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Estimates of Maturity of Greenland Halibut from 'Synoptic' Surveys

by

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Abstract

Studies on the maturation and spawning of Greenland halibut have revealed a great deal of variability. This led Morgan and Bowering (1997) to suggest that a synoptic survey of the entire stock area might provide a better estimate of the maturity pattern in Greenland halibut. In the fall of 1996-98, the Canadian Department of Fisheries and Oceans conducted synoptic surveys covering the stock area from Div. 2GH in the north to Div. 3NO in the south. This study analyses the maturity data collected during these surveys and compares it to previous information to determine if a synoptic survey does in fact decrease the variability in estimates of maturity at size for Greenland halibut.

We believe the average maturity ogives weighted by divisional population size from the synoptic survey represent the best possible estimates of Greenland halibut maturity rates in SA2+Div. 3KLMNO. If the variation between years observed in this study is considered to be a reasonable expectation for a species which experiences highly peculiar maturity and spawning cycles, then applying annual ogives to determine SSB should be acceptable. There are few empirical data for the entire stock area to determine the historic SSB. However, given the lack of trend in the Div. 2J, 3K data, applying an average from the last three synoptic survey years to the historic time series may not be unreasonable. As more synoptic data accumulate a re-evaluation of the approach may be warranted.

Introduction

Greenland halibut (*Reinhardtius hippoglossoides*) is a deep water flatfish found in the north Atlantic and north Pacific oceans (Hubbs and Wilimovsky, 1964). It has sustained a fishery in the northwest Atlantic since the mid 1800's, although intensive commercial exploitation in the Newfoundland and Labrador area did not begin until the mid 1960's with the introduction of synthetic gillnets (Bowering and Chumakov, 1989; Bowering and Brodie, 1995).

Studies on the maturation and spawning of Greenland halibut have revealed a great deal of variability. The proportion of adult fish at size and age has been found to exhibit a high degree of geographic and temporal variation (Junquera, MS 1994; Junquera and Saborido-Rey, MS 1995; Morgan and Bowering, 1997). The occurrence of immature fish at large size also appears to be common (Fedorov, 1971; Jorgensen and Boje, MS 1994; Morgan and Bowering, 1997). Greenland halibut appears to have a peak and secondary spawning period with some fish in spawning condition being found in most months (Fedorov, 1971; Junquera, MS 1994; Junquera and Zamarro, 1994). Fedorov (1971) also found that Greenland halibut (at least in the Barents Sea) may skip spawning seasons.

Morgan and Bowering (1997) hypothesised that this apparent variability in maturity may be the result of changing distribution of adult fish. This is consistent with the hypothesis of Junquera (MS 1994) that differences in the Div. 3LMN area may be caused by the movement of mature fish in relation to changes in the distribution of suitable environmental conditions. Such inconsistency in the distribution of adult fish would mean that surveys covering only a portion of the stock area would produce highly variable estimates of maturity at age or size and spawning times for this species. This idea led Morgan and Bowering (1997) to suggest that a synoptic survey of the entire stock area might provide a better estimate of the maturity pattern in Greenland halibut.

In the fall of 1996-98, the Canadian Department of Fisheries and Oceans conducted synoptic surveys covering the stock area from Div. 2GH in the north to Div. 3NO in the south. This study analyses the maturity data collected during these surveys and compares it to previous information to determine if a synoptic survey does in fact decrease the variability in estimates of maturity at size for Greenland halibut.

Materials and Methods

Data from 1996-98 from the Canadian fall (September to December) stratified random research vessel surveys in NAFO Div. 2GHJ3KLMNO were examined. Although there was some annual variation, these surveys attempted to cover depths to 1500 m in all Divisions except Div. 3NO which was only surveyed to a maximum depth of 730 m in 1996-97 (see Brodie et al, 1999, this meeting, for specific details). The areal coverage in Div. 2GH and Div. 3M was variable between years. The surveys were conducted by the research vessels TELEOST and WILFRED TEMPELMAN towing *Campelen 1800* bottom trawls with a small mesh liner in the cod end. Tows were of 15 minutes duration.

Proportions mature at length for both sexes in each year and Division were calculated from length, sex and maturity data collected from each set. Fish were assigned to the categories immature (juvenile) or mature (adult) according to the classification of Tempelman et. al. (1978). Estimated proportions mature and length at 50% maturity (L_{50}) were calculated using probit analyses with a logit link function and a binomial error structure (SAS Institute Inc., 1989). Estimates from the three years were examined graphically for geographic and temporal variability.

Estimates of proportion mature at length were constructed for each sex in 1996, 1997 and 1998 for all areas combined. Areas were weighted by population size at length when combined estimates were produced. These area-combined proportions mature at length were examined for significant year effects using generalised linear models with a logit link function and binomial error structure (McCullagh and Nelder, 1983; SAS Institute Inc., 1993). These estimates were also compared to the overall estimate produced for the area by Morgan and Bowering (1997). The overall estimate from that study combined data from commercial fisheries and surveys from Div. 0B to 3NO in an unweighted fashion.

The longest time series of maturity estimates for this stock are from the Canadian fall research vessel surveys conducted in Div. 2J and 3K during 1978-98. The L_{50}'s for females were computed from data collected in these Divisions separately for the 1978-98 period and examined for variability. The statistical significance of year and area effects on proportion mature at length was examined using a generalised linear model as described above.

Results

Both sexes showed interannual variability in most areas (Fig. 1 & 2). Div. 2GH seemed to give the most consistent results among years. There were numerous cases where there was not a significant fit of the model to the data. For example, for both males and females in Div. 3NO, there was only a significant fit to the data in 1998.

When the estimates for each of the different areas are plotted by year the geographic and temporal variability becomes even more apparent (Fig. 3 & 4). For example, males in 1996 show very little difference among areas while in 1997 there is a substantial difference between the estimates for the different areas (Fig. 3). Also, there is no consistent north to south relationship among the maturity estimates for either sex.

Estimates combining all areas for each year are shown for both sexes in Fig. 5. There was no significant difference among years for males (χ^2=4.2, df=2, p=0.12). However, females show a greater degree of variability between years and there is a significant effect of year (χ^2=17.5, df=2, p<0.0005) with 1996 being significantly different from 1998 (χ^2=15.9, df=1, p<0.0001) but 1997 not significantly different from 1998 (χ^2=1.8, df=1, NS).

Figure 6 compares the three yearly estimates for females from this study with the overall estimate from Morgan and Bowering (1997). The estimate for the synoptic surveys in this study indicate that the fish mature at a larger size than the overall estimate produced in our earlier study. The L_{50} for the overall estimate from Morgan and Bowering (1997) was 71.5 cm. For the synoptic surveys reported here there was a systematic increase in L_{50} from 74.1 cm in 1996, to 76.2 cm in 1997 and 81.7 cm in 1998.

The entire 1978-98 fall research vessel time series of L_{50} for females in Div. 2J and 3K is shown in Figure 7. Although there is considerable interannual variability there is no apparent trend in the estimates over time. Estimates since the late 1980's or early 1990's are more variable than those before that time, with much wider fiducial limits and frequent occurrences of years where the model did not give a significant fit to the data. Proportions mature at length from these surveys were examined for significant effects of year and NAFO Division. The order of entry of these factors into the model affected their significance. Therefore, the all-subset model building approach recommended by Smith and Showell (MS 1996) was used. A model including an effect of length and year was found to provide the best fit to the data (Table 1). This indicates that there was significant yearly variability but no difference between NAFO Divisions 2J and 3K. This is consistent with the analysis of Morgan and Bowering (1997) on data from 1978-94. An analysis of the 1978-88 time period (the less variable portion of the time series) also showed significant year effects (χ^2=237.0, df=10, p<0.0001). This interannual variability was without trend.

Discussion

An evaluation of maturity rates for Greenland halibut in the Northwest Atlantic was published by Morgan and Bowering (1997). The results indicated high variability both spatially and temporally based on data collected at varying times in different locations of the stock area. Similar variability between areas and years was observed in the data presented here.

Morgan and Bowering (1997) recommended that the collection of synoptic data throughout the distribution area might produce more consistent results for the population. Although the surveys examined here were intended to be "synoptic", they each comprise a time frame of more than three months to complete due to the size of the area to be surveyed and the availability of only two research vessels to conduct the surveys. Such a period may still be too long to avoid being affected by migrations throughout the area. In addition, the recent surveys, while covering the entire management area (i.e. SA2+Div. 3KLMNO), did not cover SA0+1 to the north where most spawning of Greenland halibut in the western Atlantic has been thought to occur. Potentially therefore, much of the mature biomass may not be included in the study area. Nonetheless, it is highly unlikely that any significant improvement in timing or increased coverage is forthcoming in future surveys due to constraints on resources for research.

Rates of maturity for Divisions 2J and 3K (where most of the historic fishing occurred) varied annually over the 21-year period examined. Statistically significant differences indicate that applying a constant knife-edge maturity rate (eg. L_{50}) to estimate annual SSB is inappropriate and full maturity ogives should be used where available. Also, the high variability in these data and in particular the frequent lack of fit in the maturity ogives during the late 1980's and 1990's is coincident with the observed shift in distribution (Anon. 1994) and the beginning of the large fishery in the Flemish Pass area of the NRA. Such unexplained and probably rapid shifts in distribution only serve to exacerbate the problem of determining representative maturity rates in the Greenland halibut population.

Notwithstanding the difficulties outlined, we believe the average maturity ogives weighted by divisional population size presented in Figure 5 represent the best possible estimates of Greenland halibut maturity rates in SA2+Div. 3KLMNO. If the variation between years observed in this study is considered to be a reasonable expectation for a species, which experiences highly peculiar maturity and spawning cycles, then applying annual ogives to determine SSB should be acceptable. Otherwise, a running average over several years could be considered. There are few empirical data for the entire stock area to determine the historic SSB. However, given the lack of trend in the Div. 2J, 3K data, applying an average from the last three synoptic survey years to the historic time series may not be unreasonable. As more synoptic data accumulate a re-evaluation of the approach may be warranted.

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Table 1. Analysis of deviance results for all-subset model fitting for proportion mature at length data from Div. 2J and 3K from 1978-98. A model with a logit link function and a binomial error was used. The model includes an intercept.

Factors	Change in Deviance	df	p-value
Length+year+NAFO			
Length+NAFO	578.9	20	0.001
Length+year	0	1	NS

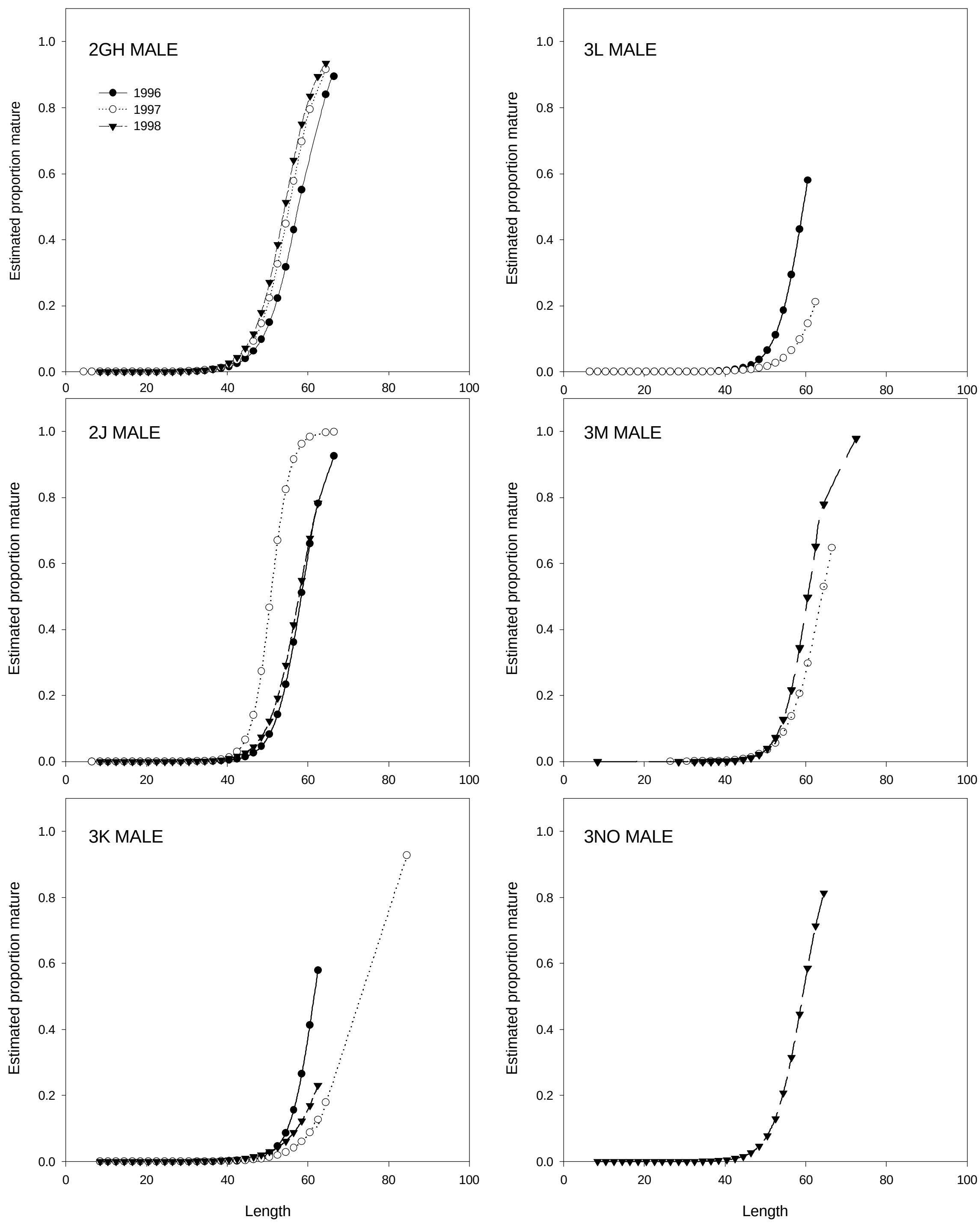

Figure 1. Estimated proportion mature at length for males from 1996 to 1998, by NAFO Division or area.

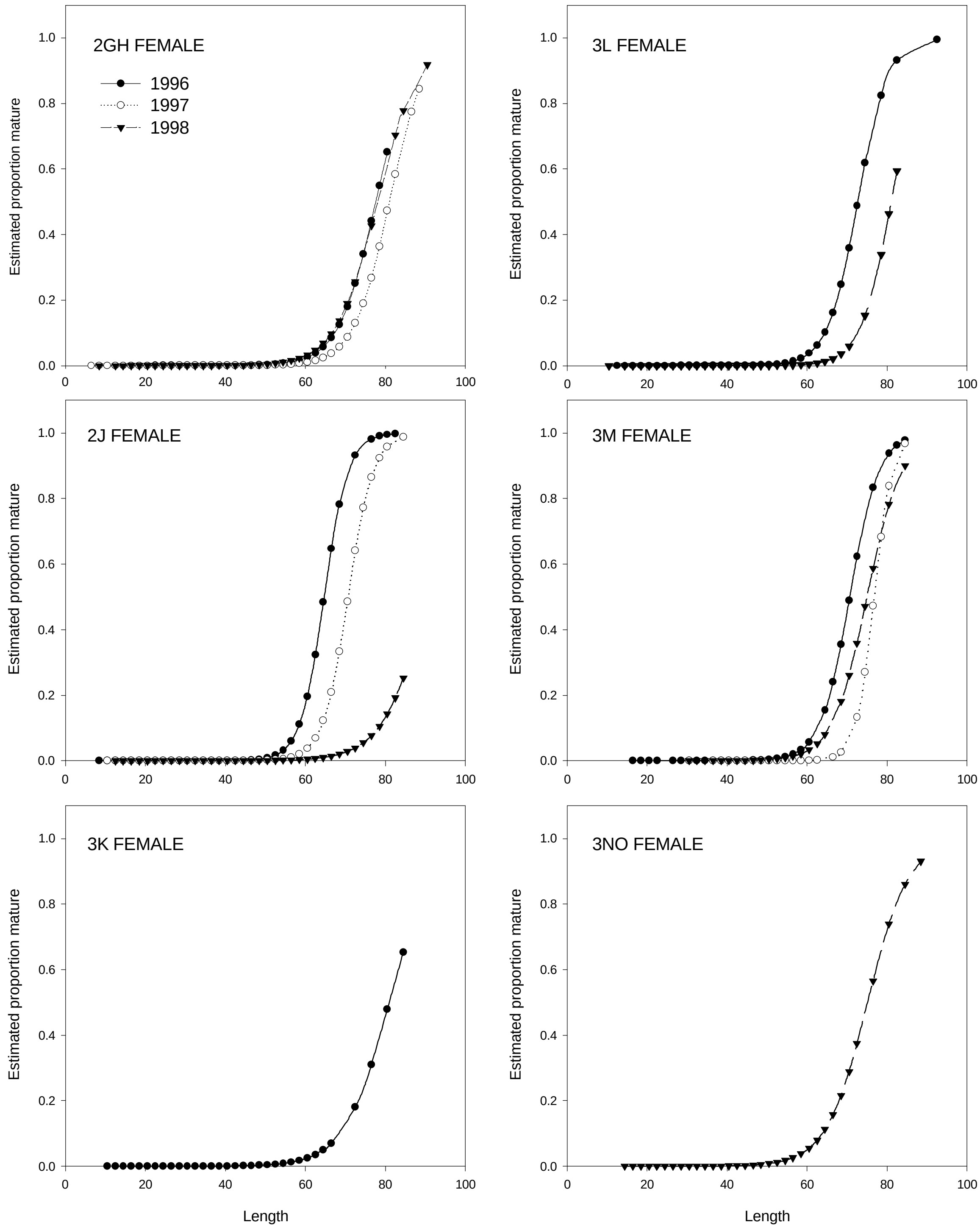

Figure 2. Estimated proportion mature at length for females from 1996 to 1998 for each NAFO Division or area.

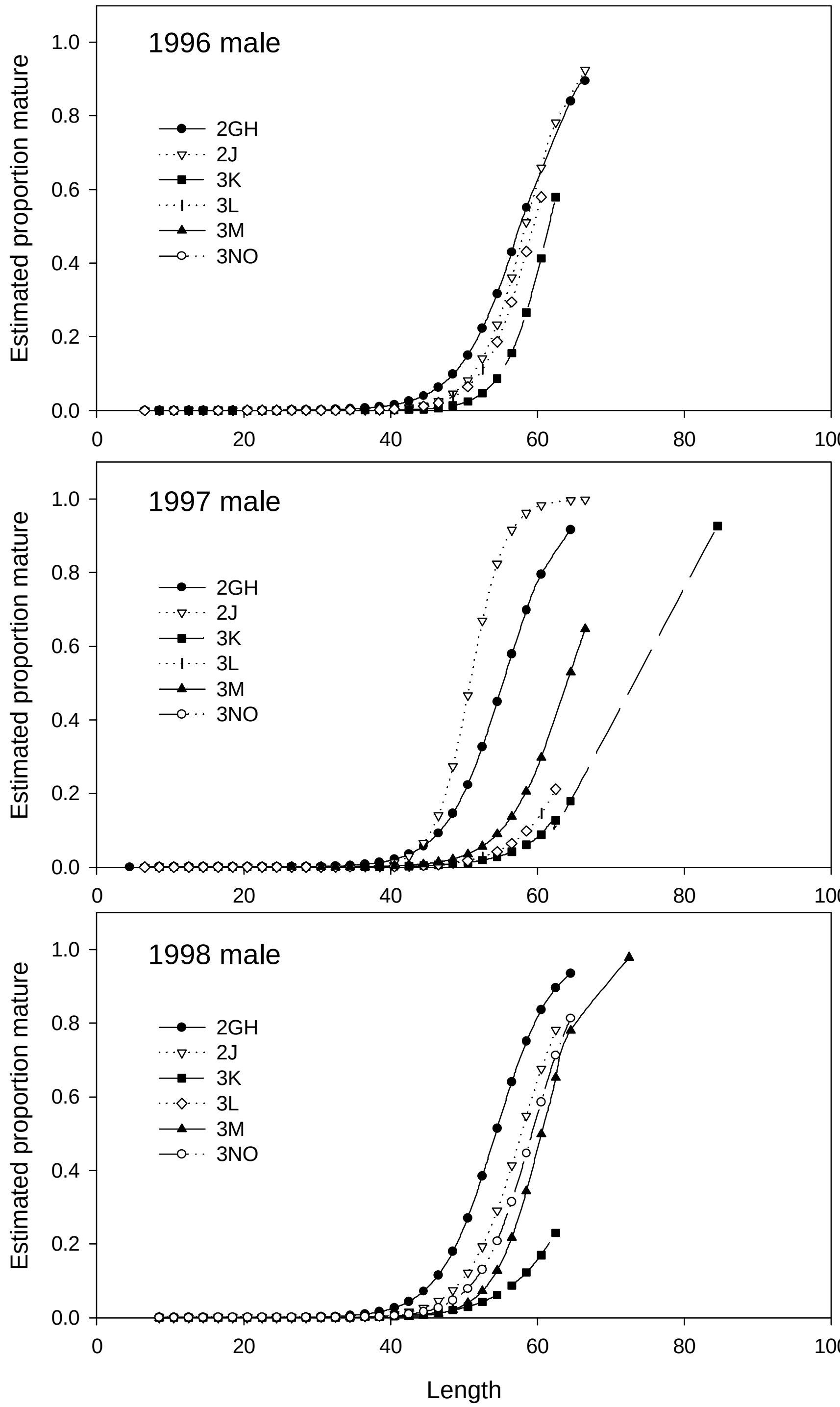

Figure 3. Estimated proportion mature at length for male Greenland halibut for each NAFO Division or area by year from 1996 to 1998.

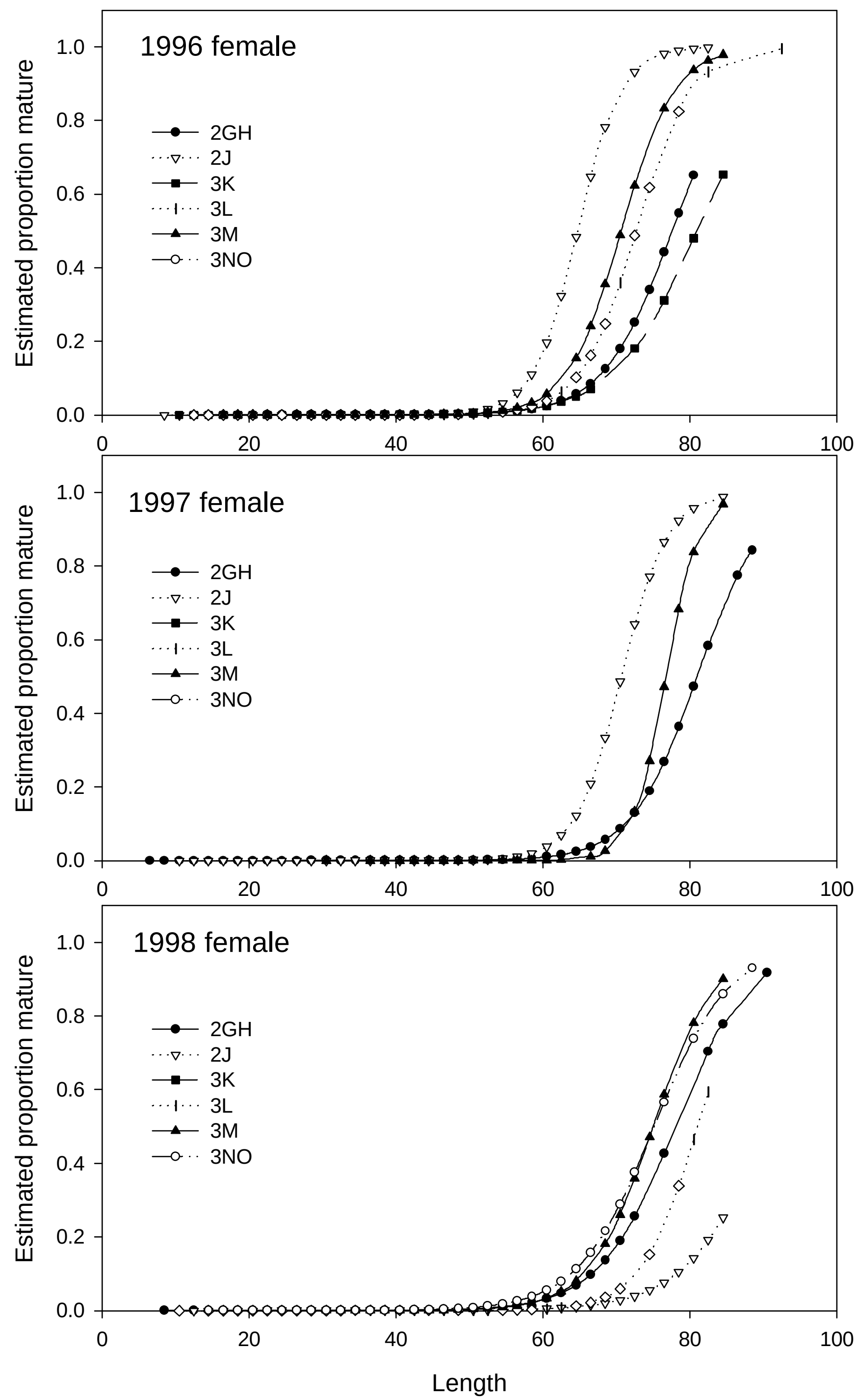

Figure 4. Estimated proportion mature at length for female Greenland halibut for each NAFO Division or area by year from 1996 to 1998.

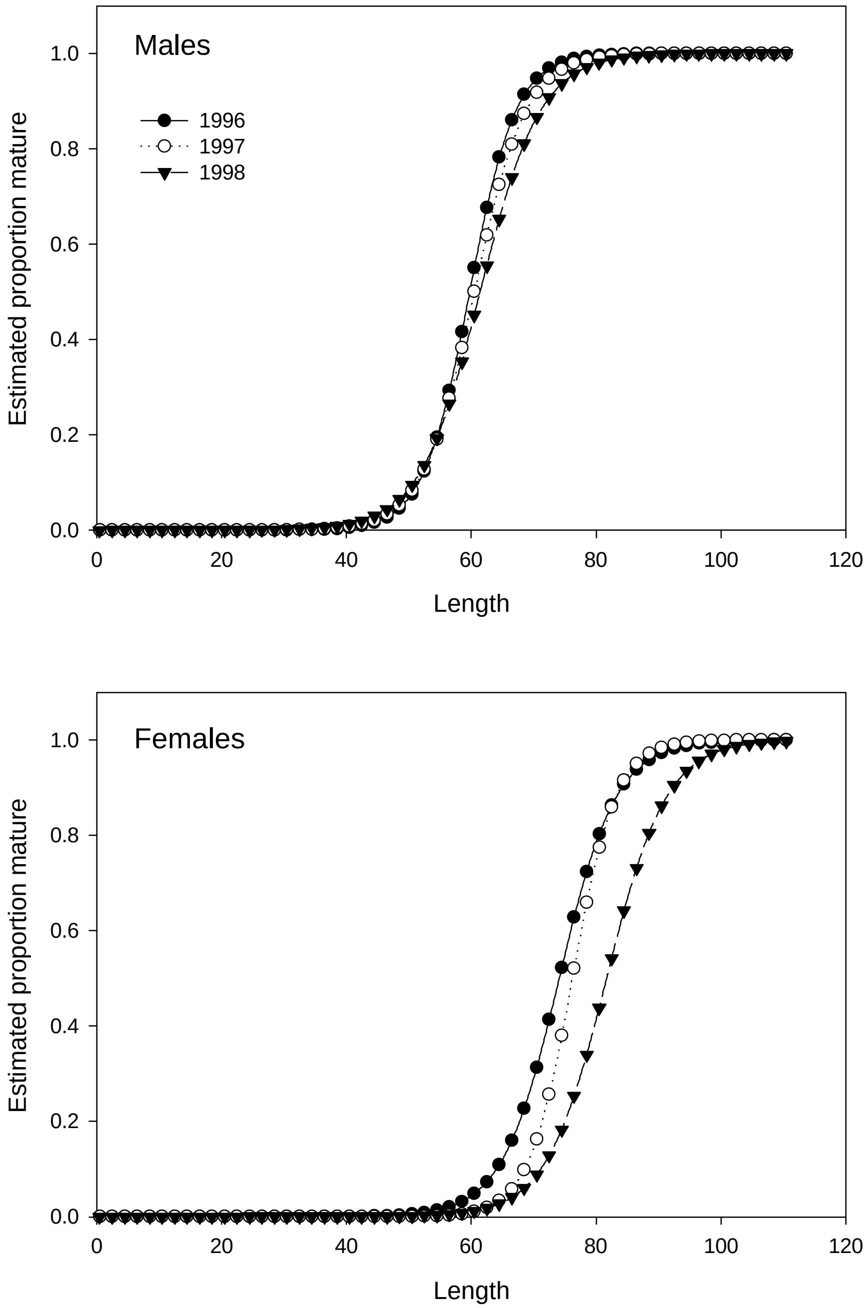

Figure 5. Estimated proportion mature at length for male and female Greenland halibut from 1996 to 1998, all areas combined.

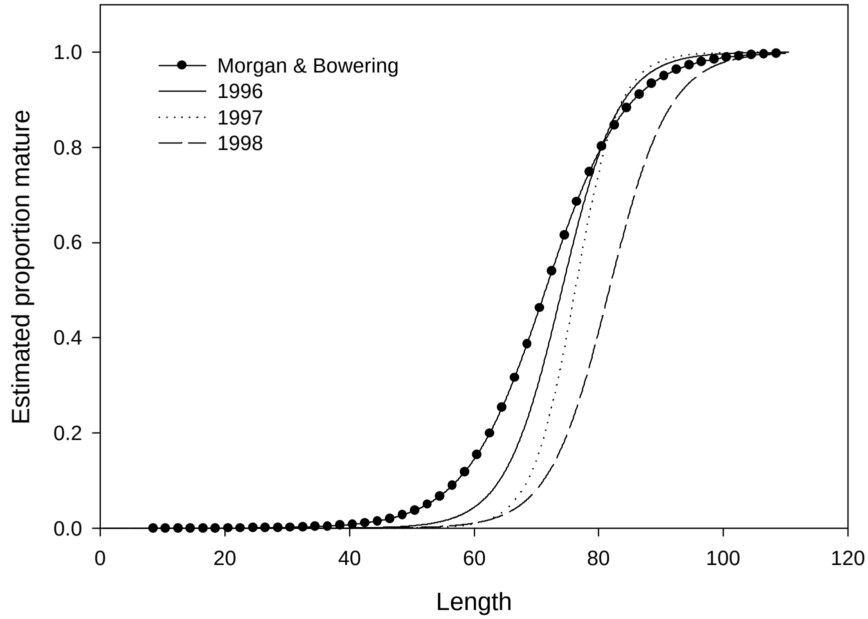

Figure 6. Estimated proportion mature at length for female Greenland halibut from the synoptic surveys in 1996 to 1998 compared to the average estimate of Morgan and Bowering (1997).

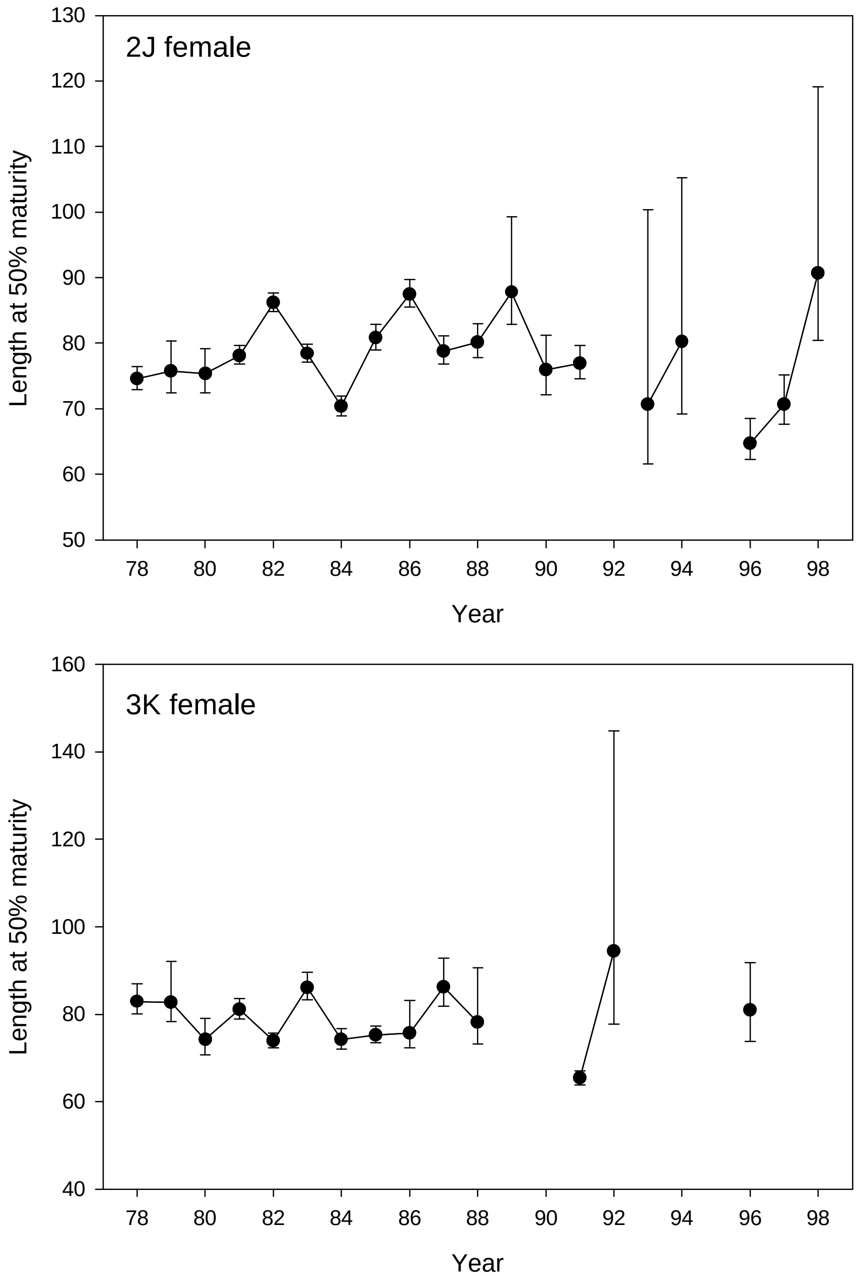

Figure 7. Length at 50% maturity (± 95% fiducial limits) for female Greenland halibut from Canadian fall RV surveys from 1978 to 1998.