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# Spatial and Temporal Variations in Greenland Halibut (*Reinhardtius hippoglossoides*) Sex Ratio-at-age in NAFO Divisions 0B, 2GH, 3K and 3LM

**K. V. Gorchinsky**
Polar Research Institute of Marine Fisheries and Oceanography (PINRO)
6 Knipovich Street, 183763, Murmansk, Russia

## Abstract

Greenland halibut (*Reinhardtius hippoglossoides*) sex ratio is subjected to spatial and year-to-year variations. Based on data collected from USSR/Russian trawl surveys for the Greenland halibut in NAFO Div. 0B, 2GH, 3K and 3LM during 1984–96, the proportion of females were found to gradually increase from the northern divisions to the southern ones. As a rule, males were predominant in catches taken in the more northern Div. 0B, 2GH and females in Div. 3K and 3LM. From 1984 to 1992 the proportion of females successively decreased in Div. 3K. With the increase of age of the Greenland halibut, the proportion of males decreased, at an earlier age in the southern divisions compared to the northern ones. In Div. 0B, all specimens above age 13 were females; males above age 11 disappeared from catches in Div. 3K and 3LM.

*Key words*: Greenland halibut, Northwest Atlantic, sex ratio

## Introduction

Since 1960s Greenland halibut (*Reinhardtius hippoglossoides*) has been an object of the directed commercial fishery in the Northwest Atlantic. In spite of the fact that this species has a wide distributional area extending from the Davis Strait to Georges Bank, an intensive fishery has taken place, as a rule, in the same general limited areas in NAFO Subarea 0 and 3. With a decline in catches taken in traditional fishing grounds in the late-1980s, the fishery shifted to deeper areas and to new areas in the more southern Div. 3KLM. Since the early 1990s, the main portion of the Greenland halibut catch has been taken in the NAFO Regulatory Area in Subarea 3, mainly off the Flemish Pass at depths down to 1 800 m (Bowering *et al*., MS 1994).

It is expected that fish undergo certain adaptations to the impact of intensive fishing and to environmental conditions throughout the area. It is accepted that adaptations can take different forms. When determining the biological structure of the stocks, it must be recognized that the differences between the males and females by natural and fishing mortality factors, selectivity of different fishing gears exploiting certain length-age groups of fish, as well as season, along with the other factors can influence the conditions. In these cases, biological peculiarities of Greenland halibut, such as variation in length composition of fish in aggregations by depth, sex separation on spawning grounds and others, should be considered. The aim of this paper is to assess difference in sex ratio of Greenland halibut (according to relative number of females) during the period 1984–92 in Div. 0B, 2GH, 3K and from 1993 to 1996 in Div. 3LM.

## Materials and Methods

Data from USSR/Russian directed trawl surveys for the Greenland halibut stock in Div. 0B, 2GH, 3K for 1984–92 were taken as the basis of analysis. The surveys were annually conducted during autumn-winter at the depths to 1 500 m, except for Div. 3K where in 1984–85 and in 1987 the data were collected during groundfish surveys in spring–summer. Additionally, data from the groundfish trawl surveys in Div. 3LM (Flemish Pass) during 1993–94 were analyzed. These surveys were to a depth of 730 m. Data were also collected from the Greenland halibut surveys conducted in May 1995 to 1 100 m depth and to 1 460 m in February 1996. Total length of fish was measured to the nearest cm. Most of the fish were aged using scales removed from the anterior dorso-lateral area, while in 1996 they were aged using otoliths. Random subsamples were taken and 15 specimens from each sex were aged from each 2 cm length group. Age composition of catches were then determined and mean length-at-age of males and females were determined using length-age keys derived annually, and revised for each Division. The proportion of females in the stock was determined by their numbers divided into the total number of fish in catch. The ratio values for females-at-age were smoothed through the use of a three point moving average.

## Results

The results from the surveys carried out during 1984–92 showed the total proportion of females progressively increased from the northern Subareas to the southern ones (Table 1). Reduction in proportion of females in Div. 0B, 2GH was pronounced from 1985 to 1988, and during subsequent years this index remained to be higher or at the long-term mean level. In Div. 3K successive reduction in the proportion of females was observed from 1984 to 1992.

During surveys of the Greenland halibut stock in Div. 0B, 2GH in autumn-winter, males were predominant in catches. Proportion of females in Div. 0B varied from 0.29 to 0.37 and from 0.37 to 0.50 in Div. 2GH. Prior to 1990, females were predominant in catches taken in Div. 3K and their proportion gradually decreased from 0.70 in 1984 to 0.48 in 1992. In Flemish Pass males were predominant during spring-summer period (surveys in 1993–94); females were predominant at greater depths during winter-spring surveys in 1995–96.

Proportion of females in catches gradually increased with age (Fig. 1). In Div. 0B an increase in proportion of males under age 8 was registered. The relative amount of females sharply increased at ages above 9 in 1984–92 and at ages above 7 in 1992. Greenland halibut catches consisted only of females at ages greater than 14 during the years 1984–92 and at ages greater than 11 in 1992. In Div. 2GH the proportion of females increased at ages above 9 in 1984–92 and at ages above 7 in 1992. The catches consisted only of females at ages above 13–14 in years 1984–92 and at ages above 11 in 1992. In Div. 3K, a notable increase in the proportion of females as a general pattern took place at ages above 6–8. Females at ages above 11–12 (1984, 1988, 1990) and at ages above 14 (1986, 1992) made up 100% of the catches. In Div. 3LM, the data from summer surveys conducted at depths down to 730 m, the proportion of males in catches began to reduce at ages 4 and up. Catches of Greenland halibut at ages 11 and above consisted only of females. The data from winter-spring surveys showed that

TABLE 1. Variation of the proportion of females in the sex ratio by year and area (number of specimens analyzed are in brackets).

| | Divisions | | | |
|---|---|---|---|---|
| Years | 0B | 2GH | 3K | 3LM |
| 1984 | 0.29 (8 550) | 0.37 (9 412) | 0.70 (8 044) | |
| 1985 | 0.37 (12 453) | 0.50 (4 126) | 0.66 (3 960) | |
| 1986 | 0.31 (13 323) | 0.44 (3 068) | 0.54 (15 141) | |
| 1987 | 0.29 (5 224) | 0.44 (6 109) | 0.55 (7 341) | |
| 1988 | 0.30 (6 788) | 0.40 (4 651) | 0.53 (9 407) | |
| 1989 | 0.39 (5 269) | 0.41 (7 505) | 0.53 (5 455) | |
| 1990 | 0.36 (4 215) | 0.47 (2 520) | 0.50 (7 104) | |
| 1991 | 0.37 (2 763) | 0.45 (9 368) | 0.49 (2 535) | |
| 1992 | 0.34 (2 192) | 0.43 (6 060) | 0.48 (951) | |
| 1993 | | | | 0.49 ( 2 441) |
| 1994 | | | | 0.47 ( 3 555) |
| 1995 | | | | 0.58 ( 2 152) |
| 1996 | | | | 0.55 (10 969) |
| Average | 0.34 | 0.43 | 0.55 | 0.52 |

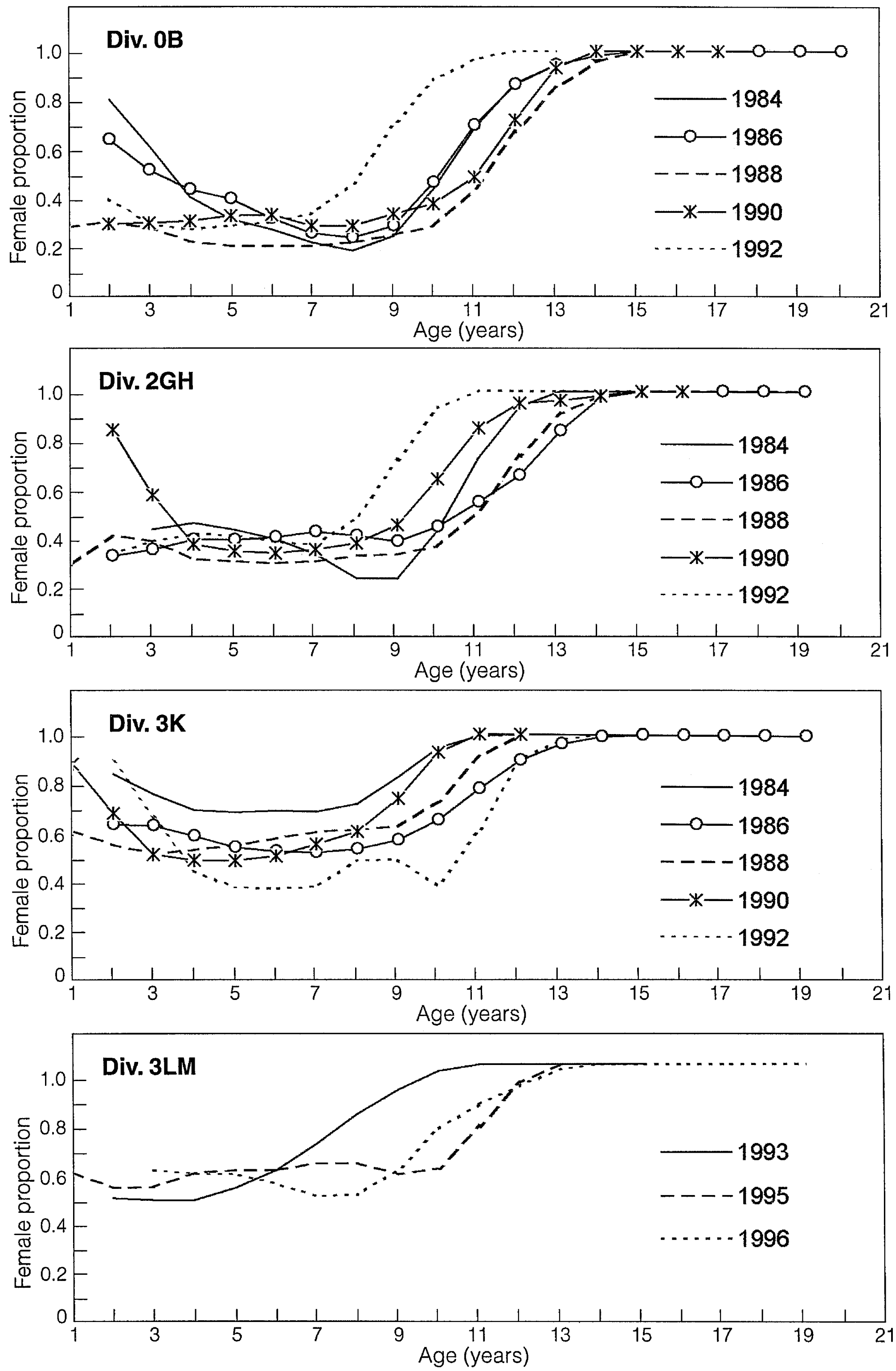


Fig. 1. Greenland halibut sex ratio-by-age in 1984–96 depicted as proportion of females.

at greater depths the proportion of males began to reduce at ages 9–10 and no males were encountered in catches at ages above 13.

At ages below 9 the variation in mean length of males- and females-at-age was very similar in all surveys in all areas. This was also generally the age at which the males began to disappear in catches (Fig. 2). During this age interval of up to 9, the growth rate in both males and females was close to linear. A decrease in yearly increments in male mean length, compared to female, was observed at ages 9–10 and greater. No males above age 13 and females above age 20 were found in the samples.

## Discussion

In a population, the male and female ratio is genetically conditioned to be around 1:1, however this can essentially vary in populations and during individual development of fish. This parameter is one of the most important factors characterizing the stock structure, peculiarities of behaviour, migration, and in some cases, impact of fishery upon the stock status. Sex separation in Greenland halibut is known to occur during a formation of prespawning and spawning aggregations. Males appear earlier on spawning grounds and leave them later than females (Nizovtsev, 1989; Zilanov *et al.*, MS 1976). As far as the USSR/Russian surveys carried out in the northern Subareas in Div. 0B and 2GH during prespawning period, a predominance of males in catches was regular. With an increase in depth the Greenland halibut were found to share an increasing mean length. Along with this the proportion of females were found to increase and the largest specimens are represented only by females. Similar patterns have been reported elsewhere (Gorchinsky and Vaskov, MS 1992; Junquera and

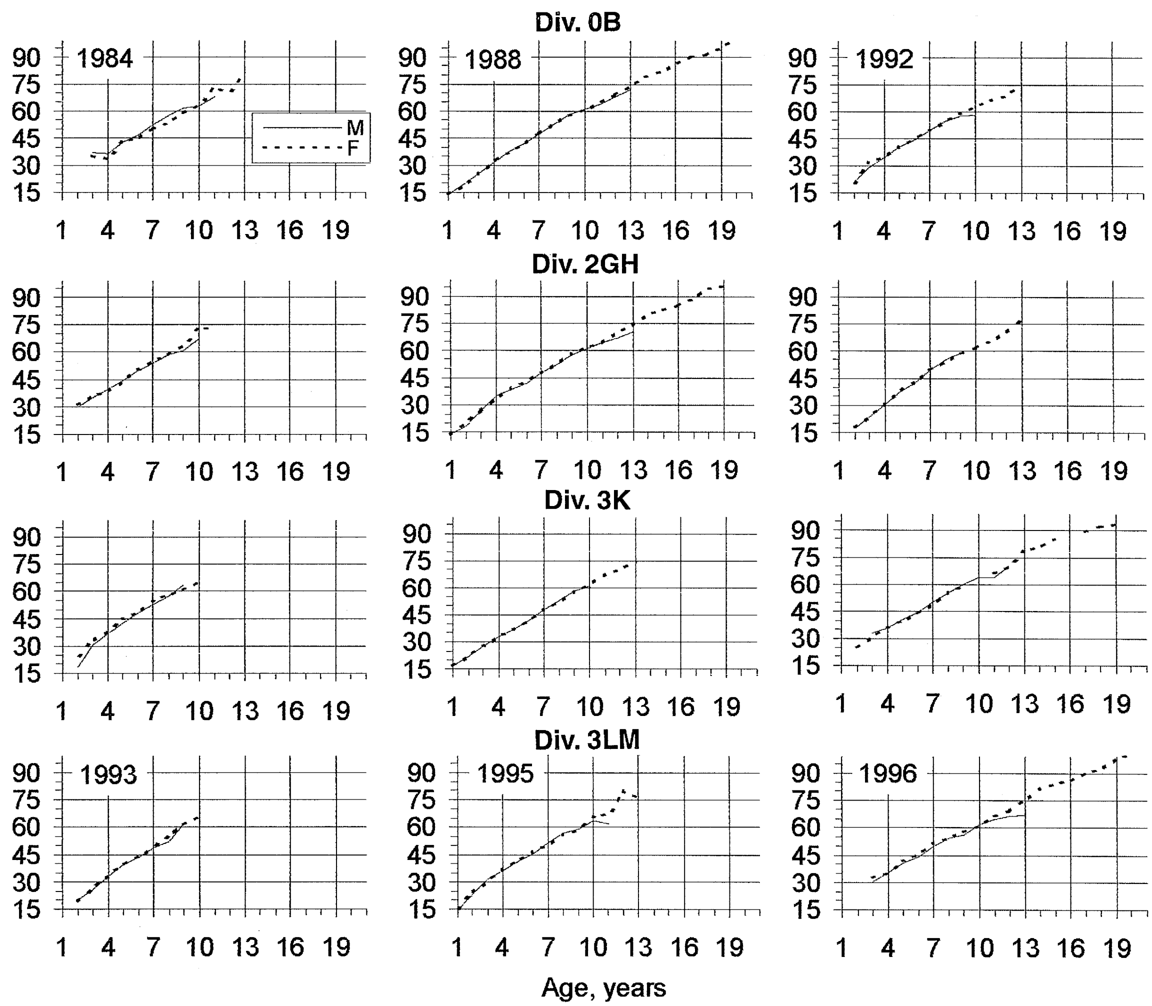


Fig. 2. Greenland halibut mean length (cm) at age during 1984–96.

Zamarro, MS 1992; Gorchinsky, MS 1993; MS 1996). For the Flemish Pass area, the difference in depth at which the surveys are carried out in 1993–94 and in 1995–96 was probably the main reason of the variations observed in total proportion of females and the age at which males disappeared from catches during those years (Table 1 and Fig. 1). The survey results of the present study generally agree with the assumption made by de Cardenas (MS 1996), on the existence of a relationship between geographical latitude and sex ratio.

As a rule, the males are predominant in the northern areas whereas females are in the southern ones. Data presented by Nizovtsev and Troyanovsky (1970) show the proportion of females in catches from Iceland area varied from 0.44–0.48 on the northern and northwestern slopes, and 0.79–0.81 in the southeastern and northeastern slopes. Similarly, in the area from the Rockall-Hatton seamounts to the Faroe-Icelandic Rapid western slope area, there were more males, approximately by 4 times as many as females (Nizovtsev, 1989). Such a north/south pattern was also apparent for the NAFO area. Along the eastern coast of Canada the proportion of females increased from 38.9% off the Davis Strait to 51.5% on the Northern Newfoundland Bank (Zilanov *et al.*, MS 1976) and it constituted 51–58% in Flemish Pass (de Cardenas, MS 1996). By our data, this distributional pattern represented 34, 55 and 52%, respectively (56.5% – at the greatest depths).

Age, at which catches consisted only of females, decreased from north to south from ages greater than 13–15 in Div. 0B to ages greater than 11–14 in Div. 3K and 3LM (i.e. the incremental part of curves in Fig. 1 shifted in general to the left). These data agree with the observations reported by Chumakov *et al*. (MS 1978) that in Subareas 0+1 males and ages 14+ disappear from catches. Also the present results agree with those by de Cardenas (MS 1996) that the proportion of females at age 12 and greater are 100% off Flemish Pass. It is noted that the increase in proportion of females in catches occurred as a rule at ages 7–9, i.e. at the age corresponding to when sexual maturation of males occur and to their 100% recruitment to the fishery (Serebrayakov *et al*., 1992; de Cardenas, MS 1996).

No clear regularities of increase in proportion of females were found during the period investigated from 1984 to 1992 (Fig. 1). However, proportion of females at ages 7–9 had rather an upward trend in the northern areas, and a downward trend in the southern areas. Age at which males begin to mature (represented as age at $M_{50}$ and $M_{100}$) have been reported to increase from Subareas 0+1 in the north to Div. 2J (Serebryakov *et al*., 1992). Similarly an increase in age at $M_{50}$ was observed from Div. 3K to Div. 3L by Morgan and Bowering (MS 1995). Comparing these with the above-mentioned pattern of a shift to the left of female proportion at age from north to south (Fig. 1), one can suggest that the earlier the age at maturity of males commences the longer they remain in the stock. The northern (Div. 0B and 2GH) and southern (Div. 3K and 3LM) areas showed a general difference between them by sex ratios and the pattern of variation in proportion of females-at-age. The reason for that was probably a shifting of mature males from the southern to northern spawning grounds which could have taken place during the surveys. In this case, the spawning would probably be intermittent and occurring during winter. It should be recognized that the entire study area is inhabited by a single population (Templeman, 1973; Zilanov *et al*., MS 1976; Bowering, MS 1982). However, it is also possible that separate populations of Greenland halibut inhabit the southern Divisions. In such a case the main difference would be that the periods of spawning are prolonged during the year or have several peaks (Junquera and Zamarro, MS 1992). In such a case both male and female representatives would inhabit these areas together, without separating, and they would not migrate far resulting in their ratio being around 1:1. Supporting this, the present study showed no essential difference in growth rate between males and females when the mean length-at-age was analyzed (Fig. 2). Reduction of the proportion of males in trawl catches might have been explained by a sharp decline in their growth rate compared to females. In this connection it may be suggested that there could be a reduction in trawl efficiency regarding males. However, that was not observed in any area investigated. In this case, males and females could be assured to be fished approximately in equal ratio.

With respect to other fishing gear, such as longline and gillnet, in fact, data presented by Chumakov and Soshin (MS 1991) and Nedreaas *et al*. (MS 1993) show catches taken by longline and gillnet consisted of large specimens compared to those from trawl catches and the proportion of males varied from 1/3 to 1/10. Under the circumstances it appears that the long-term impact of specific fishing gears upon the Greenland halibut stock can essentially influence sex ratio and therefore the stock status. As far as a trawl fishery in the northern areas is concerned, it is based on prespawning aggregations consisting mainly of males. Therefore longline and gillnet fisheries on the larger fish, essentially the females, will have a long-term impact. Any of these fishing gears may result in serious disturbance in the sex ratio and the natural balance. On the other hand, in connection with the fact that individual fecundity of Greenland halibut females is dependent on age, length and weight (Serebryakov *et al*., 1992), the fishing of large females which are contributing to the populational fecundity can notably attenuate the stock reproductive capacity and finally result in the reduction of population size.

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