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Growth Pattern of Greenland Halibut (Reinhardtius hippoglossoides W.) from the Northeast Atlantic

by

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ABSTRACT

The pattern and peculiarities of linear and weight growth of Greenland halibut from the Barents Sea and Icelandic area are investigated.

Notable variations in length and weight typical of males and females from the same age group reflect the adaptation of fish to fuller consumption of food and, apparently, to regular recruitment. Males of the Barents Sea and Icelandic halibut under 5 and 7 years of age, respectively, are longer than females of the same age.

The linear growth of Greenland halibut follows the pattern common for most fishes: it is the highest in young fish slowing down with age. The linear growth rate complies with this pattern as well: the yearly length increments are the greatest for the young and the lowest for the old fish.

The weight of fish body is on a steady increase till the old age, then its growth gets slower. The rate of weight growth also follows this trend. The weight of females from the Barents Sea and Icelandic halibut stocks under 3 and 7 years of age, respectively, is higher than that of males of the same age.

The weight increment per unit of length is higher for the Barents Sea halibut. Fish from the Icelandic stock are longer and heavier than the Barents Sea halibut of the same age.

SPECIAL SESSION ON DEEPWATER FISHES

The pattern and peculiarities of Greenland halibut growth should be regarded as manifestation of fish adaptation developed during phylogenesis.

INTRODUCTION

The growth pattern of Greenland halibut from the Northeast Atlantic is covered poorly in literature. The only known work dwelling on this point was contributed by the Polish investigator Krzykawski (1975). Besides, basing on the data collected by the Polar Research Institute in the Barents Sea and off Iceland in 1965-1969, the linear and weight growth, yearly length and weight increments, length/weight ratios of Greenland halibut from the Barents Sea and Icelandic stocks were determined. The paper is devoted to solving these problems.

MATERIAL AND METHODS

The paper is based on age samples of halibut collected in the Barents Sea in 1965-1969 and off Iceland in 1967-1969.

To estimate the linear growth pattern of the Barents Sea halibut the weight of 2,325 specimens and the age of 2,108 specimens were analysed, and to determine the relationship between the linear and weight growth the data for 1,960 specimens were utilized. The same features of the life cycle of Icelandic halibut were studied on the basis of the data for 1,588, 998 and 1,759 specimens, respectively.

The fish were measured accurate within 1 cm and weighed to within 50 g. The age was estimated, mainly, from the scales by means of a microscope projector with a 20X magnification. In case of uncertainty the age was read from otoliths.

Mean length and weight were estimated for each age group. As far as variations in length and weight of fish of the same age are notable (Fig. 1), the mean values were calculated by mathematical weighting of frequencies. As a result, theoretical values of length and weight were obtained and the curves of linear and weight growth, length/weight ratio, growth rates drawn. The linear growth curve was calculated by

the formula $L = L_{\infty}(1 - e^{-k(t-t_o)})$, the weight growth curve - by $W = W_{\infty}(1 - e^{-k(t-t_o)})^3$ and the length/weight ratio curve - by $W = al^3$. The yearly length and weight increments were estimated as the difference between the mean lengths and weights of fishes from two neighbouring year classes.

RESULTS

Length and weight variations in fish from the same age group

To determine the amplitude of length and weight variations in fish from the same age group those of the Barents Sea halibut females are analysed (Fig. 1). The central part of the figure with the length and weight data for the most frequently occurring fish aged 8 to 14 years is the most revealing. The length of females aged 12 ranges from 64 to 98 cm. Weight variations are still more significant:females at that age are of the weight of 1.4 to 6.3 kg, and those aged 13 - 2.0 to 8.4 kg. The same is characteristic of males. Large variations in length and weight of fish from one age group are observed both for the Barents Sea and Icelandic halibut.

Linear growth and its rate

The linear growth of halibut follows the pattern characteristic of most fish species. The highest growth of halibut males and females happens at young age (Fig. 2). For the Barents Sea halibut males this period lasts till the age of 5-7 years and for females till 7-9 years. For Icelandic halibut males the period of the most intensive growth lasts till the age of 7-8 years and for females - till 9-10 years. The older the fish, the slower their growth. It should be mentioned that males of the Barents Sea halibut under the age of 5 years and those from Icelandic stock under 7 years are longer than females of the same age. The linear growth rate of halibut, i.e. yearly length increments, follows the most common pattern: the highest is at the start of the life cycle, the lowest - at its end Figs. 3, 4). Thus, if females of the Barents Sea halibut

aged 3-4 have a length increment of 6.5 cm and males of the same age - 6 cm, then at the age of 14 to 15 years the linear increment of females amounts to 3.5 and males - 2.5 cm. Females of Icelandic halibut 6-7 years of age become 5.5 cm longer, males - 5.4 cm longer, while at the age of 12 to 13 - only 4.5 and 3.0 cm longer, respectively. It should be noted that the linear growth rate (Fig. 3) of females from the Barents Sea upwards of 3 years of age is higher than that of males. The linear growth of Icelandic halibut females is higher than that of males from 6 years of age and upwards (Fig.4). Unfortunately, fish under 3 years of age were absent from the samples taken in the Barents Sea and those under 3 years - from the area of Iceland, while for fish namely of these ages, judging by the curves, the growth rates of males and females must be inversely related. The growth rate of males at their first years of life is apparently much higher than that of females, and this phenomenon has its biological grounds which will be discussed later.

Weight growth and its rate

The curves of weight growth of Greenland halibut both from the Barents Sea and Icelandic stocks follow the pattern typical of most fish species. At the start of the life cycle the weight growth is comparatively low, with age it increases, reaches its maximum and slows down at an old age (Fig. 5). Females of the Barents Sea halibut, from the age of 4 years and upwards have the larger weight than males and this difference grows with age. Thus, if the weight of females aged 5 averages 500 g and that of males - 400 g, then at the age of 15 years the average weight of females amounts to 5500 g and that of males - only to 4700 g.

Even more striking is the difference in weight growth of males and females of Icelandic halibut. At the age of 5-6 years males are, on the average, 100 g heavier than females. At the age of 7-8 their weight is similar, but over 8 years of age the weight growth of males is becoming

much lower than that of females. If at the age of 9 years females are 100 g heavier than males, then at the age of 12 this difference in weight becomes appreciable and averages 1,200 g. Retardation in weight growth becomes noticeable in males of the Barents Sea halibut at their 14-15th and in females at their 18-19th years of life. The weight growth of the Icelandic halibut males begins to decelerate at their 11-12th and of females - at their 12-13th years of life.

The rate of weight growth increases with age both in males and females from both populations (Figs. 3, 4). For instance, the weight increment for males and females from the Barents Sea stock aged 4-5 years, amounts to nearly 200 g, while the yearly increment for 14-15 year old fish is about 530 g for males and 660 g for females. Judging by the curves, the growth rate of the Barents Sea halibut under 3 years of age is higher for males than for females but with age it becomes lower. This phenomenon is well seen in halibut from the Icelandic stock where the weight growth of females is about that of males at the age of 6 to 7 years (Fig. 5).

Length/weight ratio

The curves of length/weight ratio reflect the above growth pattern of Greenland halibut. The weight of young males is higher than that of females from the same age group. This phenomenon is characteristic of the Barents Sea halibut below 30 cm and of the Icelandic halibut below 40 cm of length. While growing, females, being equal to males in length, excel them in weight, and this difference increases with linear growth (Fig. 6). It should be mentioned that the weight increment per unit of length is somewhat greater for the Barents Sea halibut rather than for the Icelandic.

Difference in growth and its rate in the Barents Sea and Icelandic halibut

Separation of the Barents Sea and Icelandic halibut

stocks, differences in abiotic conditions and feeding produce an effect on growth patterns of fish from both stocks. Males and females of Icelandic halibut are longer than the Barents Sea fish from the same age group (Fig. 7).

Unfortunately, the data series is not complete for lack of information on younger fish. The trend of the curves suggests that for young fish (aged 1-3 years) the above growth pattern does not remain unchanged, i.e. young halibut from the Barents Sea stock have the length equal to or even greater than that of young Icelandic halibut.

As is seen in Fig. 8, at a certain stage of the fish life the weight growth of Icelandic halibut is also slightly higher than that of the Barents Sea halibut.

The same pattern is exhibited in the linear and weight growth rates (Figs. 9, 10). The weight growth rate of males from the Icelandic stock at the age of 5 to 12 years is noticeably higher than that of males from the Barents Sea halibut stock; as for the linear growth rates, here the difference is less significant (Fig. 9).

The weight growth rate of females is close to that of males in both stocks; the curves of weight growth rates are tending to intercept at the beginning and at the end (Fig. 10). That means that the weight growth rate of the Icelandic halibut during the first years of life being lower than that of the Barents Sea halibut becomes higher at the 4-5th years of life, remains so for the greatest part of the life cycle and only at an old age it slows down.

The linear growth rate of males and females from both stocks has its peculiarities. It is noticeably higher for 6-7-year old males from the Icelandic stock than for halibut males from the Barents Sea. If the length increment of males from the Icelandic stock amounts to 5.3 cm at an age of 6 to 7 years, then the yearly length increment of the Barents Sea halibut males at this age is 4.8 cm. However, with age the difference in yearly increments declines, and at the age of 12-13 years the linear growth rates of males from both stocks are similar.

The linear growth rate of the Barents Sea halibut females aged 3 to 8 years is higher than that of females from the Icelandic stock, and later it becomes much lower. Thus, the yearly increments in females aged 15 to 16 years are 4 cm for the Icelandic stock and 3.5 cm for the Barents Sea.

DISCUSSION
(Growth pattern as adaptation of the species)

Greenland halibut is an oceanic species best adapted to ambient conditions. Adaptive mechanisms of this fish are diverse and flexible. It would be sufficient to say that it is one of few fishes of the North Atlantic dwelling at the 150 to 1600 m depths. The range of halibut, for their comparatively low abundance, covers a vast area from the shallow Novaya Zemlya Island in the east to the American shelf in the west and from Spitsbergen and Baffin Island in the north to the latitude of Bergen and the Gulf of Maine in the south. Constitution and coloration of halibut are so that the fish are well adapted to deep and pelagial waters. Halibut go well through the rapid forced ascend from below 1,000 m depth to the surface remaining fully viable. This shows that in the process of phylogenesis halibut adapted to rapid vertical migrations and acquired access to food at all depths. In the years when rich year classes enter the spawning stock local spawning grounds, in addition to the main ones, are formed ensuring the better food supply to the progeny.

Extraordinarily prolonged spawning (Fedorov, 1968) and maturation of fish from the same age group and a great number of other features of their biology convince us of highly developed adaptive mechanisms of the species.

The above growth pattern of Greenland halibut should be regarded as well as a sort of adaptation of the species to ambient conditions developed during phylogenesis.

Notable variations in length and weight of fish from one year class are of great adaptive importance as far as

they enlarge the food spectrum and, consequently, the food supply of the species. Thus, in the Barents Sea the food of small halibut (35-40 cm long) consists mainly of small schooling fishes (capelin, polar cod) and shrimp; small crustaceans (krill and Themisto) are also important. In fish 40 cm long and upwards the frequency of capelin and polar cod occurrence in food decreases gradually. Polar cod are not found in the stomachs of halibut over 70 cm long. In contrast to this the frequency of large fishes occurrence - blue whiting, redfish, halibut as well as of Cephalopoda increases.

Significant variations in length and weight of fish from the same age group not only increase the food supply but also generate maturation of fish from one year class at different ages (Nizovtsev, 1969) which improves the regularity of recruitment.

The most intensive growth is observed in halibut under 7-9 years of age; in males it begins to slow down 2 years earlier than in females. In this period halibut are feeding actively, and the energy supply accumulated in fishes is spent for the linear growth (Nikolsky, 1965). Halibut males are known to mature mainly at the age of 7-8 years while females - at 9-10 years (Nizovtsev, 1969). On attaining maturity, the main function of the organism is not to grow in length but to ensure formation of sex glands, ripening of spawning products and accumulation of reserve substances in the organisms to sustain metabolism during spawning migrations and spawning proper (Nikolsky, 1965) when halibut, like other fishes, spend much energy. Their feeding in this period is much weaker or ceases at all.

Males of the Barents Sea halibut grow faster than females till the age of 6 years. This also should be regarded as a mechanism of adaptation to dwelling conditions. The number of males on spawning grounds is always 2-3 times higher than that of females, and the majority of males participating in

spawning are on the average 2 years younger than spawning females. To get mature sooner, males must grow faster than females. Besides, in order that to the moment of spawning the number of males might be higher than that of females, young males must get rid of the pressure of predators as soon as possible by way of a higher compared to females growth rate at the first years of their life.

Namely at the age of 7-8 years the growth rate of females is about that of males and higher.

Halibut are repeat spawners, that is why their further liner growth is much lower than before their first spawning. At the same time aging affects adversely the growth. In females, owing to their earlier maturation, the process of aging develops faster than in females. Malos upwards of 15 years of age were not found in samples. Apparently, at this time they were eliminated from the population.

The linear growth of females is also delayed in the period of maturation, i.e. at the age of 9 to 12 years. However, the rate of their growth retardation is not so high as in males and the old age comes some years later; specimens aged 19-20 years are found occasionally.

CONCLUSIONS

1. Notable variations in length and weight typical of males and females from the Barents Sea and Icelandic halibut stocks are a sort of adaptation to a wider food spectrum and, apparently, to regular recruitment. Males of the Barents Sea and Icelandic halibut under 5 and 7 years of age, respectively, are longer than females from the same age group.

2. The linear growth of Greenland halibut follows the pattern common for most fishes: it is the highest in young fish slowing down with age. The linear growth rate complies with this pattern: the yearly length increments are the greatest for the young and the lowest for the old fish.

3. The weight of halibut is on a steady increase till the old age, then its growth slows down. The rate of weight

growth also follows this trend. The weight of females from the Barents Sea and Icelandic halibut stocks under 3 and 7 years of age, respectively, is higher than that of males of the same age.

4. The weight increment per unit of length is higher for the Barents Sea halibut.

5. Fish from the Icelandic stock are longer and heavier than the Barents Sea halibut of the same age.

6. The pattern and peculiarities of Greenland halibut growth should be regarded as manifestation of fish adaptation developed during phylogenesis.

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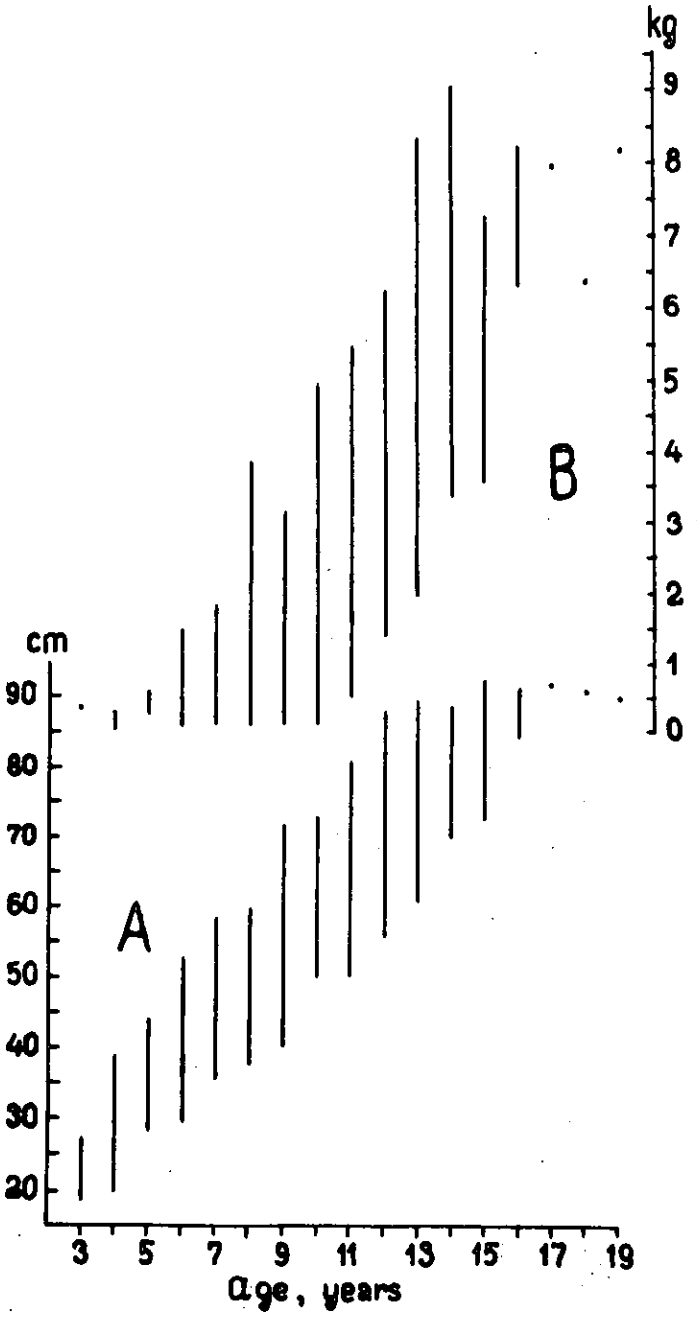

Fig. 1. Variations in length and weight of the Barents Sea halibut females at different ages
A - length variations; B - weight variations

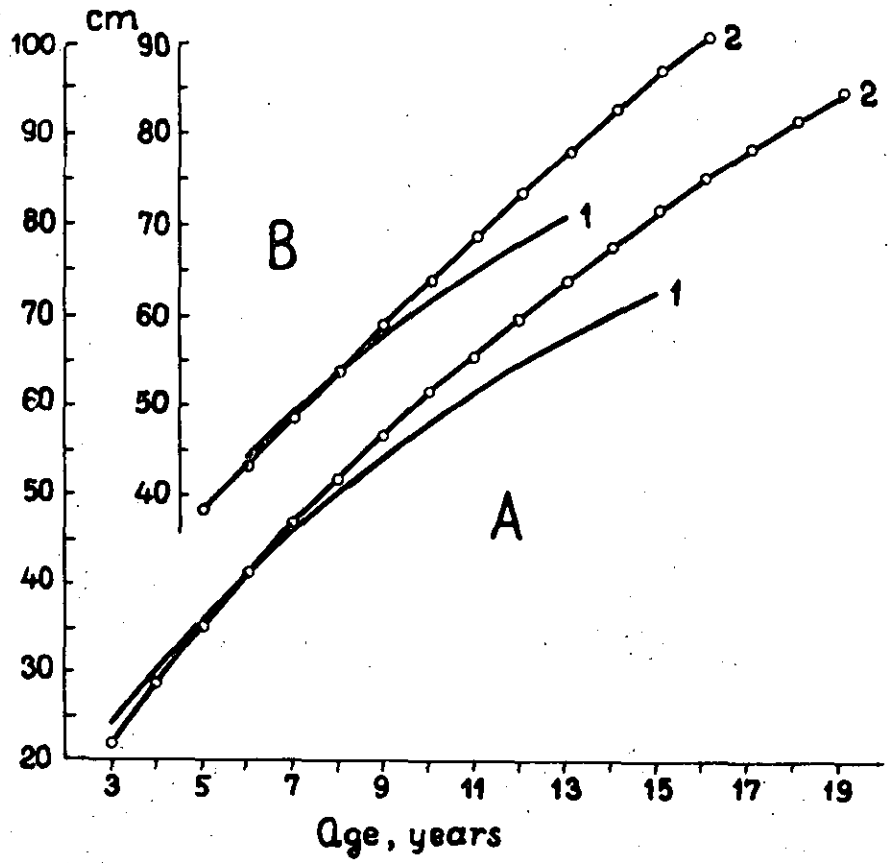

Fig. 2. Linear growth of halibut from A - Barents Sea and B - Icelandic stocks; 1 - males, 2 - females

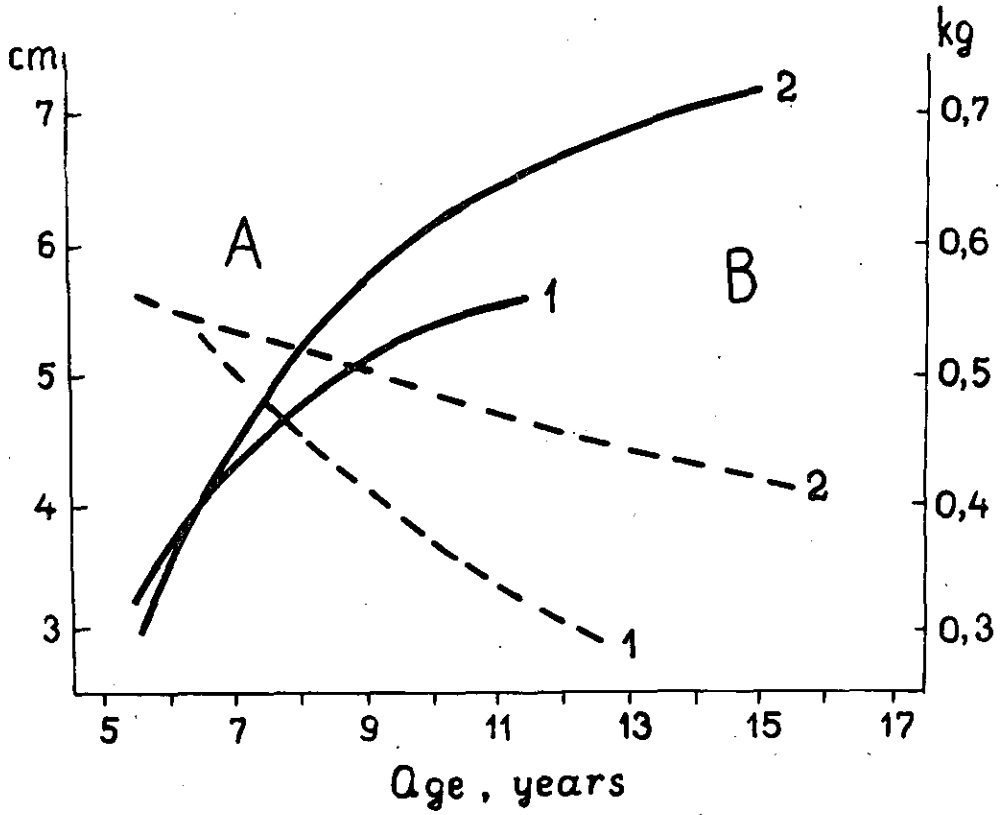

Fig. 3. Rates of linear (A) and weight (B) growth of Greenland halibut from the Barents Sea; 1 - males, 2 - females

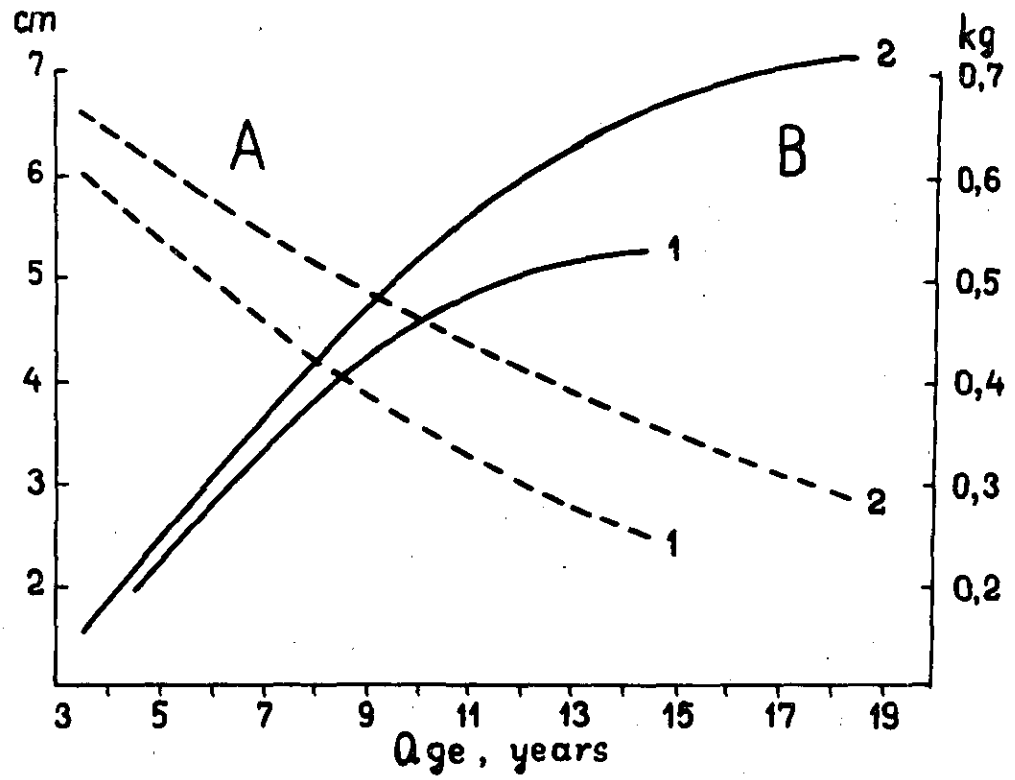

Fig. 4. Rates of linear (A) and weight (B) growth of Greenland halibut from the Icelandic stock; 1 - males, 2 - females

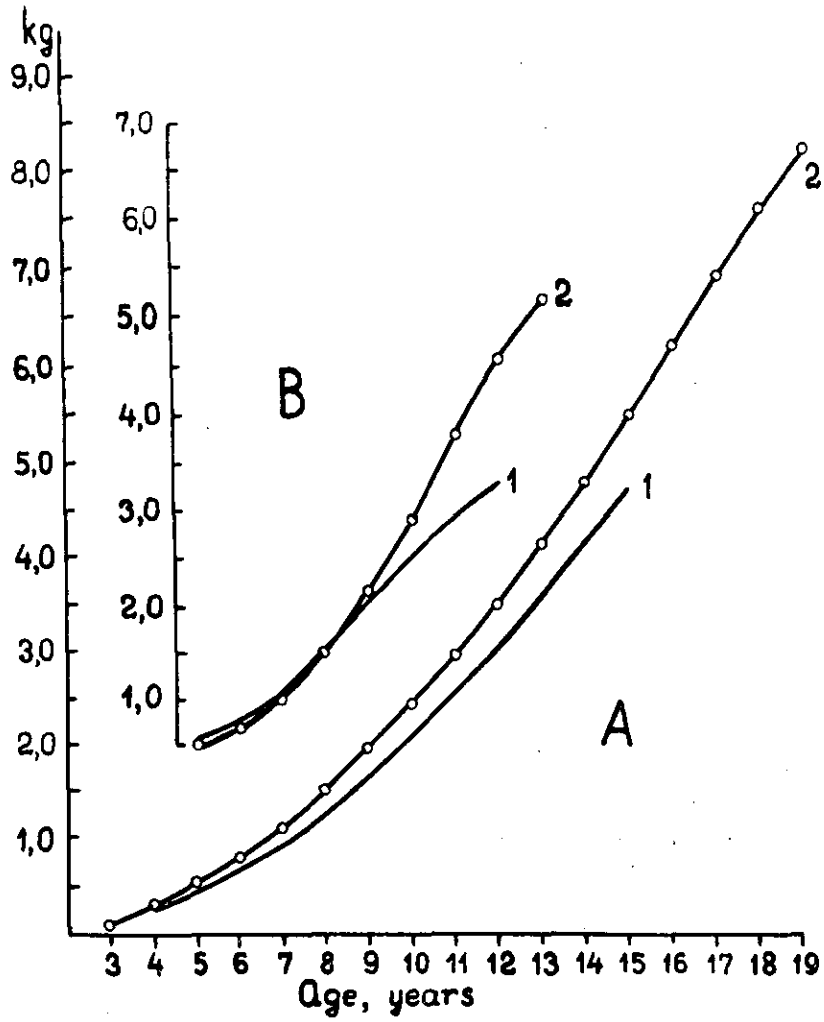

Fig. 5. Weight growth of Greenland halibut from A - Barents Sea and B - Icelandic stocks; 1 - males, 2 - females

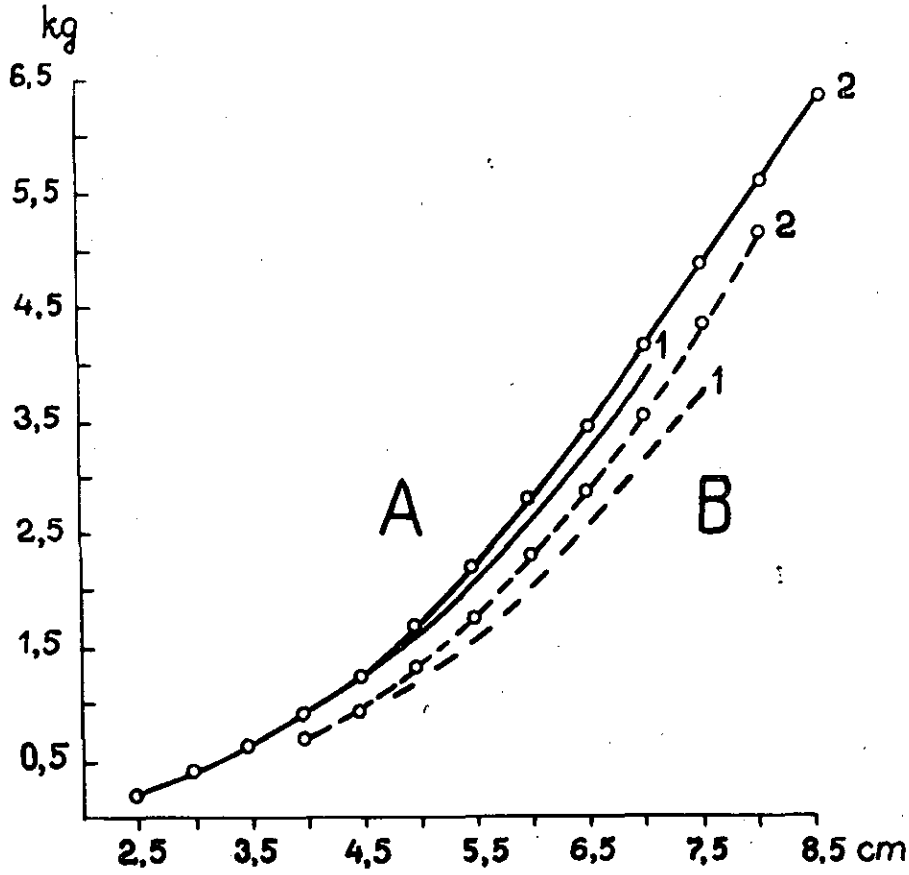

Fig. 6. Length/weight ratio of Greenland halibut from A - Barents Sea and B - Icelandic stocks; 1 - males, 2 - females

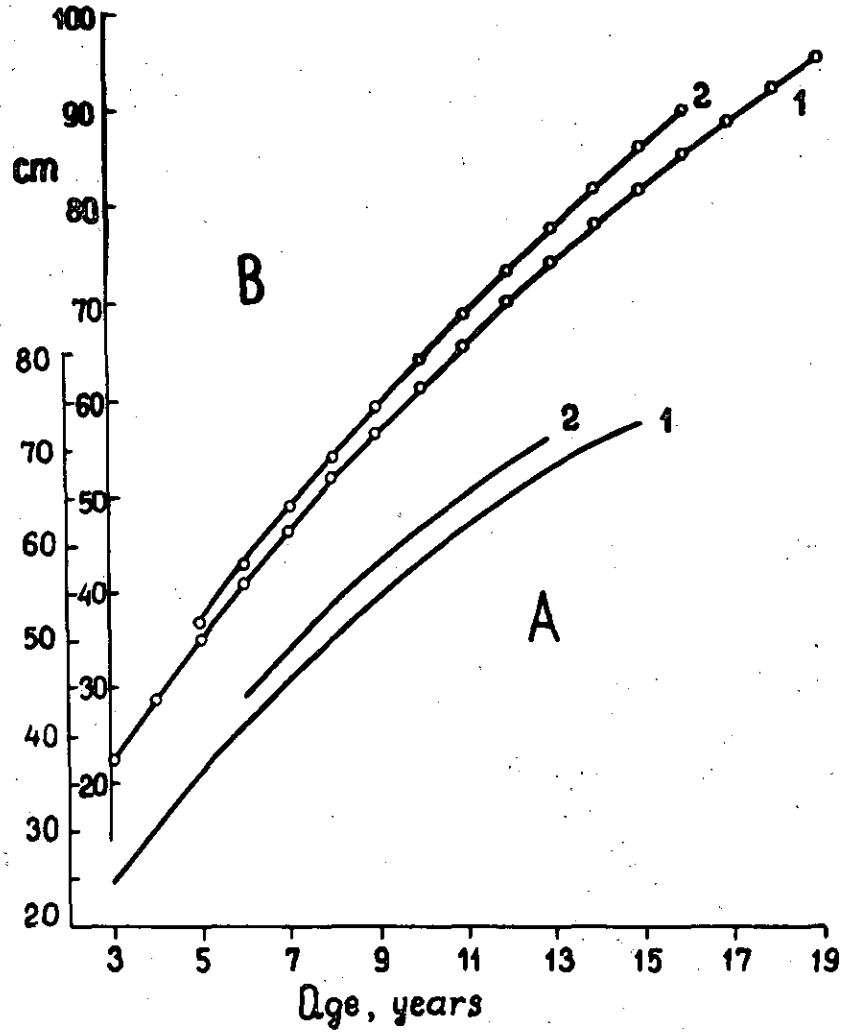

Fig. 7. Linear growth of Greenland halibut from 1 - Barents Sea and 2 - Icelandic stocks; A - males, B - females

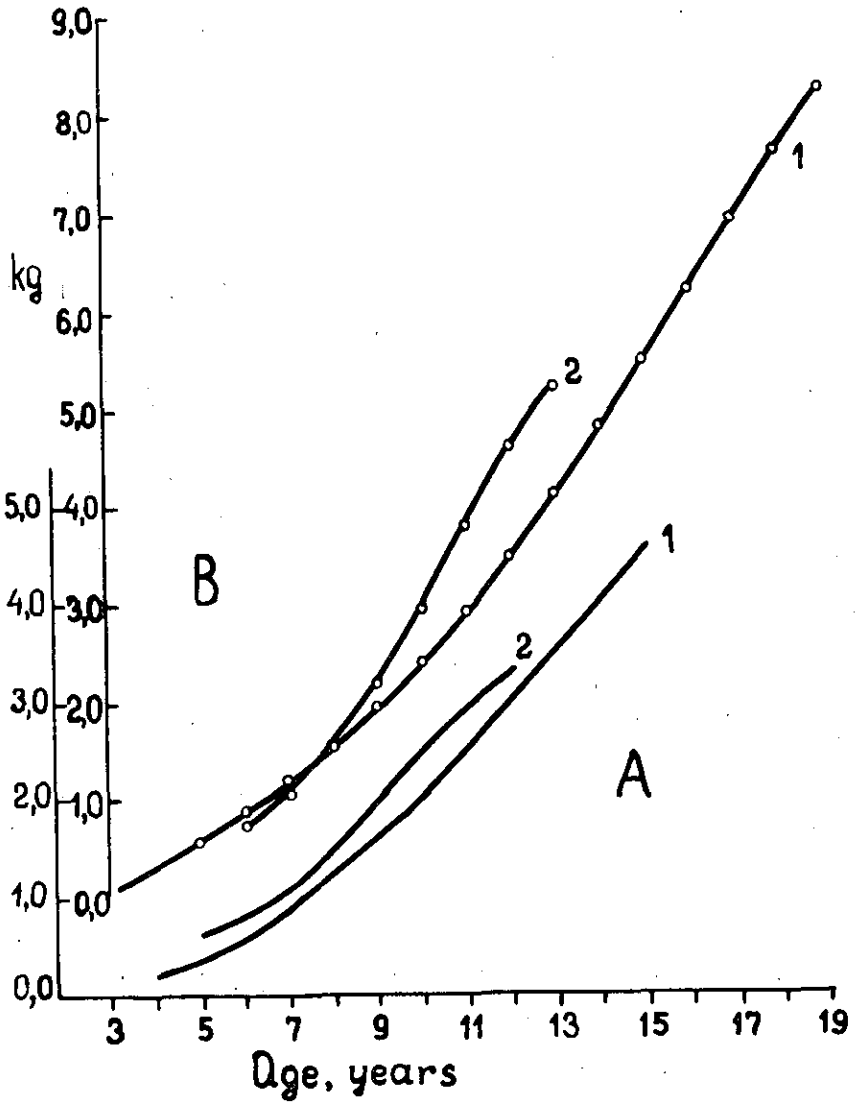

Fig. 8. Weight growth of Greenland halibut from 1 - Barents Sea and 2 - Icelandic stocks; A - males, B - females

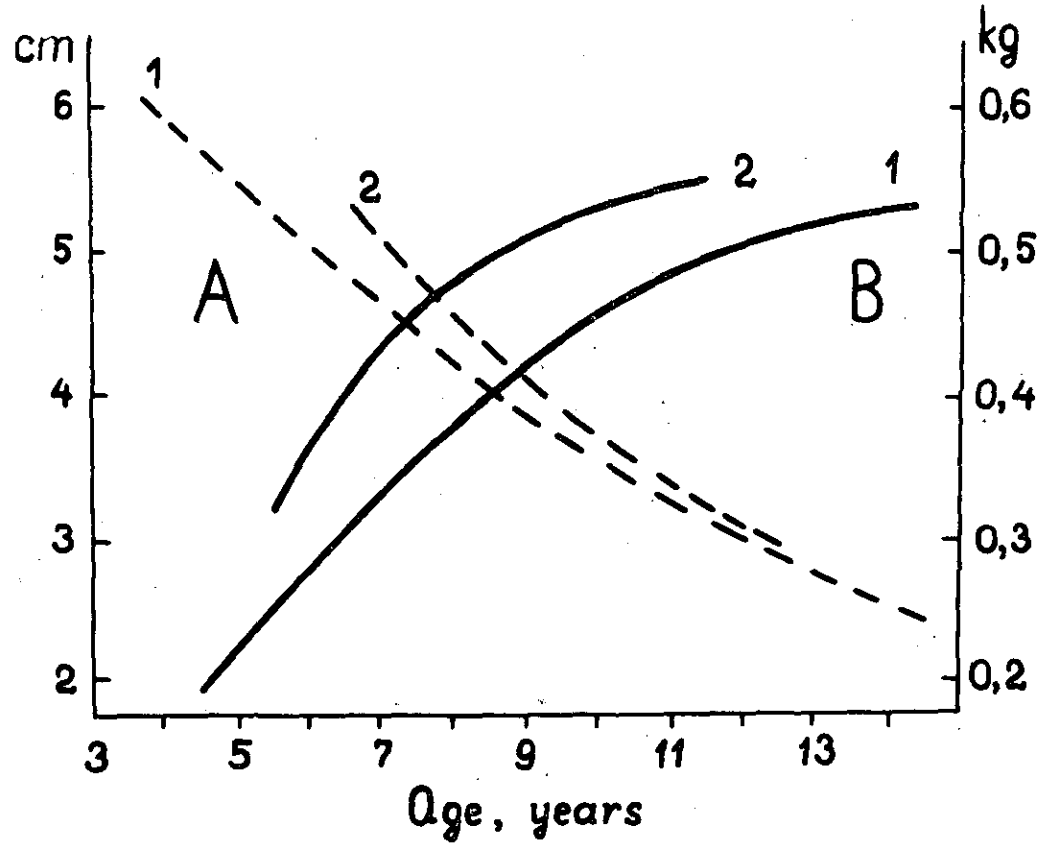

Fig. 9. Rates of linear (A) and weight (B) growth of halibut males from 1 - Barents Sea and 2 - Icelandic stocks

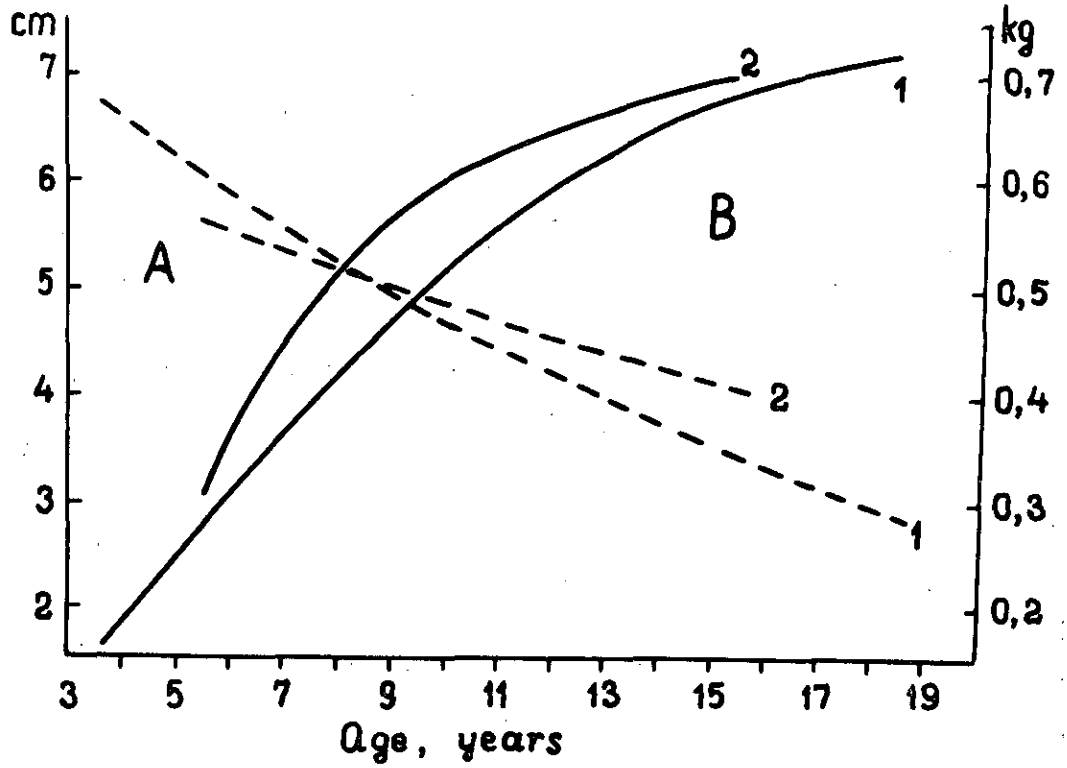

Fig. 10. Rates of linear (A) and weight (B) growth of halibut females from 1 - Barents Sea and 2 - Icelandic stocks