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Growth Patterns of Greenland Halibut (*Reinhardtius hippoglossoides*) in the Northeast Atlantic

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Abstract

The patterns and peculiarities of linear and weight growth of Greenland halibut (*Reinhardtius hippoglossoides*) from the Barents Sea and Icelandic waters are investigated. Notable variations in length and weight typical of males and females from the same age group reflect the apparent adaptation of fish to fuller consumption of food and to regular recruitment. Males under 5 and 7 years of age of both areas are longer than females of the same age. The linear growth of Greenland halibut follows the pattern common to most fishes with the yearly length increments greatest for the young and lowest for the old fish. However, the weight of fish show a steady increase until old age, then growth gets slower. The rate of growth in weight also follows this trend. The weights of females under 3 and 7 years of age from both areas are higher than those of males of the same age. The weight increment per unit length of fish in the Barents Sea is higher while those from Icelandic waters are longer and heavier at the same age. The growth patterns are regarded as manifestations of phylogenetic adaptation.

Introduction

The growth patterns of Greenland halibut (*Reinhardtius hippoglossoides*) from the Northeast Atlantic is not well documented. The only known contribution is a brief report by Krzykawski (MS 1975). This paper is devoted to a further elaboration on growth patterns based on data collected by the Polar Research Institute, Murmansk, USSR, in the Barents Sea and off Iceland between 1965 and 1969. The linear and weight growth, yearly length and weight growth patterns and length-weight ratios of Greenland halibut from the Barents Sea and Icelandic waters are determined.

Materials and Methods

Age samples were collected in the Barents Sea in 1965-69 and off Iceland in 1967-69. To estimate the linear growth pattern in the Barents Sea the weight of 2,325 specimens and the age of 2,108 specimens were analyzed. To determine the relationship between the linear and weight growth, data from 1,960 specimens were utilized. The same features were studied on 1,588, 998 and 1,759 specimens, respectively, collected from Icelandic waters.

The total length of fish were measured accurate to the nearest 1 cm, and the total weight taken to the nearest 50 g. The age was estimated mainly from fish scales using a microscope projector with a 20x magnification. In cases of uncertainty, the ages were read from otoliths.

Mean length and weight were estimated for each age-group. When variations in length and weight of fish of the same age were noticeable (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 and growth rates drawn. The linear growth curve was calculated by the von Bertalanffy formula:

$$L = L_{\infty} (1 - e^{-k(t-t_o)})^3$$

where L represents total length and t the time in years;

the weight (w) 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 of same age group fish

To determine the amplitude of length and weight variations in fish from the same age group, data of

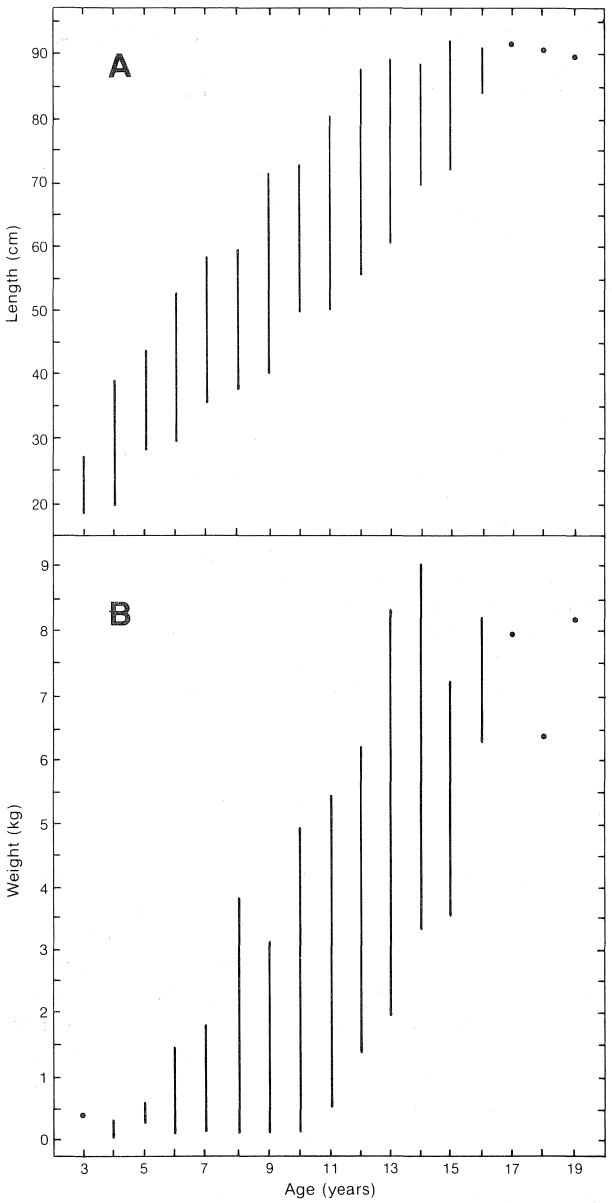

Fig. 1. Variations in length (**A**) and weight (**B**) of female Greenland halibut at different ages from the Barents Sea.

females from the Barents Sea were analyzed (Fig. 1). The length and weight data for the most frequently occurring fish aged 8–14 years showed the largest variations. The length of females aged 12 showed the widest range from 54 to 98 cm (Fig. 1A). Weight variations were more significant in females at the same age with a range of 1.4–6.3 kg, and those at age 13 ranging from 2.0 to 8.4 kg. The same characteristics were seen in males. The large variations in length and weight of fish from a given age group were observed both for the Barents Sea and Icelandic waters.

Linear growth

The linear growth of Greenland halibut followed the pattern characteristic of most fish species. The highest growths were observed in both males and females at the younger ages (Fig. 2). For males from the Barents Sea, this period lasted to the age of 5–7 years and for females to 7–9 years. For males from the Icelandic waters, the period of the most intensive growth lasted to the age of 7–8 years and for females to 9–10 years. As these fish grew older, their growth became slower. Males from the Barents Sea under the age of 5 years and those from Icelandic waters under 7 years were longer than females of the same age.

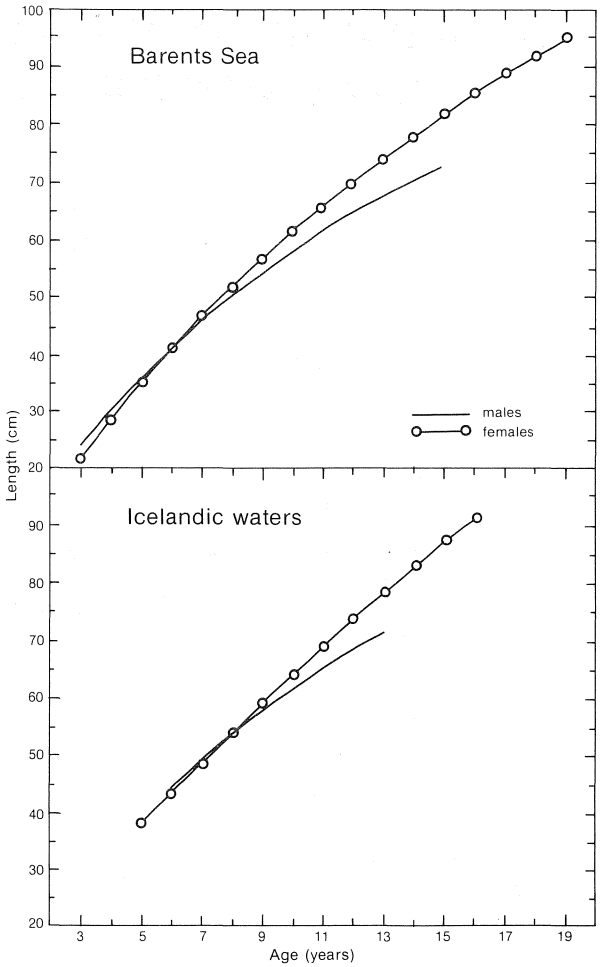

Fig. 2. Linear growth of Greenland halibut from the Barents Sea and Icelandic waters.

The linear growth rate measured as yearly length increments, also followed the common pattern seen in most fish. The highest rate was at the start of the life cycle, the lowest was at its end (Fig. 3 and 4). Thus, females from the Barents Sea at 3–4 years of age had a length increment of 6.5 cm, and males of the same age 6 cm. At the age of 14 to 15 years, the linear increment of females amounted to 3.5 cm and males 2.5 cm. Females from Icelandic waters at 6–7 years of age had an increment of 5.5 cm and the males increased 5.4 cm, while at the age of 12 to 13 the increments were only 4.5 and 3.0 cm, respectively. It was noted that the linear growth

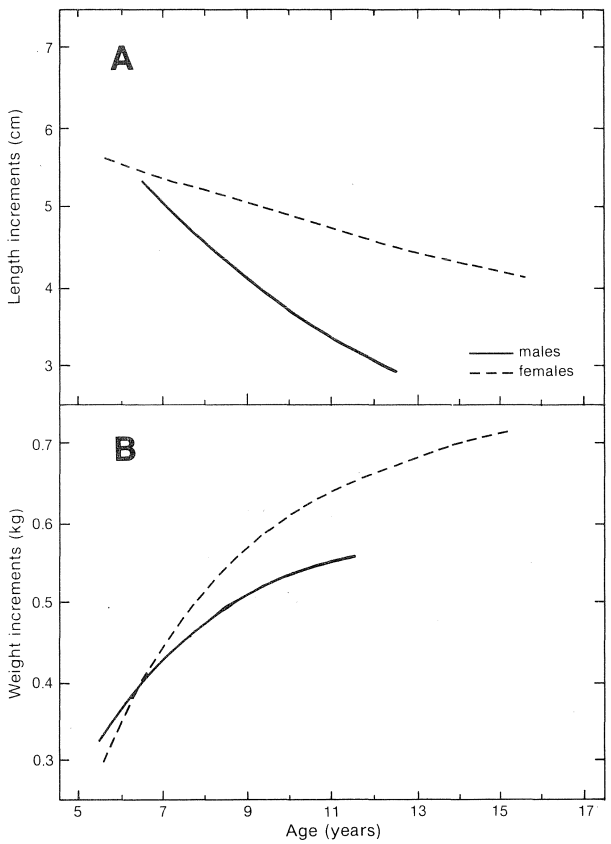

Fig. 3. Rates of linear (**A**) and weight (**B**) growth of Greenland halibut from Icelandic waters.

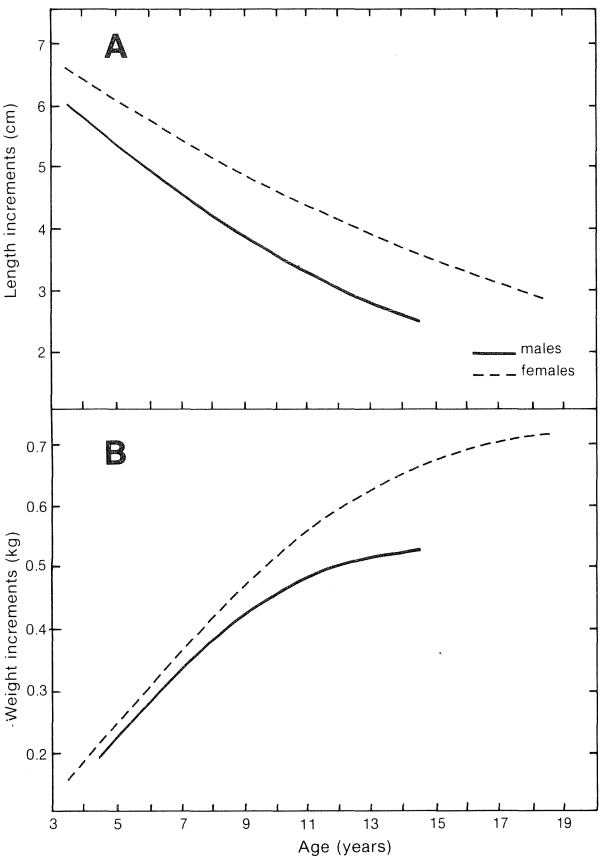

Fig. 4. Rates of linear (**A**) and weight (**B**) growth of Greenland halibut from the Barents Sea.

rate of females upwards of 3 years of age from the Barents Sea was higher than that of males. The linear growth of females from Icelandic waters was higher than that of males from 6 years of age and upwards. Unfortunately, fish under 3 years of age were absent from the samples taken in both areas. However, judging by the curves for fish of these ages, the growth rates of males and females appeared to be inversely related. The growth rate of males at their first years of life was apparently much higher than that of females.

Weight growth

The weight growth curves of Greenland halibut from both areas also followed the pattern typical of most fish species. At the start of the life cycle the growth was comparatively low, it increased with age and reached its maximum at the mid-ages and then subsequently slowed down at older ages (Fig. 5). Females from the Barents Sea, from 4 years and upwards were greater in weight than males and this difference increased with age. In terms of actual weight, females at age 5 averaged 500 g and males 400 g, while at age 15, the average weight of females was 5,500 g and that of males was only 4,700 g.

Even more striking was the difference in weight growth of the males and females from Icelandic waters. At the age of 5–6 years males were on the average 100 g heavier than females. At the age of 7–8 their weights were similar, but over 8 years of age, the growth of males was becoming much less than that of females. Figure 5 shows that age 9 females were only 100 g heavier than males, while at age 12 this difference in weight became appreciable and averaged 1,200 g. In the Barents Sea, retardation in growth becomes noticeable in males at 14–15 years and in females at 18–19 years, while in Icelandic waters males begin to decrease in growth at 11–12 years and the females at 12–13 years.

The rate of growth in weight increased with age both in males and females from both areas (Fig. 3 and 4). For instance, the weight increment for males and females from the Barents Sea aged 4–5 years amounted to nearly 200 g, while the yearly increment for 14–15 year old fish was about 530 g for males and 660 g for females. Judging by the curves, the growth rate in the Barents Sea for under 3-years-olds was higher for males than for females but with age it became lower. This phenomenon was quite apparent in Greenland

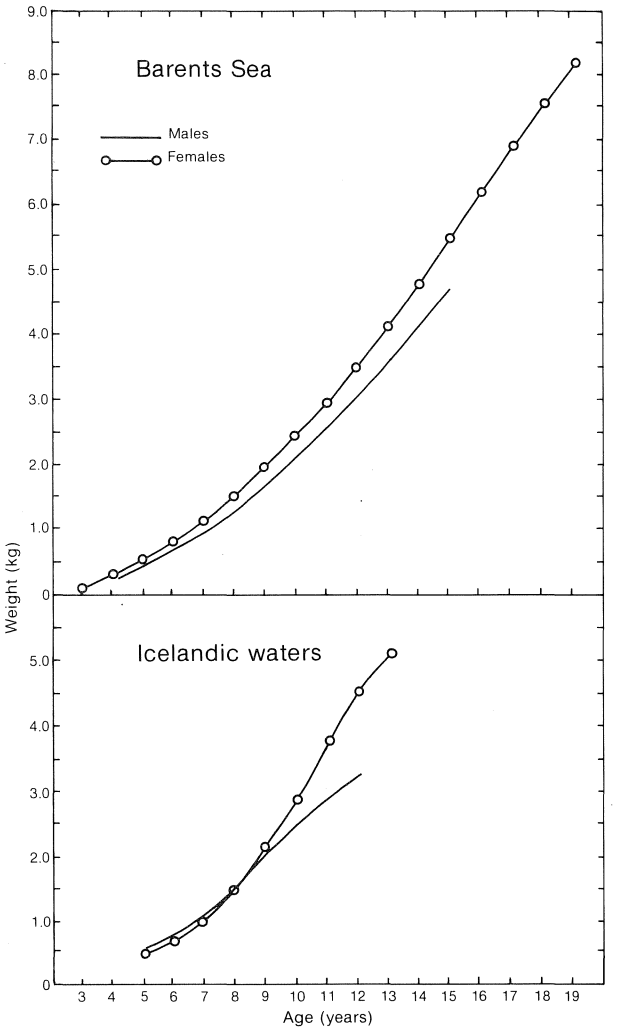

Fig. 5. Growth in weight of Greenland halibut from the Barents Sea and Icelandic waters.

halibut from the Icelandic area where growth in females was about the same as that of males at the age of 6–7 years (Fig. 3).

Length-weight ratio

The length-weight ratio reflected the growth pattern discussed above (Fig. 6). The weight of very young males was higher than that of females from the same age group. This was characteristic of fish under 30 cm from the Barents Sea and of the fish under 40 cm from Icelandic waters. As growth progressed, females equal in length to males exceeded them in weight and this difference increased with increased lengths. The weight increment per unit length was somewhat greater for the Barents Sea than for the Icelandic fish.

Differences between Barents Sea and Icelandic Greenland halibut

The geographic separation between the Barents Sea and Icelandic waters, the differences in abiotic

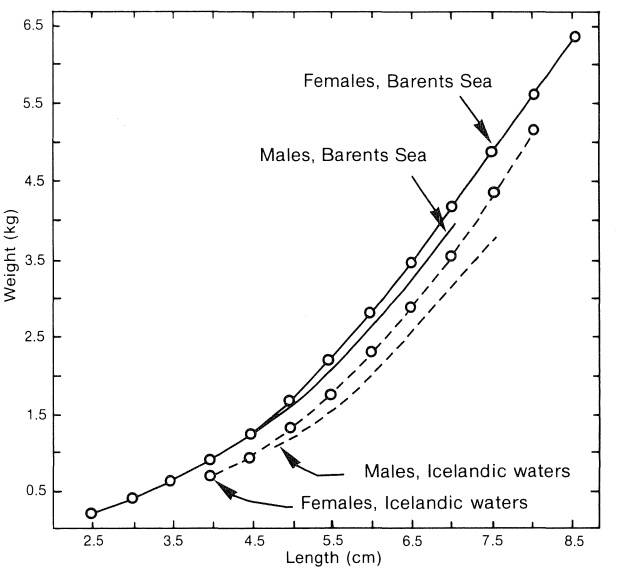

Fig. 6. Length-weight relationships of Greenland halibut from the Barents Sea and Icelandic waters.

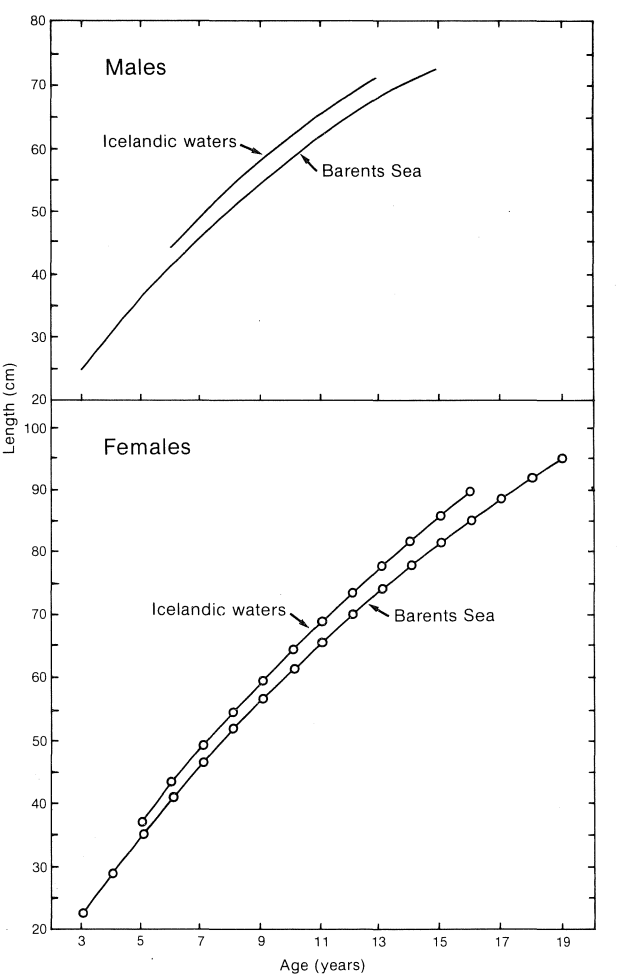

Fig. 7. Comparison of linear growth of Greenland halibut from the Barents Sea and Icelandic waters.

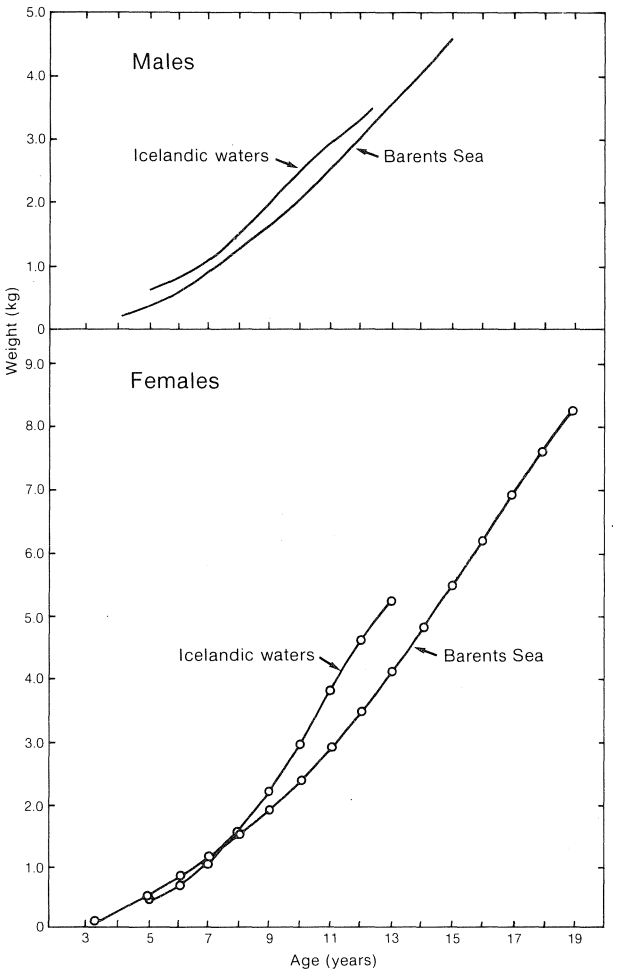

Fig. 8. Comparison of growth in weight of Greenland halibut from the Barents Sea and Icelandic waters.

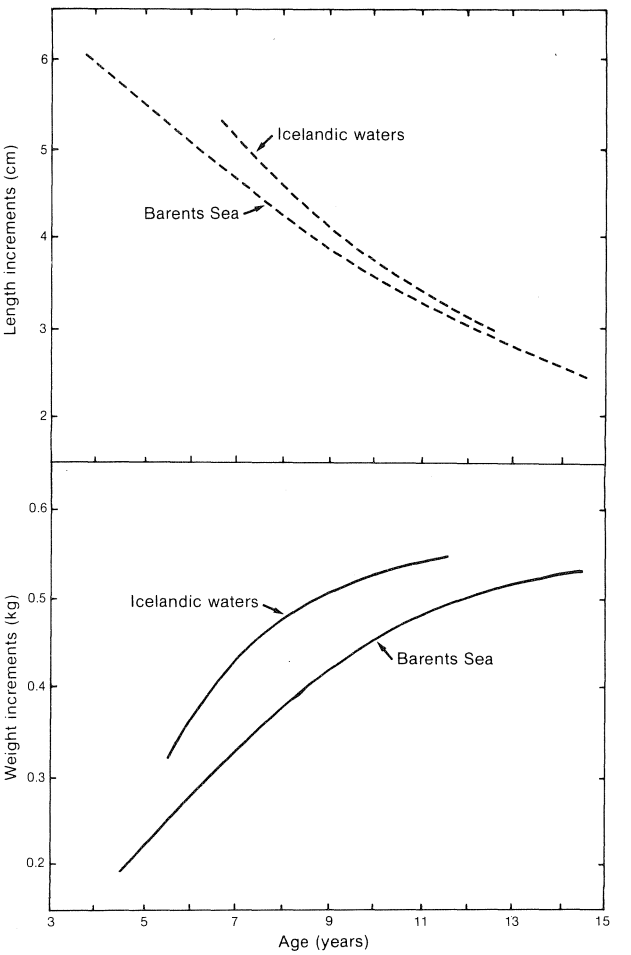

Fig. 9. Comparison of rates of linear and weight growth of male Greenland halibut from the Barents Sea and Icelandic waters.

conditions and feeding parameters were probable causes for some of the different patterns of growth in the two stocks. Both males and females from the same age group in Icelandic waters were longer than those from the Barents Sea (Fig. 7). Unfortunately, the data series was not complete for younger fish. The trend of the curves, however, suggested that for young fish (ages 1-3 years) the growth pattern changed, i.e. young Greenland halibut from the Barents Sea had a length equal to or greater than those from Icelandic waters. As shown in Fig. 8, at a certain stage of life the growth in weight of fish in Icelandic waters was also slightly higher than those in the Barents Sea.

The same pattern was exhibited in the linear and weight growth rates (Fig. 9 and 10). The weight growth rate of males from Icelandic waters at the age of 5-12 years was noticeably higher than those in the Barents Sea, while the difference was less significant for the linear growth rates (Fig. 9). The weight growth rate of females was close to that of males in both areas and the curves tended to intersect at the beginning and at the end (Fig. 10). This means that the weight growth rate during the first years of life is lower in Icelandic waters, becomes higher at 4-5 years and remains so for the greatest part of the life cycle, and slows down only at an old age.

The linear growth rate of males and females from both areas showed some peculiarities. Growth rate was noticeably higher for age 6-7 year males from Icelandic waters than for males from the Barents Sea; the yearly length increment of males from Icelandic waters was 5.3 cm at age of 6-7 years, while it was 4.8 cm in the Barents Sea. However, the difference in yearly increments declined with age and at the age of 12-13 years the linear growth rates of males from both areas were similar. The yearly linear growth rate of females from the Barents Sea at age 3-8 years was higher than that of females from Icelandic waters but became much lower at older ages. The yearly increments at age 15-16 years were 4 cm for Icelandic waters and 3.5 cm for the Barents Sea.

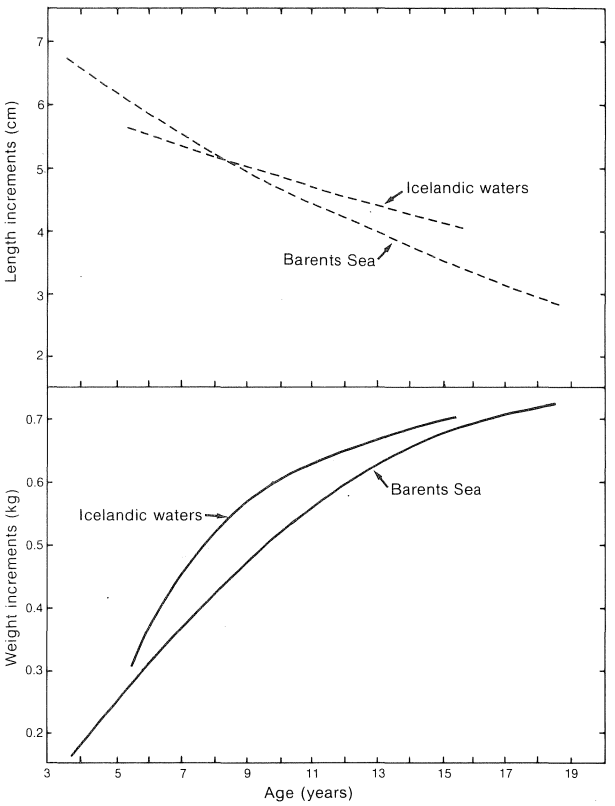

Fig. 10. Comparison of rates of linear and weight growth of female Greenland halibut from the Barents Sea and Icelandic waters.

Discussion

Greenland halibut is an oceanic species. Adaptive mechanisms of this fish are diverse and flexible and it would be appropriate to say that it is one of few fishes of the North Atlantic adapted to dwell at depths ranging from 150 to 1,600 m. The geographic range, although at comparatively low levels of abundance, also covers a vast area from the shallows off the Novaya Zemlya Island in the east to the American continental shelf in the west and from Spitsbergen and Baffin Island in the north to areas between Bergen and the Gulf of Maine in the south. Their constitution and coloration are well adapted to deep and pelagical waters, and are known to fair well through rapid ascend from below 1,000 m depth to the surface. Their phylogenetic adaptation is not only to permit rapid vertical migrations but to also access food at all depths.

Among the other specialized adaptations, they are noted to have an extraordinarily prolonged spawning period (Fedorov, 1968) to accommodate the maturation patterns of fish from the same age group. The significant variations in length and weight of fish of the same age group, as observed in this study, also result in fish from one year-class maturing at different ages (Nizovtsev, 1969). This improves the regularity of recruitment and also increases the food supply to the progeny.

The growth patterns observed in this study should also be regarded as an adaptation of the species to ambient conditions. Notably, the variations in length and weight of the fish in one year-class are of great adaptive importance in that they enlarge the food spectrum and, consequently, the food supply to the species. In the Barents Sea the food of small Greenland halibut (35–40 cm) consists mainly of small schooling fishes (capelin, polar cod), shrimp and small crustaceans (krill and Themisto). In fish larger than 40 cm the frequency of capelin and polar cod occurrence in food decreases gradually while polar cod are not found in the stomachs of those over 70 cm. At the same time, the frequency of occurrence of large fishes such as blue whiting, redfish, halibut, as well as Cephalopoda increases.

The most intensive growth is observed in fish under 7–9 years of age; in males it begins to slow down 2 years earlier than in females. During this period they feed actively, and the energy supply accumulated is spent on linear growth (Nikolsky, 1965). Males are known to mature mainly at the age of 7–8 years and females at 9–10 years (Nizovtsev, 1969). On attaining maturity, the main biological function of the fish is not to grow in length but to ensure development of reproductive organs, ripening of spawning products and accumulation of energy reserves to sustain metabolism during spawning migrations and spawning activities (Nikolsky, 1965). Like other fishes during this period, they spend a great deal of energy while their feeding decreases or ceases completely.

Males in the Barents Sea grow faster than females up to the age of 6 years. This also should be regarded as a mechanism of adaptation to environmental 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 mature sooner, males must grow faster than females. Additionally, in order that the number of males might be higher than that of females at this age, young males must overcome the pressure of predators during the most vulnerable first years of their life, sooner than females. They achieve it until the age of 7–8 years when the growth rate of females catch up to about that of males and higher.

Greenland halibut are repeat spawners. As a result of energy usage for spawning and changes in feeding rates, linear growth becomes much lower after their first spawning. Aging also adversely affects the growth. In males, owing to their earlier maturation, the process of ageing develops faster than in females. Males

upwards of 15 years of age were not found in samples. This may in fact be related to the ageing and early mortality of the males.

The linear growth in females is also retarded during the period of sexual activity, *i.e.* at the ages of 9–12 years. However, the rate of their growth retardation is not as high as in males and they live longer; specimens aged 19–20 years were found occasionally.

Conclusions

1. Male Greenland halibut from the Barents Sea and Icelandic waters under 5 and 7 years of age respectively, are longer than females of the same age group.
2. The linear growth of Greenland halibut follows the pattern common to most fishes; it is highest in young and slows down with age. The linear growth rate also complies with this pattern; the yearly length increments are greatest in the young and lowest in the old fish.
3. The weight of Greenland halibut increases steadily until old age, then it slows down. The rate of weight growth also follows this trend. The weight of females from the Barents Sea and Icelandic waters under 3 and 7 years of age, respectively, is higher than that of males of the same age.
4. The weight increment per unit length of Greenland halibut is higher for the Barents Sea than for Icelandic waters.
5. Greenland halibut of the same age from Icelandic waters are longer and heavier than those from the Barents Sea.

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