Sexual Maturity and Spawning of Greenland Halibut (*Reinhardtius hippoglossoides*) from Flemish Pass Area

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Abstract

Description of the reproductive aspects of Greenland halibut (*Reinhardtius hippoglossoides*) in the Flemish Pass area in NAFO Div. 3L and 3M based on data from observers on board the Spanish commercial fishing fleet between May 1990 and December 1991 is presented. A maximum in the proportion of spawning females was found in summer with a secondary peak in December, while some spawning activity was observed throughout the rest of the year. The length at 50% maturity varied from 67.3 cm in 1990 (Div. 3L and 3M) to 73.2 cm in 1991 (Div. 3M). The influence of the reproductive behaviour on the evolution of catch rates is discussed.

Key words: Flemish Pass, Greenland halibut, *Reinhardtius hippoglossoides*, Maturity, Spawning

Introduction

Greenland halibut (*Reinhardtius hippoglossoides)* has been the major component of the Spanish deep water trawl fishery since 1990, which has operated mainly along the continental slopes between NAFO Div. 3L and 3M (Fig. 1). Fishing activities of this fleet are restricted to depths between 800 and 1 700 m, a range of depths where the available information on the biology of this species is very scarce.

Greenland halibut is known to spawn mainly in the Davis Strait area around latitude 67°N (Smidt, 1969). Spawning is also reported to occur to a lesser extent in the Gulf of St. Lawrence (Bowering, 1980; MS 1982), off Labrador (Templeman, 1973) and in West-Greenland fjords (Riget and Boje, 1989). However, most of the information available about the reproduction of this species pertains to its shallower area of distribution.

In this paper we deal with the description of reproductive aspects of the Greenland halibut in the Flemish Pass area in Div. 3L and 3M (Fig. 1), based on data supplied by observers on board the Spanish commercial fishing fleet. The information is of interest because, on the one hand it provides an insight to Greenland halibut from a long period of systematic sampling all year round, and on the other hand, on their reproductive activity in deep waters (800–1 700 m) and areas from where there

has been no information available until now. The study presents data clarifying some unknown aspects of the biology and dynamics of this species.

Materials and Methods

The data used here were supplied by observers on board Spanish commercial deep-water trawlers, and collected from May to December in 1990 and all year in 1991. Sampling depth ranged from 800 to 1 700 m. For sampling design and data processing these depths had been divided into three strata: ≤900 m, 901–1 100 m and ≥1 101 m.

Length of fish was recorded as total length and the stage of maturity in females determined visually using a scale of four maturation stages:

Stage 1. IMMATURE – Ovary very small and pinkish, thin walled, eggs not visible to the naked eye.

Stage 2. MATURING – Eggs opaque and visible to the naked eye, ovarian wall thin.

Stage 3. SPAWNING – Eggs visible to the naked eye, some or all the eggs clear (hydrated).

Stage 4. SPENT – Ovary reddish with thickened wall, new eggs not visible to the naked eye.
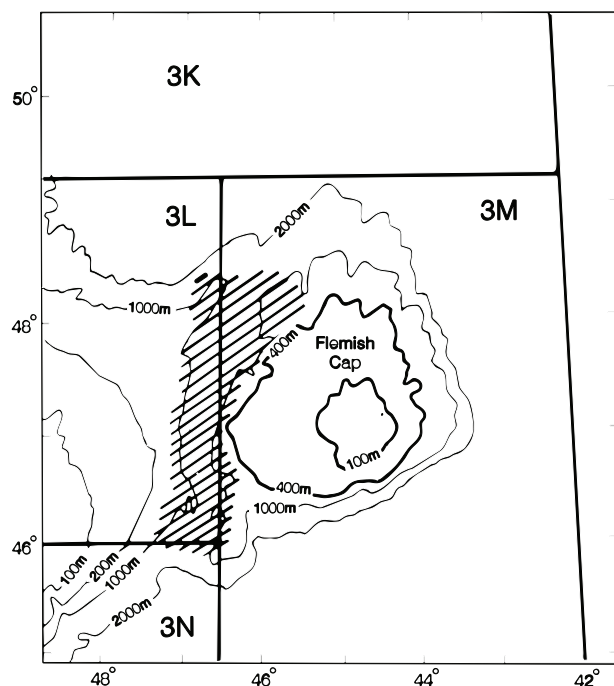
Fig. 1.   Area of fishing by the Spanish fleet in the Flemish Pass area (shaded area) in Div. 3L and 3M in 1990–91.

The proportion of spawning females (Stage 3) in the sample population was used as a reference point and followed through the year to determine the spawning season.

Female maturity-at-length data from 1990 to 1991 in Div. 3L and 3M and depth strata were used to generate maturity curves and to determine the length at 50% maturity (M_{50}) by the "probit transformation" method (Fisher and Yates, 1948), as applied to cod by Fleming (1960) and this species by Bowering (1983). Fish were considered immature if they had ovaries in Stage 1 and mature in Stages 2, 3 or 4. Goodness-of-fit was tested with the Chi-square test.

To analyse seasonal changes in the catchability that could be related to vertical movements through depth strata or to migrations in and out of the fishing area, we used the catch rates standardized with a multiplicative model (Vazquez, 1981).

Results

In the Flemish Pass area during the study period there was an increase in the size and proportion of females with depth in both Div. 3L and 3M (Fig. 2). The sex-ratios in the catches showed a clear dominance of females in the whole area during

the second half of 1991, and their proportion increased even more in the last part of the year (Table 1).

The goodness-of-fit for maturity curves (Fig. 3) were significant in all the cases considered ($P<0.05$). Length at 50% maturity varied from 67.3 cm for 1990 when data were combined from Div. 3L and 3M, to 73.2 cm for the deepest strata of Div. 3M in 1991 (Table 2). The range of size over which sexual maturity takes place is represented by the slopes and Y-intercepts of the computed lines. The result of the ANCOVA of the fitted lines (Sokal and Rohlf, 1969) showed that there was no statistical difference either between slopes (m) or Y-intercepts at the 5% significance level (F = 1.9 and F = 0.8 respectively; d.f.= 3, ∞). Consequently it can be assumed that the variability observed in M_{50} was not significant, and the differences found could be related with a higher frequency of big sizes in the deepest strata of Div. 3M.

In both Div. 3L and 3M, several of the biggest individuals appeared unexpectedly as immatures (Fig. 3) in all depth strata. In the shallowest strata of Div. 3M, the proportion of mature females never reached the 50% level and consequently a maturity curve could not be fitted there.

The percentage of spawning females in 1991 is shown in Table 3. The peak of spawning during the sampling period was found in July and August, with 20% of the mature females in spawning Stage 3, with hydrated eggs. It is also worth noting the presence of a secondary peak in December (7%) and some spawning activity all the rest of the year.

The possibility exists as in other species, that the reproductive behaviour could affect fishing activities in a similar way. In Fig. 4, the trend of the standardized catch rates is represented. It can be seen that the maximum values were attained in both Div. 3L and 3M in winter, and a general decline in the catch rate coincided with the peak of spawning. The values in Div. 3L showed slighter seasonal variations than in Div. 3M.

Discussion

Spawning of Greenland halibut is considered to occur mainly in the deep warm waters of Davis Strait (Smidt, 1969), from where both northern and southern areas are colonized (Templeman, 1973). Adult mature fish are believed to undertake a migration northward to the main spawning area (Bowering and Brodie, 1991), while the smaller immature fish remain in southern areas (Zilanov et al., MS 1976; Bowering, MS 1977). The results of this paper show that spawning also takes place in the Flemish Pass
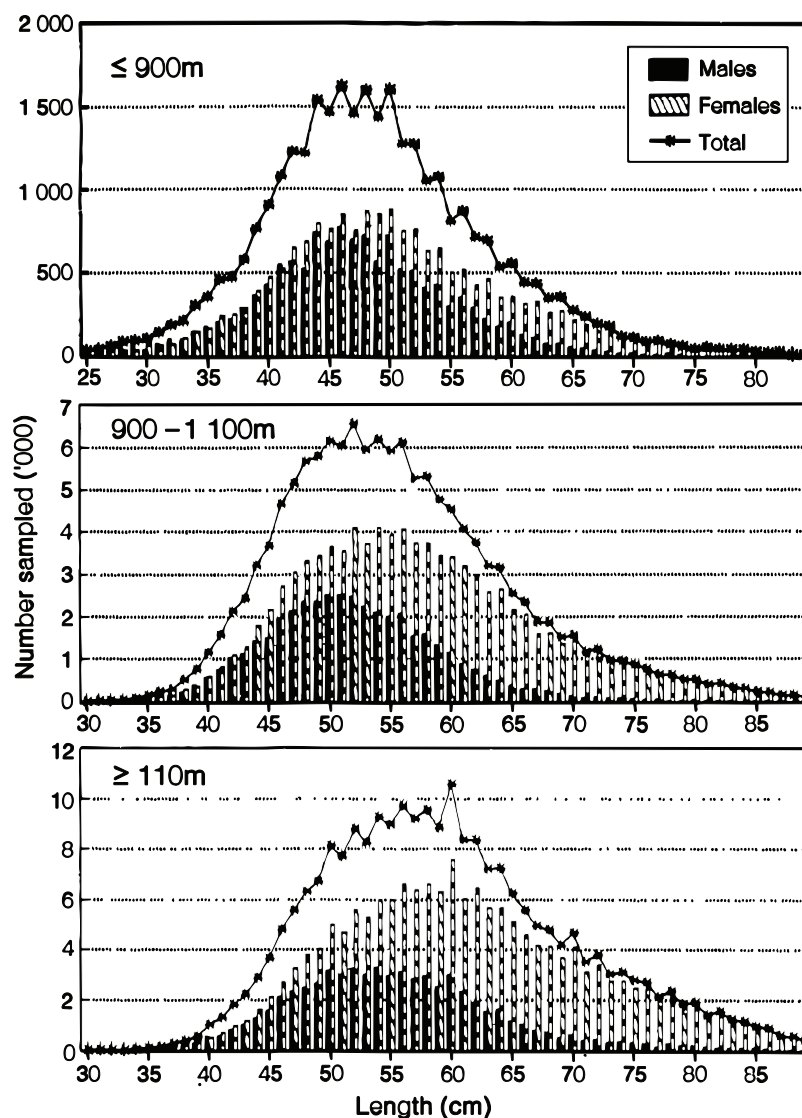
Fig. 2. Length distributions of Greenland halibut by sex and depth strata in Div. 3L and 3M in 1990–91.

TABLE 1. Percentage of Greenland halibut females in the catch in Div. 3L and 3M.

Division	Month						
	Jul	Aug	Sep	Oct	Nov	Dec	Jan
3L	62.3	58.3	67.9	69.7	72.3	73.2	73.6
3M	66.5	66.0	70.5	73.4	74.6	72.7	–

area and this occurs mainly in summer. However, there is also a significant spawning activity in December as represented by 7% of the mature females, and a lower level of reproductive activity during the whole year. This asynchronous spawning behaviour of Greenland halibut was also found by Fedorov (1971) in Barents Sea, where he indicates the existence of two peaks of spawning, one in winter and another secondary one in May–June, with some spawning activity detectable all through the year.

The length frequencies observed showed an increase in size with depth, and the clear dominance of females in the deepest strata all through the year. This segregation by depth is a usual feature in this species (Zilanov et al., MS 1976; Bowering, MS 1982). This seemed to be related mainly with size rather than with the spawning activity, since the slopes of the maturity curves did not show significant differences by depth strata.
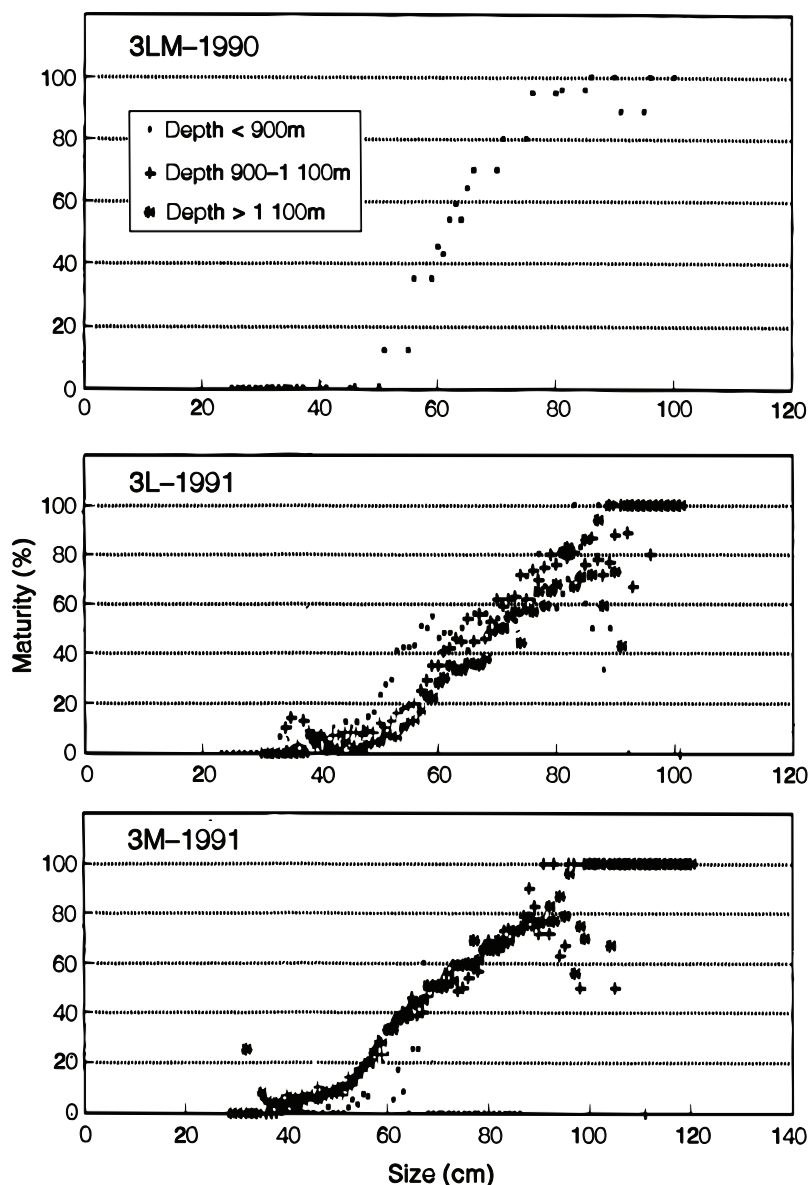
Fig. 3.   Sexual maturity ogives of female Greenland halibut in Div. 3L and 3M in 1990–91, by depth strata.

TABLE 2.   Probit analyses of sexual maturity in female Greenland halibut in Div. 3L and 3M in 1991, and combined Div. 3L and 3M in 1990. All Chi-square tests at P <0.05. (Depths **A** ≤900 m, **B** = 900–1 100 m, **C** ≥1 101 m).

| | 1991 | | | 1990 |
| | Div. 3L | | Div. 3M | Div. 3LM |
	A	B+C	B+C	A+B+C
Chi-Square Test Fit				
Slope (m)	0.05	0.05	0.06	0.07
Y-intercept	1.59	1.53	0.62	0.96
M_{50} (Length of 50% maturity)	68.2	69.4	73.2	67.3
Standard error of M50	0.41	0.1	0.17	0.26
Standard error of the slope (m)	3.7×10^{-4}	2×10^{-3}	5.1×10^{-4}	3.1×0^{-4}
Number of females analyzed	16 062	61 729	123 802	16 925

TABLE 3.   Monthly percentage of spawning females (Stage 3, with hydrated eggs) in the Flemish Pass during 1991.

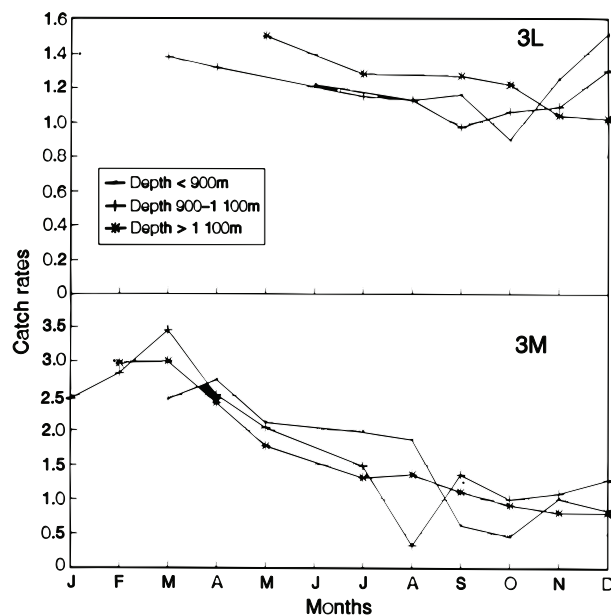| Month	Percentage	Number
January	0	423
February	2.8	776
March	0.8	1 948
April	1.9	639
May	–	–
June	–	–
July	20	987
August	20.9	1 106
September	7.3	1 159
October	3.3	1 353
November	1.6	2 275
December	7.1	792

Fig. 4.   Annual evolution of the standardized catch rates in the Greenland halibut fishery in Div. 3L and 3M by depth strata during 1991.

The range of sizes at M_{50} obtained for Flemish Pass area (67–73 cm) was similar to those reported by Bowering (1983) for the northern areas (Subareas 0 and 2) and somewhat lower than the values obtained by him for the northwestern Newfoundland Shelf (79.6 cm). Some of the largest individuals sampled (above 80 cm) were unexpectedly found to be immature, although according to their size they were well above the M_{50} value. This could be explained by processes of failure to mature as described by Fedorov (1971) and Walsh and Bowering (1981). The present data seems to indicate that the occurrence of this process could be quite frequent in the species.

The maximum values of catch rates and of spawning did not coincide in time, which seemed to indicate that the reproductive status of fish did not have a major influence on fishing efficiency. It is therefore possible that environmental factors could have stronger effects, as has been pointed out by some authors (Smidt, 1969; Ernst, MS 1984; Chumakov and Savvatimsky, 1990).

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