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Maturity at Size and Age of Greenland Halibut in NAFO Subarea 2 and Divisions 3KLM

by

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Abstract

Maturity at size and age of Greenland halibut in NAFO Subarea 2, and Div. 3K, 3L and 3M were investigated using three separate data sources. Data from Canadian fall surveys from 1978 to 1994 in NAFO Divs. 2J and 3K were examined. Data from Canadian deep water surveys in NAFO Divs. 3K, 3L and 3M in 1991, 1994 and 1995 were also analyzed as were data collected from the Canadian deep water gillnet fishery in 1993 and 1994 in Div 0B, 2G, 2H, 3K and 3L. Proportions mature at length showed large spatial and temporal variability from all sources of data. There were no apparent trends in this variability, which may be a result of irregularities in the maturation process and spawning of Greenland halibut and/or variability in the distribution of mature fish.

Introduction

Greenland halibut is widely distributed in the northwest Atlantic ranging from 78°N to Georges Bank in the south. They are believed to spawn mainly in the Davis Strait at about 67°N at depths of 600 to 1000 m (Smidt, 1969) although spawning has been observed elsewhere (Jorgensen and Boje, 1994, Junquera and Zamarro, 1994).

Maturity at length appears generally to increase from south to north (Bowering, 1983). However, there has been much variability observed in the proportion mature at length (Bowering, 1982, Fedorov, 1971, Jorgensen and Boje, 1994, Junquera, 1994, Junquera and Zamarro, 1994). Little work has been done to directly estimate maturity at age.

The purpose of this study was to produce yearly estimates of the proportion of mature fish at length (and where possible at age) in NAFO Subarea 2 and Div. 3KLM.

Methods

Three sources of data were analyzed; Canadian fall research vessel surveys, Canadian deep water surveys, and the Canadian deep water gillnet fishery.

Data from 1978 to 1994 were examined from the Canadian fall stratified random rv surveys in NAFO Div. 2J and 3K. These surveys have generally covered depths of up to 750 m but since 1989 this coverage has been extended to 1000 m. The surveys have been in the last 3 months of the year. Maturity at length for females was determined.

Three deep water surveys have been conducted in the area of NAFO Div. 3KLM by Canada. The first in summer 1991 covered depths of 750 to 1500 m. The surveys in 1994 and 1995 were both conducted in winter months and covered depths from 500 to 1500 m. Maturity

at age and length were examined from these surveys for both males and females.

Sampling of the Canadian deep water gillnet fishery has been carried out in 1993 and 1994. In 1993 sufficient samples were obtained to examine female maturity at length in NAFO Div. 0B, 2G, 2H and 3K. In 1993 there were sufficient samples to examine female maturity at length in NAFO Div. 2G, 3K and 3L.

Maturity ogives at length were constructed in each case using probit analyses assuming a normal distribution. Proportions mature at age were calculated from the deep water surveys according to the method of Morgan and Hoenig (1993) and then analyzed using probit analyses in the same manner as for length. Fish were assigned to maturity stages by visual examination of the gonads according to the scheme of Templeman et al. (1978). In this scheme males are divided into 7 categories; immature (Imm), maturing for the present year (Mat p); partly spent (Psp); spent in the present year (Spp); spent in the present year and maturing for next year (Sppmatn); maturing for next year (Matn) and spent last year maturing for next year (Splmp). Females are divided into 9 categories; immature (Imm); spent last year (Spl); maturing this year with no clear eggs (Matap); maturing for this year with up to 50% clear eggs (Matbp); maturing for this year with more than 50% clear eggs (Matcp); partly spent (Psp); spent in the present year (Spp); spent in the present year and maturing for next year (Spmatn); and maturing for next year (Matan). For purposes of estimating size and age at maturity, the first category is considered to be immature and all other categories are mature or adult fish.

Results

Canadian Fall Surveys

Figure 1 shows yearly maturity ogives for females collected in Div. 2J from 1978 to 1993. No graph is shown for 1992 as the probit model could not be fitted to the data in that year. The shape and position of the ogives are highly variable from year to year. The rate of increase varies greatly and in some years there are no length groups where all the fish are mature. Even greater variability in the estimates of maturity at length can be seen for females in Div. 3K (Figure 2). Many of the ogives are incomplete and there was a non significant fit in 1989 and 1990.

This variability in maturity at length is very evident when the observed proportions are examined (Figures 3 and 4). The proportion of adult fish assigned to any given length group varies greatly from year to year. The jagged nature of the curves comes from the large number of cases where there is a lower proportion of mature fish at large length groups than at smaller ones. In many cases even at very large sizes there are immature fish.

There also appears to be no consistent patterns in the estimated length at 50% maturity (Figure 5). There is much year to year variability in both NAFO Div. 2J and 3K with no consistent trends over time. There is also no consistent relationship between the two divisions, with the estimate for Div. 2J being higher in some years and that of Div. 3K higher in others. In Div. 2J estimates of length at 50% maturity varied from 71 cm to 88 cm. In 3K the estimates ranged from 66 cm to 86 cm.

Tables 1 and 2 give the absolute and percentage frequency of occurrence of the various maturity stages for Div. 2J and 3K. In all years the majority of the sampled fish were immature. The frequency of immature fish among the males was so high that ogives could not be constructed in most cases for that sex. A small number of females in spawning condition were observed in some years (Matcp and Psp). Of the adult fish observed most were maturing for the next spawning season (Spmatn and Matan for females and Sppmatn and Matn for males). This would indicate that spawning does not occur in the fall in this area but likely occurs in the winter/spring.

Canadian Deep Water Surveys

Maturity ogives at length for males and females are presented for the 3 deep water surveys by division in Figure 6. A complete ogive could be estimated for females collected in 1991 in each division as well as for males in Div. 3K. In 1994 however, complete ogives could not be estimated for any division or sex. The estimated proportion mature at length was highest in 1991, lowest in 1994 and intermediate in 1995. The length at 50%

maturity for females ranged from 63.2 cm to 98.9 cm and for males ranged from 51.4 cm to 96.6 cm (Table 3). Figures 7 and 8 show the observed proportion mature at length from these surveys. The curves have a similar jagged appearance and display a similar degree of variability as those from the fall surveys.

Maturity at age was estimated for males and females in each division (Figure 9). These estimates show the same pattern as the estimates of maturity at length with the highest proportion mature at age being in 1991, the lowest in 1994 and 1995 being intermediate. The ages at 50% maturity for females in these surveys ranged from 9.5 to 15.5 and for males ranged from 8.2 to 12.7 (Table 3). The observed proportions mature at age exhibit the irregularity and variability shown by the proportions mature at length (Figure 10 and 11).

Table 4 shows the occurrence of the various maturity stages in the surveys. As with the fall surveys, most fish were immature. In 1991 however, there is a much smaller percentage of immature fish, especially females, than in the other years. In 1991, the fish that were adults were mainly spent in the present year or maturing for the next spawning season.

Canadian Deep Water Gillnet Fishery

Ogives of estimated proportion mature at length for females showed a progression from south to north in 1993 with fish maturing at a smaller size in the north (Figure 12). Length at 50% maturity was 85.7 cm in Div. 3K, 77.2 cm in Div. 2H, 75.2 cm in Div. 2G and in 69.4 cm Div. 0B. In 1994, fish in Div. 3L appeared to mature the earliest and fish in Div. 2G the latest (Figure 12). The length at 50% maturity was 66.3 cm in Div. 3L, 66.9 cm in Div. 3K and 70.0 cm in Div. 2G. When the results for the same divisions in the two years are plotted on the same graph the difference between the years is evident (Figure 13). In both Div. 2G and 3K the fish appear to have matured at a smaller size in 1994 compared to 1993, with the difference being more pronounced in Div. 3K.

Discussion

Propotions mature at size and age from the data examined showed variability in Greenland halibut, regardless of the depth or season sampled. Variability in maturity of Greenland halibut has been observed previously. The occurrence of large fish that are not mature is not unusual (Bowering, 1982, Fedorov, 1971, Jorgensen and Boje, 1994, Junquera and Zamarro, 1994). Both Federov (1971) and Junquerra and Zamarro (1994) found some indication that Greenland halibut may have a main and secondary spawning period during some years and Fedorov (1971) found that Greenland halibut may skip spawning seasons.

Difficulties in determining the correct stage of maturity from visual inspection of the gonads may add to the variability. Walsh and Bowering (1981) found discrepencies between visual and histological determinations of stage of maturity. They found that the estimated length at 50% maturity tended to be lower from visual than from histological inspection of the gonads.

Greenland halibut are thought to undertake spawning migrations (Bowering 1983). If there is either spatial or temporal variability in these migrations then different proportions of adult fish could be in the study area at different times. When many adult fish are in the area it will appear as if a greater proportion of fish were mature at certain length/age groups. This hypothesis remains to be tested.

Despite the large amount of variablity in maturity, estimates of length at 50% maturity have often been remarkably similar from different studies. Bowering (1983) estimated the length at 50% maturity for the northeast Newfoundland shelf to be 79.6 cm, while the average for that area in this study was 78.6 cm. However, in this study estimates for this area ranged from 66 cm to 88 cm. Given the large spatial and temporal variability it may not be appropriate to take an estimate from a single Division or year as representative of the population in that area. Rather, it may be more appropriate to combine data over several years and perhaps several (all) NAFO Divisions to produce representative estimates of maturity at age and size. Unfortunately, this will make the detection of any trends more difficult.

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Table 1. Frequency of various maturity stages of Greenland halibut in Canadian fall surveys in NAFO Division 2J.

FEMALES

	Imm		Spl		Matap		Matbp		Matcp		Psp		Spp		Spmatn		Matan	
Year	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1978	596	86	0	0	1	0.1	0	0	17	2.4	0	0	11	1.6	31	4.5	37	5.3
1979	904	97.2	0	0	0	0	0	0	0	0	0	0	0	0	6	0.6	20	2.2
1980	1063	95.2	0	0	0	0	0	0	3	0.3	0	0	0	0	2	0.2	48	4.3
1981	2225	92	0	0	0	0	0	0	16	0.7	1	0.04	0	0	78	3.2	98	4
1982	4343	96.7	0	0	0	0	4	0.09	12	0.3	1	0.02	0	0	5	0.1	128	2.8
1983	2432	91.5	0	0	2	0.08	0	0	0	0	0	0	0	0	23	0.9	202	7.6
1984	528	73.7	0	0	0	0	0	0	0	0	0	0	2	0.3	0	0	186	26
1985	652	85.4	0	0	0	0	0	0	0	0	0	0	1	0.1	0	0	110	14.4
1986	696	91	0	0	0	0	0	0	0	0	0	0	1	0.1	0	68	8.9	
1987	626	88.8	0	0	0	0	0	0	0	0	0	0	2	0.3	7	1	70	9.9
1988	538	90.3	0	0	0	0	1	0.2	0	0	0	0	13	2.2	0	0	44	7.4
1989	361	98.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1.4
1990	299	90.3	0	0	0	0	1	0.3	0	0	0	0	5	1.5	2	0.6	24	7.2
1991	269	99.3	0	0	0	0	0	0	0	0	0	0	1	0.4	0	0	1	0.4
1992	1529	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	1833	99.8	0	0	0	0	0	0	0	0	0	0	1	0.05	0	0	3	0.2
1994	2428	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MALES

	Imm		Splmp		Matp		Psp		Spp		Sppmatn		Matn	
Year	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1978	396	81.5	26	5.3	0	0	0	0	57	11.7	0	0	7	1.4
1979	710	80.8	0	0	0	0	0	0	0	0	0	0	169	19.2
1980	934	93.1	0	0	0	0	0	0	0	0	1	0.1	68	6.8
1981	1944	97.4	0	0	0	0	0	0	0	0	1	0.1	51	2.6
1982	3841	95.6	0	0	0	0	0	0	0	0	2	0.05	174	4.3
1983	2236	94	0	0	0	0	0	0	0	0	7	0.3	135	5.7
1984	416	93.3	0	0	0	0	0	0	0	0	2	0.4	28	6.3
1985	499	92.9	0	0	0	0	0	0	1	0.2	2	0.4	35	6.5
1986	417	91.6	0	0	0	0	0	0	0	0	2	0.4	36	7.9
1987	464	91.7	0	0	0	0	0	0	1	0.2	8	1.6	33	6.5
1988	427	92.2	0	0	0	0	0	0	0	0	1	0.2	35	7.6
1989	294	97.4	0	0	0	0	0	0	0	0	0	0	8	2.6
1990	230	93.9	0	0	0	0	0	0	0	0	0	0	15	6.1
1991	241	99.2	0	0	0	0	0	0	0	0	0	0	2	0.8
1992	1553	99.9	0	0	0	0	0	0	0	0	0	0	2	0.1
1993	1924	99.1	0	0	0	0	0	0	0	0	0	0	17	0.9
1994	2661	99.8	0	0	0	0	0	0	0	0	0	0	5	0.2

Table 2. Frequency of various maturity stages of Greenland halibut in Canadian fall surveys in NAFO Division 3K.

FEMALES

	Imm		Spl		Matap		Matbp		Matcp		Psp		Spp		Spmatn		Matan	
Year	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1978	892	95.4	1	0.1	1	0.1	0	0	1	0.1	0	0	24	2.6	2	0.2	14	1.5
1979	1057	99.5	0	0	0	0	0	0	0	0	0	0	0	0	4	0.4	1	0.1
1980	1652	96.7	0	0	0	0	0	0	2	0.1	0	0	0	0	0	0	54	3.2
1981	3258	94	0	0	0	0	0	0	0	0	0	0	0	0	23	0.7	46	1.3
1982	3575	98	0	0	0	0	0	0	4	0.1	0	0	0	0	15	0.4	55	1.5
1983	4407	99.2	0	0	1	0.02	0	0	0	0	0	0	0	0	12	0.3	20	0.4
1984	662	85.4	0	0	0	0	0	0	8	1	0	0	86	11.1	3	0.4	16	2.1
1985	729	88.4	0	0	0	0	0	0	12	1.4	0	0	80	9.7	0	0	4	0.5
1986	576	98.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1.4
1987	645	97.7	0	0	1	0.2	0	0	0	0	0	0	12	1.8	0	0	2	0.3
1988	556	99.1	0	0	0	0	0	0	0	0	0	0	2	0.4	0	0	3	0.5
1989	284	99.6	0	0	0	0	0	0	0	0	0	0	1	0.4	0	0	0	0
1990	296	99	0	0	0	0	0	0	0	0	0	0	1	0.3	0	0	2	0.7
1991	292	98	0	0	0	0	0	0	0	0	0	0	6	2	0	0	0	0
1992	2930	99.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.1
1993	5446	99.9	0	0	0	0	0	0	0	0	0	0	4	0.1	0	0	0	0
1994	4593	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MALES

	Imm		Splmp		Matp		Psp		Spp		Sppmatn		Matn	
Year	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1978	624	90.8	10	1.4	0	0	0	0	37	5.4	2	0.3	14	2
1979	562	68.6	0	0	0	0	0	0	0	0	0	0	257	31.4
1980	1548	97.3	0	0	0	0	0	0	0	0	4	0.2	39	2.4
1981	535	98.9	0	0	0	0	0	0	0	0	0	0	6	1.1
1982	3244	99.6	0	0	0	0	0	0	0	0	0	0	12	0.4
1983	3909	99.4	0	0	0	0	0	0	0	0	0	0	22	0.6
1984	546	96.1	0	0	1	0.2	0	0	15	2.6	1	0.2	5	0.9
1985	625	98.6	0	0	0	0	0	0	1	0.2	0	0	8	1.3
1986	527	99.4	0	0	0	0	0	0	0	0	0	0	3	0.6
1987	528	99.1	0	0	0	0	0	0	0	0	0	0	5	0.9
1988	492	99.8	0	0	0	0	0	0	0	0	0	0	1	0.2
1989	247	99.2	0	0	0	0	0	0	0	0	0	0	2	0.8
1990	213	99.1	0	0	0	0	0	0	0	0	0	0	2	0.9
1991	265	99.6	0	0	0	0	0	0	0	0	0	0	1	0.4
1992	2516	99.9	0	0	0	0	0	0	0	0	0	0	2	0.1
1993	5406	99.9	0	0	0	0	0	0	0	0	1	0.02	2	0.04
1994	3886	99.9	1	0.02	0	0	0	0	0	0	0	0	0	0

Table 3. Length and age at 50% maturity of Greenland halibut in NAFO Divs. 3K, 3L and 3M as estimated from data collected during Canadian deep water surveys. Dashes indicate instances when the model could not estimate an age or length at 50% maturity.

		Male		Female	
Year	Div.	Length	Age	Length	Age
1991	3K	51.4	8.2	64.0	10.0
	3L	62.1	9.5	63.2	9.7
	3M	62.1	9.6	60.8	9.5
1994	3K	-	-	90.4	15.0
	3L	92.9	12.7	98.9	15.5
	3M	83.5	10.4	95.5	14.2
1995	3K	63.9	9.9	77.8	12.6
	3L	84.8	10.0	74.3	12.3
	3M	-	-	76.6	12.5

Table 4. Frequency of various maturity stages of Greenland halibut in Canadian deep water surveys in NAFO Division 3KLM.

FEMALES

Div/Year	Imm		Spf		Matap		Matbp		Matcp		Psp		Spp		Spmatn		Matan	
3K	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1991	750	67.5	1	0.1	0	0	0	0	0	0	1	0.1	265	23.8	50	4.5	44	4
1994	474	99.8	1	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	5474	99.4	7	0.1	7	0.1	0	0	0	0	0	0	1	0.02	0	0	16	0.3
3L																		
1991	641	71.1	0	0	0	0	1	0.1	0	0	0	0	99	11	134	14.8	27	3
1994	1535	99.8	3	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	2292	97.7	21	0.9	33	1.4	0	0	0	0	0	0	0	0	0	0	0	0
3M																		
1991	684	64.2	0	0	0	0	0	0	0	0	11	1	193	18.1	162	15.2	15	1.4
1994	559	99.5	2	0.4	1	0.2	0	0	0	0	0	0	0	0	0	0	0	0
1995	795	93.9	16	1.9	36	4.2	0	0	0	0	0	0	0	0	0	0	0	0

MALES

Div/Year	Imm		Splmp		Matp		Psp		Spp		Sppmatn		Matn	
3K	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1991	514	55.3	0	0	2	0.2	0	0	288	31	118	12.7	7	0.8
1994	570	100	0	0	0	0	0	0	0	0	0	0	0	0
1995	5450	99.7	0	0	12	0.2	0	0	2	0.04	0	0	2	0.04
3L														
1991	397	90	0	0	0	0	1	0.2	14	3.2	21	4.8	8	1.8
1994	1202	99.9	0	0	1	0.1	0	0	0	0	0	0	0	0
1995	1998	99.8	2	0.1	2	0.1	1	0.05	0	0	0	0	0	0
3M														
1991	412	91.6	0	0	0	0	0	0	20	4.4	7	1.6	11	2.4
1994	328	99.4	1	0.3	1	0.3	0	0	0	0	0	0	0	0
1995	432	99.5	0	0	2	0.5	0	0	0	0	0	0	0	0

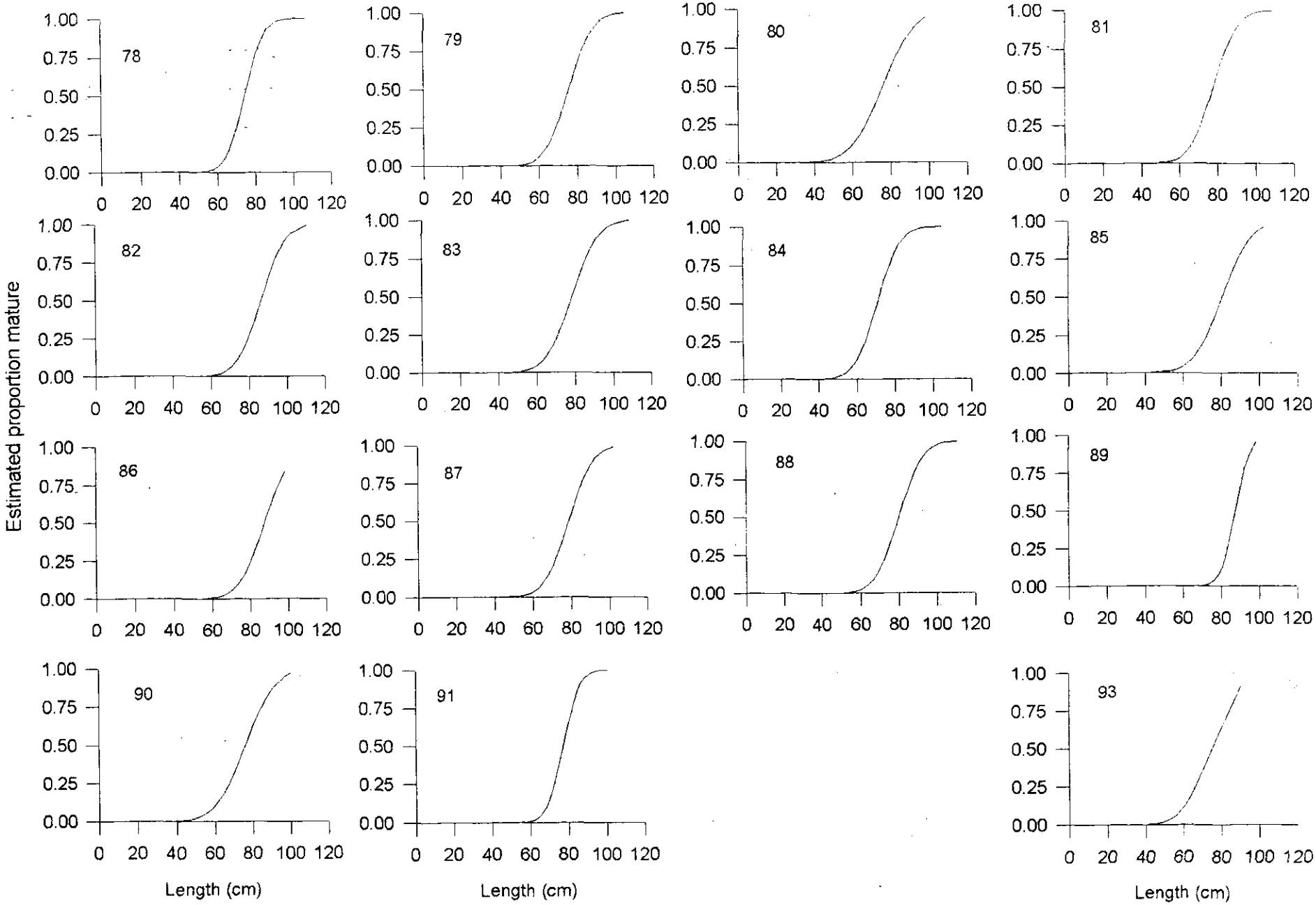


Figure 1. Estimated proportion mature at length for female Greenland halibut in NAFO Div. 2J collected during Canadian fall surveys from 1978 to 1994. The model did not fit the data in years that are missing.

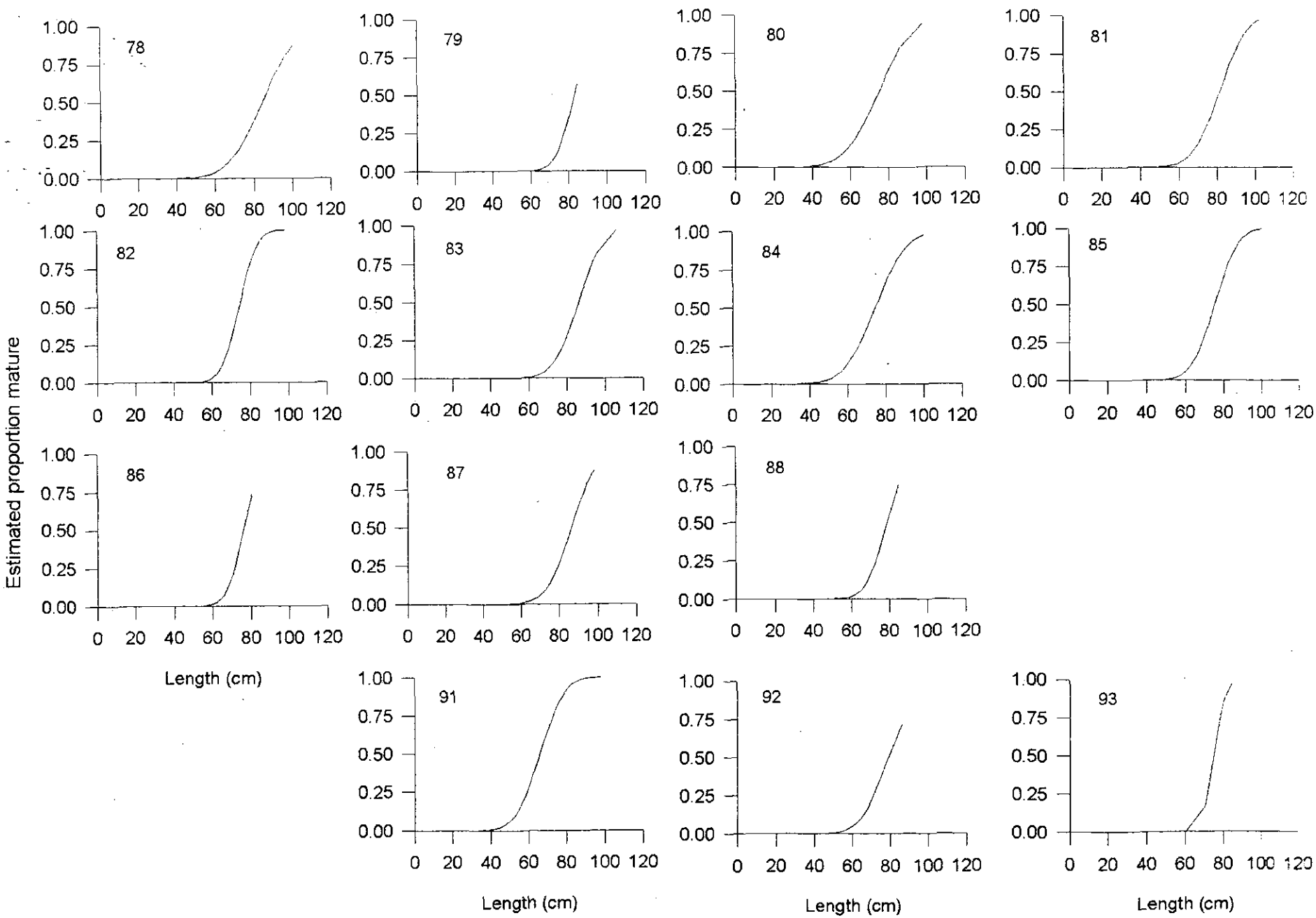


Figure 2. Estimated proportion mature at length for female Greenland halibut in NAFO Div. 3K collected during Canadian fall surveys from 1978 to 1993. The model did not fit the data in those years that are missing.

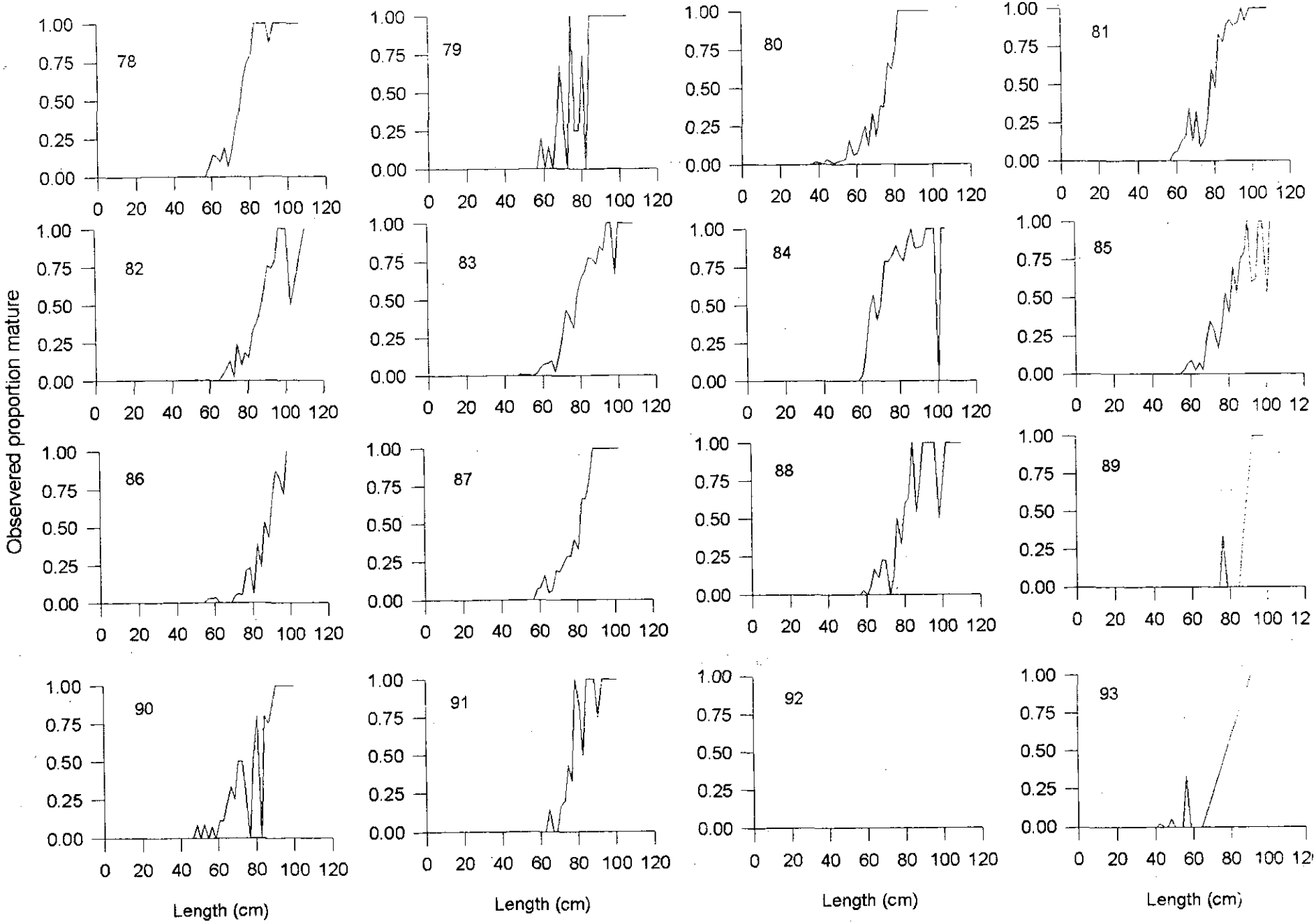


Figure 3. Observed proportion mature at length for female Greenland halibut in NAFO Div. 2J collected during Canadian fall surveys from 1978 to 1993.

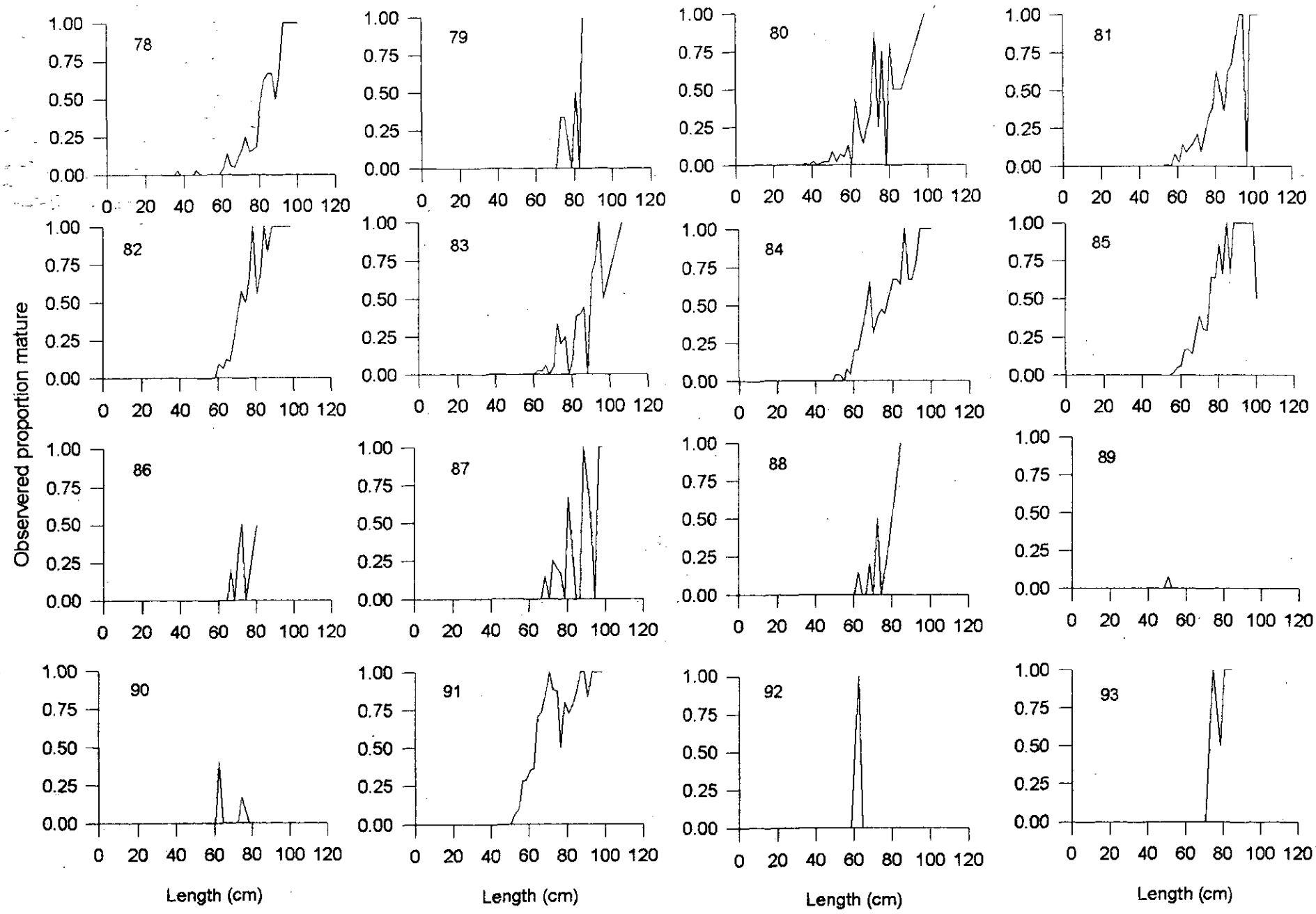


Figure 4. Observed proportion mature at length for female Greenland halibut in NAFO Div. 3K collected during Canadian fall surveys from 1978 to 1993.

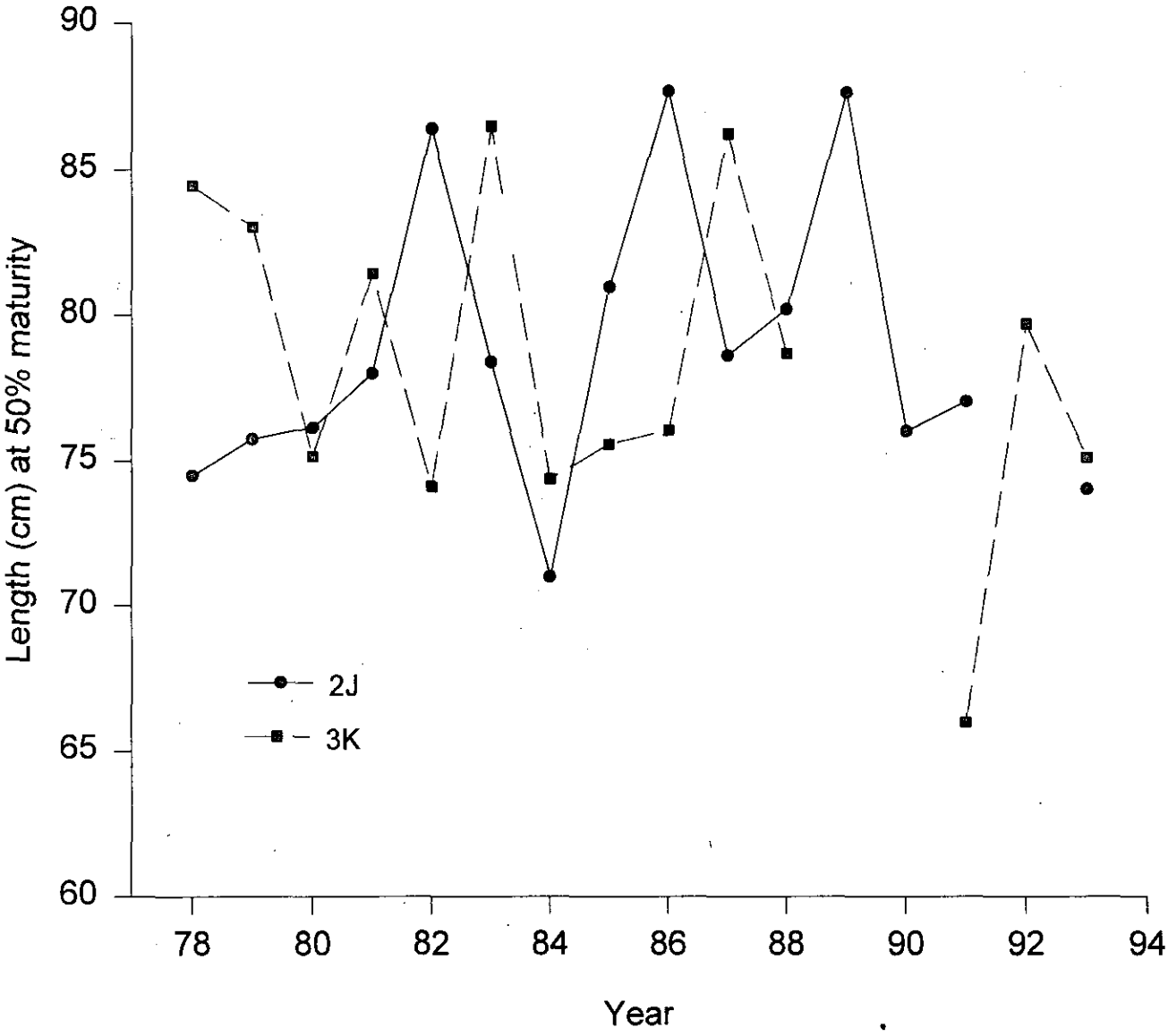


Figure 5. Length (cm) at 50% maturity for female Greenland halibut in NAFO Div. 2J and 3K as estimated from data collected during Canadian fall surveys.

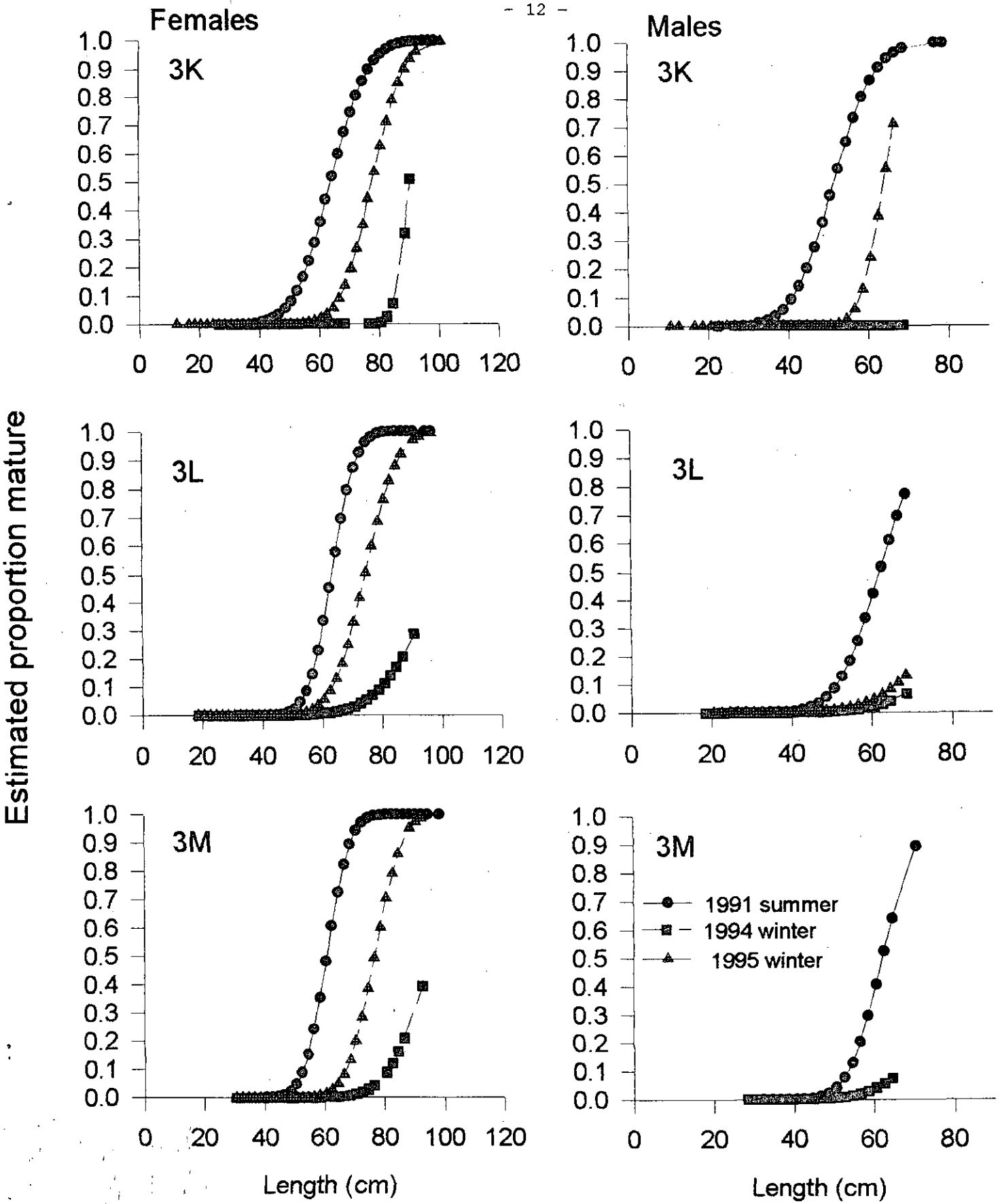


Figure 6. Estimated proportion mature at length for male and female Greenland halibut in NAFO Div. 3K, 3L and 3M collected during Canadian deep water surveys.

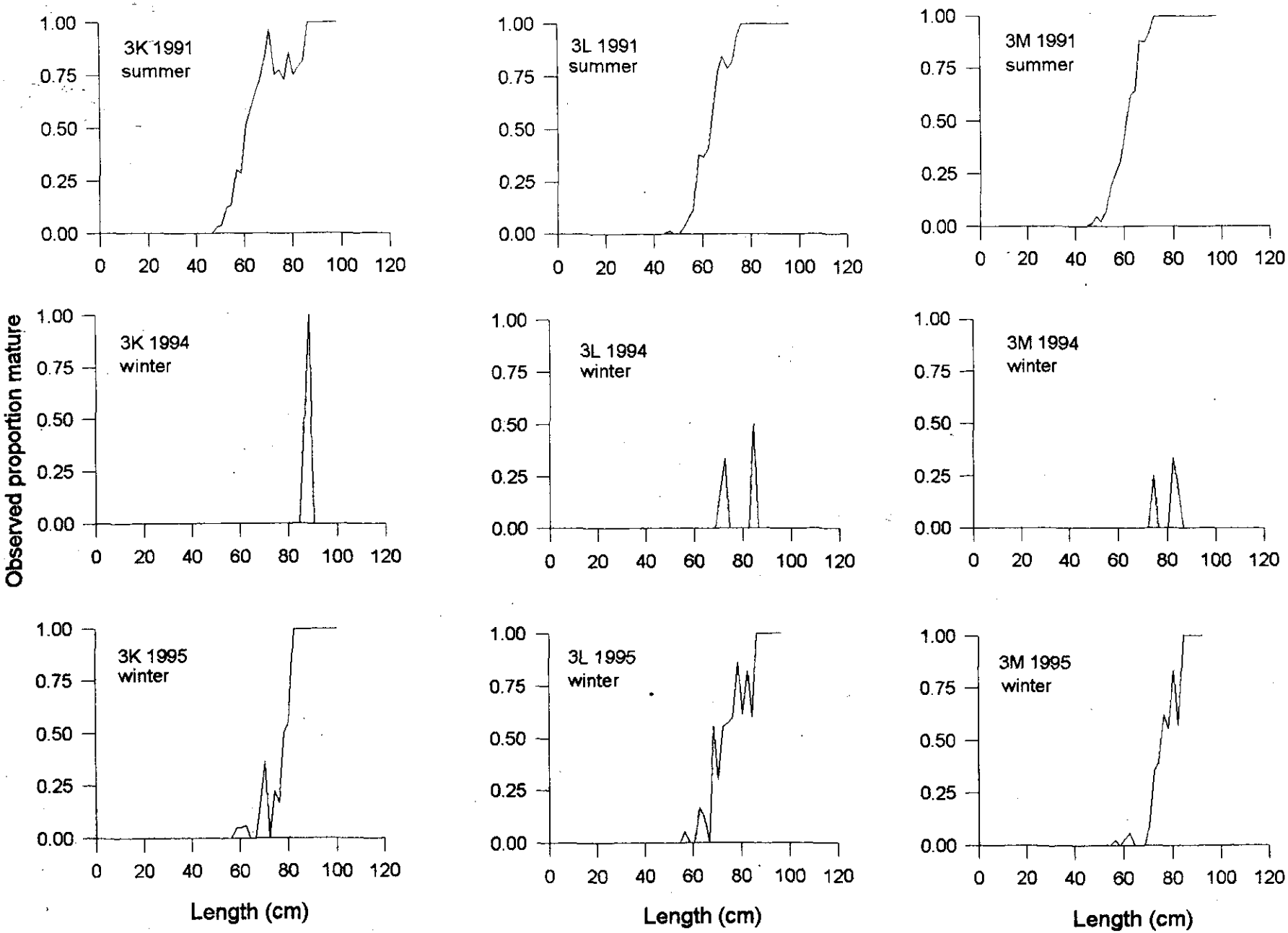


Figure 7. Observed proportion of mature female Greenland halibut at length in Canadian deep water surveys.

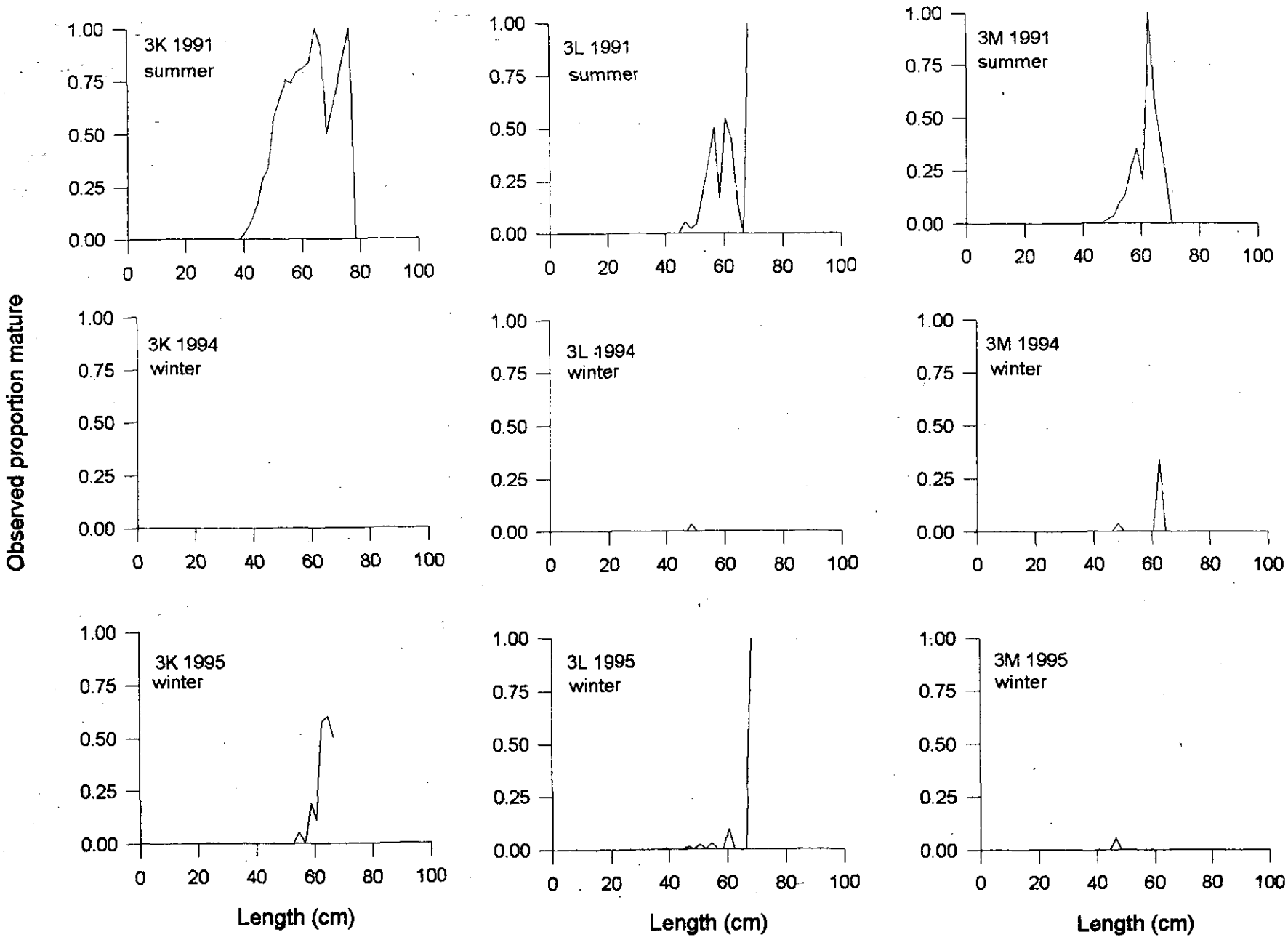


Figure 8. Observed proportion of mature male Greenland halibut at length in Canadian deep water surveys.

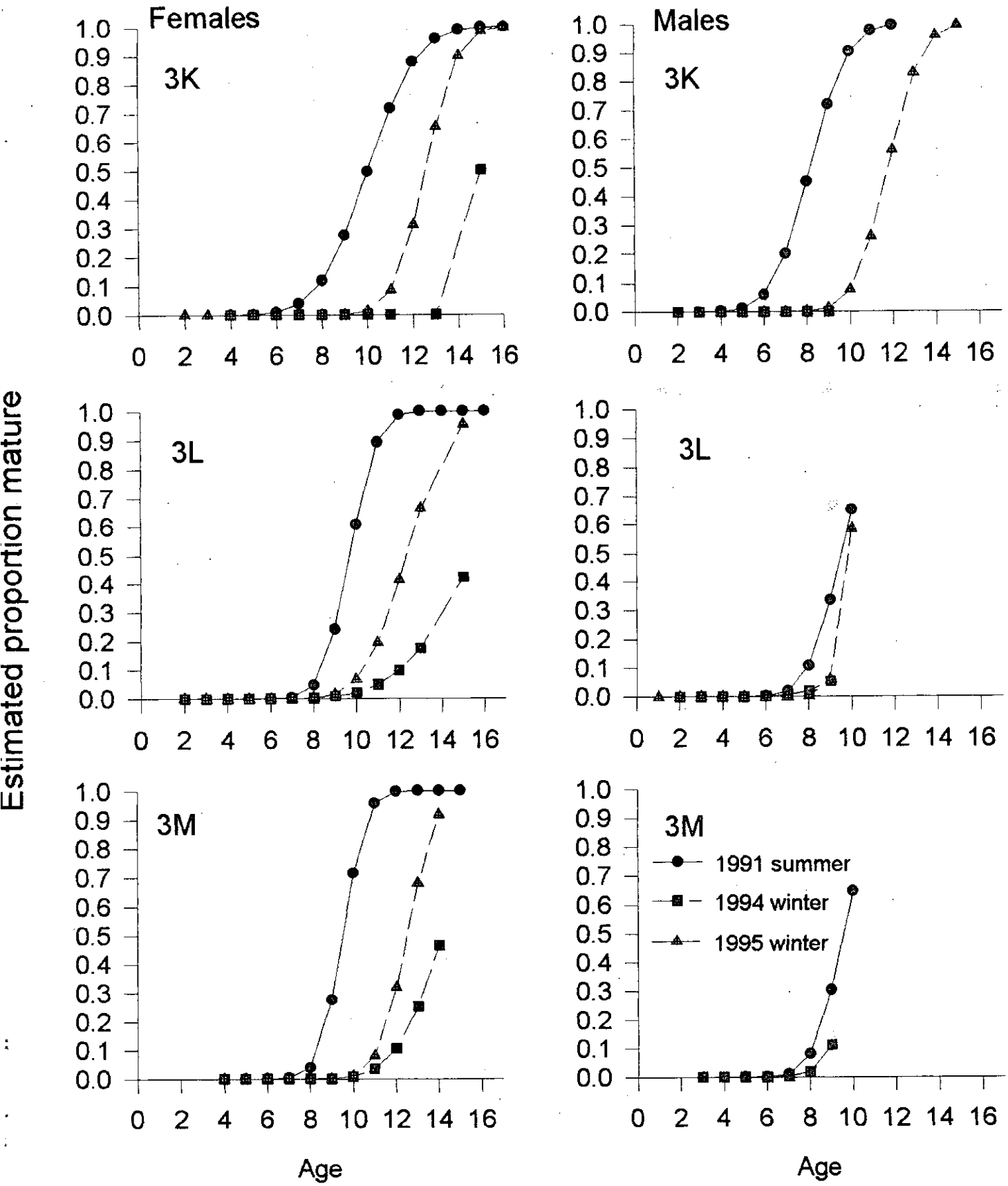


Figure 9. Estimated proportion mature at age for male and female Greenland halibut in NAFO Divs. 3K, 3L, and 3M collected during Canadian deep water surveys.

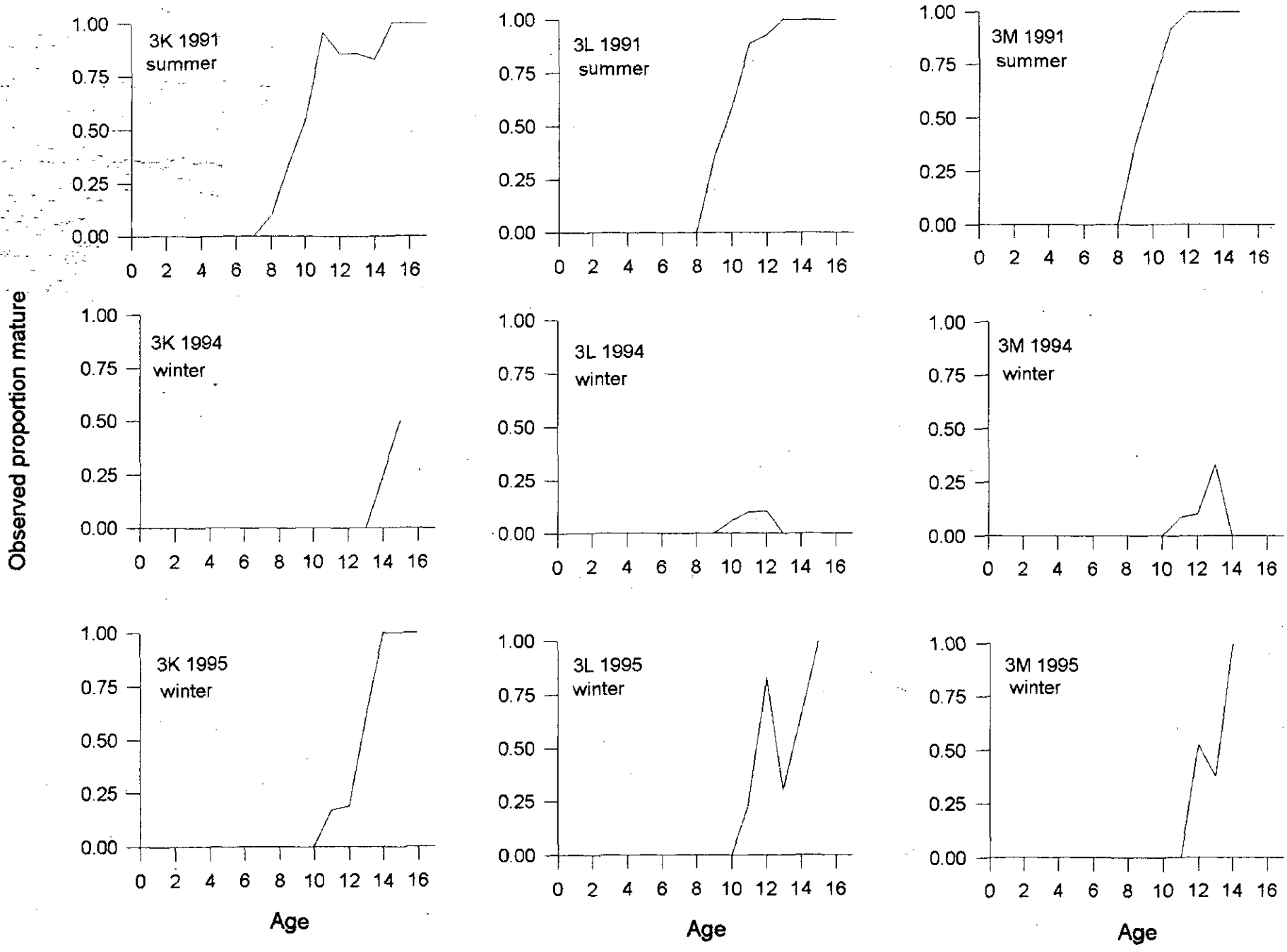


Figure 10. Observed proportion of mature female Greenland halibut at age in Canadian deep water surveys.

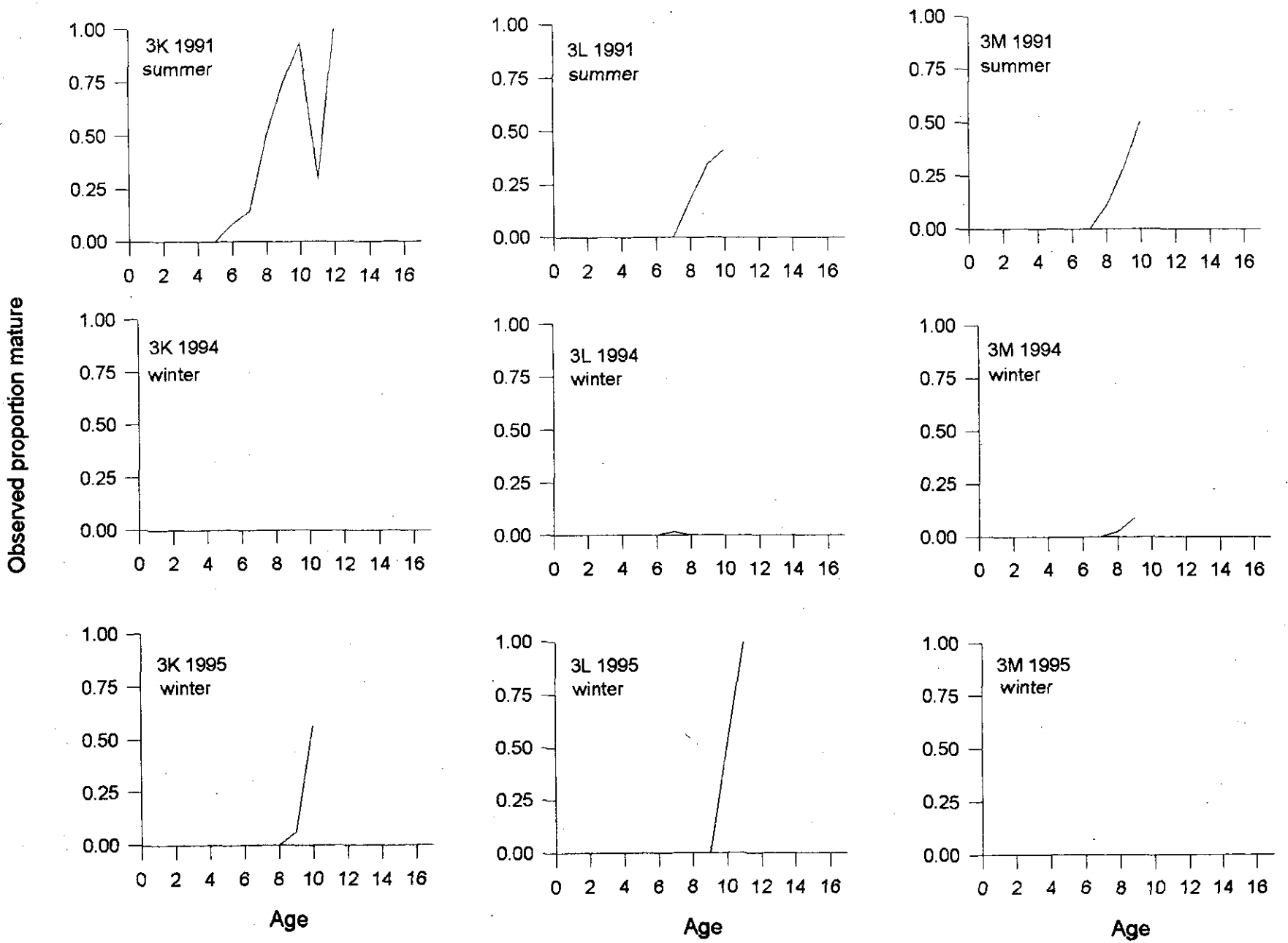
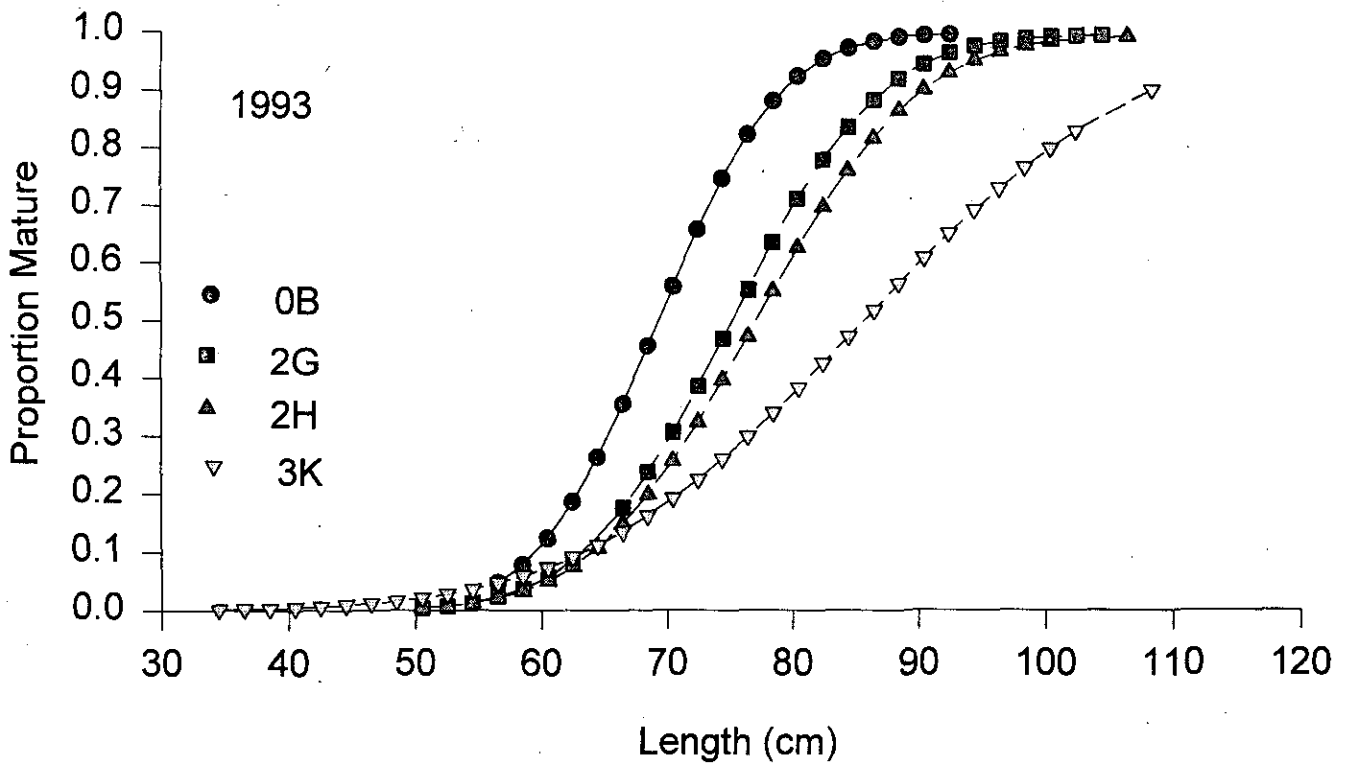


Figure 11. Observed proportion of mature male Greenland halibut at age in Canadian deep water surveys.



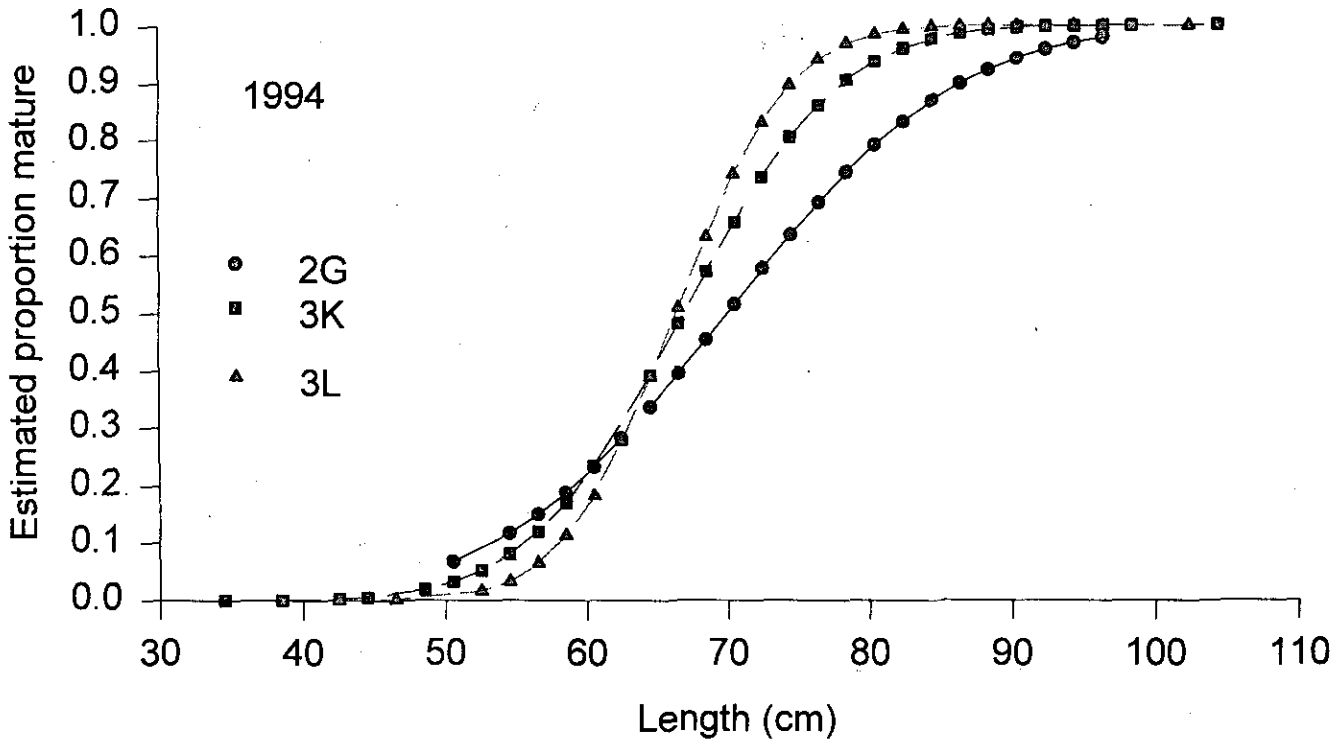


Figure 12. Estimated proportion mature at length for female Greenland halibut sample from the Canadian deep water gillnet fishery at the continental slope in 1993 and 199

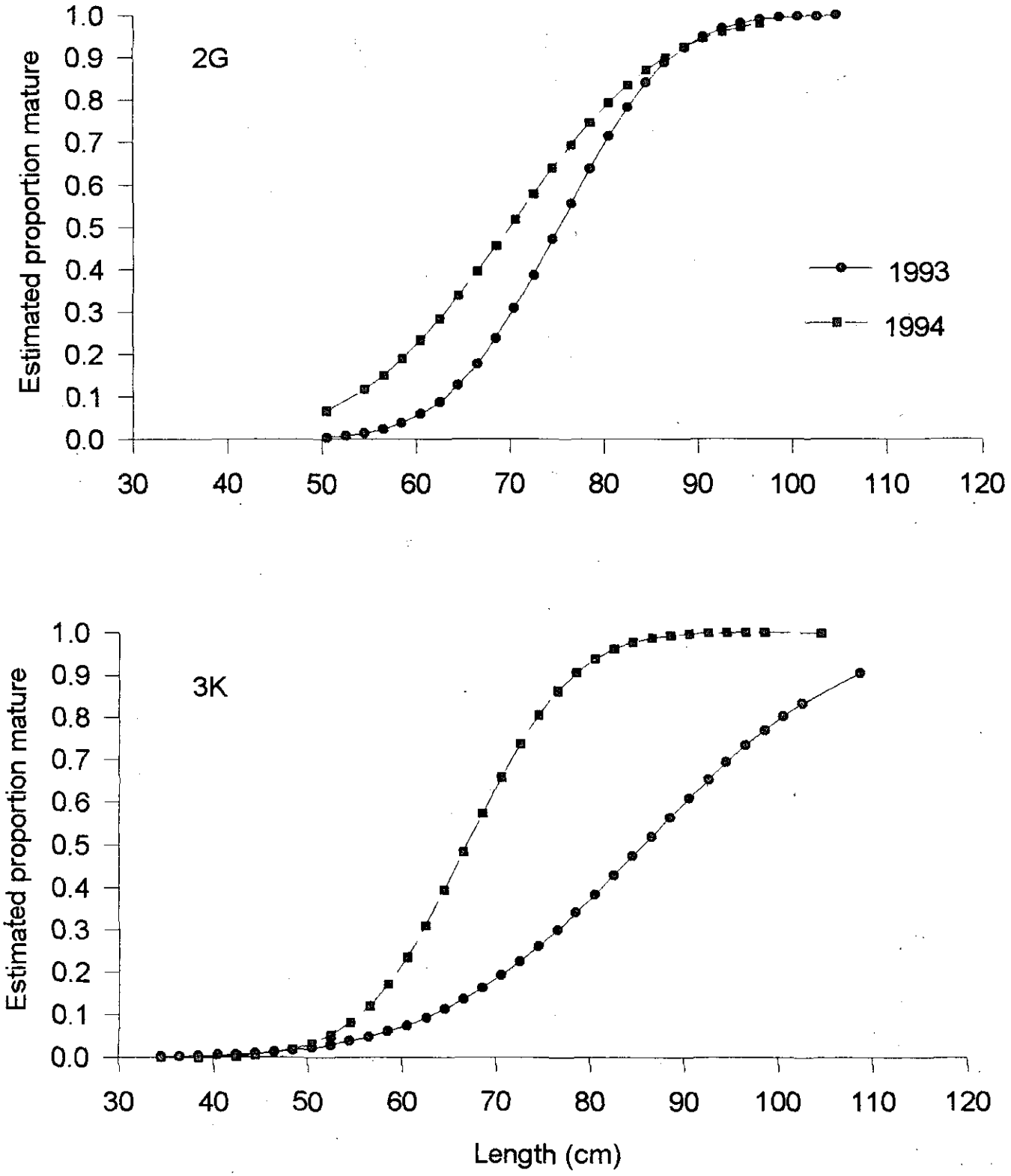


Figure 13. Estimated proportion mature for female Greenland halibut sampled from the Canadian deep water gillnet fishery at the continental slope in NAFO Div. 2G and 3K in 1993 and 1994.