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Investigation on Growth of the Greenland Halibut Stock (Reinhardtius hippoglossoides Walb.) off Canada and West Greenland

by

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1. Introduction

Up to now investigations on the growth of Greenland halibut have been scarcely published internationally. Investigations of the growth in length concerning stocks in the Northwest-Atlantic were presented by SMIDT (9) and BOWERING (2). KRZYKAWSKI (7) carried out comparing investigations for the growth in length and mass of different stocks in the North Atlantic using the von BERTALANFFY function. But he did not take into consideration the growth peculiarities of the sexes. BOWERING and STANSBURY (3) also investigated length-mass relationships without performing specific analysis concerning sex.

Object of our investigations is the growth in length and in mass as well as the length-mass relationship concerning Greenland halibut of the Canadian-Westgreenlandic stock (5) regarding sex peculiarities.

2. Material and Methods

In the Divisions 2 G, 2 H, and 3 K of the ICNAF/NAFO area the investigations refer to the 4th quarter during the periods from 1977 to 1979 and from 1982 to 1984.

All specimens investigated were taken from the catch in the "round fresh" condition. Fish with their stomachs filled (more than traces or residuals) were not taken into consideration.

In each case the total length were recorded as 1-cm below (L_t below) and summarized to 2-cm groups. The mid-point values of the groups were used as input data for the computations.

Mass was recorded as nearest 50 g.

The computation of growth parameters according to von BERTALANFFY was performed by the extended programme BGC (1) which makes use of the least squares method.

According to empirical data (Tables 1 and 2) the growth of both the sexes proved to be different. Therefore collection and evaluation of the material as well as the computation of the growth parameters were performed by sex.

Mean weights per 2-cm group were used as input data for the computation of the length-mass relationship. Calculations were performed by sex for each year. For comparing the length-mass relationships of the sexes the curves were calculated by using data of the same length range (47-69 cm).

According to RICKER (8) the general expression of the mass-length relationship is

$$W = a\,L^{b}.$$

The parameters were estimated by means of linearization by logarithmizing

$$\text{Log } W = \log a + b\,(\log L).$$

3. Results

3.1. Growth in length and mass

The calculated curves extend beyond the empirical values. They obviously show the difference in growth between males and females which occurs from the 7 age group onwards (Figures 1 and 2).

The increment of length per age group concerning females is higher from age group 7 onwards compared with that of males.

In the range of the age groups 3 and 7 the length increment per age group is nearly the same for both the sexes, where in males the increment is somewhat higher. These findings agree with the results of the length-mass relationship.

Up to the age group 3 the growth in length is only based on few empirical data because of the small abundance of these age groups at the time of sampling.

The increment of mass per age group is characterized by a larger mass increment of females compared with that of males from age group 7 onwards. This corresponds to the growth in length.

The growth in mass of males is characterized by a steep ascending limb of the curve up to the age of 7 years. From age group 7 to 9 the growth curve flattens. This is related with the maturity ogive. In the range of the age groups 7 to 9 males attain their sexual maturity (4).

3.2. Length-mass relationship

The comparison of the expected mean mass per length group of both the sexes show the following results (Figure 3) where the

curves are based on the same main length range every year:

- The shape of the curve is the same for the years investigated
- Males and females of the length range up to about 51-57 cm are equal in mass per length group. Therewith fluctuations of the portions of males and females between the length group occur in this length range
- Above this length range females generally have a higher mass per length group than males. The differences of the mass per length group between males and females increase with increasing length.

For the same sexes mean mass per length group (Figures 4 A and 4 B) is not the same in all years of the period investigated. Mass differences per length group are striking in different years. 1984 and 1979 were the extreme years for females, and 1984 and 1977 were the extreme years for males. In the range of the main commercial length groups referring to the maximum value of the extreme years are

concerning females (Figure 4 A)

within the lengthgroup of 41 cm (extreme years 1982/1979) = 20 %
45 cm (" " 1982/1979) = 18 %
55 cm (" " 1984/1977) = 16 %
65 cm (" " 1984/1977) = 16 %
75 cm (" " 1984/1979) = 9 %
85 cm (" " 1978/1983) = 10 %
95 cm (" " 1984/1983) = 9 %

and concerning males (Figure 4 B)

within the lengthgroup of 41 cm (extreme years 1978/1977) = 23 %
45 cm (" " 1983/1977) = 25 %
55 cm (" " 1984/1977) = 10 %
65 cm (" " 1984/1977) = 16 %
75 cm (" " 1984/1982) = 5 %

At increasing length the difference between the extreme values of mass per length group decreases concerning both the sexes.

4. Discussion

4.1. Growth in length and mass

The curve of growth in mass concerning females is atypical for the von BERTALANFFY function (6) because of the want of the inflection point. The incorrect age determination concerning the older age groups, the small number of data in those age groups, and the beginning of the curve only from age group 3 due to the lack of input data could be responsible for this defect.

The "total" curves of growth in length and in mass, respectively, are based on the weighted mean of males and females over all years. Because there are only a few or even no data for the older age groups of the males, the "total" curve is influenced by the values

of the females. Therefore the "total" curve is similar to that for females.

The parameters of the von BERTALANFFY function were not determined for single years, because the characteristic growth of a fish species can't be described in this way. The reason is the potential different growth of individual year-classes that influences the course of the curve. The increment from one age group to the next of the particular year-classes cannot be estimated by means of von BERTALANFFY growth curves of one year, too, because each age group represents another year-class.

Because of the gaps within the time series during the period of investigation,it was not possible to estimate differences in growth between particular years induced by the influence of different environmental conditions.

SMIDT (9) proved by interpreting empirical data that both the sexes show the same growth in length up to the age group 9. After the ninth year of life the length of females increases more rapidly than that of males of the same age group.

On the basis of empirical growth data and by means of recalculations BOWERING (2) also ascertained a different growth in length of males and females. The shape of the curves is the same for the areas investigated in Divisions 0 B, 2 G, 2 H, 2 J, and 3 K. It is obvious that for the area St. Lawrence Golf (Div. 4 R, S, T) the ascending limb of the curve is steeper and thus different from the other Divisions. According to Canadian investigations the different growth in length of males and females of the same age group begins between the fifth and the seventh year of life. This results differing from our begin of different growth in length of the sexes, can be due to the differences in age interpretation (4).

Considering the results of all investigations by KRZYKAWSKI (7), the inflection point of the curves for growth in mass, which is typical for the von BERTALANFFY function for growth in mass, does not exist in any investigation area. The small sample sizes (n = 180) and the herefrom resulting minimum number of data per age group as well as the predominance of data of females in the older age groups can be taken as causes for the deviating shape of the curves.

There is a significant conformity in the approximately similar growth in length of both the sexes (small advantage for males) from age group 3 onwards up to the beginning of the sex specific growth between our investigations and that of BOWERING (2). This statement confirms the conformity of age interpretation for juveniles in spite of the different methods of age determination (4).

KRZYKAWSKI (7) performed comparing investigations of growth in length and mass of Greenland halibut in the fishing areas New-

foundland, Barents Sea, and Iceland. The parameters of the von BERTALANFFY growth function were calculated without separating the sexes.

The following values of the asymptotic length and the asymptotic mass, respectively, were estimated

	L_∞ (♂♂ + ♀♀) (cm)	W_∞ (♂♂ + ♀♀) (g)
Newfoundland	126.5	22 990
Barents Sea	116.5	18 660
Iceland	144.0	25 840

The value L_∞ (♂♂ + ♀♀) = 126.5 cm estimated by KRZYKAWSKI (7) for the fishing area Newfoundland (fishing area within the Canadian-Westgreenlandic stock) corresponds well with the results L_∞ (♂♂ + ♀♀) = 125.3 cm (Figure 1) by ERNST (4) concerning the Canadian-Westgreenland stock. Deviations occur when the asymptotic mass is discussed. According to KRZYKAWSKI the value amounts to W_∞ (♂♂ + ♀♀) = 22 990 g for the area Newfoundland. We estimated a value of W_∞ (♂♂ + ♀♀) = 38 447 g for the Canadian-Westgreenland stock. Differences in age determination and the small sample size used by KRZYKAWSKI (n = 180) may be the causes for the difference between the W_∞ = values.

4.2. Length-mass relationship

For the period from 1980 to 1982 investigations of length-mass relationship by BOWERING and STANSBURY (3) are presented for the Divisions 2 G, 2 J, 3 K, and St. Lawrence Golf (4 R, S, T). Analysis by sex were not performed, because these data were also used for the calculation of the number of specimens in the catch as basis for the calculation of the biomass of the total stock.

The shape of the curve of the length-mass relationship (total: ♂♂ + ♀♀) of these investigations corresponds with our results, which refer to the Subarea 2 and Division 3 K. The curve of the length-mass relationship concerning the stock of the St. Lawrence Golf is more flat than those of the other areas investigated, i.e. the mass per length group of the Greenland halibut within the Golf area is smaller than that of the Canadian-Westgreenland stock.

The exponent b of the length-mass function by RICKER (8) describes the character of growth.

Males show an isometric growth because of b = 3. In 1977 b deviates from 3 (b = 2.78343) because of the insufficient number of data per length group.

An unchanging body form and unchanging specific gravity during the process of growth are characteristical for the isometric growth (8).

The exponent b of the females is ≥ 3. Herewith an allometric growth is shown, i.e. the body form and/or the specific gravity are changing during their life. The reason for the allometric growth is according to RICKER (8) "presumely associated with their nutritional condition", which is also the reason for differences within the same population between different years.

5. Summary

Only G.D.R. data were used for the investigations of the growth in length and mass. These data formed the basis of empirical evaluations and of the calculation of parameters of the von BERTALANFFY function, respectively.

The growth is not the same for both the sexes. The increment of length and mass per age group of the females is higher from the age group 7 onwards compared to that of males.

Growth curves of the "total" stock are similar to that of the females. The reason for this similarity is the predominance of females in older age groups.

Investigations of the growth by SMIDT (9) and BOWERING (2) show the sex specific differences in growth, too, where from a certain age group onwards in females the increment is larger compared to that in males. These results are only presented for the investigations of growth in length. The beginning of different length increment of the sexes is said to be within the period from the fifth to the seventh year of life (2) and from age group 9 (9) onwards, respectively. These results concerning the beginning of growth differences between the sexes, which differ from our results, are to be seen in the differences of the age interpretation.

The investigations of growth in length and in mass of different stocks in the North Atlantic by KRZYKAWSKI (7) using the von BERTALANFFY function can only be compared and discussed in the light of the parameters for the asymptotic length and mass without considering the peculiarities of the growth in both the sexes. Investigations by sex were not presented. For the stock off Canada and Westgreenland our results concerning the asymptotic length $L_{\infty} = 125.3$ cm are well corresponding with his result ($L_{\infty} = 126.5$ cm) for the Newfoundland fishing area (fishing area within the Canadian-Westgreenland stock).

Considering the differences of the asymptotic mass occurred between our results ($W_{\infty} = 39447$ g) and those of KRZYKAWSKI (7) ($W_{\infty} = 22990$ g). This could be caused by the low number of data per age group of the input material ($n = 180$) used by KRZYKAWSKI.

The parameters of the length-mass relationship were estimated by the generally used length-mass function (8).

The mean mass per length group is the same for both the sexes within the same main range of length during the years of investigation (1977-1979, 1982, 1982). Up to 51-57 cm males and females show the same mass per length group. Above this length range females generally have a higher mass than males. The differences increase with increasing length and in favour of females. Males grow isometrically but females allometrially.

BOWERING and STANSBURY (3) also investigated the length-mass relationship of parts of the Greenland halibut stock off Canada and Westgreenland during the period from 1980 to 1982.
The results, which are not presented by sexes, corresponding with our results concerning the total stock.

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Table 1: Mean lengths per age group of Greenland halibut according to empirical data (G.D.R., 4th quarter, ICNAF/NAFO 2 and 3K)

A Males

Age group	1977		1978		1982		1983		1984	
	$\emptyset L_t$ (cm)	n	$\emptyset L_t$ (cm)	n	$\emptyset L_t$ (cm)	n	$\emptyset L_t$ (cm)	n	$\emptyset L_t$ (cm)	n
0										
1			17.92	8						
2			22.42	64						
3			30.03	124			29.00	1		
4	43.71	9	38.77	111	37.00	1	38.00	1	38.50	1
5	48.17	44	47.63	127	41.33	6	42.00	4	44.50	4
6	53.33	109	55.08	192	45.50	24	46.19	21	47.50	23
7	57.02	210	59.94	153	48.58	57	49.06	43	50.68	62
8	59.54	114	64.13	197	52.49	82	52.68	64	53.66	93
9	62.93	25	67.86	38	54.76	111	55.92	67	56.88	82
10	63.68	11	70.15	47	56.77	98	59.10	53	59.11	41
11	67.00	1	74.23	9	59.31	58	62.22	30	62.13	30
12					61.94	35	65.36	23	64.00	16
13					64.56	9	66.09	15	68.17	12
14					68.40	3	70.92	8	70.70	9
15					68.42	7	78.60	1	71.00	2
16					67.00	1	82.00	2	73.50	2
17										
18										
19										
20										
21										
22										
Total	56.27	523	51.01	1070	55.03	494	56.36	333	55.97	373

B Females

Age group	1977		1978		1982		1983		1984	
	$\emptyset L_t$ (cm)	n	$\emptyset L_t$ (cm)	n	$\emptyset L_t$ (cm)	n	$\emptyset L_t$ (cm)	n	$\emptyset L_t$ (cm)	n
0			15.00	1						
1			19.65	34						
2			25.20	100						
3			33.35	127						
4	47.80	5	41.56	93			41.00	3	42.50	1
5	51.74	48	48.70	84	48.00	4	44.10	4	46.75	4
6	55.52	127	55.58	113	47.00	11	48.18	4	48.77	11
7	59.25	104	60.30	79	50.96	69	52.31	26	52.92	67
8	62.63	48	65.05	87	54.92	95	56,01	22	57.21	48
9	63.69	11	69.13	65	59.00	95	60.91	16	60.71	28
10	64.00	2	72.79	40	60.82	80	63.89	24	63.59	23
11	61.00	1	76.69	34	66.57	83	66.73	17	66,88	34
12			79.91	27	75.00	60	70.02	21	71.74	17
13			83.23	23	73.24	58	73.30	30	75.28	23
14			88.56	23	77.11	53	77.16	31	79.47	31
15			88.43	21	81.00	35	80.54	28	81.72	45
16			95.69	14	82.43	28	81.75	29	84.98	33
17			98.22	6	85.64	22	85.70	42	87,89	23
18			101.68	5	89.67	12	88.05	31	91.41	23
19			101.00	1	93.45	11	93.49	24	96.58	13
20			107.50	1	93.00	2	97.33	7	98.94	94
21					98.00	2	101.33	3	102.17	3
22							103.83	3		
Total	57.31	346	53,91	978	66.81	700	74.75	365	70.77	432

Table 2: Mean mass per age group of Greenland halibut according to empirical data (G.D.R., 4th quarter ICNAF/NAFO 2 and 3 K)

Age group	1977		1978		1982		1983		1984	
	w (g)	n	w (g)	n	w (g)	n	w (g)	n	w (g)	n
0										
1			32.0	8						
2			83.1	62						
3			200.9	124						
4	672,2	9	460.0	111	350.0	1	300.0	1	400.0	1
5	983.4	44	928.6	127	600.0	6	800.0	2	670.0	4
6	1370.1	109	1485.5	192	773.0	24	888.5	14	890.9	23
7	1698.5	210	1966.7	153	997.0	57	1049.0	20	1040.5	62
8	1909.1	114	2360.5	191	1202.0	83	1333.9	38	1231.5	93
9	2186.4	25	2738.2	37	1376.0	114	1531.1	39	1499.1	82
10	2209.1	11	3027.0	47	1524.0	104	1831.0	30	1690.5	41
11	2550.0	1	3917.2	10	1842.0	53	1830.8	15	1987.7	30
12					2082.0	31	2379.0	11	2105.7	16
13			5300.0	1	2189.0	9	2365.0	6	2390.0	12
14			8150.0	1	2650.0	5	3029.9	7	2684.0	5
15					2583.0	6	3350.0	1	2870.0	2
16					2750.0	1			3070.0	2
17										
18										
19										
20										
21										
22										
Total	1633.8	523	1430.3	1062	1435.8	494	1624.8	184	1453.5	373

B Females

Age group	1977		1978		1982		1983		1984	
	w (g)	n	w (g)	n	w (g)	n	w (g)	n	w (g)	n
0			20.0	1						
1			61.3	34						
2			116.4	100						
3			290.2	127						
4	1038.0	5	615.0	93					540.0	1
5	1232,4	48	1029.8	84	850.0	4	685,0	2	850,0	4
6	1652.0	127	1482.9	112	786.0	11	1000.0	1	899.1	11
7	1874.8	104	2002.0	79	1149.0	49	1278.6	20	1169.3	67
8	2364.4	48	2536.5	87	1407.0	93	1578.1	15	1507.5	48
9	2367.3	11	3367.3	65	1786.0	95	1917.8	12	1822.9	28
10	2125.0	2	3893.3	40	2079.0	77	2344.4	17	2104.7	23
11	1900.0	1	4519.1	36	2647.0	81	2972.9	7	2637.6	34
12			5361.9	27	3104.0	53	3062.8	14	3025.9	17
13			8306.5	23	3629.0	53	3887.2	26	3778.7	23
14			7050.0	22	4474.0	49	4684.0	29	4672.9	31
15			8195.1	21	5355.0	32	5184.3	24	5183.7	45
16			9611.5	13	5702.0	25	6103.7	27	6046.7	33
17			10666.7	6	6618.0	20	6882.9	31	7031.3	23
18			12890.2	5	7527.0	11	7356.5	25	7975.7	23
19			11600.0	1	8931.0	8	8768.3	16	9121.5	13
20			6200.0	1	10300.0	2	11020.0	6	9958.0	5
21					11050.0	2	11525.0	2	10193.3	3
22							12817.0	3		
Total	1776.9	346	2215.7	977	2951.4	665	4944.0	277	3735.6	432

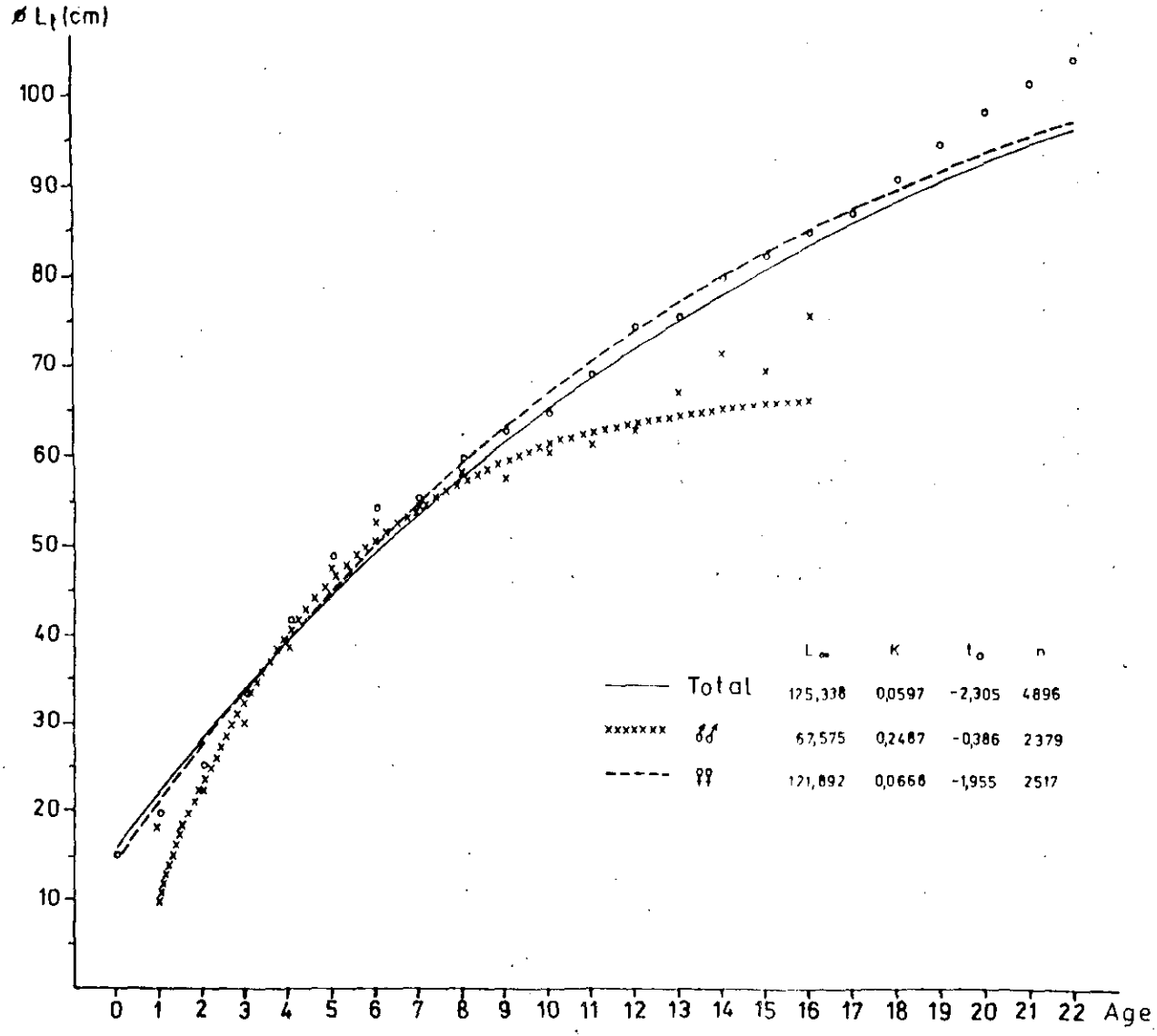

Fig.1 Length - growth curves after VON BERTALANFFY and empirical average values of all age groups of the Greenland halibut, 1977-1984, 4th quarter, NAFO 2 and 3K

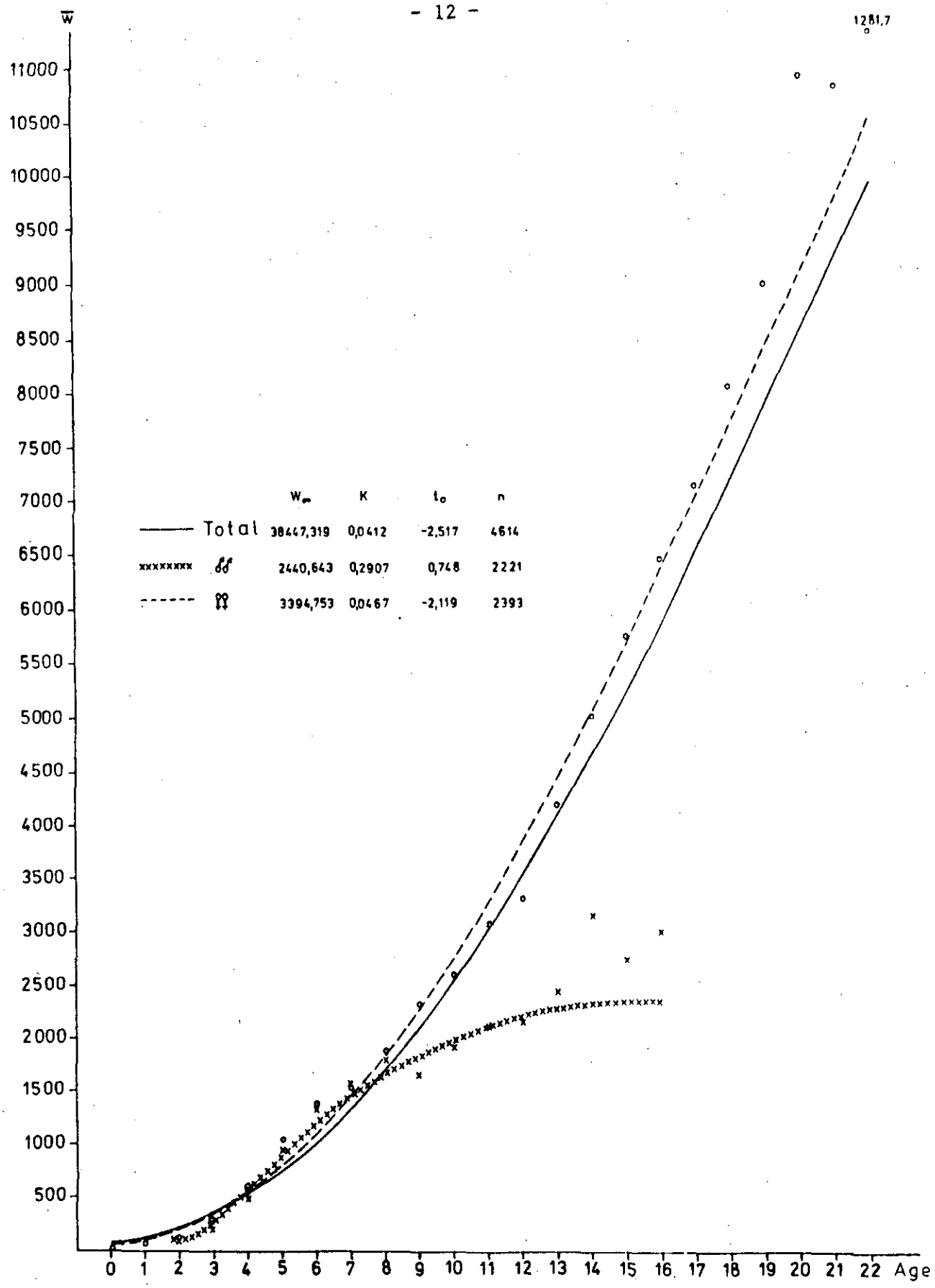

Fig. 2 Weight-growth curves after VON BERTALANFFY and empirical average values of all age groups of the Greenland halibut, 1977-1984, 4th quarter, NAFO 2 and 3K

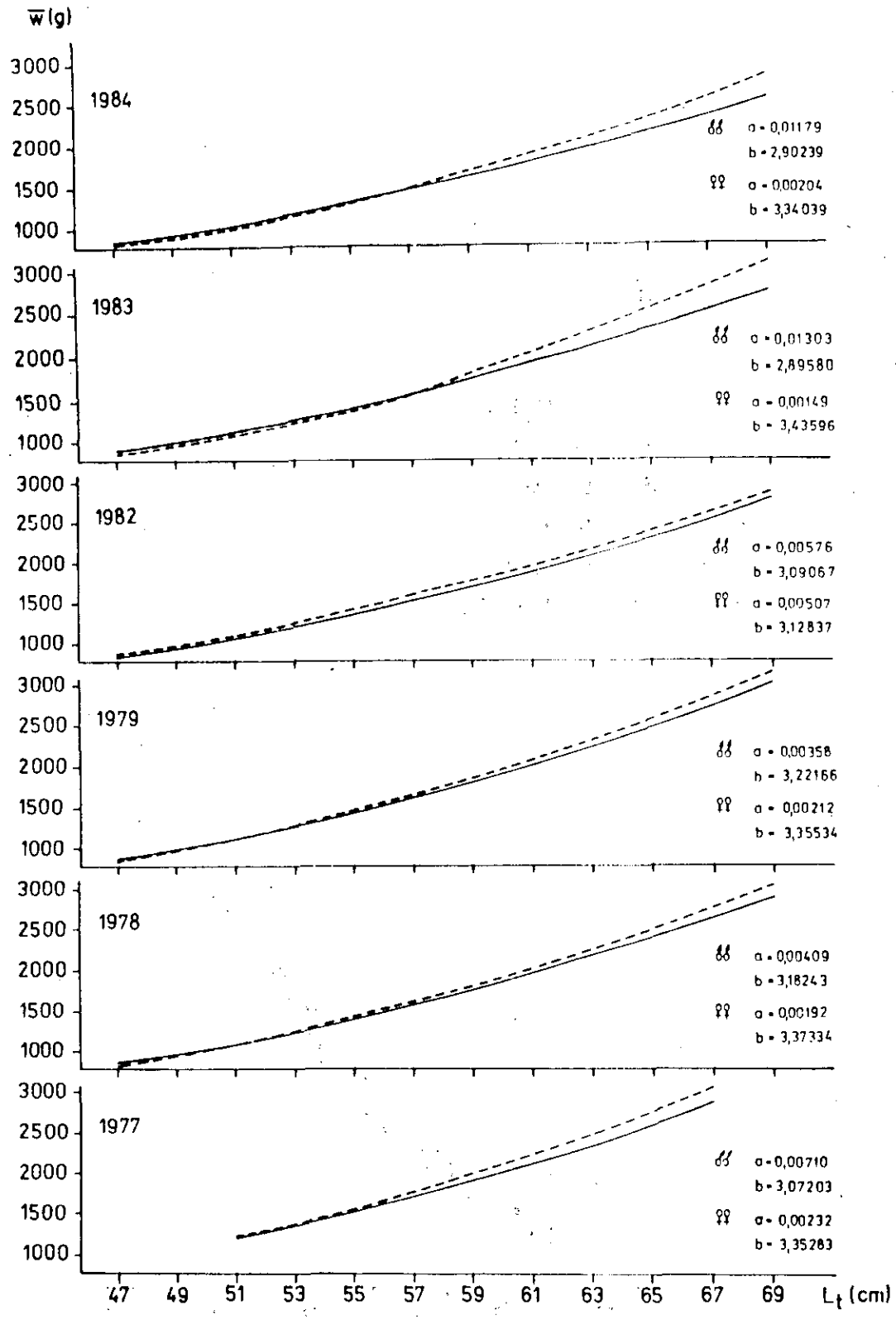

Fig.3 Comparison of the mean weights per length group by sex in the particular years for the same mean length range based on the back calculations, Greenland halibut, NAFO 2 and 3K, G.D.R. data 1977 - 1984 —♂♂ ----♀♀

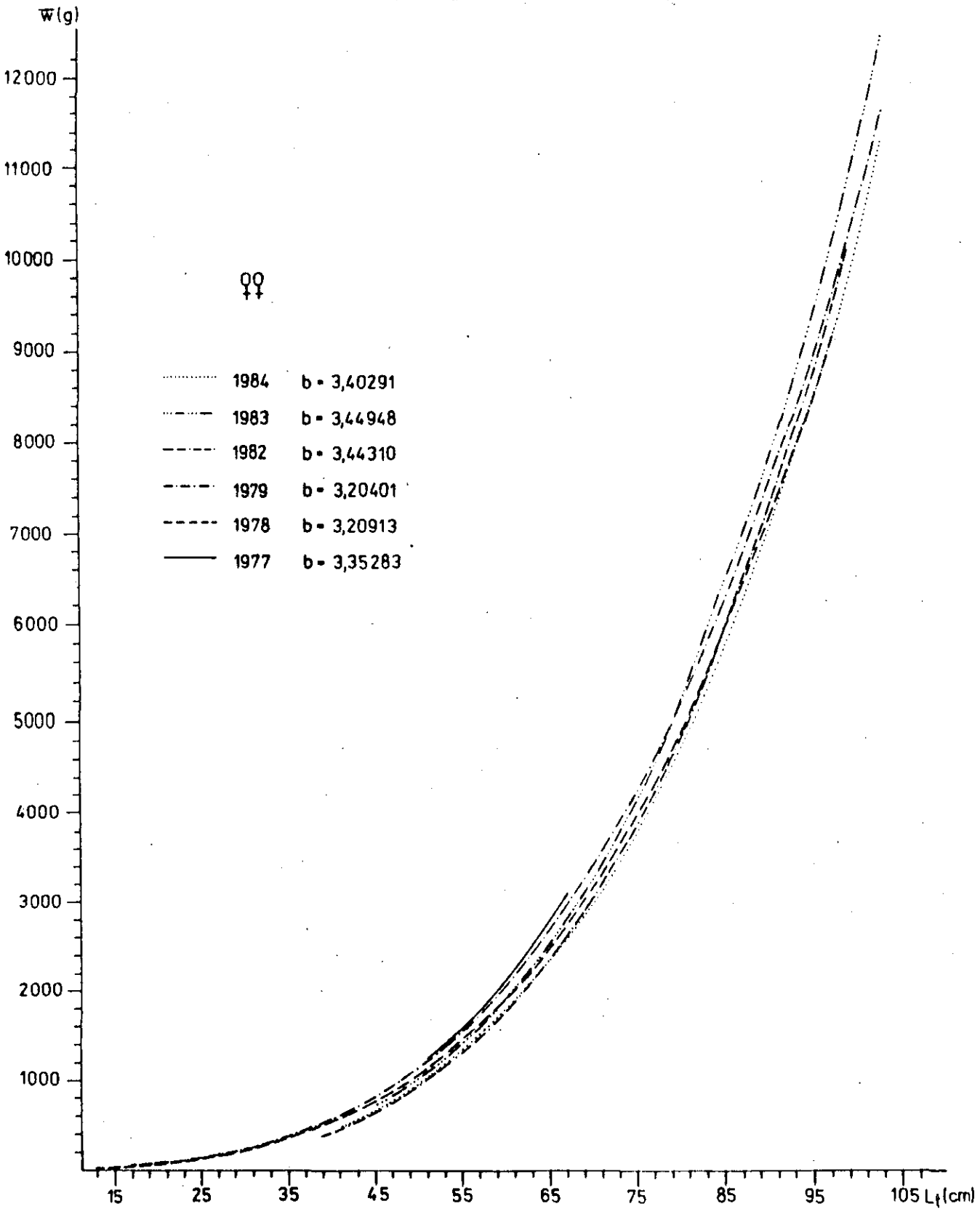

Fig.4A Comparison of the mean weights per length group of the females between the particular years (1977-1984) based on the back calculations, Greenland halibut, NAFO 2and3K, G.D.R. data

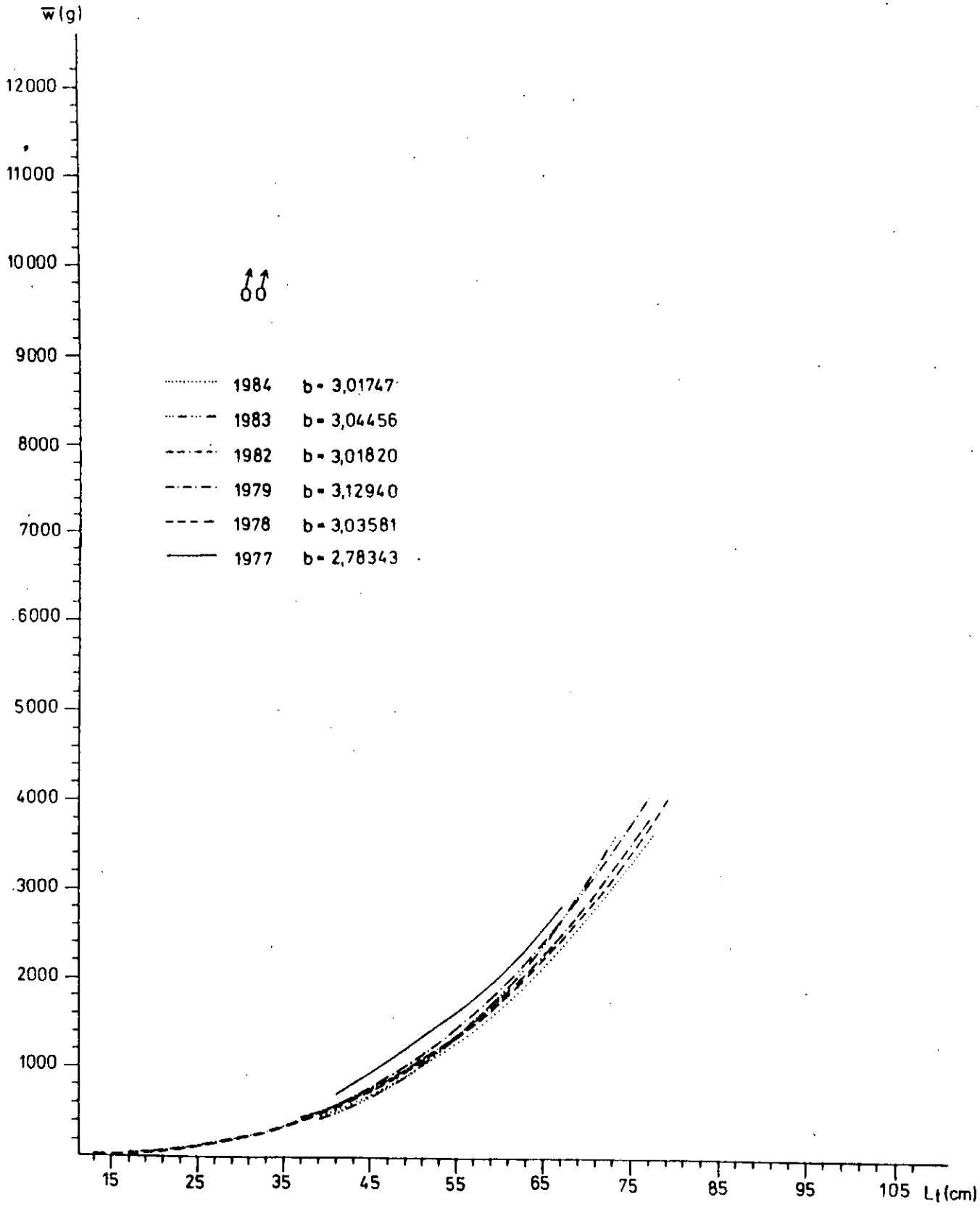

Fig.4B Comparison of the mean weights per length group of the males between the particular years (1977-1984) based on the back calculations, Greenland halibut, NAFO 2 and 3K, G.D.R. data