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Biological Characteristics and Bathymetric Distribution of Greenland Halibut  
(*Reinhardtius hippoglossoides*) of the Flemish Pass (3LM) Area  
during the Fishery of Russia in 1998

by

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**Abstract**

Material for investigations was collected by researchers-observers on board of two fishing vessels of Russia in May-December, 1998.

The densest concentrations were being formed by halibut from May to July at depth of 600-800 m, as well as in December at depth of 600-800 m and deeper than 1.200 m. The trawling efficiency during that period exceeded 400 kg/hr. From August to November, the density of concentrations decreased, and the efficiency did not exceed 300 kg/hr.

The basis of catches was immature specimens and those maturing for the first time. This conforms to the existing conceptions on the Flemish Pass area as one of the nursery area of Greenland halibut habitat in the North-West Atlantic.

In the period of observations a gradual increase of feeding intensity took place, but it decreased in December. Fish, cephalopods and shrimp were the most important objects in feeding. Biology of Greenland halibut of Flemish Pass and that of halibut from other areas of the North Atlantic have similar features. By analogy with the year cycle of halibut from the area of Greenland-Canadian Threshold, that of halibut from the area of Flemish Pass is supposed to have periods of feeding and wintering as well.

Summer/autumn feeding took place from May to November. From May to July, halibut concentrated at depths 600-800 m. The increase of feeding intensity was caused by the increase of consumption of shrimp and squid and was accompanied by the disperse of Greenland halibut concentrations.

Wintering has started in December. During this time, the concentrations became more dense, and catches increased because of concentration of young fish at the depth of 600-800 m and deeper than 1.200 m.

**Introduction**

The first messages on deepwater fishery for Greenland halibut in the area of Flemish Pass appeared in the end of 1980's. Since that time, this species fishery became very important for some countries. In spite of a short period of observations, some specific features of biology and distribution of Greenland halibut have recently been determined in this area.

In 1998, 74 % of the Russian quota were fished in the NAFO area. Material on biology of Greenland halibut was collected during the directed fishery for this species.

Results of Russian investigations in 1998 are presented in this paper.

### Materials and Methods

Material was collected by researchers-observers on board of two fishing vessels during the directed fishery for Greenland halibut from May to December, 1998. The main fishery was carried out in Div. 3L. In Div. 3M the fishery was conducted episodically.

Bottom trawls with opening 25 x 3.5 m with mesh size 130 to 140 mm in the codend were used. The duration of trawlings constituted in average 5-6 hours and reached 8 hours. Fishery for halibut was carried out at the depth of 640 to 1.430 m, and 800-900 m, predominantly. In total, 1.134 trawlings were carried out in Div. 3LM and catches of 299 trawlings were analyzed.

The density of Greenland halibut concentrations was assessed by value of catch per unit effort -kg/hr, the latter was estimated by the outcome of final product.

Sampling was carried out by methods accepted by NAFO and PINRO. Mass measurements of halibut were done with separation by sexes and measurement of full zoological length. Maturity, index of stomach fullness and qualitative composition of feeding were determined visually. Stages of maturation of Greenland halibut were determined by 6-point scale (1-6), stomach fullness - by 5-point scale (0-4). It is necessary to note that we are not always a success to distinguish prey of a predator and fishery wastes consumed by a predator.

Intensity of halibut feeding was estimated by a number of fish with empty stomachs and by average index of stomach fullness (ISF). Frequency of occurrence (FO) of food objects was calculated by a number of stomachs with food. For convenience of comparison between our data on feeding and results of investigations obtained earlier (Rodriguez-Marin et al., 1995), the analysis of feeding is presented with separation "small" and "large" halibut. Fish less 60 cm were considered as "small", whereas those longer 60 cm - as "large" specimens.

The volume of the used ichthyological material is presented in Table 1.

### Results

The fishing efficiency for Greenland halibut from May to December was not high. Mean efficiency for the whole period constituted 310 kg/hr. (Table 2). The densest concentrations were formed by halibut from May to July, as well as in December. Fishing efficiency in this period at depths 600-800 m exceeded 400 kg/hr., and in some cases it reached 1.100 kg/hr. Density of concentrations decreased from August to November, and mean catch at this time did not exceed 300 kg/hr.

Males 23 to 79 cm long and females 23 to 99 cm occurred in catches (Fig. 1). the predominated sizes and mean length of halibut increased with depth (Fig. 2). For the period of observations at depths 640 to 1.430 m, mean length increased gradually from 40.2 to 45.2 cm in males and from 43.6 to 50 cm in females. Young halibut less 30 cm were registered in the whole surveyed range of depths, especially often on the western slope of the Grand Bank of Newfoundland (3L) at depths to 800 m. Occurrence of such fish constituted in average 1.2 % for the whole cruise. In the middle of June in 3L Div., 12 % of young fish were registered in a catch at the depth of 740 m.

Length composition of halibut in the period of observations was being changed (Fig. 3, 4). In the period from July to September, mean length and predominated lengths of fish increased at depths 600 to 1.000 m. In the period from October to December, mean length and predominated length of halibut decreased at depth range 800-1.000 m. Decrease of length was observed for halibut from 800 m. At depths less than 800 m, mean length increased.

A portion of females constituted in average 61 % and increased with the depth (Table 3). At all levels the sex ratio varied slightly with the time. However, in spite of female predominated in catches, a portion of males in some catches was also large. For example, in June in Div. 3L at depths 1.000-1.100 m females predominated more than two times

in abundance over males. At the same time, at depths 650-670 m, sex correlation was opposite.

Immature specimens and those maturing for the first time predominated in catches (Table 4). Immature males in catches constituted 84 %, whereas immature females - 79 %. A number of mature fish increased with depth. Mature fish (males at maturation stages 3, 4 and 5 and females at 4 and 5 maturation stages) were found occasionally during the whole period of observations. Males at these stages constituted 9 % and females - 1 %. The occurrence of mature fish of small sizes is of interest. From September to December, one male at stage 3 with length 33 cm and 2 females at stage 4 with length 50-51 cm.

The number of fish with empty stomachs constituted in average 63 % (Table 5). ISF was equal to 1. During observations, a gradual increase of feeding intensity took place, that was registered in the whole range of depths. At depths of 800-1.000 m, halibut fed more actively than at other depths.

In feeding of both "small" and "large" specimens fish objects predominated (Tables 6 and 7). The summarized FO of fish of 20 different species constituted 43 %. Shrimp and cephalopods had also a great importance in feeding, their FO constituted 24 and 18 %, correspondingly. Squid had the greatest importance among cephalopods in feeding of Greenland halibut.

The feeding intensity of "small" fish was lower than that of "large" fish. "Large" halibut consumed fish mainly (FO is 57%). Shrimp and cephalopods were mainly consumed by "small" specimens and occurred rarely in a food bolus of "large" fish. From May to December, the consumption of shrimp and cephalopods by "large" and "small" specimens increased. However, growth of consumption of these organisms by "small" specimens was higher.

It should be mentioned that in December the feeding intensity of both "small" and "large" specimens began to decrease. Compared to November, the number of empty stomachs in "small" halibut increased from 59 to 63 %. In "large" specimens, this increase was less pronounced, from 50 to 52 %.

The consumption by halibut of their own young specimens (cannibalism) was not high - 0.6 % FO.

### Discussion

The length composition of Greenland halibut in catches in May-December 1998 did not change much compared to changes with the similar period of 1997 (Alpoim et al., 1998; Junquera et al., 1998). Modal length in catches of 1997 and 1998 was 42-43 cm (Fig. 5). Mean length of Greenland halibut in commercial catches decreased slightly (from 45.5 to 44.6 cm). By-catch of young fish less 30 cm increased (from 0.7 to 1.1 %).

In the Flemish Pass area, a gradual change of sex composition takes probably place, and a slow decrease of a number of females in catches in 1991-1998 prove it. In July-December, 1991, a number of females in commercial catches constituted 69 %, and their portion increased gradually with the coming winter (Junquera and Zamarro, 1994). In 1993, a portion of females in the Regulatory Area constituted 63 % (Enrique de Cardenas, 1996). In 1998, a portion of females constituted 61 %, and compared to 1991, there was no great changes from season to season. A decrease of a portion of females is apparently a result of the fishery press, which withdraws first of all large mature females.

Due to published data, halibut males of the Northwest Atlantic begin to mature at length of 46 cm, whereas females - at 52 cm length (Trojanovsky and Chumakov, 1992). In our catches, maturing specimens of less size were registered. These data widen the present knowledge on possible sizes at which halibut begin to mature.

Compared to 1992 (Rodrigues-Marin et al., 1995), a level of cannibalism is less (1.7 in 1992 and 0.6 % FO in 1998). It is necessary to note that it is somewhat difficult to estimate this parameter (see "Material and methods"). A low level of cannibalism at a plenty of small fish can be a consequence of two circumstances:

- small number of very large fish able to consume their own young specimens;
- the availability of enough food for big specimens.

Most likely, both these circumstances take place in the Flemish Pass.

Change of biological characteristics is connected with fish behavior, distribution and density of concentrations. Greenland

halibut behavior depended mainly on the specific feeding of small and middle-sized specimens during different seasons and on the distribution of food objects.

The obtained data on feeding correlate well with results of previous investigations. A number of fish with empty stomach constituted in different years 62-84 % (Chumakov and Podrazhanskaya, 1986; Rodriguez-Marin et al., 1995). The intensity of halibut feeding in the Subarea 3 was higher than in other areas of Northwest Atlantic (Chumakov and Podrazhanskaya, 1986). If to make a comparison between our results and investigations done earlier, than the intensity of Greenland halibut feeding in the period of observations can be considered as average.

In 1992, the intensity of feeding of "small" halibut decreased from May to June, increased from June to September, and decreased again from September to December (Rodriguez-Marin et al., 1995). The increase of intensity of feeding of "small" fish happened at the expense of increased consumption of shrimp and squids that corresponds to our observations.

Similar to year cycles of Greenland halibut in other parts of North Atlantic (Trojanovsky and Chumakov, 1992), one can assume the existence of two different stages of the year cycle: summer/autumn feeding and wintering.

Summer/autumn feeding lasted from May to November. In May-July, halibut made concentrations at depths 600-800 m. In this period, a stable increase of feeding intensity takes place because of the consumption of shrimp and squids by small and middle-sized halibut. The increase of feeding intensity is accompanied by dispersal of concentrations. As a result, densities of halibut concentrations decreased from August to November.

Wintering period of halibut began apparently in December. The intensity of feeding decreased, it was especially typical for small and middle-sized specimens. Halibut begin to concentrate again, that is caused by migration of small fish (modal group 34-44 cm) from depths less than 800 m to depths more than 1.200 m.

A shift of small and middle-sized fish to depths with the beginning of winter conforms to the behavior of Greenland halibut on the Greenland-Canadian threshold in autumn/winter of 1970's (Trojanovsky and Chumakov, 1992). With the beginning of winter in this area halibut concentrations migrated to large depths. All specimens, feeding together, took part in that migration: the mature ones - to the spawning grounds, immature specimens - to wintering grounds. Greenland halibut of Flemish Pass differ from those of Greenland-Canadian Threshold in size composition and small number of mature fish. The results of investigations confirm the existed opinions on the area of deepwater Flemish Pass as one of the nursery areas of Greenland halibut in the Northwest Atlantic (Trojanovsky and Chumakov, 1992).

The basis of catches there is immature fish and those maturing for the first time which determine the distribution in this area.

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**Table 1. Volume of biological material used in the paper.**

| <b>Months</b>    | <b>Divisions</b> | <b>Mass measurements</b> | <b>Biological analysis</b> |
|------------------|------------------|--------------------------|----------------------------|
| <b>May</b>       | <b>L</b>         | 1740                     | 167                        |
|                  | <b>M</b>         | 432                      | 63                         |
|                  | <b>LM</b>        | <b>2172</b>              | <b>230</b>                 |
| <b>June</b>      | <b>L</b>         | 8124                     | 637                        |
|                  | <b>M</b>         | 221                      | 32                         |
|                  | <b>LM</b>        | <b>8345</b>              | <b>669</b>                 |
| <b>July</b>      | <b>L</b>         | 10536                    | 1581                       |
|                  | <b>M</b>         | 1116                     | 167                        |
|                  | <b>LM</b>        | <b>11652</b>             | <b>1748</b>                |
| <b>August</b>    | <b>L</b>         | 14112                    | 1958                       |
|                  | <b>M</b>         | 907                      | 186                        |
|                  | <b>LM</b>        | <b>15019</b>             | <b>2144</b>                |
| <b>September</b> | <b>L</b>         | 5202                     | 754                        |
|                  | <b>L</b>         | <b>5202</b>              | <b>754</b>                 |
| <b>October</b>   | <b>L</b>         | 8832                     | 1855                       |
|                  | <b>M</b>         | 4314                     | 670                        |
|                  | <b>LM</b>        | <b>13146</b>             | <b>2525</b>                |
| <b>November</b>  | <b>L</b>         | 6757                     | 1103                       |
|                  | <b>M</b>         | 5273                     | 861                        |
|                  | <b>LM</b>        | <b>12030</b>             | <b>1964</b>                |
| <b>December</b>  | <b>L</b>         | 6774                     | 993                        |
|                  | <b>L</b>         | <b>6774</b>              | <b>993</b>                 |
| <b>Total</b>     | <b>L</b>         | <b>62077</b>             | <b>9048</b>                |
|                  | <b>M</b>         | <b>12263</b>             | <b>1979</b>                |
|                  | <b>LM</b>        | <b>74340</b>             | <b>11027</b>               |

**Table 2. Mean catches (kg/hr.) of Greenland halibut by bottom trawl by depths. Flemish Pass (3LM), May-December, 1998.**

| <b>Depth, m</b>  | <b>May</b> | <b>June</b> | <b>July</b> | <b>August</b> | <b>September</b> | <b>October</b> | <b>November</b> | <b>December</b> | <b>Mean</b> |
|------------------|------------|-------------|-------------|---------------|------------------|----------------|-----------------|-----------------|-------------|
| <b>600</b>       | -          | -           | -           | -             | 270              | -              | -               | -               | <b>270</b>  |
| <b>601-800</b>   | 470        | 410         | 410         | 230           | 220              | 300            | 280             | 400             | <b>340</b>  |
| <b>801-1000</b>  | 400        | 360         | 360         | 260           | 270              | 250            | 290             | 330             | <b>310</b>  |
| <b>1001-1200</b> | 290        | 300         | 290         | 270           | 280              | 250            | 270             | 300             | <b>270</b>  |
| <b>1201-1400</b> | -          | 280         | 400         | -             | 270              | 250            | 270             | 390             | <b>310</b>  |
| <b>&gt; 1401</b> | -          | -           | 270         | -             | -                | -              | -               | 340             | <b>320</b>  |
| <b>Mean</b>      | <b>380</b> | <b>370</b>  | <b>370</b>  | <b>250</b>    | <b>270</b>       | <b>260</b>     | <b>280</b>      | <b>344</b>      | <b>310</b>  |

**Table 3. Female proportion in catches of Greenland halibut at different depths. Flemish Pass (3LM). May-December 1998.**

| Depth, m    | Quarters  |           |           |           |
|-------------|-----------|-----------|-----------|-----------|
|             | II        | III       | IV        | mean      |
| < 800       | 57        | 56        | 56        | 56        |
| 801-1000    | 62        | 62        | 63        | 63        |
| 1001-1200   | 57        | 66        | 65        | 65        |
| > 1201      | -         | 66        | 62        | 63        |
| <b>Mean</b> | <b>58</b> | <b>62</b> | <b>61</b> | <b>61</b> |

**Table 4. Ratio (%) between immature fish\* in catches of Greenland halibut of different depths. Flemish Pass (3LM), May-December, 1998.**

| Depth, m    | Quarters       |                |                |                |
|-------------|----------------|----------------|----------------|----------------|
|             | II             | III            | IV             | mean           |
| < 800       | 92 : 96        | 90 : 98        | 90 : 94        | 90 : 92        |
| 801-1000    | 75 : 84        | 84 : 78        | 89 : 84        | 84 : 81        |
| 1001-1200   | 76 : 74        | 84 : 72        | 78 : 75        | 80 : 75        |
| > 1201      | -              | 75 : 52        | 68 : 59        | 67 : 56        |
| <b>Mean</b> | <b>84 : 87</b> | <b>86 : 79</b> | <b>82 : 78</b> | <b>84 : 79</b> |

\* males : females

**Table 5. Portion (%) of Greenland halibut with empty stomachs by length groups Flemish Pass (3LM), May December, 1998.\*.**

| Depth, m  | Length groups,<br>cm | Quarters |     |    |      |
|-----------|----------------------|----------|-----|----|------|
|           |                      | II       | III | IV | mean |
| 600-800   | <60                  | 85       | 65  | 57 | 64   |
|           | >60                  | 55       | 63  | 57 | 59   |
|           | t                    | 84       | 64  | 57 | 63   |
| 801-1000  | <60                  | 83       | 63  | 57 | 63   |
|           | >60                  | 45       | 49  | 46 | 48   |
|           | t                    | 79       | 60  | 55 | 59   |
| 1001-1200 | <60                  | 84       | 72  | 68 | 70   |
|           | >60                  | 66       | 62  | 52 | 57   |
|           | t                    | 81       | 69  | 64 | 67   |
| 1201-1400 | <60                  | -        | 77  | 69 | 70   |
|           | >60                  | -        | 57  | 52 | 53   |
|           | t                    | -        | 69  | 62 | 63   |
| Mean      | <60                  | 84       | 66  | 62 | 66   |
|           | >60                  | 56       | 55  | 52 | 53   |
|           | t                    | 82       | 63  | 60 | 63   |

\* <60 - less them 60 cm;  
 >60 - 60 cm and longer;  
 t - without separation by length groups



**Table 6. Frequency of occurrence (%) of main components of feeding\* in stomachs of Greenland halibut less than 60 cm. Flemish Pass (3LM), May-December, 1998.**

| Depth, m  | Main food | Quarters |     |    |      |
|-----------|-----------|----------|-----|----|------|
|           |           | II       | III | IV | mean |
| 600-800   | S         | 13       | 19  | 31 | 27   |
|           | C         | 7        | 25  | 17 | 18   |
|           | F         | 56       | 45  | 43 | 45   |
| 801-1000  | S         | 3        | 23  | 17 | 21   |
|           | C         | 9        | 23  | 32 | 25   |
|           | F         | 57       | 37  | 36 | 38   |
| 1001-1200 | S         | 28       | 26  | 17 | 20   |
|           | C         | 28       | 34  | 45 | 40   |
|           | F         | 24       | 32  | 27 | 28   |
| 1201-1400 | S         | -        | 17  | 12 | 13   |
|           | C         | -        | 43  | 55 | 53   |
|           | F         | -        | 23  | 23 | 24   |
| Mean      | S         | 13       | 22  | 22 | 22   |
|           | C         | 12       | 26  | 32 | 27   |
|           | F         | 50       | 38  | 35 | 37   |

\* S-shrimp;  
C-cephalopods;  
F-fish

**Table 7** Frequency of occurrence (%) of main food objects\* in stomachs of Greenland halibut 60 cm and longer. Flemish Pass (3LM), May-December, 1998.

| Depth, m  | Mean food | Quarters |     |    |      |
|-----------|-----------|----------|-----|----|------|
|           |           | II       | III | IV | mean |
| 600-800   | S         | -        | 3   | 22 | 13   |
|           | C         | -        | -   | 18 | 10   |
|           | F         | 67       | 69  | 41 | 54   |
| 801-1000  | S         | -        | 9   | 2  | 7    |
|           | C         | -        | 3   | 2  | 3    |
|           | F         | 69       | 59  | 60 | 60   |
| 1001-1200 | S         | 8        | 4   | 3  | 3    |
|           | C         | -        | 1   | 12 | 9    |
|           | F         | 69       | 67  | 55 | 59   |
| 1201-1400 | S         | -        | 8   | 1  | 2    |
|           | C         | -        | 13  | 14 | 14   |
|           | F         | -        | 32  | 55 | 51   |
| Mean      | S         | -        | 7   | 4  | 5    |
|           | C         | 3        | 4   | 12 | 8    |
|           | F         | 68       | 59  | 54 | 57   |

\* Legend is in Table 6.

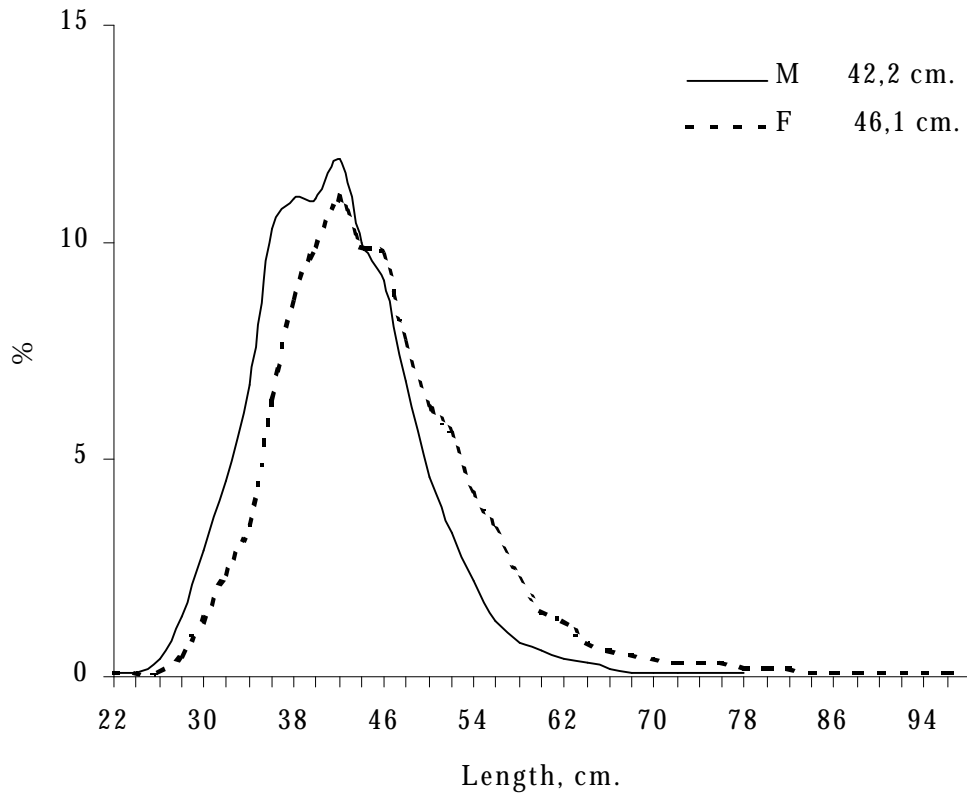


Fig. 1 Length composition of Greenland halibut from catches by a bottom trawl. Flemish Pass (3LM), May-December, 1998.

Legend:  
M - males;  
F - females;  
figures - mean length, cm.

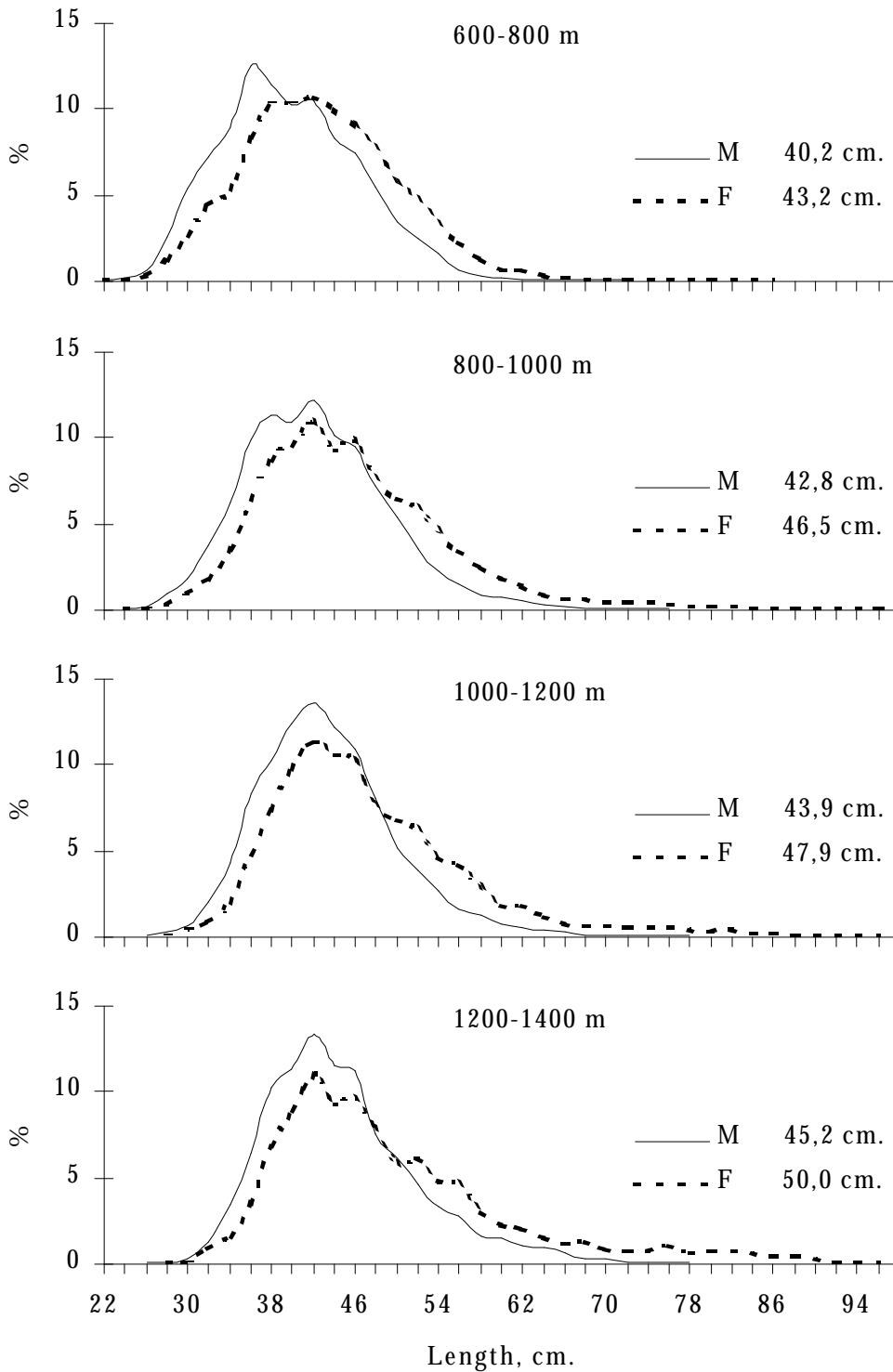


Fig. 2 Variation of Greenland halibut length with the depth in catches by a bottom trawl. Flemish pass (3LM), May-December, 1998.

Legend is in Fig.1.

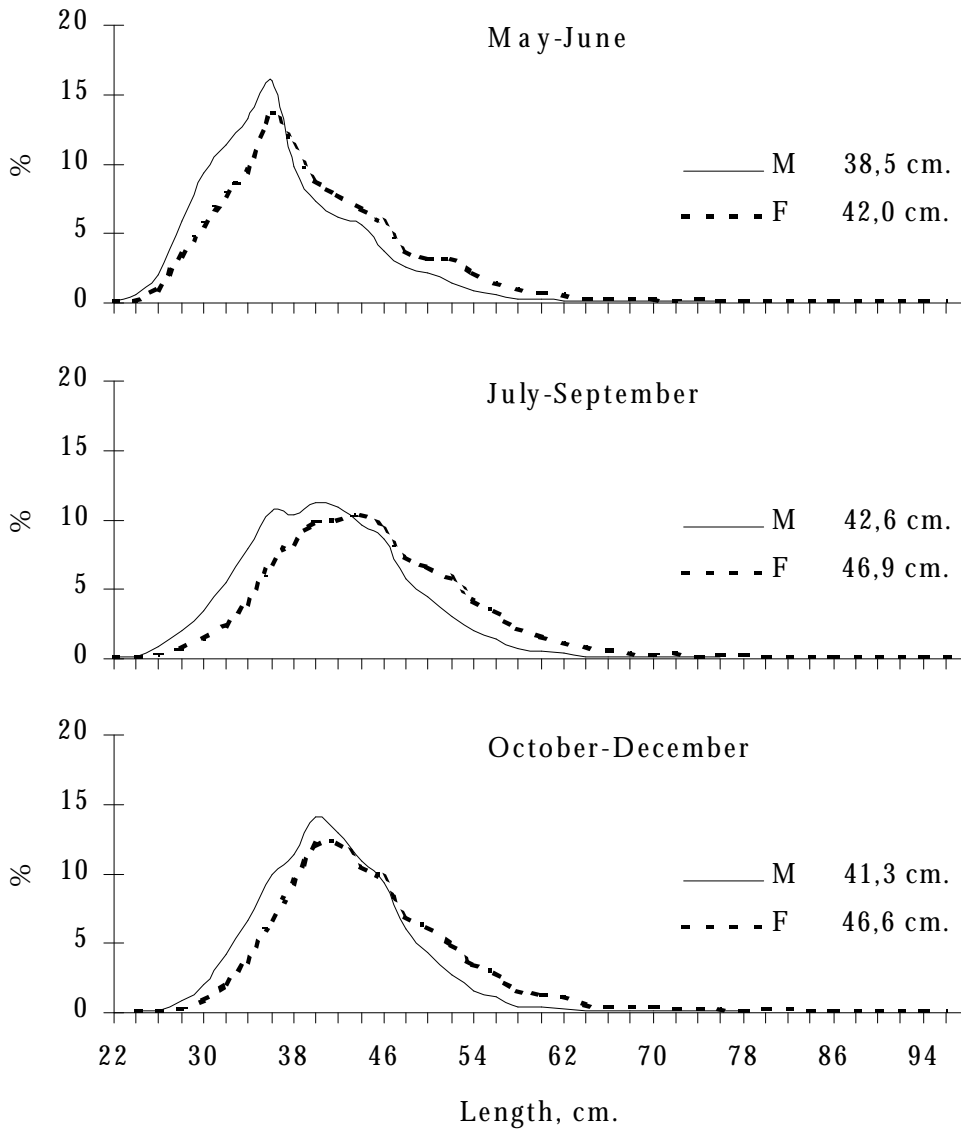


Fig.3. Seasonal variations of Greenland halibut length composition in catches by a bottom trawl. Flemish Pass (3LM), May-December, 1998.

Legend is in Fig. 1.

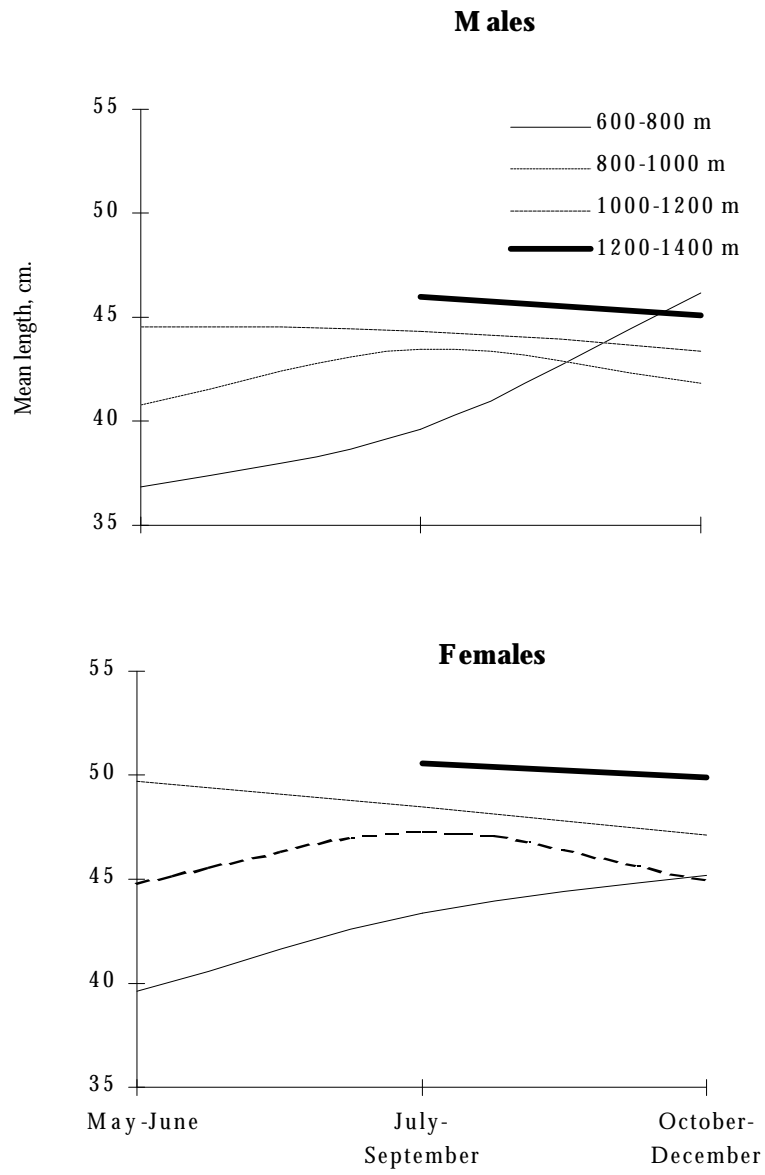


Fig. 4. Seasonal variations of mean length of Greenland halibut in catches by a bottom trawl by depths.

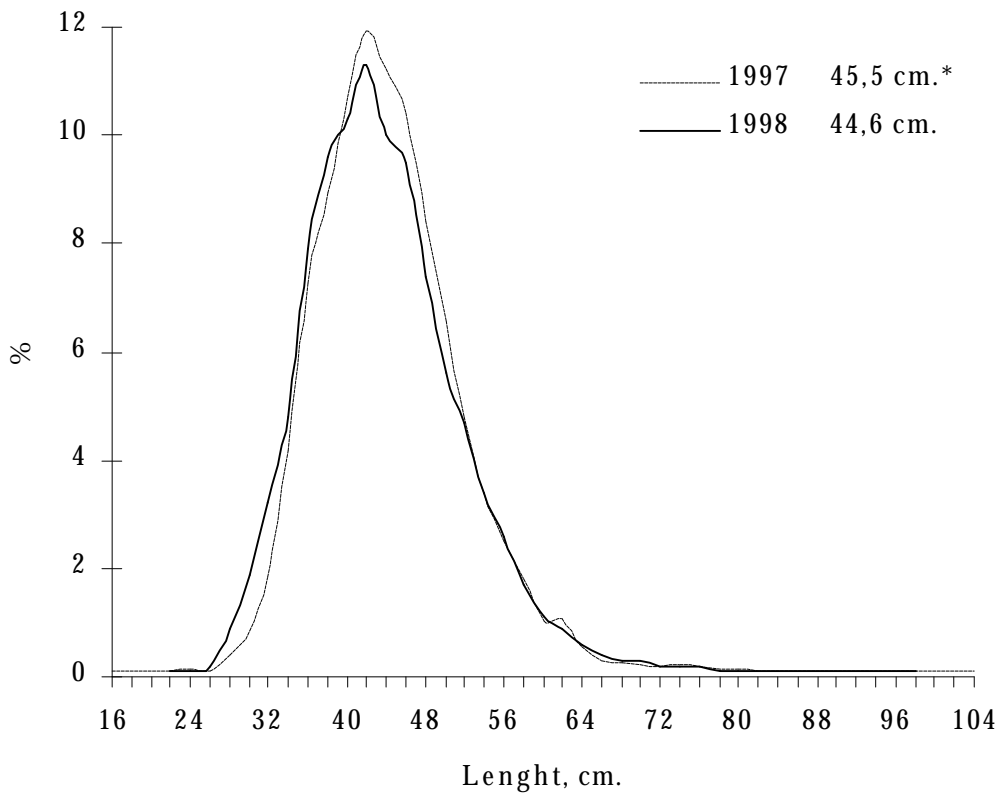


Fig. 5. Length composition of Greenland halibut from Flemish Pass (3LM) in commercial catches from May to December, 1997 and 1998.

Legend is in Fig. 1.

**Note:**

\* Data for May-December, 1997, were calculated by summarized data from reports of Spain (S. Junquera et al., 1998) and Portugal (R. Alpoim et al., 1998).