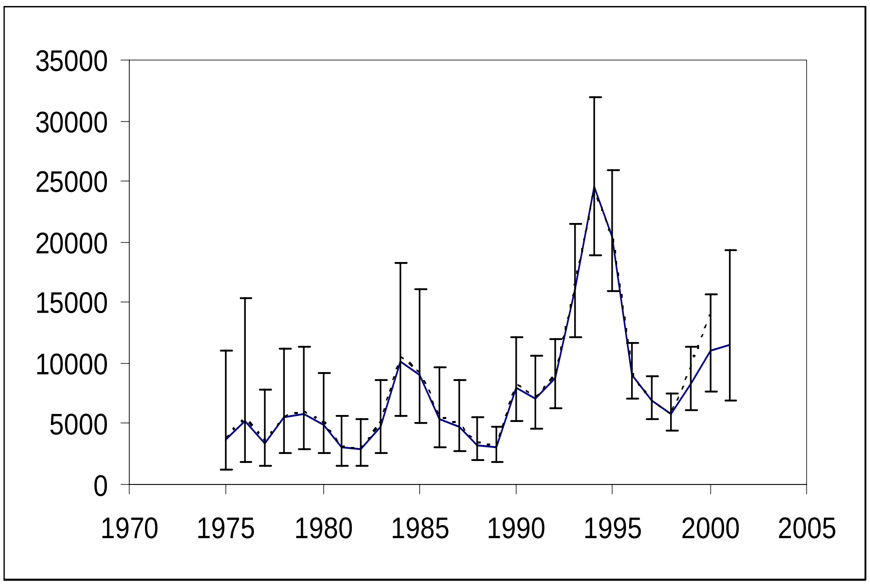
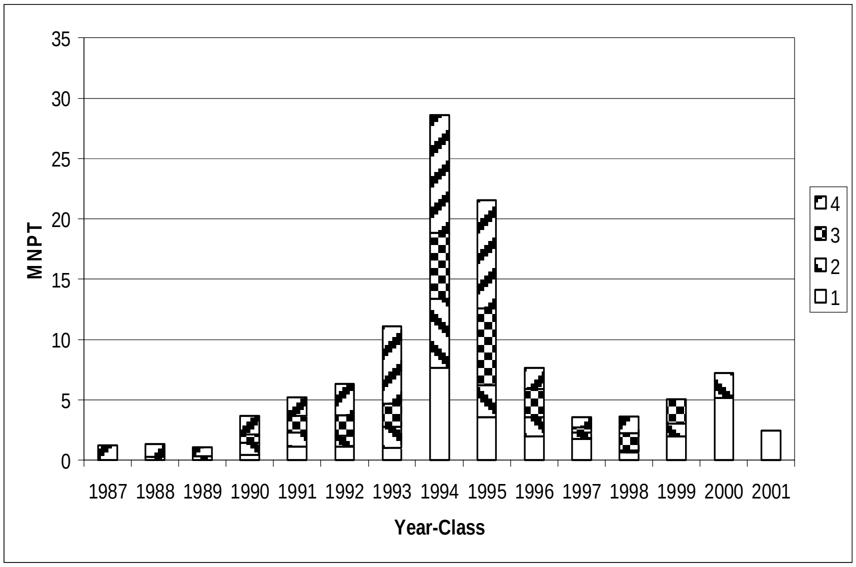


Fig. 2. Estimate of year-class strength from 8 variance parameter model for 2003 assessment using survey abundance data. The dashed line is the estimate from the 2002 assessment. The error bars (+/- 2 SE's) pertain to the updated (2003) run.

EU Div. 3M Series



Div. 2J+3K Canadian Autumn Series

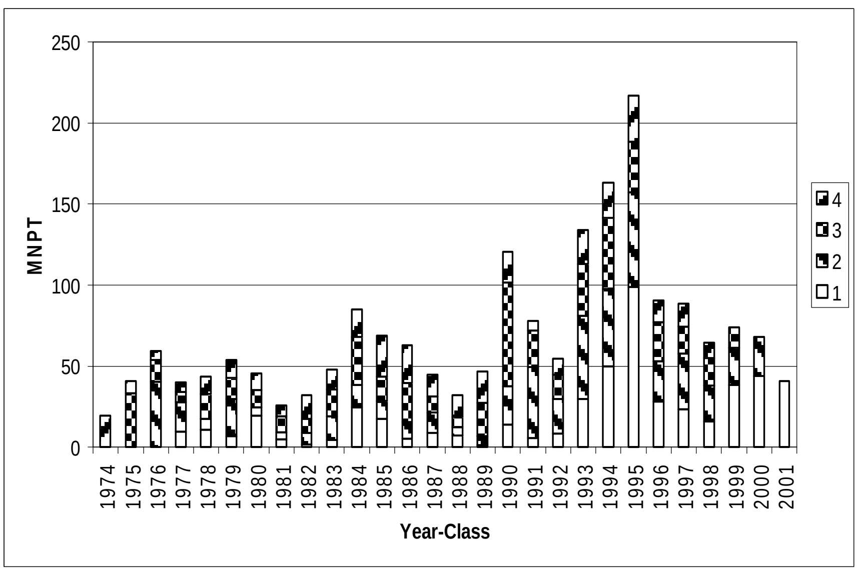
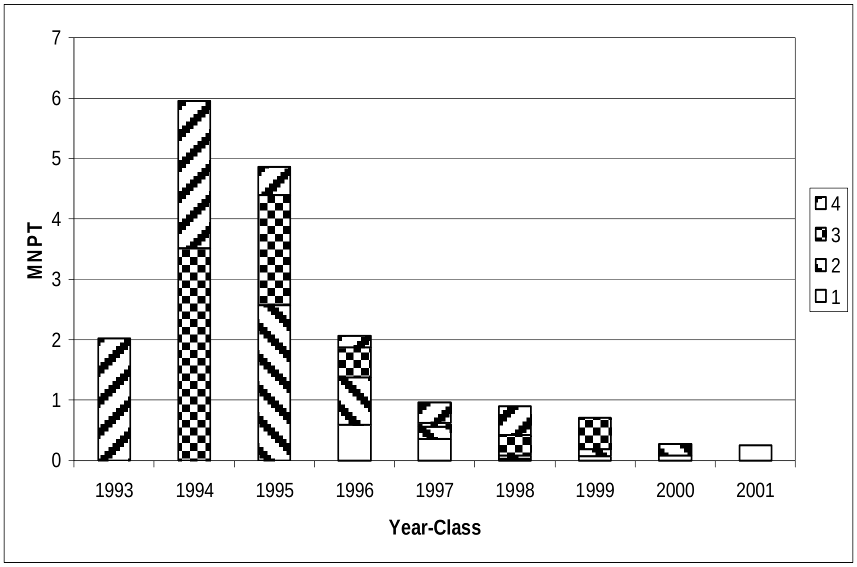


Fig. 3. MNPT Index Data, by cohort, for Greenland Halibut in SA2 & Div. 3KLMNO.

Div. 3NO Canadian Autumn Series



Div. 3L Canadian Autumn Series

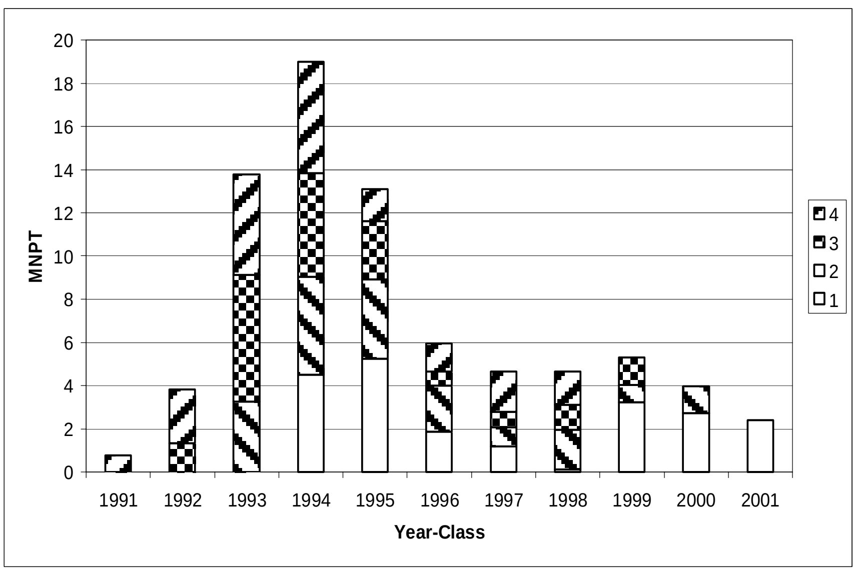


Fig. 3 (cont.).

Div. 3LNO Canadian Spring Series

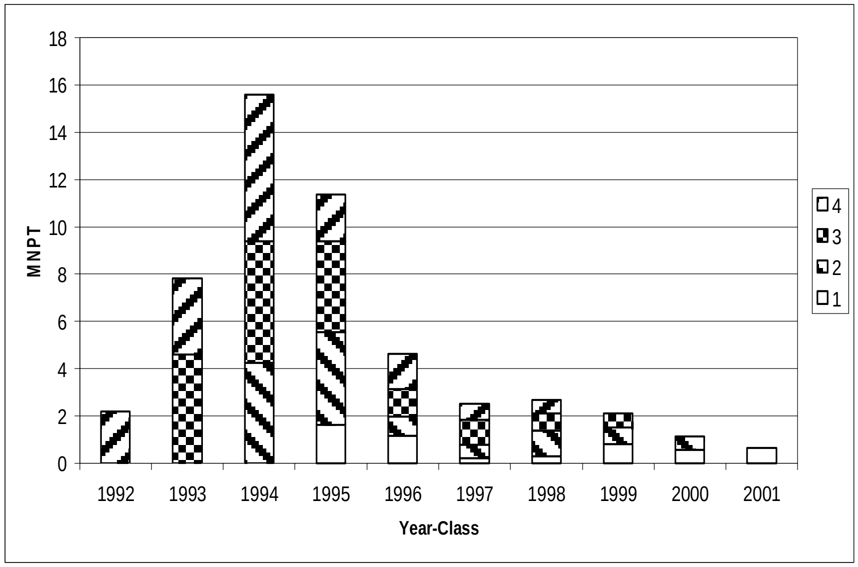


Fig. 3 (cont.).

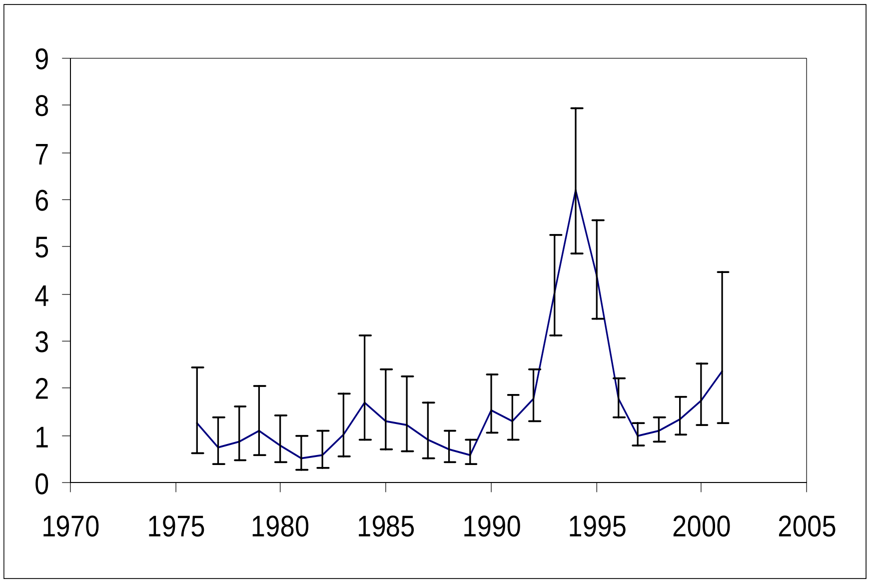


Fig. 4. Estimate of year-class strength using MNPT survey data (+/- 2 SE's). Each index has a distinct variance parameter; total of 20 variance parameters (5 "surveys", 4 ages each).

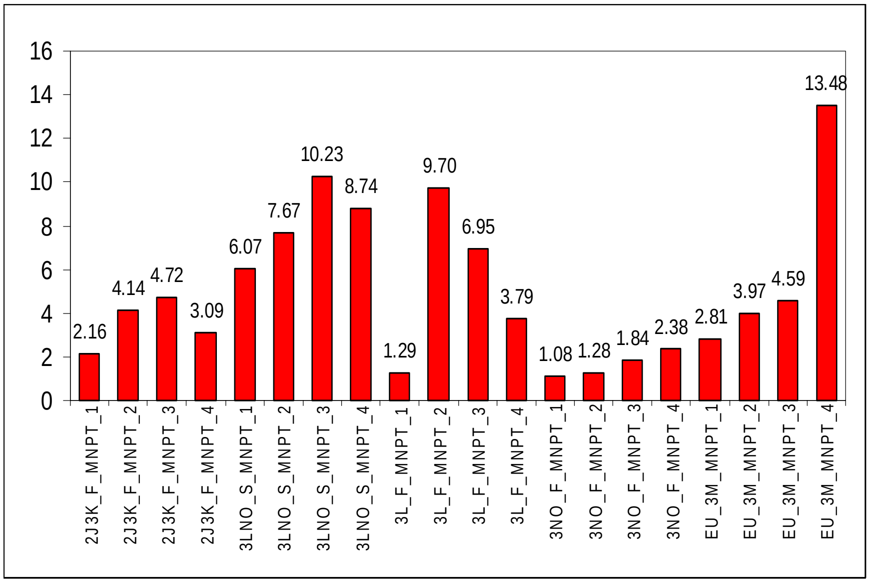


Fig. 5. Estimated weights for the full model run using MNPT survey data.

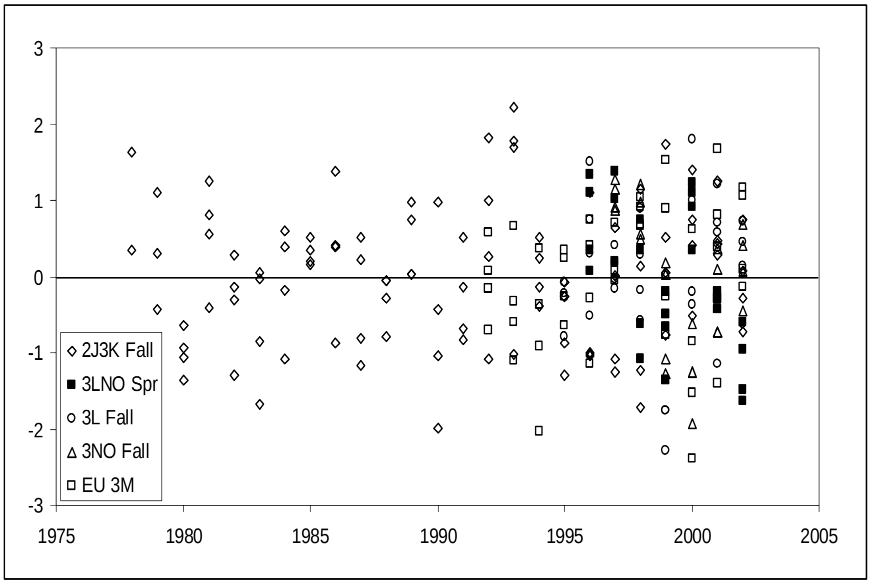


Fig. 6. Standardized Residuals for full model using MNPT survey data.

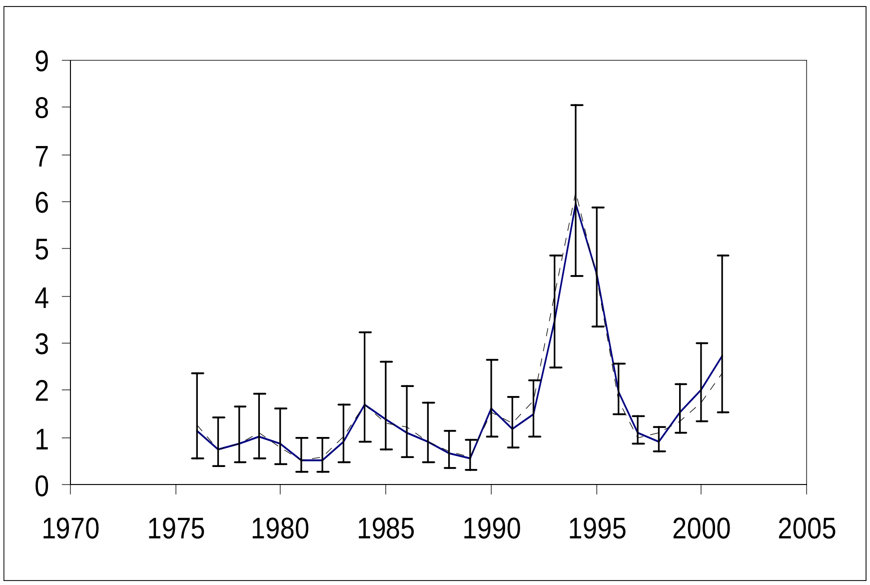


Fig. 7. Estimate of year-class strength using MNPT survey data (+/- 2 SE's). Indices have a common variance parameter (equal weighting). The estimated year-class strength for the full model is presented for comparison.

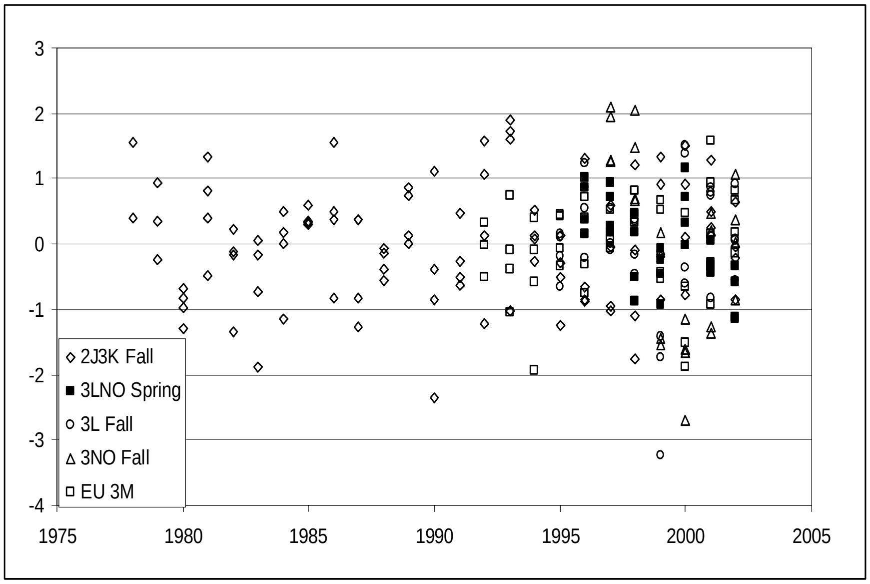


Fig. 8. Standardized Residuals for final model using MNPT survey data.

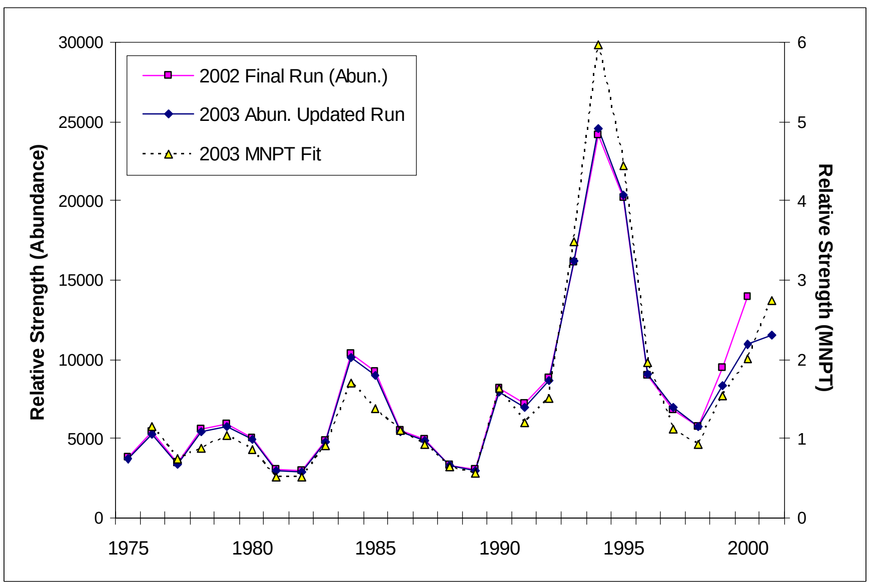


Fig. 9. Comparison of last year's estimated year-class strength ("2002 Final Run (Abun.)"), an update of last year's model ("2003 Abun. Updated Run") and the final MNPT estimate ("2003 MNPT Fit").

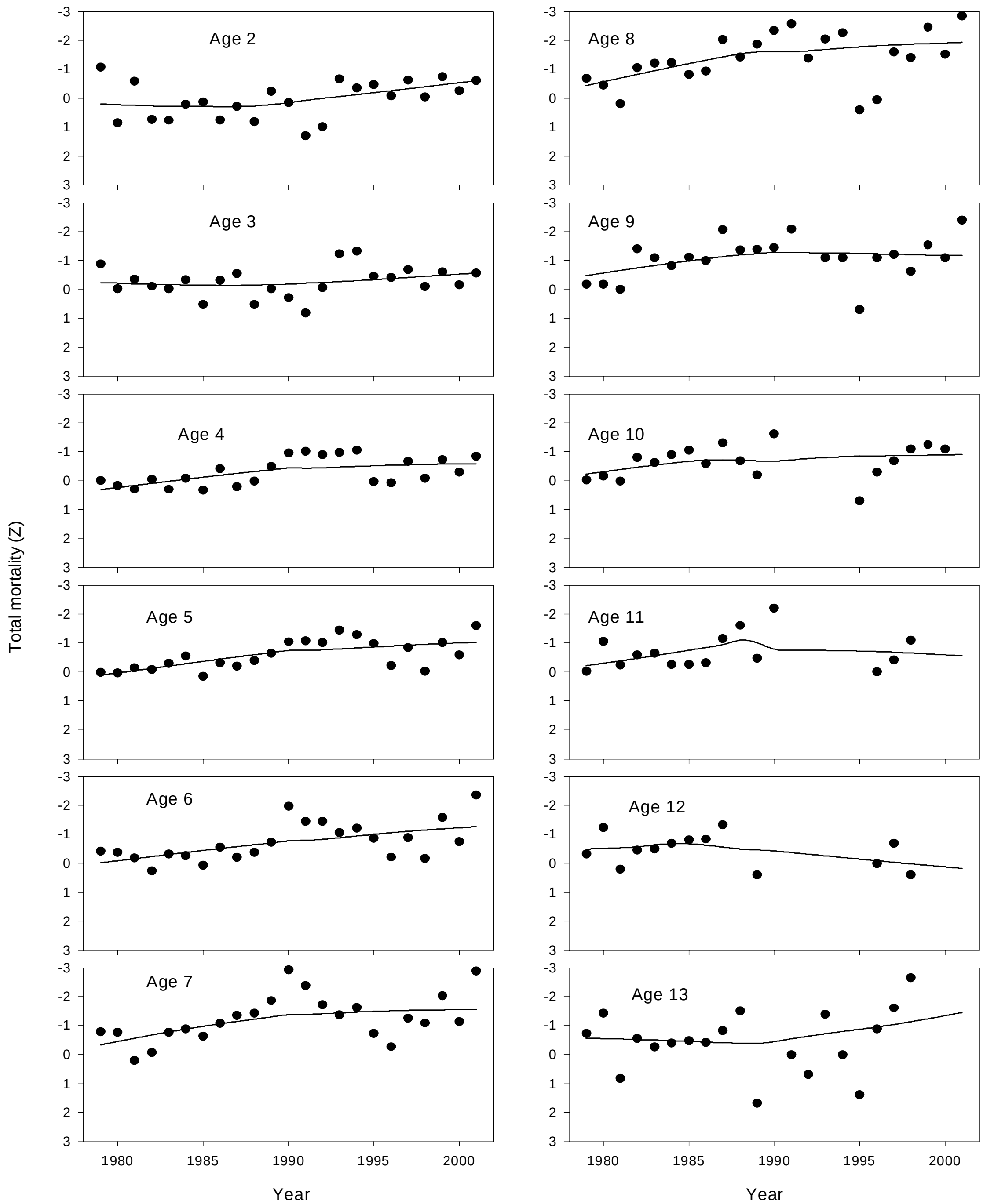


Fig. 10 Total mortality estimates at age for Greenland halibut ages 2-13 from Canadian fall surveys in Div. 2J3K conducted during 1978-2002.

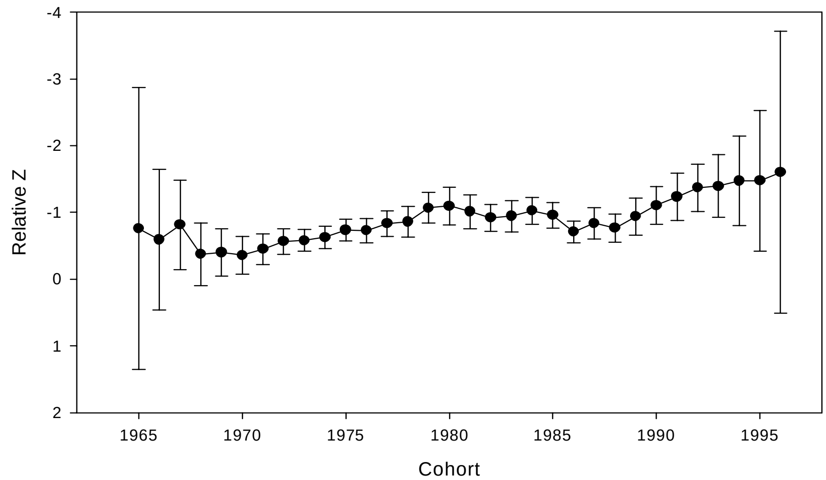


Fig. 11 Trend in relative total mortality of Greenland halibut for ages 5-14 in Divisions 2J, 3K combined from 1965-96 cohorts. Data from the Canadian fall surveys conducted during 1978-2002 in Div. 2J and 3K.