Northwest Atlantic Fisheries Organization

Serial No. N4225 **NAFO SCR Doc. 00/6**

SCIENTIFIC COUNCIL MEETING – JUNE 2000

Maturity at Age and Size of Greenland Halibut (*Reinhardtius hippoglossoides*) and Geographic Distribution of Spawning Fish

by

M.J. Morgan and W.R. Bowering

Dept. of Fisheries and Oceans, P. O. Box 5667
St. John's, NF, A1C 5X1, Canada

Abstract

Maturity at size and age of Greenland halibut (*Reinhardtius hippoglossoides*) were investigated using survey information. Maturity at size is highly variable when examined on a Divisional basis. Estimates are much less variable when examined over the entire Subarea 2 and Div. 3KLMNO area. During the 1996-1999 period using data from the entire area, estimates of length at 50% maturity for males have varied from 57 to 61 cm and for females from 74 to 82 cm. Estimates for age at 50% maturity have varied from 9 to 10 years for males and from 12 to 13 years for females. The distribution of spawning fish was also investigated using survey and commercial fishery data. Some spawning fish were found in all areas. This raises the possibility that a number of spawning components exist and heightens the concern about the distribution of commercial catch relative to the distribution of biomass, as spawning components could be eliminated by excessive catch in an area.

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; Morgan and Bowering, MS 1999). 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. The main location of Greenland halibut spawning has been thought to be in the Davis Strait, but fish in spawning condition have been observed elsewhere (Smidt, 1969; Jorgensen and Boje, MS 1994; Junquera and Zamarro, 1994; Morgan and Bowering, MS 1995).

This study updates information on maturity at length from Canadian fall surveys, presents estimates of maturity at age and some information on the distribution of female Greenland halibut in spawning condition.

Materials and Methods

Data from 1996-99 from the Canadian fall (September to December) stratified random research vessel surveys in NAFO Subarea 2 and Div. 3KLMNO were examined. 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 at length 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 of proportion mature at length were constructed for each sex in 1996, 1997, 1998 and 1999 for all areas separate and combined. Areas were weighted by population size at length when combined estimates were produced.

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 1978-99. The L_{50}'s for females were computed for each of these Divisions separately from data collected in the 1978-99 period.

Fish collected for age determination were assigned to maturity stage according to the same criterion. Proportion mature at age was calculated using the method of Morgan and Hoenig (1997). Estimates of proportion mature and age at 50% maturity were constructed for each sex in 1996, 1997, 1998 and 1999 for all areas combined. Areas were weighted by population size at length to produce combined estimates. Estimates were not produced for individual Divisions or areas because of the more limited nature of the data set.

The area-combined proportions mature at length and age 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).

Length, sex and maturity information collected during fall surveys from 1978-99 and from the Canadian fishery from 1993-1999 were used to classify female fish as immature, spent last year, maturing for the present year, spawning, spent in the present year or maturing for the next spawning season. Fish were classed as spawning if there was evidence of hydrated eggs. Data were arbitrarily grouped into three time periods, 1978-86, 1987-95 (1993-95 for the commercial data) and 1996-99. About 90% of the commercial fishery data came from fishing sets of 500 m depth or more and about 70% of these data were from gillnets.

Results

Maturity at length

Both sexes showed interannual variability in estimated proportion mature at length 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 of proportion mature at length for each of the different areas are plotted together 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 of proportion mature at length combining all areas for each year are shown for both sexes in Fig. 5 and 6. Estimates for males are less variable across the four years than are the female estimates. However, for both sexes the estimates are less variable than when only a portion of the Subarea 2 and Div. 3KLMNO area is examined. For males the difference among years was marginally significant (χ^2=7.3, df=3, p=0.06) and tests for contrasts showed that 1996 was significantly different from 1998 and 1999 but that the other years were not significantly different from one another (Table 1). There was a significant difference among years for females for proportion mature at length (χ^2=20.0, df=3, p<0.0005) with 1996 being different from the other years which were not

significantly different from one another (Table 1). L_{50} for these combined estimates are given in Table 2 and have varied from 57.4 to 61.4 cm for males and from 74.1 to 81.7 cm for females.

The entire 1978-99 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.

Maturity at age

Estimates of proportion mature at age combining all areas for each year are shown for both sexes in Fig. 8 and 9. For males the difference among years was marginally significant (χ^2=7.4, df=3, p=0.06) and tests for contrasts showed that 1996 and 1997 were significantly different from 1999 but that the other years were not significantly different from one another (Table 1). There was a significant difference among years for females for proportion mature at age (χ^2=18.0, df=3, p<0.0005) with 1996 being different from the other years which were not significantly different from one another (Table 1). Age at 50% maturity (A_{50}) for these combined estimates are given in Table 2 and have varied from 8.8 to 10.2 years for males and from 12.0 to 13.3 years for females.

Spawning

In both the fall RV data and the Canadian commercial fishery data, the majority of females in most samples were immature, although the percentage of immature females was substantially less in the commercial samples (Tables 3 & 4). In the fall RV data there is a large percentage of female adults that are spent or maturing for the next year, indicating that the survey occurs well after the peak of spawning. The sampling from the commercial fishery was more variable in time and contained some samples collected several months before the fall survey. More fish in spawning condition were seen in the commercial samples. Spawning fish were seen in all areas except 3NO, the highest percentages being 15% and 24% from areas Divisions 0B and 2GH respectively, in the commercial samples.

Discussion

Estimates of maturity at length for Greenland halibut were highly variable when examined on a geographic scale smaller than the entire Subarea 2 and Div. 3KLMNO area. Previous work has also shown that the proportion of adult fish at size and age exhibits a high degree of geographic and temporal variation (Junquera, MS 1994; Junquera and Saborido-Rey, MS 1995; Morgan and Bowering, 1997; Morgan and Bowering, MS 1999).

The estimates of maturity at length for the entire area appear to be less variable and as suggested by Morgan and Bowering (MS 1999) probably represent the best possible estimates of Greenland halibut rates in the Subarea 2 and Div. 3KLMNO area. The estimates of maturity at age for the entire area show a similar pattern and degree of variability to the estimates of maturity at length. These probably provide the best estimates to use if spawning stock biomass is to be produced from any age structured model. The estimates of maturity at age presented here are from a fall survey and are for fish spawning in the next spawning season. If they are to be used in calculations of SSB then both the age and the year must be incremented by one.

More spawning fish were observed in the commercial samples than in the fall RV survey. The commercial data included samples that were taken several months before the fall survey. As well, the commercial data contained a high proportion of fish caught with gillnets which are more effective at catching larger fish. The fall survey data had a high proportion of females that were spent or maturing for the next year. This indicates that the fall survey (conducted from October to December in most years) occurs after the peak of spawning for Greenland halibut. This is consistent with the results of Junquera and Zamarro (1994) who found that peak spawning in the Flemish Pass area occurred mainly in the summer.

Spawning fish were found in all areas except Div. 3NO. This is consistent with the results of other work which found spawning fish in areas other than the Davis Strait, including in the Div. 3LM area (Jorgensen and Boje, MS 1994; Junquera and Zamarro, 1994). There were also fish in all areas that were maturing for the present year and which were spent in the present year. The spawning location of these fish is not known. Scientific Council has

expressed concern about the distribution of catch relative to the biomass of Greenland halibut (Anon. 1999). The presence of spawning fish throughout the area raises the possibility that a number of spawning components exist. This would heighten the concern about the distribution of catch as spawning components could be eliminated.

References

Anon. 1999. Northwest Atlantic Fisheries Organization Scientific Council Report 1999. Northwest Atlantic Fisheries Organization, Dartmouth, Nova Scotia.

Bowering, W. R. and W. B. Brodie. 1995. Greenland halibut (*Reinhardtius hippoglossoides*). A review of the dynamics of its distribution and fisheries off eastern Canada and Greenland. In: NATO ASI Series Volume XX: Deep water fisheries of the North Atlantic Oceanic slope, pp. 113-160. A. G. Hopper (Ed), Netherlands, Kluwer Academic Publisher

Bowering, W. R. and A. K. Chumakov. 1989. Distributions and relative abundance of Greenland halibut (*Reinhardtius hippoglossoides* (Walbaum)) in the Canadian northwest Atlantic from Davis Strait to the northern Grand Bank. Fish. Res. **7**: 301-327.

Fedorov, K. Ye. 1971. The state of the gonads of the Barents Sea Greenland halibut [*Reinhardtius hippoglossoides* (Walb.)] in connection with the failure to spawn. J. Ichth. **11**: 673-682.

Hubbs, C. L. and N. J. Wilinovsky. 1964. Distribution and synonymy in the Pacific Ocean and variation of the Greenland halibut (*Reinhardtius hippoglossoides*). J. Fish. Res. Bd. Can. **21**: 1129-1154.

Jorgensen, O. and J. Boje. MS 1994. Sexual maturity of Greenland halibut in NAFO Subarea 1. NAFO SCR Doc., No. 42, Serial No. N2412, 17p.

Junquera, S. MS 1994. Analysis of the variations in the spatial distribution and spawning of the Greenland halibut in Divisions 3LMN (1990-93). NAFO SCR Doc., No. 25, Serial No. N2391, 12p.

Junquera, S. and F. Saborido-Rey. MS 1995. Temporal and spatial variation in length at maturity in 3LM and 3NO Greenland halibut. NAFO SCR Doc., No. 29, Serial No. N2538, 6p.

Junquera, S. and J. Zamarro. 1994. Sexual maturity and spawning of Greenland halibut (*Reinhardtius hippoglossoides*) from Flemish Pass area. NAFO Sci. Coun. Studies. **20**: 47-52.

McCullagh, P. and J. A. Nelder. 1983. Generalized Linear Models. London, Chapman and Hall.

Morgan, M.J. and W.R. Bowering. MS 1995. Maturity at size and age of Greenland halibut in NAFO Subarea 2 and Divisions 3KLM. NAFO SCR Doc., No. 54, Serial No. N2565, 19p.

Morgan, M. J. and W. R. Bowering. 1997. Temporal and geographic variation in maturity at length and age of Greenland halibut (*Reinhardtius hippoglossoides*) from the Canadian north-west Atlantic with implications for fisheries management. ICES J. Mar. Sci. **54**: 875-885.

Morgan, M.J. and W.R. Bowering. MS 1999. Estimates of maturity of Greenland halibut from 'synoptic' surveys. NAFO SCR Doc. No. 9, Serial No. N4056, 11p.

Morgan, M.J. and J.M. Hoenig. 1997. Estimating maturity-at-age from length stratified sampling. J. Northw. Atl. Fish. Sci. **21**: 51-63.

SAS Institute Inc. 1989. SAS/STAT User's Guide. Cary, NC. SAS Institute Inc.

SAS Institute Inc. 1993. SAS Technical Report P-243, SAS/STAT Software: The Genmod Procedure, Release 6.09. Cary, NC. SAS Institute Inc.

Smidt, E. L. B. 1969. The Greenland halibut, Reinhardtius hippoglossoides (Walb.), biology and exploitation in Greenland waters. Meddelelser Danmarks Fiskeri-og Havundersogelser/g. (N.S.) **6**: 79-148.

Templeman, W., V. M. Hodder, and R. Wells. 1978. Sexual maturity and spawning in haddock *Melanogrammus aeglefinus* of the southern Grand Bank. ICNAF Res. Bull., **13**: 53-65.

Table 1. Results of likelihood ratio tests for contrast among years for proportion mature at length and age, for males and females. Years with the same letter are not significantly different.

Year	Male		Female	
	Length	Age	Length	Age
1996	A	A	A	A
1997	A B	A	B	B
1998	B	A B	B	B
1999	B	B	B	B

Table 2. Length (cm) and age at 50% maturity for males and females for Div. 2GHJ3KLMNO combined from 1996 to 1999.

Year	Male		Female	
	Length	Age	Length	Age
1996	59.8	10.1	74.1	12.0
1997	60.5	10.2	76.2	12.6
1998	61.4	10.0	81.7	13.3
1999	57.4	8.8	79.2	12.7

Table 3. Percentage and (number) of adult females in Canadian fall RV surveys that were spent in the last year (SPL), maturing for the present year (MATAP), spawning (SPAWN), spent in the present year (SPENT), or maturing for the next year (MATNEXT). The survey series is divided into three time periods, 1978-1986, 1987-1995 and 1996-1999. The percentage that was immature (IMM) is also given.

Period	Area	IMM	SPL	MATAP	SPAWN	SPENT	MATNEXT
1978-1986	2GH	88	0	0.2 (2)	7.5 (80)	0	92 (983)
	2J3K	95	0.1 (1)	0.3 (5)	4.8 (77)	13 (205)	82 (1319)
1987-1995	2GH	95	0	0.2 (1)	0.5 (2)	48 (207)	52 (225)
	2J3K	99	0	0.9 (2)	0.9 (2)	22 (48)	76 (165)
1996-1990	2GH	99.8	0	0	2.6 (1)	18 (7)	80 (31)
	2J3K	99.9	0	0	0	8 (4)	92 (51)
	3LM	99.7	0	0	0	23 (10)	77 (34)
	3NO	99.9	0	0	0	8 (1)	92 (11)

Table 4. Percentage and (number) of adult females in the Canadian fishery that were spent in the last year (SPL), maturing for the present year (MATAP), spawning (SPAWN), spent in the present year (SPENT), or maturing for the next year (MATNEXT). The survey series is divided into two time periods, 1993-1995 and 1996-1999. The percentage that was immature (IMM) is also given.

Period	Area	IMM	SPL	MATAP	SPAWN	SPENT	MATNEXT
1993-1995	0B	23	0	0	0	32 (345)	68 (736)
	2GH	48	0	19 (50)	0.1 (3)	32 (838)	66 (1755)
	2J3K	69	2.8 (47)	64 (1053)	1.2 (20)	11.7 (194)	21 (345)
	3LM	71	5 (9)	94 (170)	0	1.1 (2)	0
1996-1999	0B	35	0	28 (282)	15 (148)	57 (573)	0
	2GH	64	0	38 (105)	24 (67)	38 (105)	0
	2J3K	92	0.3 (2)	82 (563)	5.7 (39)	11.3 (77)	0.4 (3)
	3LM	74	1 (3)	94 (293)	1 (3)	4 (13)	0
	3NO	45	0	91 (386)	0.7 (3)	5 (21)	3 (13)

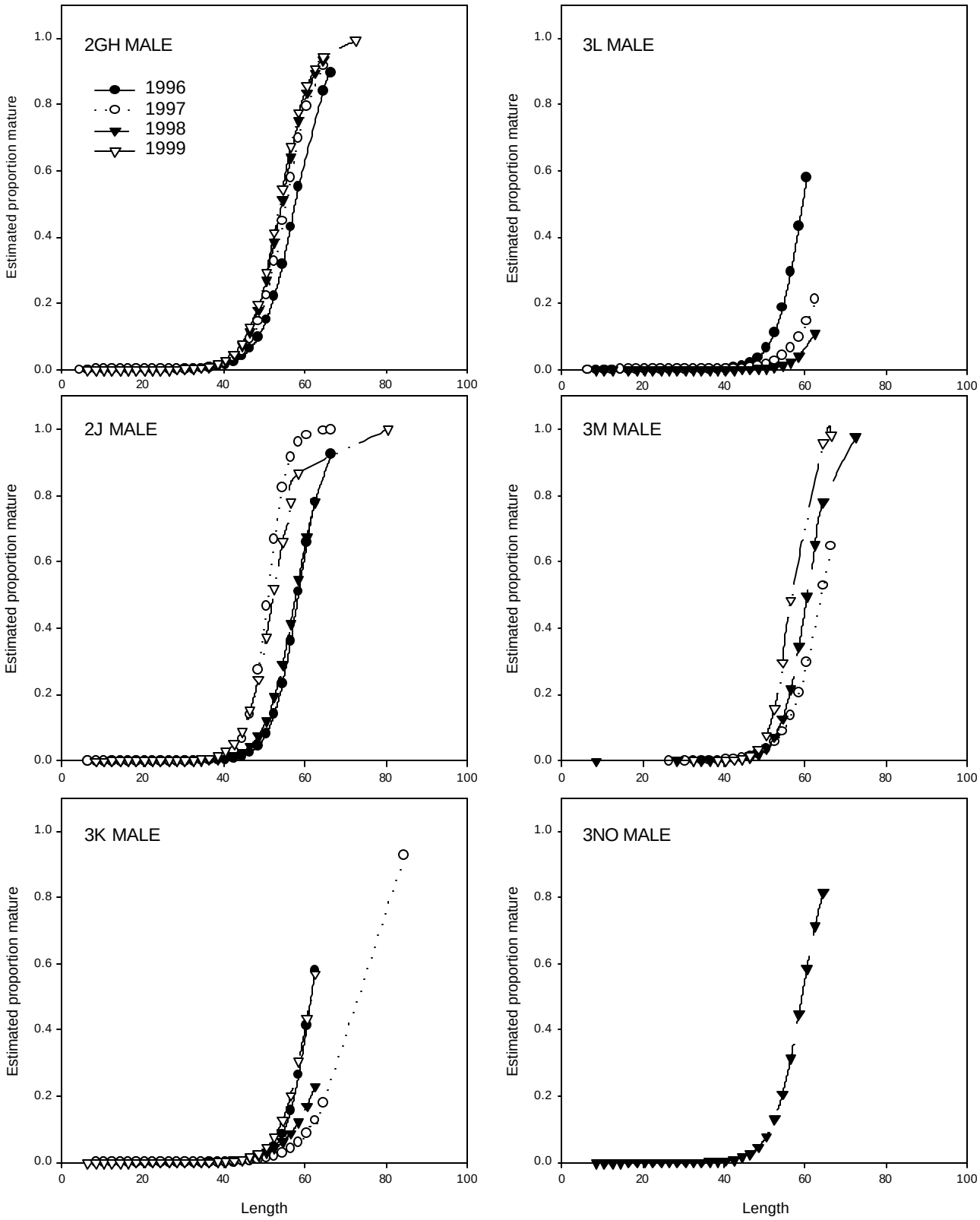


Figure 1. Estimated proportion mature at length for males from 1996 to 1999, by NAFO Division or area.

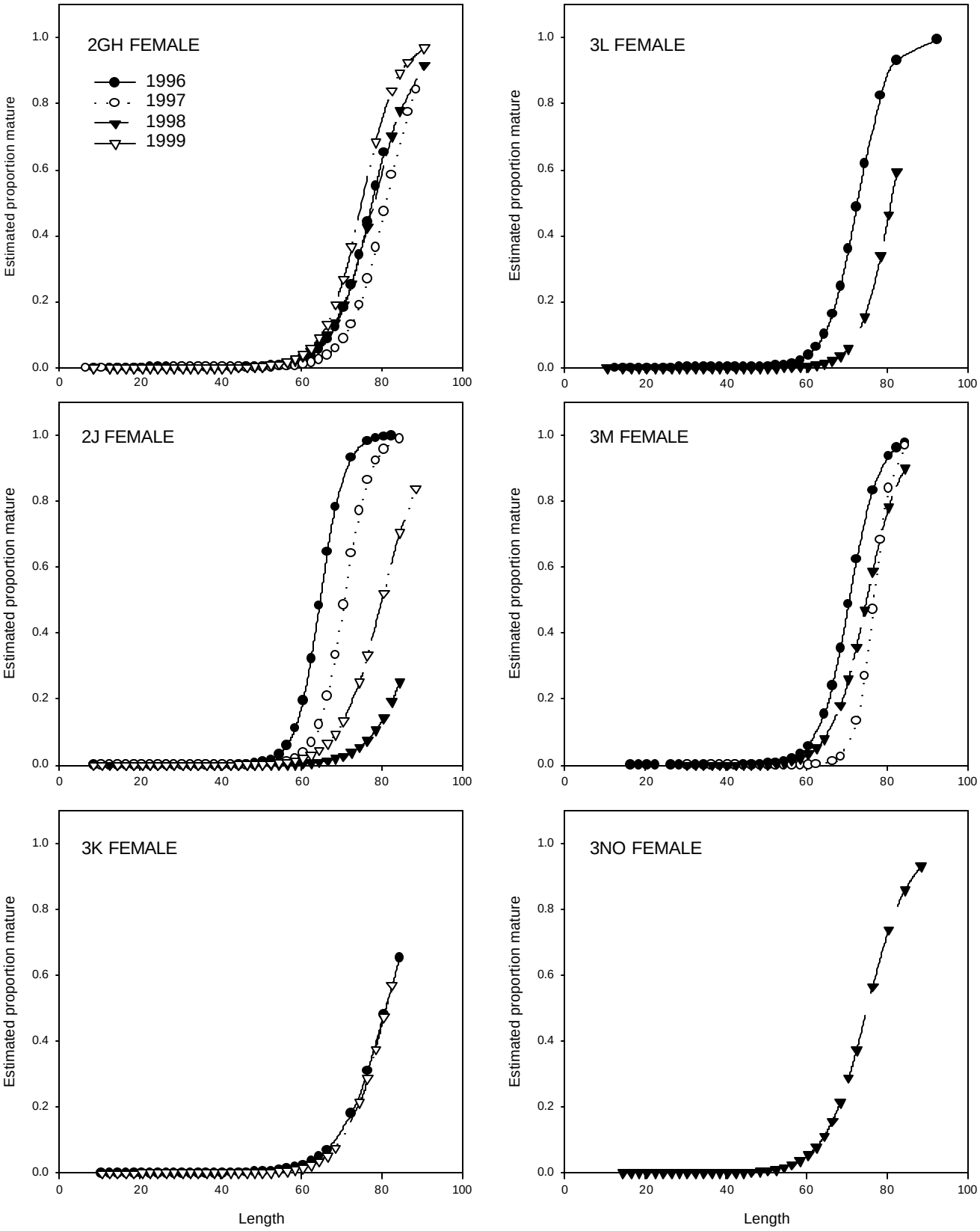


Figure 2. Estimated proportion mature at length for females from 1996 to 1999 for each NAFO Division or area.

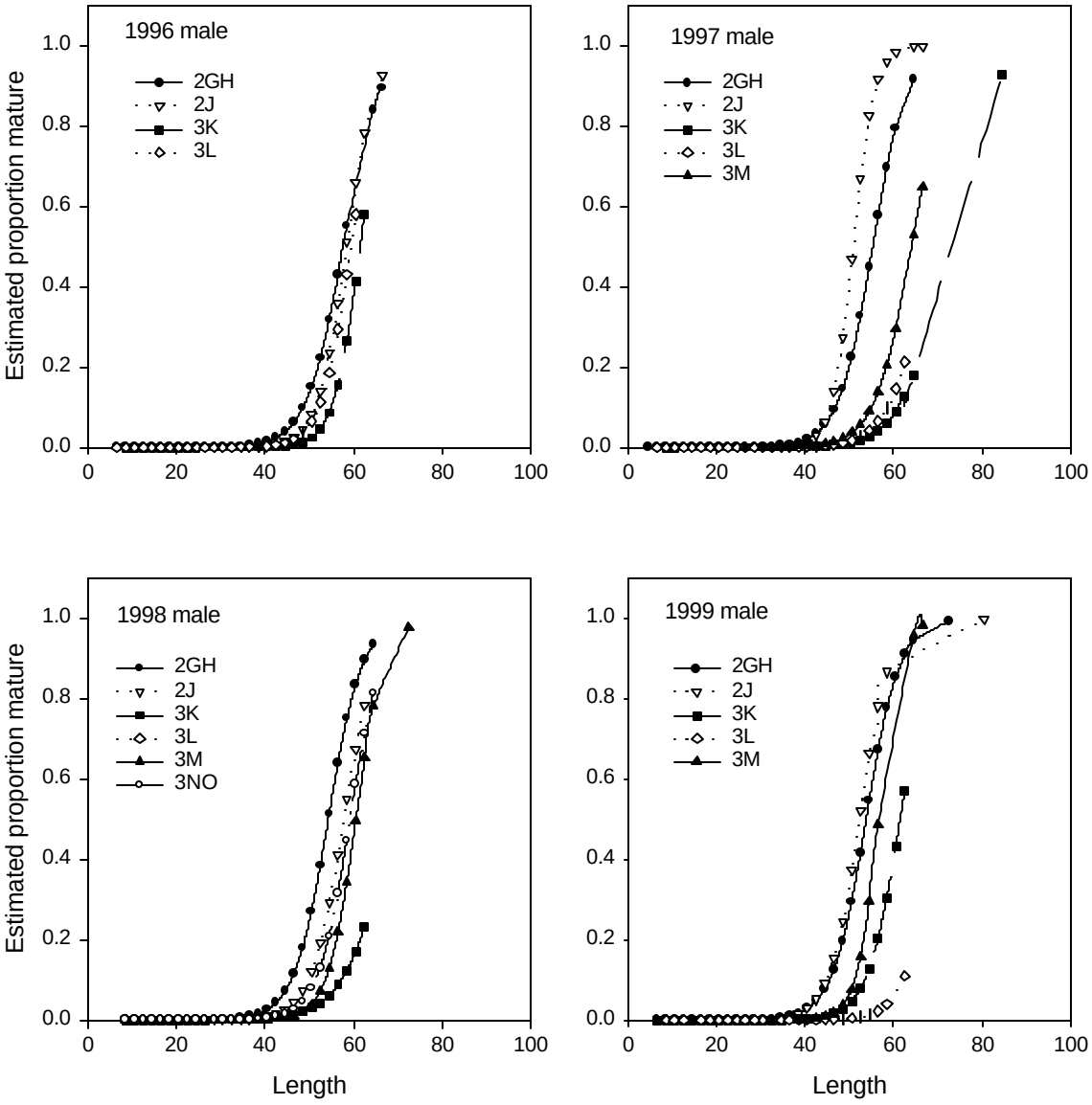


Figure 3. Estimated proportion mature at length for male Greenland halibut for each NAFO Division or area by year from 1996 to 1999.

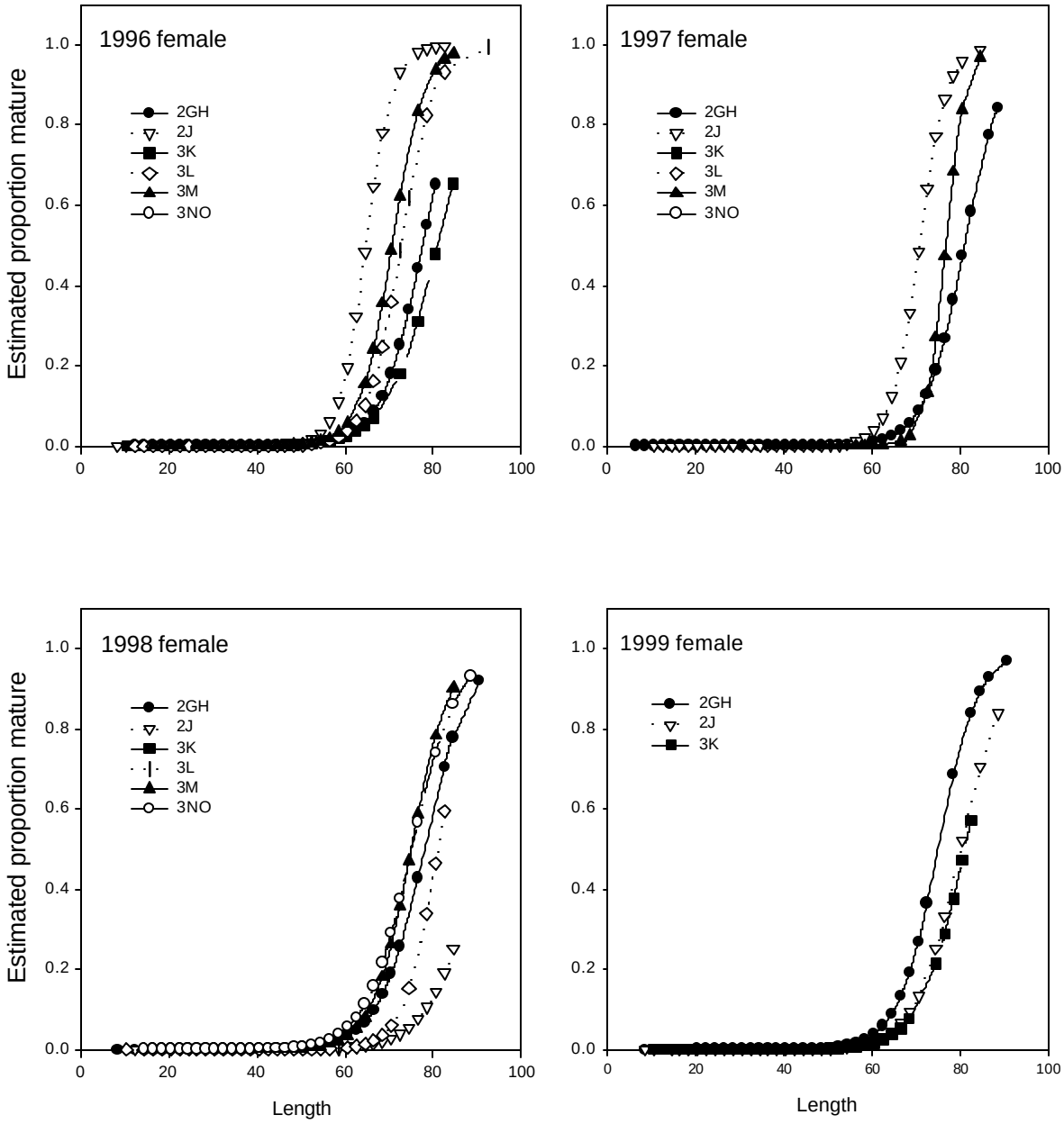


Figure 4. Estimated proportion mature at length for female Greenland halibut for each NAFO Division or area by year from 1996 to 1999.

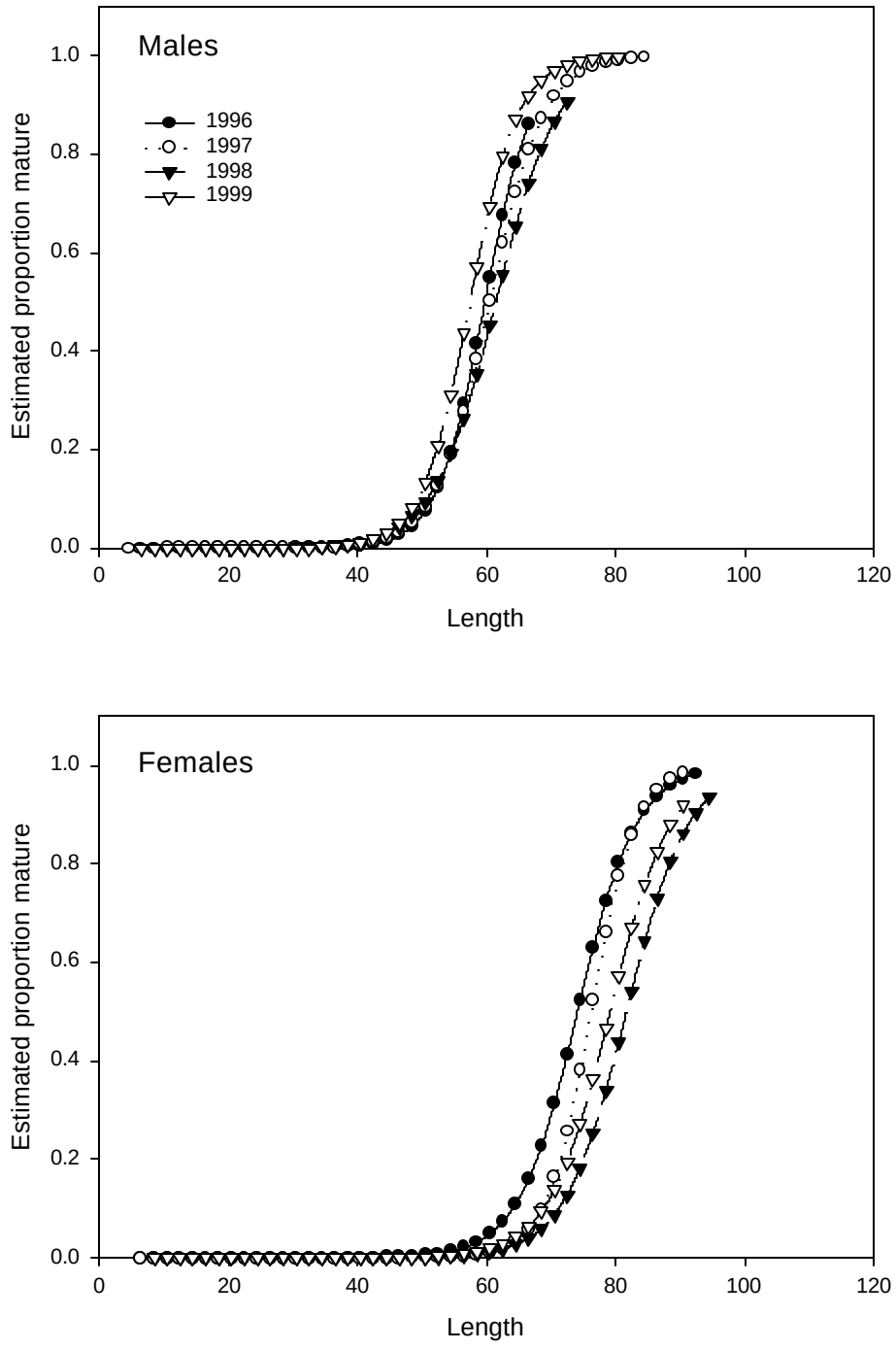
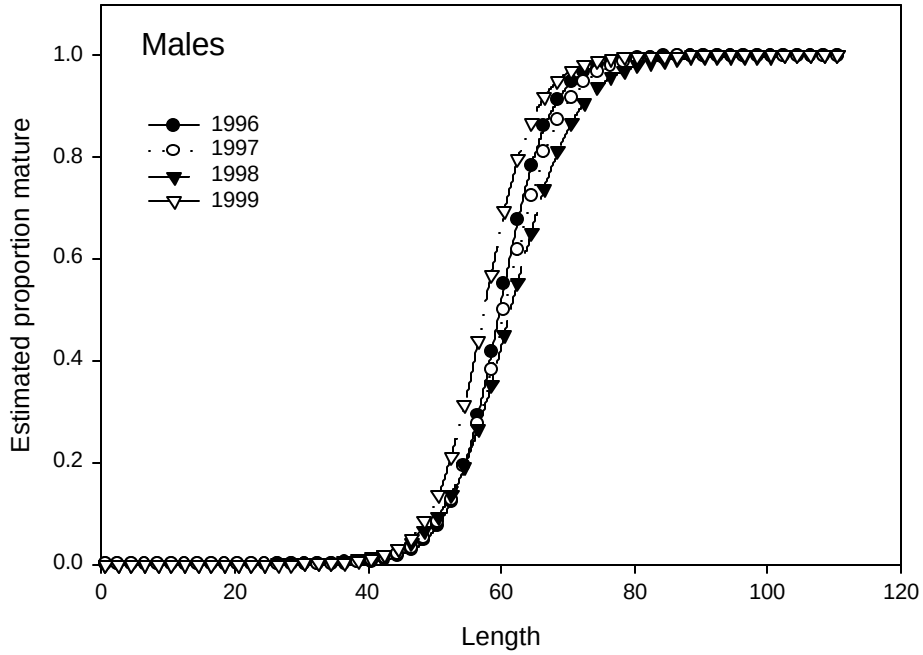


Figure 5. Estimated proportion mature at length for male and female Greenland halibut from 1996 to 1999, all areas combined. Only estimates for the range of length groups caught during the surveys are shown.



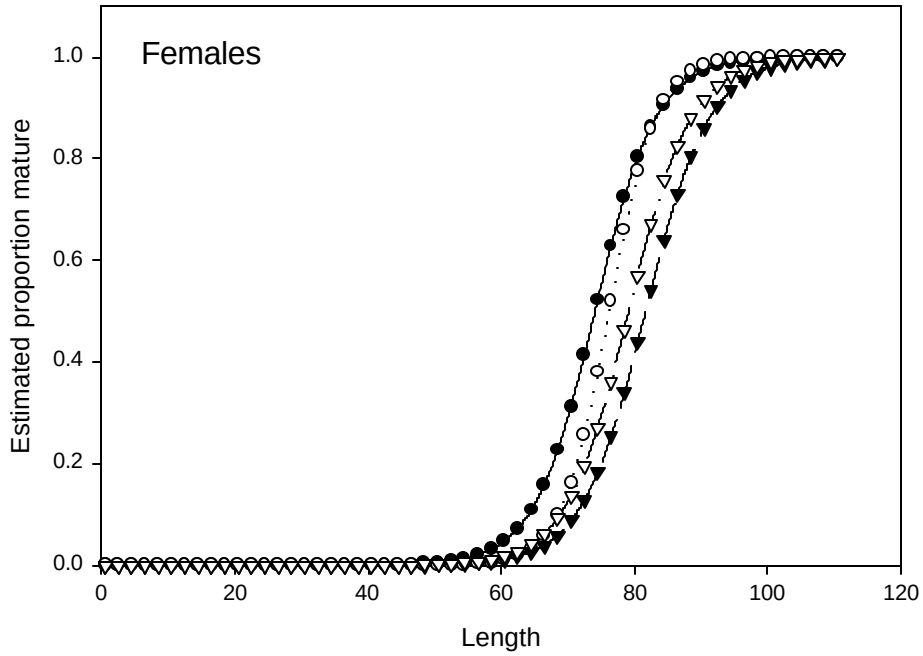


Figure 6. Estimated proportion mature at length for male and female Greenland halibut from 1996 to 1999, all areas combined. Estimates from 0.5 to 110.5 cm are shown.

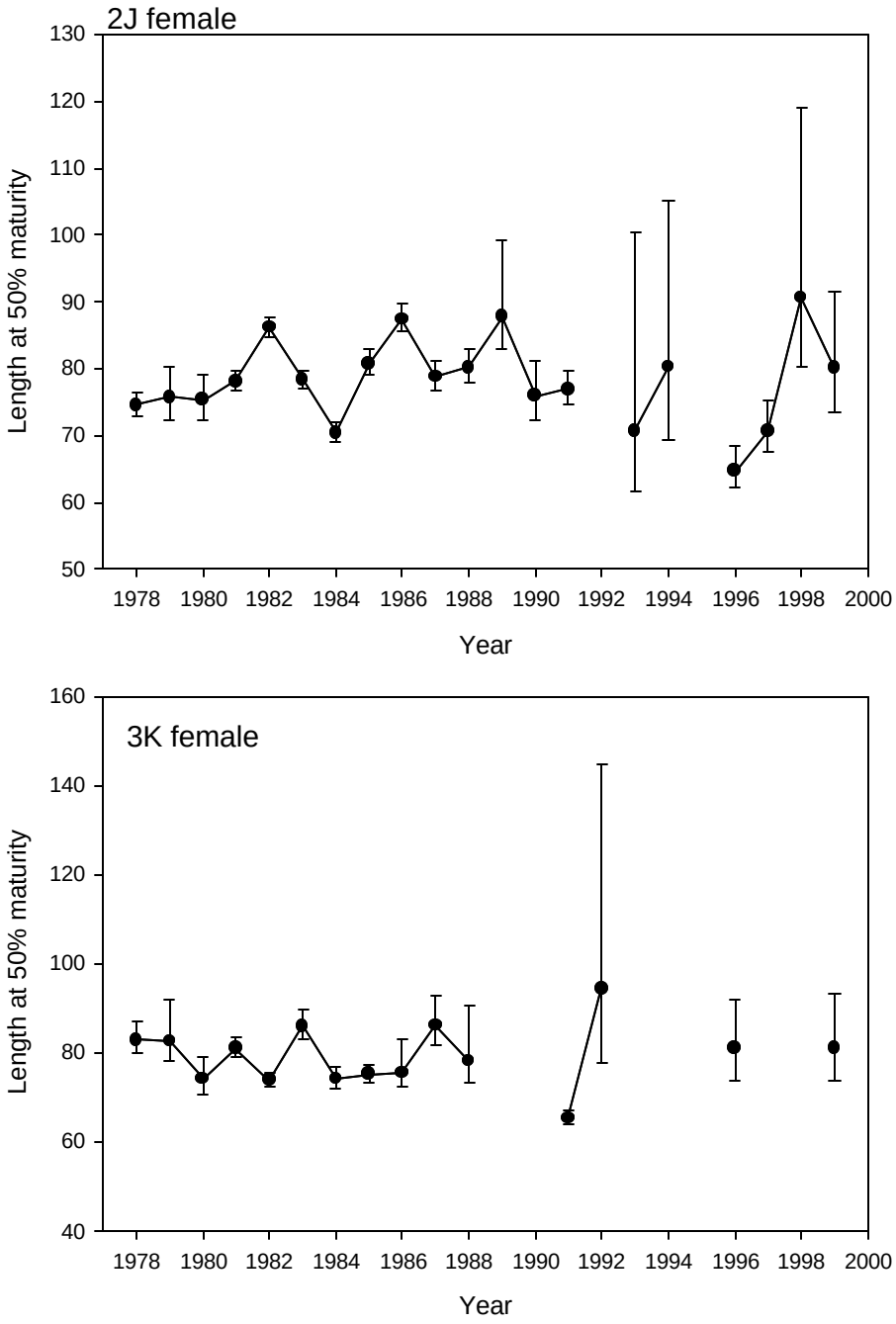


Figure 7. Length at 50% maturity (± 95% fiducial limits) for female Greenland halibut from Canadian fall RV surveys from 1978 to 1999.

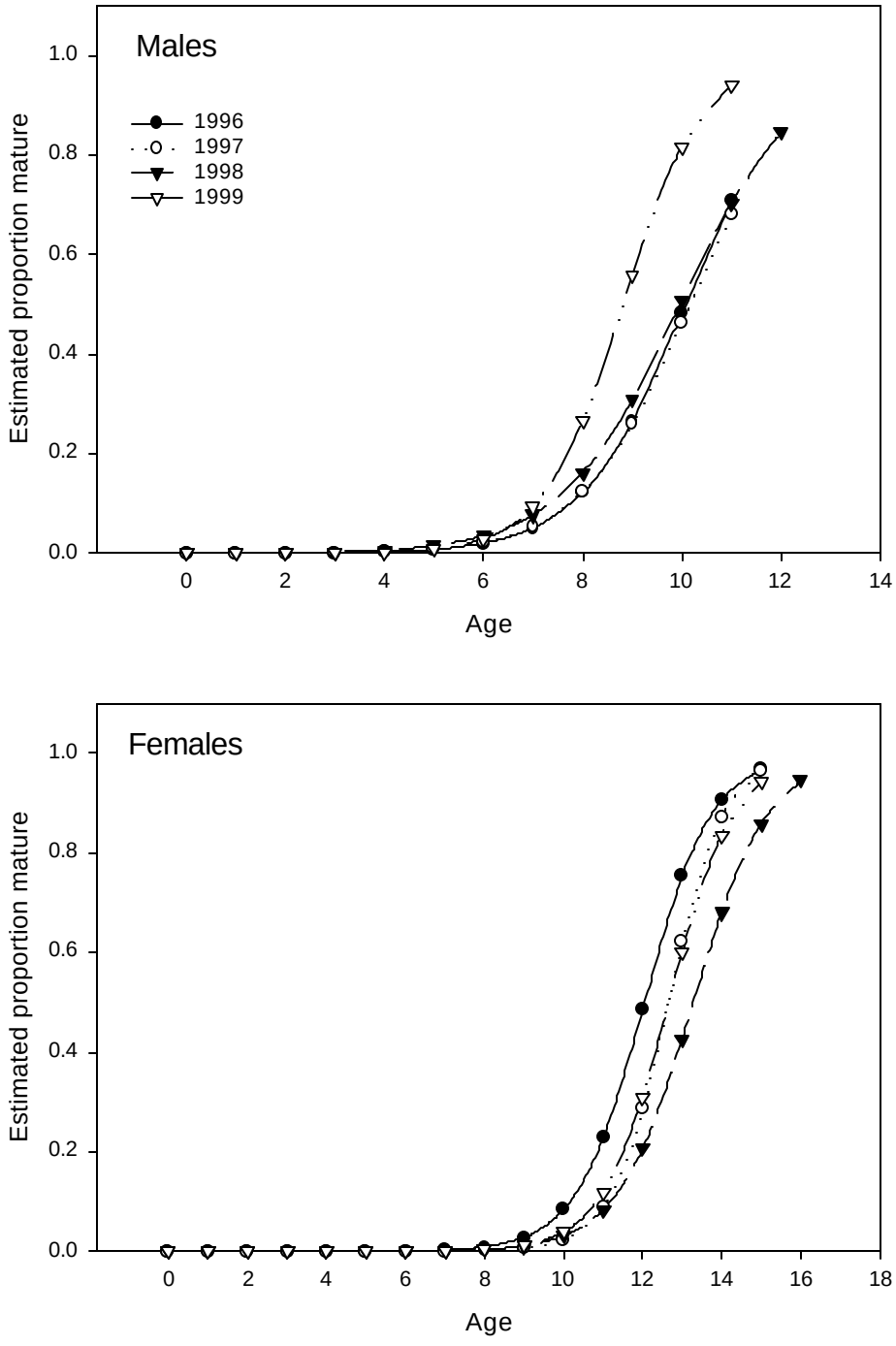


Figure 8. Estimated proportion mature at age from Canadian fall surveys for male and female Greenland halibut from 1996-1999. Only estimates for the range of ages observed in the survey are shown.

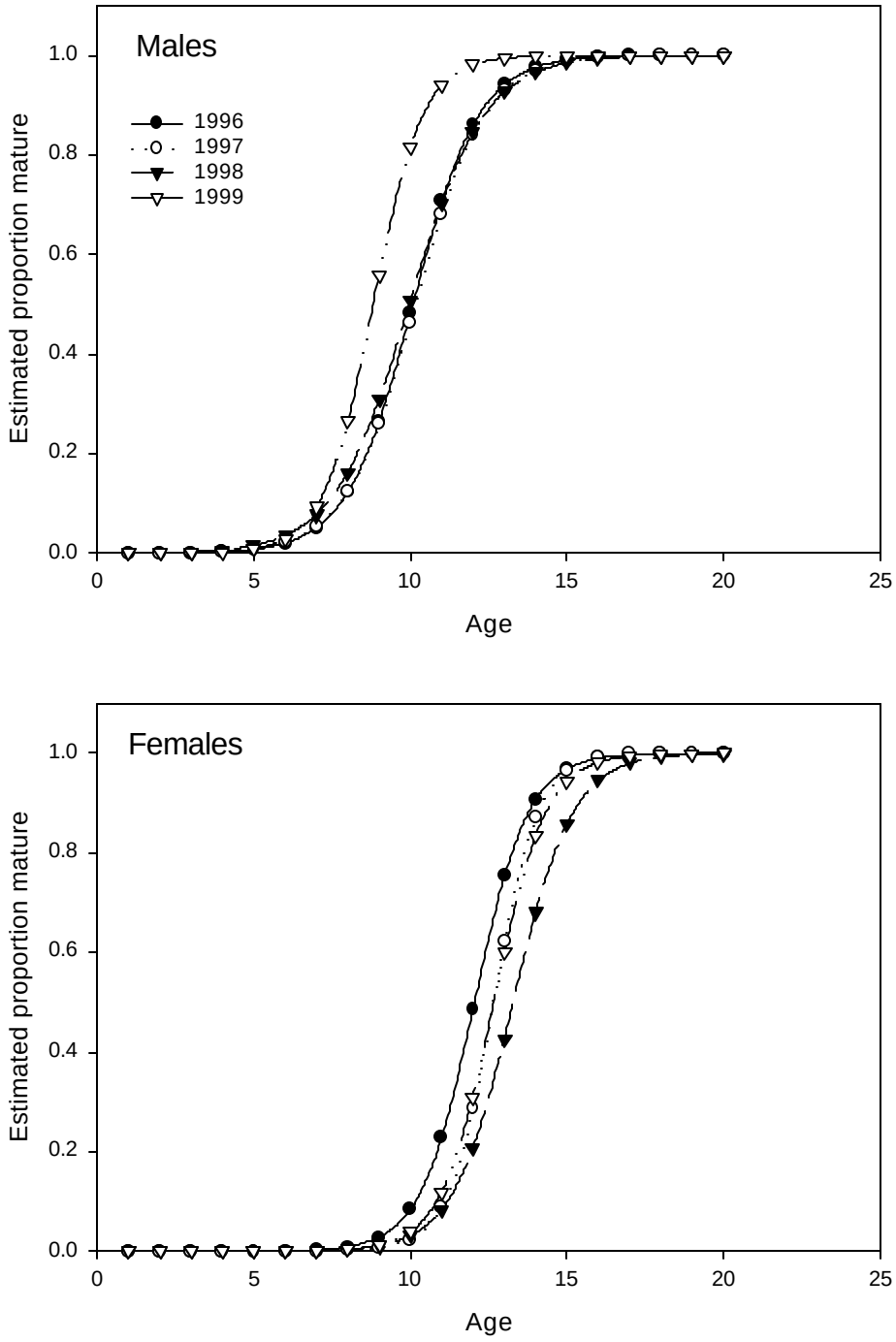


Figure 9. Estimated proportion mature at age from Canadian fall surveys for male and female Greenland halibut from 1996-1999 for ages 1 to 20.