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The Females Ratio by Length as an Indicator of Sexual Differences in Mortality of Greenland Halibut (*Reinhardtius hippoglossoides*) at Ages 8+

by

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Abstract

This paper analyses the females ratio by length for the period 1992-94 in the Greenland halibut fishery in the NAFO Regulatory Area. Females ratio by length is very consistent in the three year period, increasing dramatically from approximately 50 cm upwards until reaching over 95% at 70 cm. In order to explain this phenomenon growth and mortality by sex were analysed using data from 1993. The main conclusion is that mortality is the factor with the greatest influence on it. Using catch curves, a difference of 0.9 in Z between males and females of fully recruited ages was found. This difference is thought to be due to M. Other conclusions are that females grow slightly faster than males of over 7 years of age, and that age 7 appears to be fully recruited to the fishery.

1.- Introduction.

Since 1990 Spain has been developing a deep water fishery in the NAFO (Northwest Atlantic Fisheries Organisation) Regulatory Area. The fleet started operating in the northern area of Flemish Pass, but has gradually extended the area of its activities and now fishes in practically the whole of the slope of the Regulatory Area at between 800 and 1800 m depth (*Fig. 1*).

The target species of this fishery is Greenland halibut. From the beginning of the fishery until February 1995 one third of the Spanish vessels have been working with scientific observers on board. This has made it possible to carry out massive samplings and data collection from this new deep water fishery.

In the early days of the fishery it was observed that the proportion of females tended to increase with length, and that larger specimens were all females (Junquera *et al.*, 1992).

The fact that females reach slightly greater lengths than males is not a strange phenomenon in flatfish. Considering only the species of the Pleuronectidae family from the Northwest Atlantic, Scott & Scott (1988) affirm that females grow faster than males from first maturity in the following species: Atlantic halibut (*Hippoglossus hippoglossus*) and yellowtail flounder (*Limanda ferruginea*), and in addition to growing faster than males, females have greater longevity in witch flounder (*Glyptocephalus cynoglossus*), American plaice (*Hippoglossoides platessoides*) and Greenland halibut (*Reinhardtius hippoglossoides*).

The aim of this paper is to analyse which of the two factors, growth or mortality, has the greatest influence in the observed trend in the females ratio by length.

2.- Material and Methods.

The females ratio by 1 cm length group was made smoother through the use of a three point moving average, and was represented against length for the years 1992, 1993 and 1994, covering the range from 28 to 110 cm. Data for the elaboration of these curves were collected on board ship by a team of scientific observers who, from the beginning of this fishery to February 1995, sampled catches from one third of the Spanish vessels. The number of specimens used in the calculation of these frequencies was 263 764 in 1992, 96 599 in 1993, and 103 739 in 1994. Sampling covered every month of the year and every division in which the Spanish commercial fleet worked during this period. The curves obtained for the three years were compared with one another through a Chi -squared test, after arranging data in 5 cm groups. The habitual level of significance of 95% was chosen.

To compare our results with those from other areas a general sex ratio of the catch was also calculated by dividing the total number of males in the catch by the total number of females.

Once the general pattern of increasing females ratios with length had been observed, the data of 1993, the only year for which age-length keys by sex were available, were used to analyse the reasons for this behaviour, which has two possible explanations: sexual differences in growth, or sexual differences in the mortality rate, including both natural mortality and possible sexual differences in catchabylity; or a combination of all these phenomena.

Firstly, average lengths by age and sex were calculated from the length-age keys for Division 3L, supplied by R. Bowering (D.F.O. P.O. Box 5667 St. John's, Newfoundland, Canada), as was the length distribution of the Spanish catch of that year. The age-length keys cover the second to the fourth quarters and are made up from a total of 144 male otoliths with a length range of 34-70 cm, and 509 female otoliths covering a length range of 34-96 cm. The length distribution of the Spanish catch was obtained from stratified sampling of 295 776 specimens measured by the on board observers before the discard. Sampling covered the two components of the fleet (small and large freezers), the different months of the year and the divisions in which these fleets work. This length distribution is a good representation of the activity in the off-shore fishery, which in 1993 accounted for over 92% of the total catches estimated for Subareas 2 and 3 (Bowering *et al.*, 1994).

The hypothesis of a different mortality rate (Z) for each sex was explored by using catch curves by sex, created from the previously mentioned length distribution of the Spanish fleet for 1993, to which a sex ratio by length for that year was applied before making up the length age keys by sex. The fit of the regression lines by sex was carried out by the least squares method, using only the ages fully recruited to fishery, as indicated by Z in the two sexes (8+).

3.- Results.

The females ratios by lengths showed statistically significant differences among the different years for the length range of 35-65 cm, although the maximum difference found (group 55-59) did not reach 10% at any point (*Table 1*).

In the years studied, more than 60% of the catch in number was made up of females. The females ratio by length is 52% at around 30 cm and tends to increase gradually with length until reaching 60% at about 50 cm. From this length a much stronger increase takes place up to 70 cm, at which point the females ratio is already over 95% females. All specimens greater than 80 cm may be considered to be females (*Table 2, Fig. 2*).

Length	1992	1993	1994	
25 - 29	0,56	0,52	0,50	
30 - 34	0,52	0,51	0,54	
35 - 39	0,53	0,56	0,56	*
40 - 44	0,55	0,60	0,58	*
45 - 49	0,59	0,60	0,59	
50 - 54	0,66	0,64	0,63	*
55 - 59	0,75	0,72	0,68	*
60 - 64	0,85	0,83	0,79	*
65 - 69	0,93	0,94	0,90	
70 - 74	0,98	0,98	0,98	
75 - 79	0,99	1,00	0,99	
80 - 84	1,00	1,00	1,00	
85 - 89	1,00	1,00	1,00	
90 - 94	1,00	1,00	0,99	
95 - 99	0,99	0,98	1,00	
100-104	1,00	1,00	1,00	
105-110	1,00	1,00	1,00	

*significant differences

Table 1.- Comparison of the females ratio by length for the period 1992-1994.

The average lengths by age of males and females are very similar up to 7 years of age, at which point they reach 45 cm. From this age, the average length of females becomes slightly greater (between 1 and 2 cm) than that of males, until reaching age 12, when males begin to disappear (*Table 3, Fig. 3*). The average lengths of ages 5 and 6 are slightly overestimated, given that as the length age keys begin at 34 cm, the length distributions of these ages are truncated below this length.

Length	1992	1993	1994	Length	1992	1993	1994
29	0,56	0,52	0,50	71	0,97	0,97	0,97
31	0,54	0,51	0,53	73	0,98	0,98	0,98
33	0,52	0,51	0,55	75	0,99	0,99	0,98
35	0,53	0,53	0,55	77	0,99	0,99	1,00
37	0,53	0,55	0,56	79	0,99	1,00	1,00
39	0,53	0,58	0,56	81	1,00	1,00	1,00
41	0,54	0,60	0,58	83	1,00	1,00	1,00
43	0,55	0,60	0,57	85	1,00	1,00	1,00
45	0,57	0,59	0,58	87	1,00	1,00	1,00
47	0,59	0,60	0,59	89	1,00	1,00	1,00
49	0,60	0,60	0,59	91	1,00	1,00	1,00
51	0,63	0,62	0,63	93	1,00	1,00	0,98
53	0,67	0,65	0,63	95	0,99	0,97	1,00
55	0,70	0,67	0,64	97	1,00	1,00	1,00
57	0,74	0,72	0,68	99	1,00	1,00	1,00
59	0,78	0,75	0,72	101	1,00	1,00	1,00
61	0,82	0,79	0,77	103	1,00	1,00	1,00
63	0,87	0,86	0,80	105	1,00	1,00	1,00
65	0,90	0,90	0,84	107	1,00	1,00	1,00
67	0,93	0,94	0,90	109	1,00	1,00	1,00
69	0,96	0,96	0,95	Sex-rat.*	0,51	0,58	0,52

* males / females in the total catch

Table 2.- Females ratios by length and sex ratio of the catch for the period 1992-94.

Age	Males	Females
5	35,81	35,67
6	40,27	39,94
7	44,62	44,77
8	50,90	52,75
9	57,51	58,62
10	62,78	63,96
11	67,56	68,86
12		73,76
13		78,39
14		83,69
15		87,56
16		91,36

Table 3.- Mean lengths at age for 1993.

The females ratio by age is at around 52% at ages 5 and 6, increases suddenly to 68% at age 7, but fall again at age 8 to a level of 59%. From this age the females ratio tends to increase drastically until reaching 100% at age 12 (*Table 4, Fig. 4*).

Age	Males	Females	Ratio.
5	72339	80777	0,53
6	145559	159503	0,52
7	184556	398745	0,68
8	163220	236794	0,59
9	31624	80732	0,72
10	3245	41540	0,93
11	1266	21834	0,95
12		15257	1,00
13		3665	1,00
14		1235	1,00
15		767	1,00
16		283	1,00

Table 4.- Females ratio at age for 1993.

The curves of catch by sex would seem to indicate that the total recruitment of males in the fishery comes about at age 8, while that of females occurs one year earlier. The value of Z estimated for males was 1.7 while that of females was 0.8 (*Fig. 5*).

4.- Discussion.

The catches of the NAFO Regulatory area are dominated by females. The sex ratio in the total catch, fluctuated during these years between 0.51 in 1992 and 0.58 in 1993. These data contrast with those of the catches of the area to the north-east of the Norwegian Sea where the sex ratio varies between 2.18 and 2.39 (Nizovsev, 1969; Kovtsova, 1985; in Godo and Haug, 1989), or those of the Davis Strait area, which suggests a sex ratio of 1, since neither sex is particularly predominant in catches (Chumakov *et al.*, 1978; in Godo and Haug, 1989). This information could be indicative of an existence of a relationship between the proportion of sexes and latitude. Nevertheless, it would be premature to affirm anything with respect to this observation, as a great deal of data remain unknown, such as the depths at which samples were obtained in each area. The fishery studied in our paper is situated at depths of between 800 and 1800 m over the slope, a much greater depth than that described by Godo and Haug

(1989) for the area of population distribution to the north-east of Norway and Barents Sea. As a positive relationship seems to exist between an increase in depth and an increase in the proportion of females (for an example, see Chumakov and Serebryakov, 1982), more research would be necessary to clarify this point (evolution of the sex ratio with depth).

When the three curves reflecting the females ratio by length are observed for the period analysed, it can be appreciated that the strongest increases in the frequency are initiated at around 48-50 cm (*Fig. 2*). Serebryakov *et al.* (1992) indicate that males begin to mature at around 5-7 years, and 46-47 cm length. In the Barents Sea, males begin to mature at about 4-5 years and 40 cm length, although maturity seems to have come earlier in recent years (Kovtsova and Nizovtsev, 1985; in Godo and Haug, 1989). If it is true that the maturity of males leads to an increase in the females ratio by length, it is logical that small inter-annual differences appear, since M50 presents annual variations related to the size of the stock (Kovtsova and Nizovtsev, 1985; in Godo and Haug, 1989) and to environmental conditions (Bowering, 1983). On the other hand, it is well known that variations exist in growth, related to environmental parameters, such as the presence of food or temperature (for an example, see Wooton, 1990). This brings about variations in the age ratio present in a certain length range from one year to the next, which will, in turn, lead to annual variations in sex ratios by length.

The pattern which the three curves take seems to rule out growth as being the most important factor in the increase in the female ratio by length, since if this were the case, an accumulation of male ages would seen for lengths immediately after M50, which would reduce the proportion of females at these lengths. Following this length range, in which males would predominate, the proportion of females would increase drastically until reaching 100%, and this expected increase in the frequency of male in the range from 45 to 55 cm has not been observed in any of the years analysed.

When mean lengths at age are observed (*Fig. 3*) it is seen that both sexes grow similarly up to age 7, at a length of 45 cm (when males begin to reach maturity). From this moment, males are systematically smaller than females, but only by 1 or 2 cm. This cannot explain the strong increases in the percentage of females which appear from this age. Godo and Haug (1989) find sexual differences in Greenland halibut growth to the east of Norway and the Barents Sea, where females grow slightly more than males, but these differences appear from 5 years.

When the females ratio by age is observed (*Fig. 4*) it is seen that the point corresponding to age 7 presents a strangely high proportion of females, if compared with the remaining ages, which may be due to the low number of otoliths used in constructing the age-length keys. If this point is excluded, we observe a general pattern in which males disappear at a greater rate than females from age 8, or otherwise expressed, suffer a higher mortality rate. Chumakov and Serebryakov (1982), using data from a survey carried out between December 1980 and January 1981, obtained very similar graphs for Area 0 and Divisions 2GH, 2J and 3K, although these graphs seem to be displaced by one year. This displacement may well be due either to a discrepancy in the assignation of ages brought about by the use of a different methodology, since the Russian scientists used scales for age reading (Chumakov and Serebryakov, 1982), while the Canadian keys used were elaborated from otoliths, or to a fall in the age of first maturity of males between 1981 and 1993..

Catch curves show that females appear to be fully recruited to Z at age 7, while for males it occurs at age 8 (*Fig. 5*). This discrepancy may be explained in two ways. On one hand, as previously seen (*Fig. 4*), the females ratio at age 7 is unexpectedly high if compared with the pattern observed for the remaining ages. A balance between sexes more in accordance with that expected would somewhat raise the point corresponding to 7 years in the catch curve for males. On the other, at age 7 males begin to reach maturity. If this maturity were associated to an increase in natural mortality, or a behavioural change of males making them less accessible to the gear, Z would continue to increase between 7 and 8 years. Thus, full recruitment to Z would not come about until age 8, even though at age 7 full recruitment to F had taken place. As previously seen (*Table 2*) the mean length for age 7 is very similar in both sexes at around 45 cm. This length of full recruitment to the fishery is consistent with the data of selectivity of the 130 mm mesh in use, if it is taken into account that a retention of 75% estimates about 42 cm (de Cárdenas *et al.*, 1995).

It is not easy to put the sexual differences in Z down to the sexual differences in F, which may be due, for example, to different behaviour to the gears or formation of concentrations which made males more accessible, or to a difference in the prices of each sex in the market, leading the fleet to search harder for males. The fact that the females ratio by age remains more or less constant at around 50% in the first ages (see also Chumakoz and Serebryakov, 1982) leads us to consider that abundance and F are similar for both sexes. If, after maturity, an increase in F for males came about, the proportion of males in the catch would be seen to increase slightly, and later to fall drastically until disappearing. The same would occur with the females ratio by length in the catch, which, immediately after the M50 of males, would tend to accumulate specimens of this sex up to the lengths corresponding to ages in which they became so scarce that despite being submitted to a greater F, catches were smaller. None of these phenomena can be appreciated in our case.

The increase in M in males is the most plausible explanation. M may be picking up other phenomena, such as migration (males only), or a lack of accessibility of the gear to mature males, but this does not seem probable since, on one hand, the trend in the females ratio by age appears to be general in the different areas of the stock (see Chumakoz and Serebryakov, 1982), and on the other, if they were not accessible to the trawling gear, they would be to some other gear (long-lines, gillnets etc.), which should catch a good proportion of large males. This does not seem to happen, either (see Nedreaas *et al.*, 1993). We also have to bear in mind that a greater longevity of females is not an uncommon phenomenon in Pleuronectiforms (Scott and Scott, 1988). It would seem that in some species of pleuronectiforms, as may be the case with *Limanda limanda*, a sexual differences appears in the metabolism, oxygen consumption, length of intestinal tract, food ingestion and relative liver size in some seasons of the year (Lozan, 1992). Pauly (1994) relates the relative consumption of oxygen to the potential for growth of pleuronectiform species, and suggests that a sexual difference in this characteristic could explain a difference in growth of the sexes. In my opinion, phenomena of this kind in Greenland halibut may also explain, at least in part, the existence of a sexual differences in the natural mortality rate.

If M were really the main cause of this difference in Z, natural mortality of males older than 7 years would be at around 1.05, instead of the 0.15 currently being used in evaluations.

Independently of this, the Z estimated for females, of around 0.8, is very high, if it is taken into account that M=0.15 in this sex. Although this value may be an overestimate, if the fishery has a dome-shaped exploitation pattern, which probably occurs as the fishery is based on trawl, which hardly catches any adult specimens in comparison with other gears, such as long-liners and gillnetters working in the same areas (Jorgensen and Boje, 1992).

5.- Conclusions.

Females predominate in the catch in the NAFO Regulatory Area.

The females ratio by length follows a similar pattern in the years studied, although small interannual differences exist.

The important increases in the proportion of females appear from 47-50 cm, corresponding to age 8 .

Full recruitment to the fishery comes about at age 7.

The difference in Z between sexes for fully recruited ages is 0.9.

This difference appears to be due to M.

Fishing mortality may be high.

6.- Acknowledgements.

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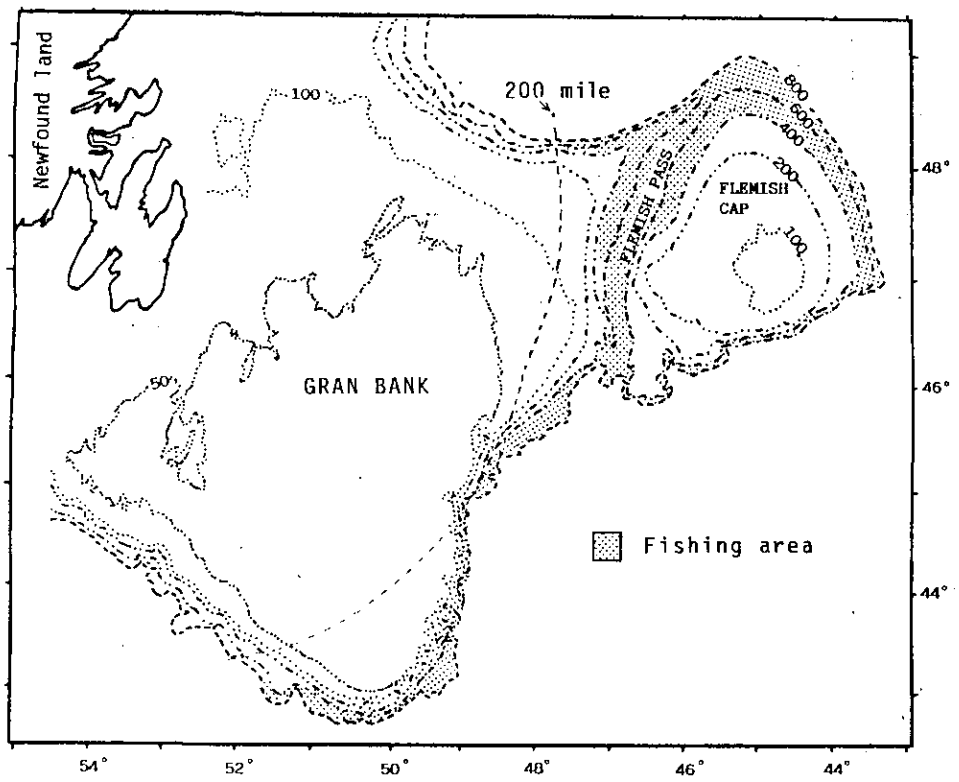

Fig 1.- Map showing the fishing areas for the spanish deep water fishery.

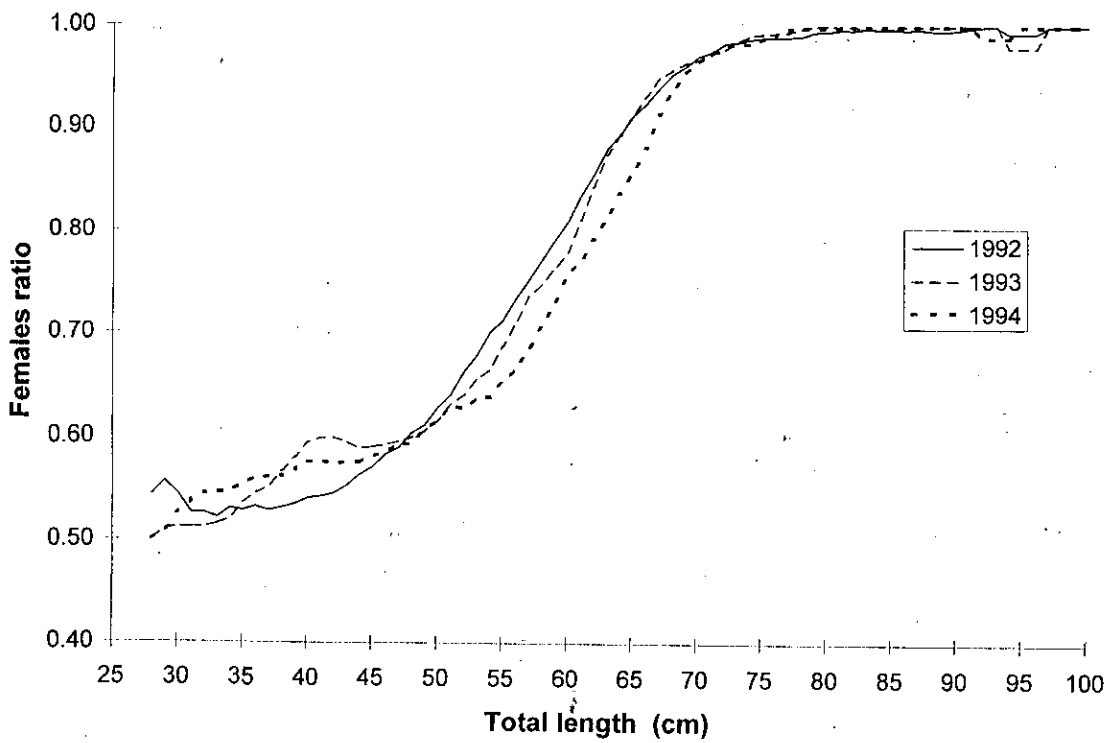

Fig. 2.- Females ratio by length in the catch for the period 1992-94

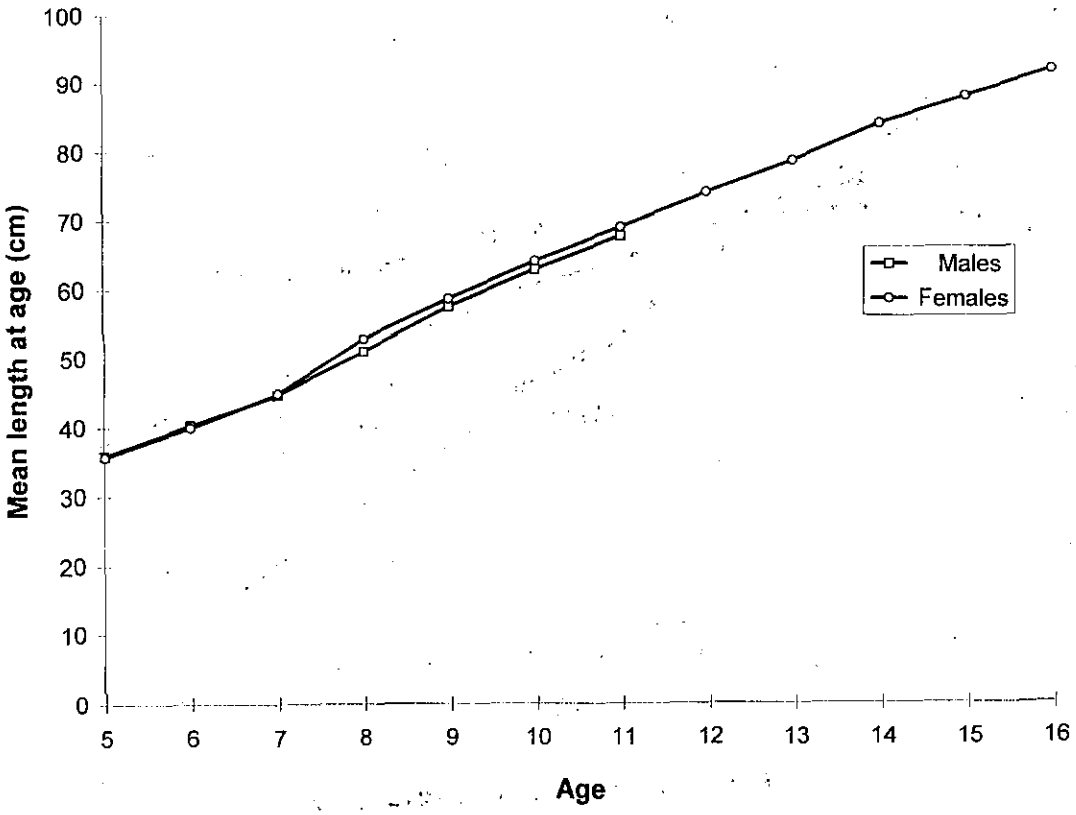

Fig. 3.- Mean lengths at age in the catch by sex for 1993

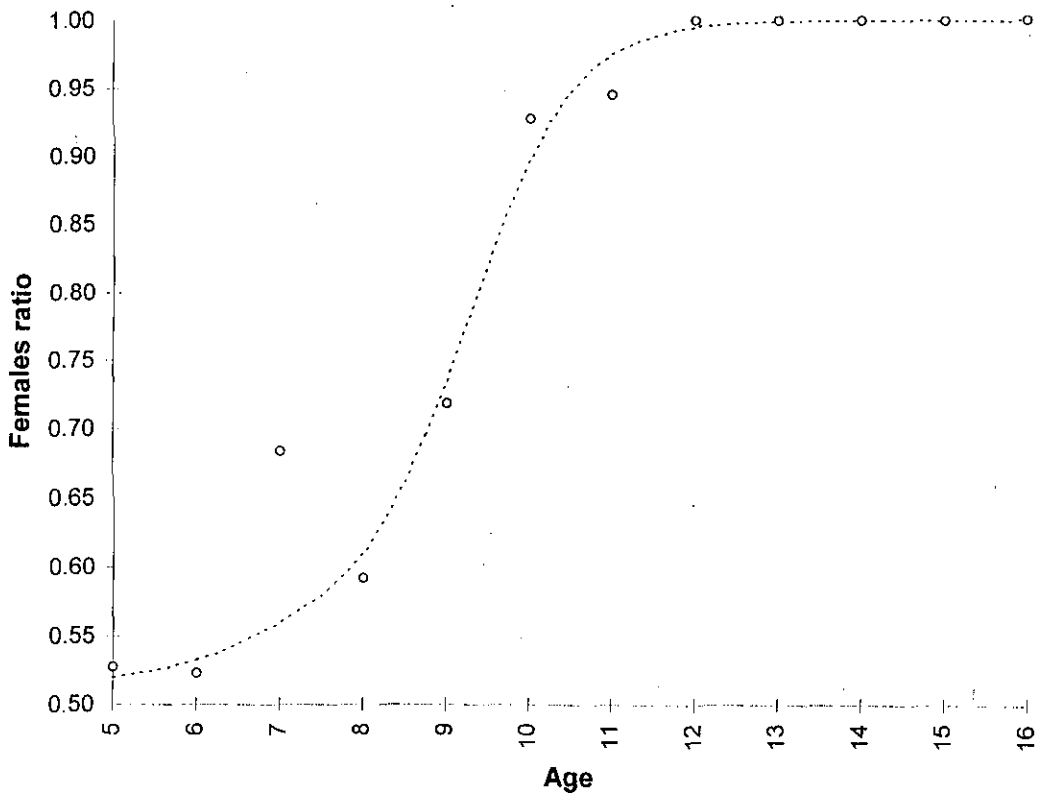

Fig. 4.- Female ratio by age in the catch for 1993

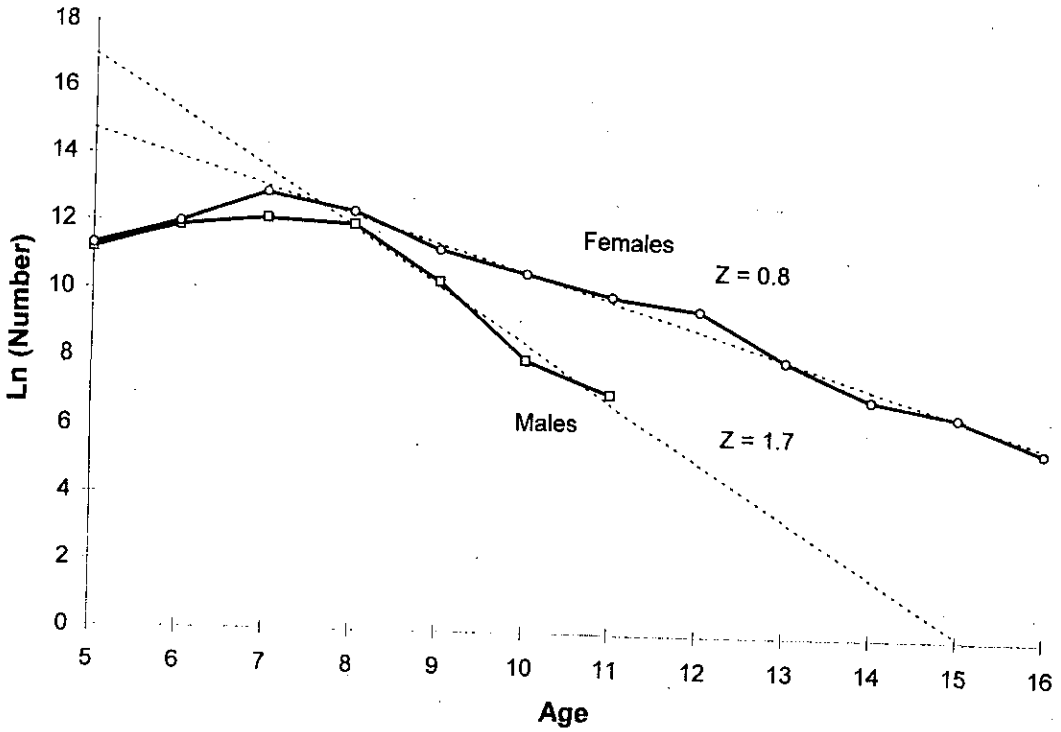

Fig. 5.- Catch curves by sex for 1993