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The Østerbø Herring

By

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A.s John Griegs Boktrykkeri, Bergen

PREFACE

The present paper is an account of a «new» herring tribe heretofore unknown to investigators. The author is greatly indebted to Fiskeribedriftens Forskningsfond whose grants have made this investigation possible. Thanks are also due to Director GUNNAR ROLLEFSEN and Fishery-Consulent FINN DEVOLD who have entrusted me with the planning and execution of the herring cruises to the Sognefjord area. I also wish to thank Mr. DITLEF RUSTAD who first informed me of rumours amongst the local fishermen that the herrings caught in the Østerbøvatn were of a special type. Further I am indebted to Mr. LEIF ØYEN ERICHSEN and Mr. ODDVAR DAHL for various assistance during the work, and finally, I wish to express my gratitude and most cordial thanks to Dr. WILLIAM HODGSON for reading over and amending the English text.

Bergen, December 1952.

Olav Aasen.

Contents

Introduction

For some years past, Fiskeridirektoratets Havforskningsinstitutt has been investigating a local herring tribe in the Lusterfjord, one of the tributaries of the Sognefjord (Fig. 1). Topographically, the Lusterfjord is wide open towards the main fjord and the possibility existed that the Lusterfjord herring also might be found in other branches of the Sognefjord (AASEN, 1951). In order to clear up this special point, yearly cruises to the Sognefjord have been carried out since 1949 and fishing with bottom nets for this particular herring type has been one of the main items on the programmes for these cruises.

So far, none of the Lusterfjord herrings has been caught outside the Lusterfjord (with one possible exception, see page 20)but last year some herrings were caught in a «poll», the Østerbøvatn, in the outer part of the Sognefjord (Fig. 1), and these herrings conformed neither to the Winter herring of the main Norwegian stock nor to the Lusterfjord herring type. In fact, the herring did not seem to correspond with any type of herring met with before in our waters. It was suspected that

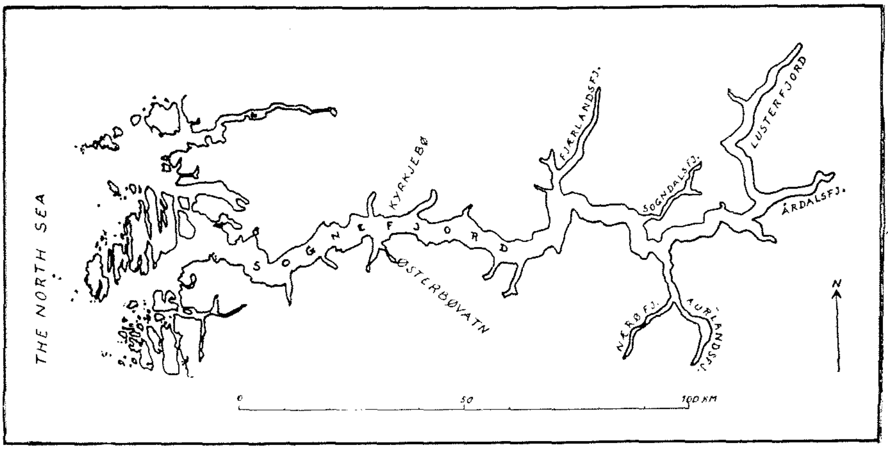

Fig. 1. The Sognefjord and its tributaries.

here one was confronted with yet another herring tribe, thus confirming the local fishermen's opinion that a local stock of herring was living in the «poll». The sample obtained was, however, quite small and comprised only 14 specimens. This year then (1952), renewed efforts were made with better suited nets to secure a representative sample of the herring. About 400 herrings were caught and of these about 200 were examined as to age, length, weight, sex, stage of maturity, weight of gonads, intestinal fat, and Vert. S. Of the remaining herrings 50 specimens were picked at random for fat analysis, and for the rest length measurements only were taken. This present paper deals wich the results of the investigation.

The Østerbøvatn

The Østerbøvatn (Østerbø-lake, Fig. 2) is connected with the Fuglsetfjord, a branch of the Sognefjord, through a shallow and narrow artificially made canal, about 2 m deep and 5 m wide (at high tide) dug through a moraine. According to information by the local population the work was carried out about the year 1860. From the canal and inwards the bottom drops down to about 90 m and appears to be fairly even along the deepest part towards the end of the lake which is shallower. The Østerbøvatn has not been sounded in details, but last year a small motor boat, fitted with an echo-sounder, was brought into the lake, and although the work was hampered by ice, one succeeded in sounding a long section. The result of the survey is presented in Fig. 3.

The hydrography of the Østerbøvatn is very little known. This

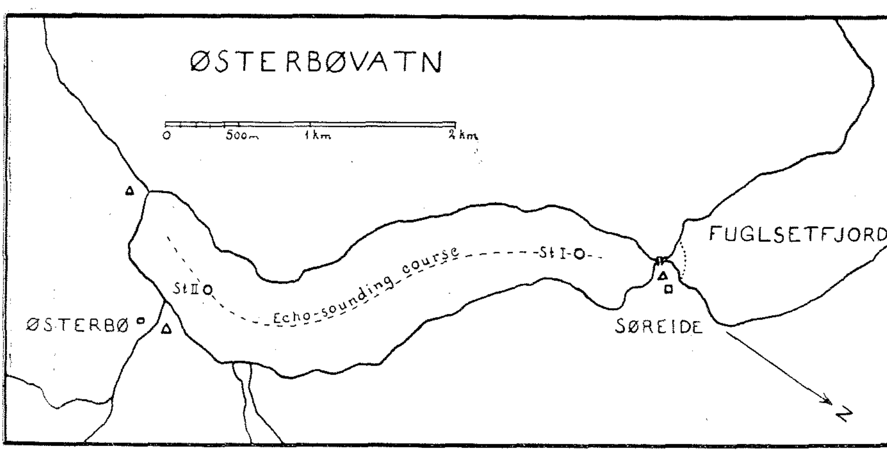

Fig. 2. The Østerbøvatn.

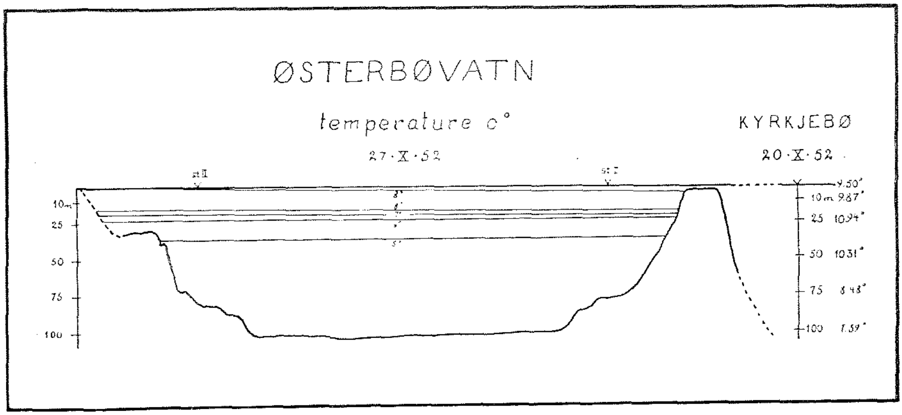

Fig. 3. The temperature conditions in the Østerbøvatn in October 1952. The bottom profile in long section based on echo-sounding.

year (1952) a portable hydrographical outfit was brought into the lake and two hydrographical stations were worked (Fig. 3) on October 27th. It appears that the temperature in the lake is somewhat lower, at this time of the year, than in the open Sognefjord (in the corresponding depths) as will be evident on comparing it with an approximately simultaneous hydrographical observation taken outside Kyrkjebø (Fig. 1) by R/V «Armauer Hansen». The data have kindly been placed at the author's disposal by the Geophysical Institute, Bergen. It must be assumed that the winter cooling will at times make itself markedly felt in such inshore waters, and there are indications that the severity of the winter temperatures is reflected in the vertebral number of the different year-broods (see page 13). However, such a correlation can only be established with certainty through direct observations on the physical and chemical properties of the sea water during the spawning and hatching periods, and no such measurements are available.

The Østerbø Herring

Age

It is common practise to name a herring tribe after the locality in which it is usually found, and in accordance with this, the name of «Østerbø Herring» is proposed for this particular herring tribe. Its scale characters make it easily distinguishable from the Winter herring (see Plate). This is particularly true for the dominating year-class which has an exceptionally narrow summer zone in its third year and is thus «marked» (HJORT and LEA 1911). In Table 1 is shown the age frequency distribution of the Østerbø herring as found in the autumns of 1951 and 1952.

Table 1.

Age frequency distributions of the Østerbø herring in the autumns of 1951 & 1952.

4. XII. 1951	Year-class Age	1950 1+	1949 2+	1948 3+	1947 4+	1946 5+	1945 6+	Total
	Frequency n	—	1	4	7	—	—	12
	%	—	8.3	33.3	58.8	—	—	100
24.—27. X 1952	Year-class Age	1950 2+	1949 3+	1948 4+	1947 5+	1946 6+	1945 7+	Total
	Frequency n	5	14	43	137	—	1	200
	%	2.5	7.0	21.5	68.5	—	0.5	100

It will be seen that the samples from the two different years present the same general picture. Surprisingly enough there is only one herring of an older year-class than 1947, and this herring has a scale character and a growth history which rather rules it out of this particular tribe. The 1947 year-class is very strong and constitutes in 1952 68.5 % of the total population. As a whole, the age distribution appears to be peculiar. This herring is, however, so little known that the reasons may only be hinted at. It might be that the conditions during spawning have been extremely unfavourable for some years prior to 1947, or it may also be that the nets have been strongly selective so that the sampling is not representative. Neither of these arguments would seem to be very convincing. It might also be that the herring has been transported into the lake as fry or at later stages and has grown to maturity there while the specific conditions in the Østerbøvatn have stamped on it its unfamiliar character. This last possibility can be tested by comparing the vertebral numbers with those of other herring tribes in adjacent waters.

Vertebrae

Of known herring tribes occurring in the Sognefjord area there are the Lusterfjord herring and the Winter herring. The Lusterfjord herring has a very low vertebral number, 56.25 ± 0.05, (AASEN 1951) and it is clear, without testing, that the difference in Vert. S. of the Østerbø herring and the Lusterfjord herring is highly significant. Of the Winter herring there are two growth types, the Northern and Southern, and it seems most natural to use the latter for comparison. Also it is a common experience that different year-broods have different vertebral numbers, even within the same tribe, and in this connection the same year-classes of the two tribes will be tested against each other. As only the 1947 and 1948 year-classes are reasonably well represented in the Østerbø herring, the tests will be restricted to these two year-classes.

In Table 2 are presented the vertebral frequency distributions for the different year-classes (and the totals) of the Østerbø herring together with the frequency-distributions for the 1947 and 1948 year-classes of the Winter herring (picked at random from the 1952 samples). Also are shown:

n = number in sample

S(x) = sum of (deviation . frequency)

$\bar{x} = \frac{S(x)}{n}$ = average excess above the «working mean» here chosen at 57 vertebrae.

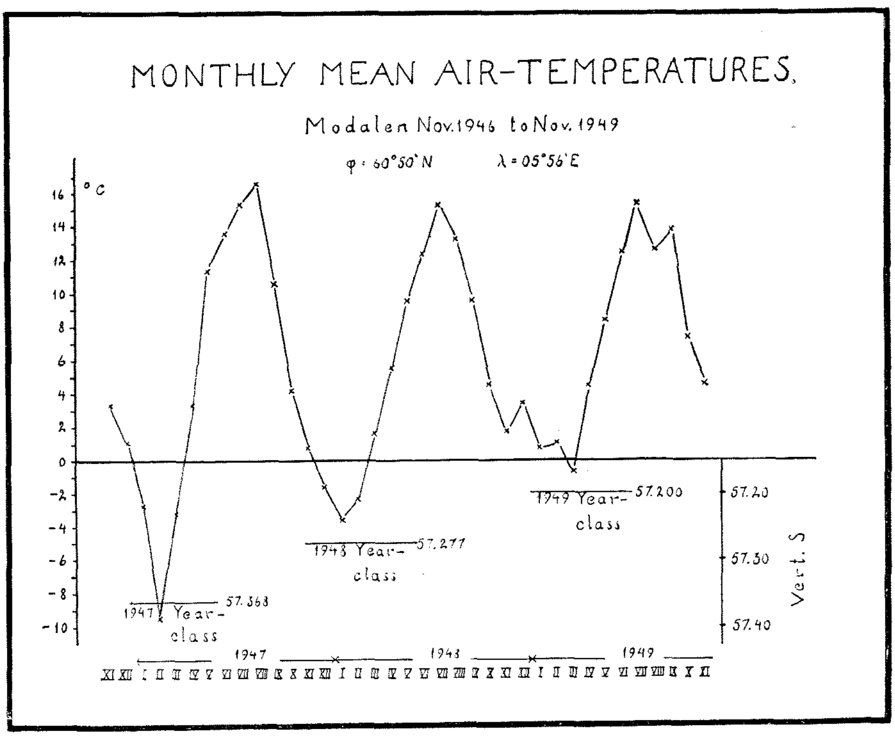

Fig. 4. Monthly mean air temperatures November—46 to November—49 at Modalen and mean values of the vertebral numbers for the year-classes 1947, 1948, and 1949 of the Østerbø herring.

Table 2.

The frequency distribution of Vert. S. for the different year-classes (1947—50) of the Østerbø herring. For comparison the corresponding figures for the 1947 & 1948 year-classes of the Winter herring, picked at random from the 1952 samples. For further explanation see text.

Type	Year-class	Vert. S						n	$S(x)$	x	$S(x^2)$	σ^2	$\pm \frac{\sigma}{\sqrt{n}}$
		55	56	57	58	59	60						
Østerbø Herring	1947	—	10	78	49	7	—	144	53	0.368	87	0.472	0.051
—»—	1948	1	7	22	13	3	1	47	13	0.277	45	0.900	0.138
—»—	1949	—	2	8	5	—	—	15	3	0.200	7	0.457	0.175
—»—	1950	—	2	2	1	—	—	5	—1	—0.200	3	0.700	0.140
—»— Total	1947—50	1	21	110	68	10	1	211	68	0.322	142	0.572	0.052
Winter Herring	1947	—	9	27	13	1	—	50	6	0.120	26	0.516	0.101
—»—	1948	—	3	28	19	—	—	50	16	0.320	22	0.344	0.083

$S(x^2)$ = sum of (deviation^2 . frequency)

$$\sigma^2 = \text{variance} = \frac{1}{n-1} S(x - \bar{x})^2 = \frac{S(x^2) - \bar{x}S(x)}{n-1}$$

$\frac{\sigma}{\sqrt{n}}$ = standard error of the mean

For testing difference between the means the *t*- test will be used. (FISHER 1948). Further calculations from the figures in Table 2 give in the first case a *t* of 2.18 (1947) and in the second case a *t* of 0.271 (1948). The first value corresponds to a probability of between 0.02 and 0.05 ($0.02 < P < 0.05$). This figure is regarded as significant, and the conclusion is that this particular year-class of the Østerbø herring has not been recruited from the Winter herring. The second value corresponds to a probability of about 0.8 and this figure is not significant. In this instance, therefore, the vertebral number does not exclude the possibility that this year-class of the Østerbø herring may originate from the Winter herring, but it constitutes no proof that such is the case.

The Østerbøvatn forms a well defined, small basin and it must be expected that the severity of the winter climate will reflect itself in the hydrographical conditions in such closed waters. In severe winters, therefore, the cooling of the water should be rather thorough, and vice versa. The three winters 1947, 1948 and 1949 differ notably in air temperatures in this region. This is demonstrated in Fig. 4 where the monthly mean temperatures at the nearest meteorological station, Modalen, are drawn in for the months November 1946 to November 1949. The mean values of the vertebral numbers are also entered on the Figure and it is seen that the lower winter temperatures correspond to the higher vertebral numbers. However, this feature is not conclusive. Firstly, because the data only comprise three years and secondly that the *a*- test (Analysis of variance) between the means shows a variance ratio of 1.005 and this figure is not significant. (FISHER loc. cit.).

In Fig. 5 is given an illustration of the total vertebral frequency-distribution of the Østerbø herring.

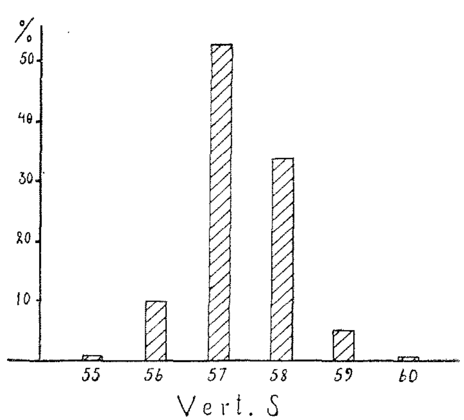

Fig. 5. Percentage vertebral frequency-distribution for the Østerbø herring.

Length

As mentioned before the Østerbø herring comprises few year-classes (in the samples). If the length, therefore, is to be compared to that of the Winter herring which comprises very many year-classes, it seems natural to do this comparison between similar age-groups. In Table 3 are presented the length frequency-distributions of the different year-classes of the Østerbø herring together with the length frequency-distributions of 5 and 4 year-old herring picked at random from the 1952 samples of Winter herring (the same fish as entered in Table 2).

Considering firstly the Østerbø herring (of the 1952 sample), it will be seen that there is a slight, although statistically significant, difference in the mean length of the 1947 and 1948 year-classes. This may be partly due to Rosa Lee's phenomenon, but as will be seen later in the Section on growth, the main reason is checked growth of the 1947 year-class in its third year. Further it is to be noted that there is no significant difference between the mean lengths of the 1948 and 1949 year-classes. This is due to the rapid growth of the 1949 year-class in the last two years (see Table 5). The mean length of the 1950

Table 3.

Length frequency distributions for the different year-classes of the Østerbø herring (Ø. h.) as appearing from the catches in 1951 & 1952. For comparison length frequency distributions

Type	Year-class	Length																					
		.5	22	.5	23	.5	24	.5	25	.5	26	.5	27	.5	28	5.	29	5.	30	.5	31	.5	32
Ø.h.	1947	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	9	24	20	40
-	1948	—	—	—	—	—	—	—	—	—	1	1	—	—	1	3	5	1	5	5	5	4	2
-	1949	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2	—	3	3	3	2
-	1950	1	—	—	—	1	2	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
-	XX	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	1	2	2	5	20	26	48
-	Total	1	—	—	—	1	2	—	1	1	2	1	—	—	2	3	6	5	12	22	52	53	92
W.h.	1947	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2	7	16
-	1948	—	—	—	—	—	—	—	—	—	1	3	8	6	6	4	7	5	5	1	—	—	2
Ø.h.	1947	—	—	—	—	—	—	—	—	—	—	—	1	1	4	—	—	1	—	—	—	—	—
-	1948	—	—	—	—	—	—	—	—	—	—	—	—	1	2	—	—	—	1	—	—	—	—
-	1949	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
-	Total	—	—	—	—	—	—	—	—	1	—	—	1	2	6	—	—	1	1	—	—	—	—

year-class is 24 cm and this seems to be about normal. The material is, however, scanty.

The mean length of the 1947 year-class of the Winter herring appears (in the Table) to be about the same as that of the Østerbø herring, but as the latter has one extra summer's growth, it would be evident that the former has the greater length. The same goes for the 1948 year-class, while the 1949 year-class of the Østerbø herring compares favourably to that of the Winter herring: there is little difference between the mean lengths of the 3+ year-old Østerbø herring and the 5 year-old Winter herring (1947 year-class) while the difference is considerable, in favour of the Østerbø herring, when compared to the 4 year-old Winter herring (1948 year-class). It must be borne in mind, however, that it is not the same year-classes which here are compared.

On the whole, the size of the Østerbø herring is very similar to that of the Winter herring of the Southern growth type. However, this detailed analysis of the length reveals that the Østerbø herrings at least are no late immigrants to the area, but to the problem of origin it gives no clue.

In Fig. 6 is given a graphical demonstration of the total length-distribution of the Østerbø herring in the 1952 sample including the fishes for which measurements only were taken.

of the 1948 & 1947 year-classes in the Winter herring (W.h.) the same fishes as in Table 2. XX Herrings sampled for length measurements only. For further explanation see text.

in cm .5	33	.5	34	.5	35	n	$S(x)$	$\bar{x}$	$S(x^2)$	σ^2	«Working» mean	«True» mean	$\pm \frac{\sigma}{\sqrt{n}}$	
24	10	3	2	—	—	137	—27	—0.197	180	1.284	32.0	31.803	0.097	1952
7	3	—	—	—	—	43	3	0.070	124.5	2.959	30.5	30.507	0.262	1952
—	—	—	—	—	—	14	3	0.214	16.5	1.220	30.5	30.714	0.295	1952
—	—	—	—	—	—	5	— 1	—0.200	10.5	2.575	24.0	23.800	0.717	1952
40	19	8	2	1	—	176	— 8.5	—0.048	219.75	1.252	32.0	31.952	0.084	1952
71	32	11	4	1	—	375	31.5	0.084	855.25	2.274	31.5	31.584	0.078	1952
9	8	6	—	—	1	50	— 6	—0.120	36	0.720	32.5	32.280	0.120	1952
1	—	—	—	—	—	50	—25	—0.500	119	2.173	29.0	28.500	0.208	1952
—	—	—	—	—	—	7	0	0.000	3.5	0.583	28.0	28.000	0.288	1951
—	—	—	—	—	—	4	0	0.000	3,75	1.250	28.5	28.500	0.560	1951
—	—	—	—	—	—	1	—	—	—	—	—	—	—	1951
—	—	—	—	—	—	12	0.5	0.042	12.75	1.157	28.0	28.042	0.320	1951

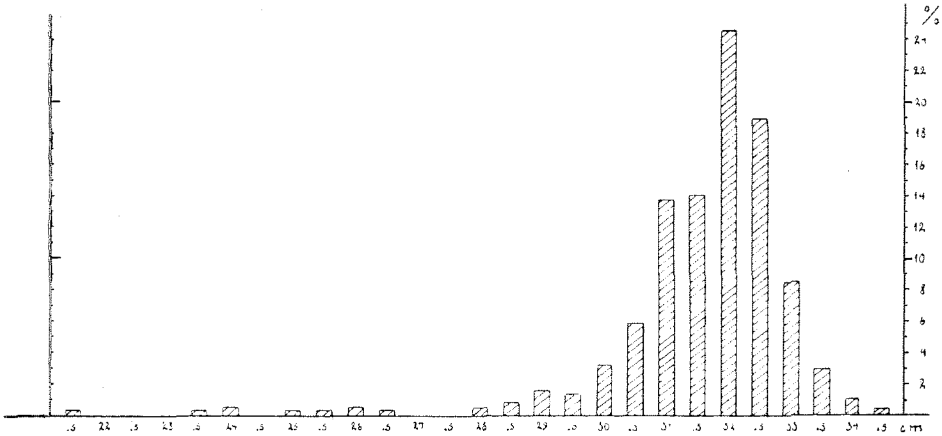

Fig. 6. Percentage length frequency-distribution for the Østerbø herring in the autumn 1952.

Weight

In accordance with the procedure in the preceding Sections the weight of the Østerbø herring will here be treated separately for each of the different year-classes. In Table 4 are presented the weight-frequency distributions in 10 gm groups of the different year-classes in the samples from 1951 and 1952. For comparison are entered the

Table 4.

Weight frequency distributions for the different year-classes of the Østerbø herring (Ø. h.) as appearing from the catches in 1951 & 1952. For comparison weight frequency distributions

Type	Year-class	Weight																					
		70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280
Ø.h.	1947	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	3	9	18	28	31	33
-	1948	—	—	—	—	—	—	—	—	1	1	—	—	—	2	4	4	3	6	1	9	2	7
-	1949	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	3	1	2	4	2	—	—
-	1950	1	—	2	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
-	Total	1	—	2	1	—	—	—	1	1	1	—	—	1	2	5	8	7	17	23	39	33	40
W.h.	1947	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	2	—	3	4	8	5	6
-	1948	—	—	—	—	1	9	3	6	6	4	5	—	2	3	4	2	1	—	1	1	—	1
Ø.h.	1947	—	—	—	—	—	—	—	—	4	3	—	—	—	—	—	—	—	—	—	—	—	—
-	1948	—	—	—	—	—	—	—	1	—	2	—	1	—	—	—	—	—	—	—	—	—	—
-	1949	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
-	Total	—	—	—	—	—	—	1	1	4	5	—	1	—	—	—	—	—	—	—	—	—	—

weight-frequency distributions of the year-classes 1947 and 1948 from the Winter herring (the same fish as in the preceding Tables). Also are entered the total number in the sample, the variances, the mean values, and the standard errors of the means (see page 11).

It will be noted that while the mean weights of the 1947 and 1948 year-classes of the Østerbø herring are not significantly different in the autumn of 1951, the 1947 year-class has gained more in weight than the other one in the following year so that there is an average difference of about 30 gm in the autumn of 1952. Even this is a small difference and although the 1947 year-class has compensated some of its checked growth in the summer of 1949, the effect is evidently still telling. Nevertheless, its mean weight of 266.9 gm ± 2.8 is very nearly equal to the 5-year-old fishes of the Winter herring. These, however, are about half a year younger at the time of sampling so that the Østerbø herrings are undoubtedly the smaller. The 1948 year-class compares more favourably with the Winter herring. The average difference is here about 80 gm in favour of the Østerbø herring. The difference in sampling time, however, could easily make up for this. The specimens of the 1949 year-class of the Østerbø herring, on the other hand, are decidedly more bulky than Winter herring of the same age. Thus the 3+ year-old herrings have an average weight of 235 gm ± 11.0, this being about 70 gm heavier than the average weight of the 1948 year-class of the Winter herring at 4 years. The latter year-class, however,

for the year-classes 1947 & 1948 of the Winter herring (W. h., the same fishes as in Tables 2 & 3). For further explanation see text.

in gm																
290	300	310	320	330	340	350	360	n	S (x)	$\bar{x}$	$S(x^2)$	σ^2	«Working» mean	«True» mean	$\pm \frac{\sigma}{\sqrt{n}}$	Year
12	1	—	1	—	—	—	—	137	940	6.9	42 000	261	260	266.9	1.4	1952
3	—	—	—	—	—	—	—	43	630	14.7	55 700	1106	230	244.7	5.1	
—	—	—	—	—	—	—	—	14	70	5.0	5 900	427	230	235.0	5.5	
—	—	—	—	—	—	—	—	5	40	8.0	3 000	670	90	98.0	11.6	
15	1	—	1	—	—	—	—	199	1110	5.6	249 100	1 227	250	255.6	2.5	
9	6	1	3	1	—	—	1	50	— 200	— 4.0	37 200	743	280	276.0	3.8	
—	1	—	—	—	—	—	—	50	— 610	—12.2	108 300	2 052	180	167.8	6.4	
—	—	—	—	—	—	—	—	7	— 40	— 5.7	400	29	160	154.3	2.0	1951
—	—	—	—	—	—	—	—	4	0	0.0	800	267	160	160.0	8.2	
—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	12	— 70	— 5.8	2 100	154	160	154.2	3.6	

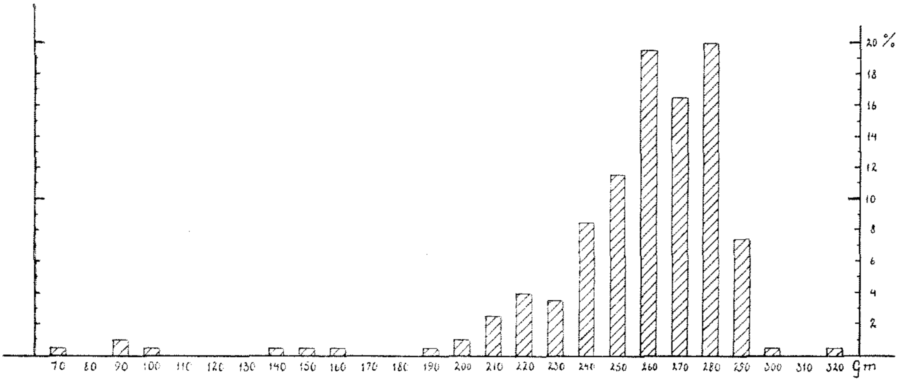

Fig. 7. Percentage weight frequency-distribution of the Østerbø herring as shown by the 1952 sample.

had reduced growth in its second year (see Table 5). The average weight of the 1950 year-class, about 100 gm in 1952, would seem about normal considering the situation presented in the preceding year. The material is, however, very scanty.

As a whole, the weight of the Østerbø herring is strikingly similar to that of the Winter herring, the difference being if any, that the Østerbø herrings normally grow better. In this connection it is interesting to note that according to information furnished by the local fishermen, herrings of 700 gm have been caught in the Østerbøvatn. This, however, must be taken for what it is worth.

In Fig. 7 is illustrated the total weight-frequency distribution of the Østerbø herrings as shown by the 1952 sample.

Growth

The growth of the Østerbø herring has been touched upon in the two preceding Sections. In this Section the problem will receive a more detailed treatment based on scale measurements. Instead of using the actual lengths at the different ages, the calculated yearly increments (t_n) are considered, this giving the better notion of the growth histories. As the basis for the length calculations LEA's revised growth formula has been used (LEA 1938).

In Table 5 are presented the yearly increments t_1, t_2, t_3, ..., t_n (and their standard errors) of the different year-classes of the Østerbø herring, separately for the 1951 and the 1952 samples. For comparison are also shown the corresponding increments for the 1947 and the 1948 year-classes of the Winter herring (the same fish as in the previous Tables).

Table 5.

Yearly increments (cm) based on scale measurements (mean values with standard errors of the means) of the different year-classes of the Østerbø herring (Ø.h.) and of the 1947 and 1948 year-classes of the Winter herring (W.h.).

Type	Year-class	t_1 mean	$\pm \frac{\sigma}{\sqrt{n}}$	t_2 mean	$\pm \frac{\sigma}{\sqrt{n}}$	t_3 mean	$\pm \frac{\sigma}{\sqrt{n}}$	t_4 mean	$\pm \frac{\sigma}{\sqrt{n}}$	t_5 mean	$\pm \frac{\sigma}{\sqrt{n}}$	t_6 mean	$\pm \frac{\sigma}{\sqrt{n}}$	t_7	t_8	n	
?	1945	8.8	—	6.7	—	4.3	—	1.4	—	0.8	—	1.4	—	0.9	2.7	1	
Ø. h.	1947	10.266	0.098	8.124	0.086	2.007	0.059	4.106	0.067	3.865	0.053	3.602	0.047	—	—	137	
—	1948	10.209	0.222	8.116	0.221	5.453	0.150	3.453	0.153	3.209	0.098	—	—	—	—	43	
—	1949	10.571	0.510	8.036	0.365	7.250	0.408	5.000	0.262	—	—	—	—	—	—	14	
—	1950	11.600	1.781	7.200	0.663	5.100	1.017	—	—	—	—	—	—	—	—	5	1952
W. h.	1947	11.400	0.189	7.760	0.243	6.190	0.140	4.440	0.114	2.470	0.076	—	—	—	—	50	
—	1948	10.030	0.207	5.590	0.170	6.299	0.173	5.950	0.251	—	—	—	—	—	—	50	
Ø. h.	1947	11.214	0.484	7.714	0.660	1.500	0.081	4.214	0.330	3.714	0.200	—	—	—	—	7	
—	1948	11.875	1.477	9.125	0.515	4.125	1.231	3.000	0.866	—	—	—	—	—	—	4	1951
—	1949	9.5	—	9.1	—	6.7	—	—	—	—	—	—	—	—	.. —	1	

The one herring of the 1945 year-class caught in the Østerbøvatn has a growth history which is different from the other fishes and it does not belong to the Østerbø herring tribe. The comparatively large increment in the 8th year suggests that it is a late immigrant to the area. In its growth it resembles a somewhat fast grown Lusterfjord herring. This is demonstrated in Fig. 8, where the yearly increments are plotted against the age (broken line). The continuous line represents the average yearly increments of the Lusterfjord herring. Whether or not this particular herring belongs to the Lusterfjord herring is, although probable, not quite certain, but in case, it is the first specimen found outside that fjord. Its rapid growth in the last summer (1952) should then indicate that the small size of the Lusterfjord herring really is connected with the scarcity of food (plankton) in the fjord (AASEN 1951). If not, then some unknown growth-limiting factor should exist. Evidently the Østerbøvatn normally provides very good feeding grounds. It would be an interesting experiment to transplant tagged Lusterfjord herring to the Østerbøvatn (or to the open sea). Maybe such an experiment also would throw some light upon the question of the herring's «homing instinct».

Regarding the other year-classes of the Østerbø herring one may note that the samples from the two different years exhibit no significant differences in growth. This is an important point as it shows that the same group of fishes has been living in the Østerbøvatn for

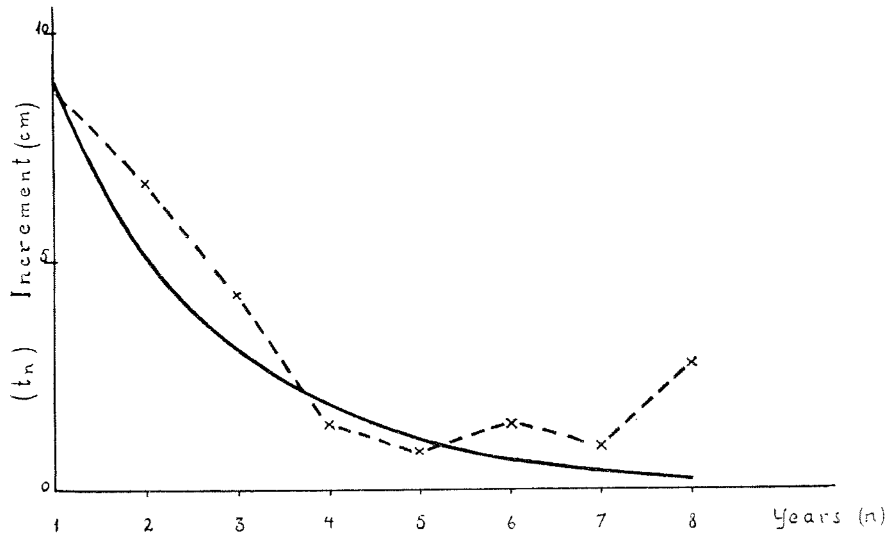

Fig. 8. The yearly length-increments of the 7+ years old herring caught in the Østerbøvatn in October 1952 (broken line) compared to the average yearly increment of the Lusterfjord herring (continuous line).

the last year at the least. Evidence to the same effect was borne out by the age analysis (see Table 1). From Table 5 is also seen that the 1947 year-class of the Østerbø herring has a first year's increment significantly different from that of the Winter herring, the former being the smaller. Recalling the difference in the vertebral numbers, it seems clear that this year-class of the Østerbø herring has been both bred and has spent its first year in an environment different from that of the Winter herring. Following this year-class it is seen that the increments t_2 of the two groups are about the same, while the t_3 of the Østerbø herring is very much the lower. The next year's increments (t_4) are again very similar, and finally, in the fifth year the growth of the Winter herring is slowed down compared with the Østerbø herring.

This strongly reduced growth rate of the 1947 year-class in its third year makes the scales very conspicuous and as a matter of fact it was this characteristic appearance which at first attracted attention when the herrings were examined and indicated that further investigations might be fruitful. In Fig. 9 is presented a graphical demonstration of the peculiarity and the difference from the Winter herring is clearly shown.

The t_1 of the 1948 year-class of the Østerbø herring is not significantly different from that of the Winter herring. Neither was the vertebral number significantly different, and this year-class provides no clue to the Østerbø herring's origin, but for the next year's increment one finds that the Winter herring has checked growth. For the two following years the Winter herring has the better growth rate. In Fig. 10 is demonstrated the difference in growth characters for the herring of

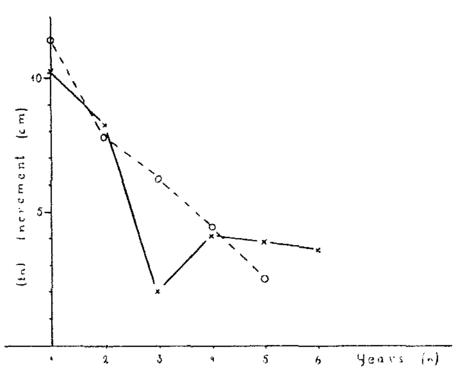

Fig.9. Growth rates of the 1947 year-class of the Østerbø herring (continuous line) and the Winter herring (broken line).

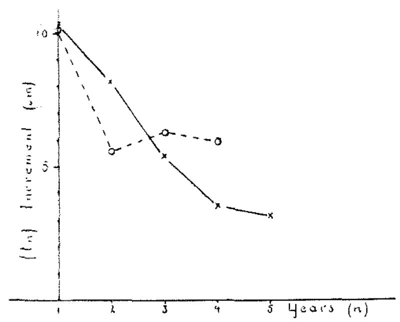

Fig. 10. Growth rates of the 1948 year-class of the Østerbø herring (continuous line) and the Winter herring (broken line).

the two groups and it is seen that after the first year the herrings have been living in evironments which have not been similar.

The 1949 year-class of the Østerbø herring has a similar growth to the preceding year-classes in the two first years, but in the last two years the growth is considerably better. Particularly noticeable is the third year's growth of 7.25 cm. This is about 5 cm more than for the corresponding year of the 1947 year-class.

Finally, of the 1950 year-class there are too few specimens to justify further comments.

If an average growth curve is to be constructed, based on the figures in Table 5, the material would appear to be awkward. Obviously the 1947 year-class has an «abnormal» growth and this is the dominating group. The 1949 year-class seems to have excessive growth in the last two years. This leaves the 1948 year-class, which on the other hand has a smooth-running growth increment curve (see Fig. 10) of a more familiar form and may be taken as «normal». In the following treatment then, the figures for the 1948 year-class will be used as the basis for the calculations.

For the Winter herring, Oscar Sund constructed a «growth curve» based on the average length at the different ages of the herring, giving the formula (SUND 1944):

$$L_n = (47.2 - 4.7\sqrt{n})\ log(n+1)$$

where L_n is the average length at the age n. From the formula is seen that the function:

$$f(n) = \frac{L_n}{log(n+1)} = 47.2 - 4.7\sqrt{n}$$

will represent a slowly decreasing curve reaching zero at about $n = 100$ (see Fig. 11). Treating the figures from the 1948 year-class of the Østerbø herring in the same way, one gets an entirely different curve, which at first rises quickly to a maximum at $n = 3$ to 4 and then slowly decreases (see Table 6 col. 5 & Fig. 11). Evidently the figures for the Østerbø herring does not fit the growth formula for the Winter herring.

Table 6.

( ) Interpolated values. For further explanation see text.

n	L_n	log $(n+1)$	$\sqrt{n}$	$\frac{L_n}{\log(n+1)}$	$\frac{L_n}{\log^2(n+1)}$	$\frac{L_n \cdot \sqrt{n}}{\log^2(n+1)}$
1	10.2	0.301	1.00	33.9	112.5	112.5
2	18.3	0.477	1.41	38.4	80.5	113.5
3	23.8	0.602	1.73	39.5	65.6	113.5
4	27.3	0.699	2.00	39.1	56.0	112.0
	(27.6)			(39.5)	(56.3)	(113.0)
5	30.6	0.778	2.24	39.3	50.3	112.5

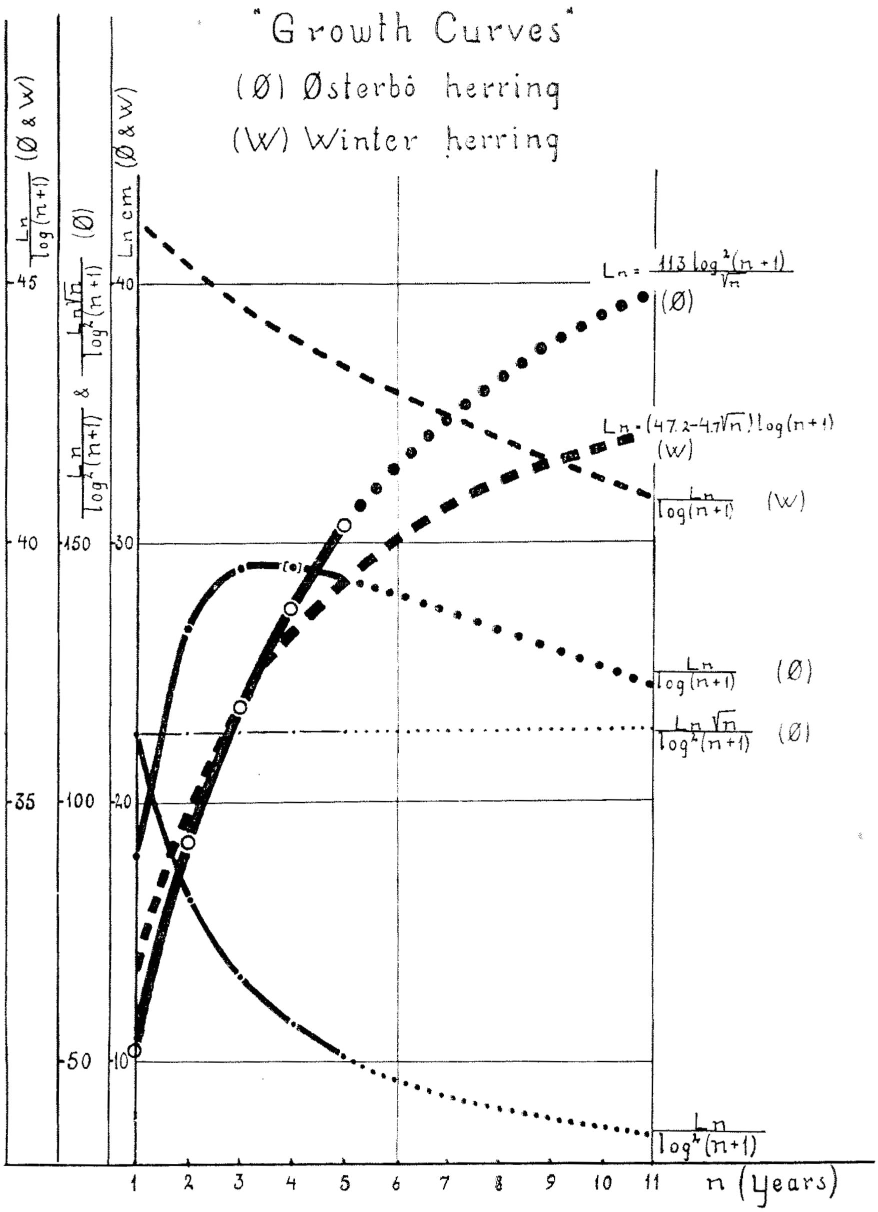

Fig. 11. «Growth Curves» for the Winter herring (W) and the Østerbø herring (Ø). For further explanation see text.

If the figures in Table 6 col. 5 are divided by log $(n+1)$ one gets a slowly decreasing series, (Table 6 col. 6 & Fig. 11), and by multip- plying this with $\sqrt{n}$, the result will be a set of constant (or nearly, constant) values (Table 6 col. 7 & Fig. 11). Choosing the constant = 113 (the average value) gives then the growth formula:

$$L_n = \frac{113.\log^2(n+1)}{\sqrt{n}}$$

Back-calculations show that the departures from the figure 113 in the last column of Table 6, will not produce differences in L_n larger than the limits of sampling errors of the observational data.

This formula of course fits nicely to the data on which it is founded. It is quite another question whether the formula will fit the growth in the following years. It implies that the next year's mean length should be 33 cm. This may seem reasonable as the 1947 year-class with its checked growth in the third year, has a mean length of about 32 cm in its 6th year. Further is seen that at the age of 10 years the mean length would be 38.7 cm. This does not seem much likely, but it is not altogether impossible. For $n = 20$, however, the mean value amounts to 44.1 cm and this figure is very improbable . If not, the local fishermen's story of giant herrings caught in the Østerbøvatn may turn out to be true, (cf. page 18). A herring weighing 700 gm would correspond to a length of 43.9 cm with a condition factor of 831 (the mean value of the condition factor for the 1952 sample, see Table 10).

The properties of the formula beyond $n = 20$ will be of purely theoretical interest, and will be discussed but briefly. If it contains a maximum, the first derivative must be zero:

$$L_n = 113\left[\frac{\log^2(n+1)}{n^{\frac{1}{2}}}\right]' = 113\,\frac{u'v - uv'}{v^2} = 0$$

where $u = \log^2(n+1)$ and $v = n^{\frac{1}{2}}$. One has then:

$$113\frac{2\log(n+1)\frac{\log e}{n+1}n^{\frac{1}{2}} - \log^2(n+1)\,\frac{1}{2}n^{-\frac{1}{2}}}{n} =$$

$$113\log(n+1)\,\frac{4\,n\log e - (n+1)\log(n+1)}{2\,n\,(n+1)\,n^{\frac{1}{2}}} = 0$$

This gives: $4n \log e = (n+1)\log(n+1)$ or $4 = \ln\,(n+1)^{\frac{n+1}{n}}$ or

$$54.3 = (n+1)^{\frac{n+1}{n}}$$

This equation is satisfied for $n = 49$ at which age the «Growth Curve» reaches its theoretical maximum. The corresponding L_n would be 46.6 cm. From here on the curve will slowly decrease, but will never reach zero as both $\log^2(n+1) \longrightarrow \infty$ and $n^{\frac{1}{2}} \longrightarrow \infty$ when $n \longrightarrow \infty$.

Maturity

The majority of the herrings sampled in the Østerbøvatn were sexually mature as will be evident from Table 7 where the frequencies of the different maturity stages are presented.

This fact provides important evidence towards establishing the Østerbø herring as a tribe of its own. As was borne out from the age distributions, it is the same group of fish that is sampled in the two different years. Because the gonads of the herring in the autumn of 1951 were in stages typical for Spring spawners, it was highly probable that spawning had taken place in the area in the ensuing spring. This conclusion is verified by the local fishermen who state that the spawning time is in the month of March. One has then a group of herring living in a well defined area and propagating there, and this is to all intents and purposes what is understood by a self-contained herring tribe.

In Table 7 are also entered for comparison the frequency distributions of the maturity stages for the Winter herring[1] and the Lusterfjord herring, the samples having been taken at about the same time

Table 7.

Frequency distributions of the maturity stages of the Østerbø herring (Ø.h.) in December—51 and October—52. For comparison the corresponding figures for the Winter herring (W. h.) caught in open Ocean in October—52 and for the Lusterfjord herring (L.h) in October—52. Figures in brackets ( ) are percentages obtained when the immature fishes are left out.

Date & Year	Type	Maturity stages						Total
		I	II	VIII	III	IV	V	
4. XII 1951	Ø. h.	—	1	—	6	6	1	14
—	-	—	7,1%	—	(46.2%) 42,9%	(46.2%) 42,9%	(7.7%) 7.1%	(100.1%) 100%
24.-27.X 1952	-	3	1	5	50	151	—	210
—	-	1.4%	0.5%	(2.4%) 2.4%	(24.2%) 23.8%	(73.4%) 71.9%	—	(100%) 100%
27. X 1952	W. h.	—	—	2	10	71	16	99
—	-	—	—	2.0%	10.1%	71.7%	16.2%	100%
31. X. 1952	L. h.	14	14	3	53	—	—	84
—	-	16.7%	16.7%	(5.3%) 3.6%	(94.6%) 63.1%	—	—	(99.9%) 100.1%

of the year. It will be seen that the Winter herring is in the most advanced stages, while the Lusterfjord herring has the least developed reproductive organs. This is in accordance with the spawning time: mid-February to mid-March for the Winter herring and mainly April for The Lusterfjord herring. According to these data the spawning time for the Østerbø herring ought to fall in between those just mentioned, thus corroborating the earlier statement. The spawning time may, however, vary in the different years for the different tribes, probably due to changing physical and chemical conditions in the sea. (AASEN 1949).

As far as can be judged by the scanty material, the fish first become mature at about 3 years of age. Of the 2+ year-old herring in the 1952 sample, one is sexually mature while the four others are immature. Also in 1951 one mature specimen of 2+ years was caught. On the other hand, all the herrings of 3+ years are sexully mature. The average length when attaining maturity would appear to be about 24 cm which is the mean length at 3 years according to the growth calculations. The actual observed data deviate somewhat from this figure, suggesting a length of about 25 cm at first maturity.

The weight of the gonads was also taken when sampling the Østerbø herring this year (1952). From these data and the weight of the herring is calculated the maturity factor, M_F, (AASEN 1951):

$$M_F = \frac{p}{P} 10^2$$

where p is the weight of the gonads and P the weight of the fish. In Table 8 is presented the frequency distribution of M_F for the Østerbø

Table 8.

Frequency distributions of M_F for the Østerbø herring (Ø.h.) and the Lusterfjord herring (L.h.) in the autumn of 1952.

Date & Year	Type	M_F						Total	Mean
		2	5	8	11	14	17		
24.—27. X. 1952	Ø.h.	22	87	58	32	6	1	206	6.5
—	-	10.7%	42.2%	28.2%	15.5%	2.9%	0.5%	100%	
31. X 1952	L.h.	19	25	10	2	—	—	56	3.9
—	-	33.9%	44.6%	17.9%	3.6%	—	—	100%	

[1] Caught in open ocean the 27.X-52 at Lat. 64°39.5′ N Long. 05°50′ W.

herring. For comparison the corresponding values from a sample of Lusterfjord herring taken at about the same time, are also entered in the Table (the same fish as in the preceding Table). The immature herrings are left out.

In Fig. 12 is given a graphical demonstration of Table 8.

It will be seen that the Østerbø herring has the higher M_F: the weight of the gonads constitutes a higher percentage of the body weight and it has consequently advanced further towards spawning. According to the formula describing the variations in M_F for the Lusterfjord herring (AASEN 1951) the difference in the mean values corresponds to about one month's difference in spawning time. This corroborates the earlier result: main spawning in April for the Lusterfjord herring against allegedly March for the Østerbø herring.

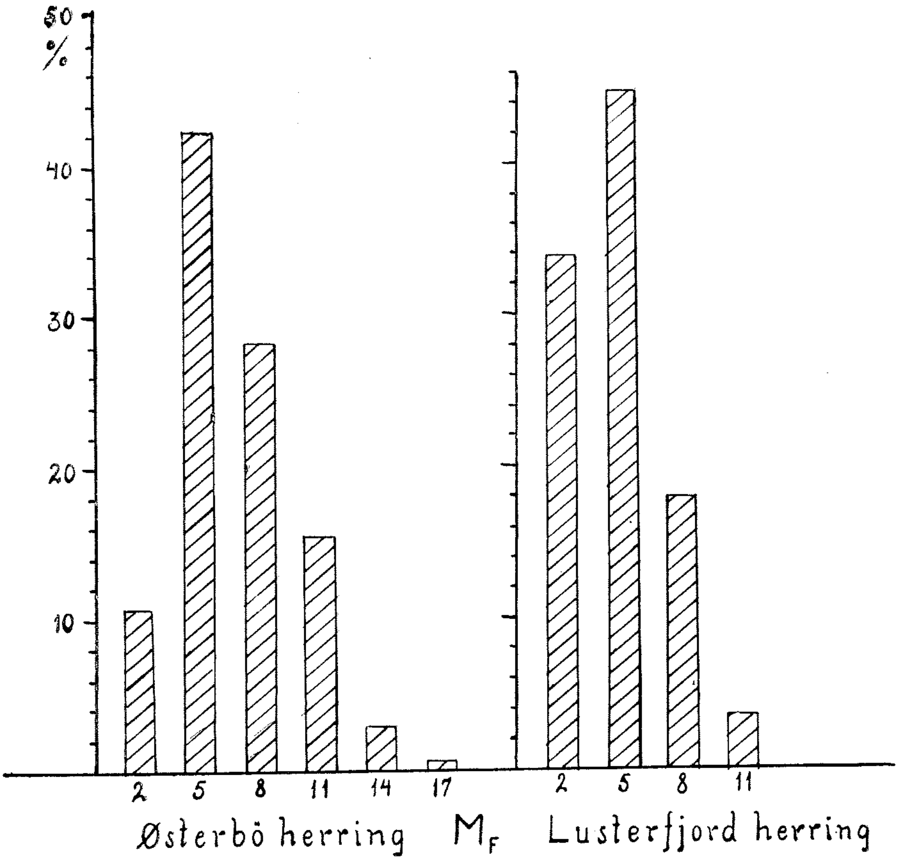

Fig. 12. The frequency distribution of M_F of the Østerbø herring compared to that of the Lusterfjord herring.

Quality

The samples of the Østerbø herring were caught fairly late in the year and it was therefore surprising to find, when the herring was first investigated, that it was in such good condition with plenty of intestinal fat. The sample from this year (1952) is still more striking. In Table 9 are presented the frequency distributions for the two samples of the amount of intestinal fat, grouped as follows:

0 = no fat (0)
\+ = traces of fat (1)
\++ = moderate fat (2)
m = much fat (3)

In the Table are also entered for comparison the corresponding values for the Winter herring and the Lusterfjord herring (the same fish as in Table 7). In Fig. 13 will be found an illustration of Table 9.

Considering the last three samples, which were caught within a few days of each other, it will be seen that the Østerbø herring is by far the fattest. The «m» group (much intestinal fat) constitutes 44.3 % of the sample, while only 4 % for the Winter herring and 3.6 % for the Lusterfjord herring. It is further borne out that more than 40 % of the Winter herring had spent their intestinal fat (the «0» group) while all

Table 9.

Frequency distributions of intestinal fat (0, 1, 2, 3) for the Østerbø herring (Ø.h.) in December—51 and October—52. For comparison the corresponding figures for the Winter herring (W.h.) and the Lusterfjord herring (L.h.) in October—52.

Date & Year	Type	o	+	++	m	Total	Mean
		0	1	2	3		
4. XII 1951	Ø.h.	1	3	9	1	14	1.71
—	-	7.1%	21.4%	64.3%	7.1%	99.9%	
24.—27. X 1952	-	—	26	91	93	210	2.32
—	-	—	12.4%	43.3%	44.3%	100 %	
27. X 1952	W.h.	40	38	17	4	99	0.85
—	-	40.4%	38.4%	17.2%	4.0%	100 %	
31. X 1952	L.h.	—	1	53	2	56	1.98
—	-	—	1.8%	94.7%	3.6%	100.1%	

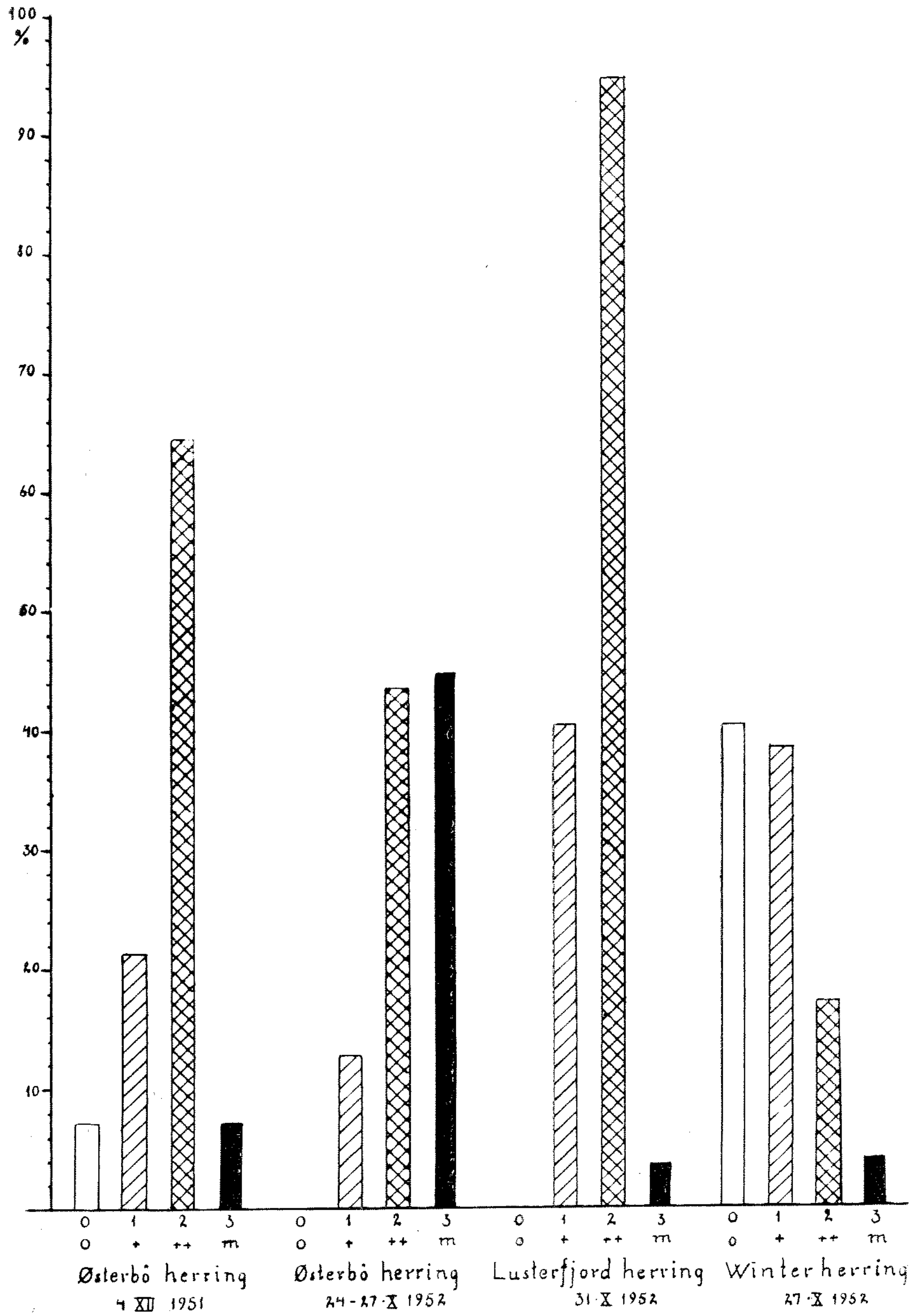

Fig. 13. The intestinal fat of the Østerbø—, Winter—, and Lusterfjord Herring.

the herrings of the other two samples have at least traces of fat in the intestines. Chemical analyses of the samples reveal an actual fat content of (whole fish) 18.8 % for the Østerbø herring and 13.2 % for the Winter herring. The analyses thus corroborate the result found by the estimation of the intestinal fat. Recalling now that the Winter herring was in the higher state of maturity, a certain difference was to be expected, but 5.6 % difference as an average is considerable and can hardly be accounted for by the relative slight difference in maturity.[1] It may be possible that it is linked with the extensive migrations of the Winter herring as borne out by the herring tagging experiments (FRIDRIKSSON & AASEN 1950).

The unusual high fat content of the Østerbø herring in late autumn, suggests that normally, it must be extraordinarily fat in the summer. Thus it should provide excellent raw material for high quality herring products. Regrettably, the stock must be considered quite small and could certainly not endure much exploitation.

Condition

The empiric formula: $P = Cl^3$ means that in a sample of fish, the weight (P) is proportional to the third pover of the length (l). In the proportionality factor (C) are involved the average body proportions of the fish and the specific weight. These properties will show seasonal variations and this feature forms the basis of OSCAR SUND's definition of the condition factor: «The quantity, the third power of the length has to be multiplied by, to equal the weight.»[2] SUND multiplies the C by 10^5 to get figures more convenient for tabulating and denotes this new quantity by K (SUND 1944):

$$K = \frac{P}{l^3}\ 10^5$$

In Table 10 are presented the frequency distributions of K for the two samples of Østerbø herring. The immature herrings are left out. For comparison are also entered the corresponding figures for the Winter herring and the Lusterfjord herring (the same fish as in Tables 7 & 9). In Fig. 14 is given a graphical demonstration of Table 10.

It will be seen that the 1951 sample of the Østerbø herring has the lowest value of K, but as the sample was taken the year before

[1] According to FINN DEVOLD a sample of Winter herring taken 6.XII.-52 at Lat. 64°28′N Long.08°55′W, showed 17,3 % fat. The majority of these were, however, immature (and some few recruit-spawners).

[2] Translated by the author from Norwegian.

Table 10.

Frequency distributions of the condition factor ($K = \frac{P}{l^3} \cdot 10^5$) for the Østerbø herring (Ø.h.) in December—51 and October—52. For comparison the corresponding figures for the Winter herring (W.h.) and the Lusterfjord herring (L.h.) in October—52.

Date & Year	Type	K								Total	Mean
		650	700	750	800	850	900	950	1000		
4. XII 1951	Ø.h.	2	6	4	1	—	—	—	—	13	717
—	-	15.4%	46.2%	30.8%	7.7%	—	—	—	—	100.1%	
24.—27.X 1952	-	—	4	35	65	51	36	13	2	206	831
—	-	—	1.9%	17.0%	31.5%	24.8%	17.5%	6.3%	1.0%	100 %	
27. X 1952	W.h.	—	—	5	22	34	25	13	1	100	861
—	-	—	—	5 %	22%	34%	25%	13%	1%	100 %	
31. X 1952	L.h.	1	12	17	17	8	1	—	—	56	770
—	-	1.8%	21.4%	30.4%	30.4%	14.3%	1.8%	—	—	100.1%	

and about one month later in the season, it is not directly comparable with the others. Considering the last three samples, it is seen that the Winter herring has the highest value of K, and the Lusterfjord herring the lowest. This corresponds with the average stage of maturity which normally appears to be negatively correlated with the amount of intestinal fat (AASEN 1951).

The fact that the Winter herring has a higher value of the condition factor while the fat content is 5.6 % lower, clearly demonstrates that «condition» must not be confused with «quality»; of two herrings with the same bulk (volume) the one with the higher weight is of the inferior quality.

Conclusion

The herring tribe described in the preceding pages is interesting from various points of view. The Østerbøvatn is quite small, covering only about 2.5 square km. Yet the herrings inhabiting it are rather large and of excellent quality. Further, considering the limited space, the lake appears to be densely populated. This may be a temporary phenomenom, however, in view of the rather strange age distribution. Also the local fishermen state that the abundance fluctuates heavily.

As mentioned, the canal connecting the Østerbøvatn with the sea,

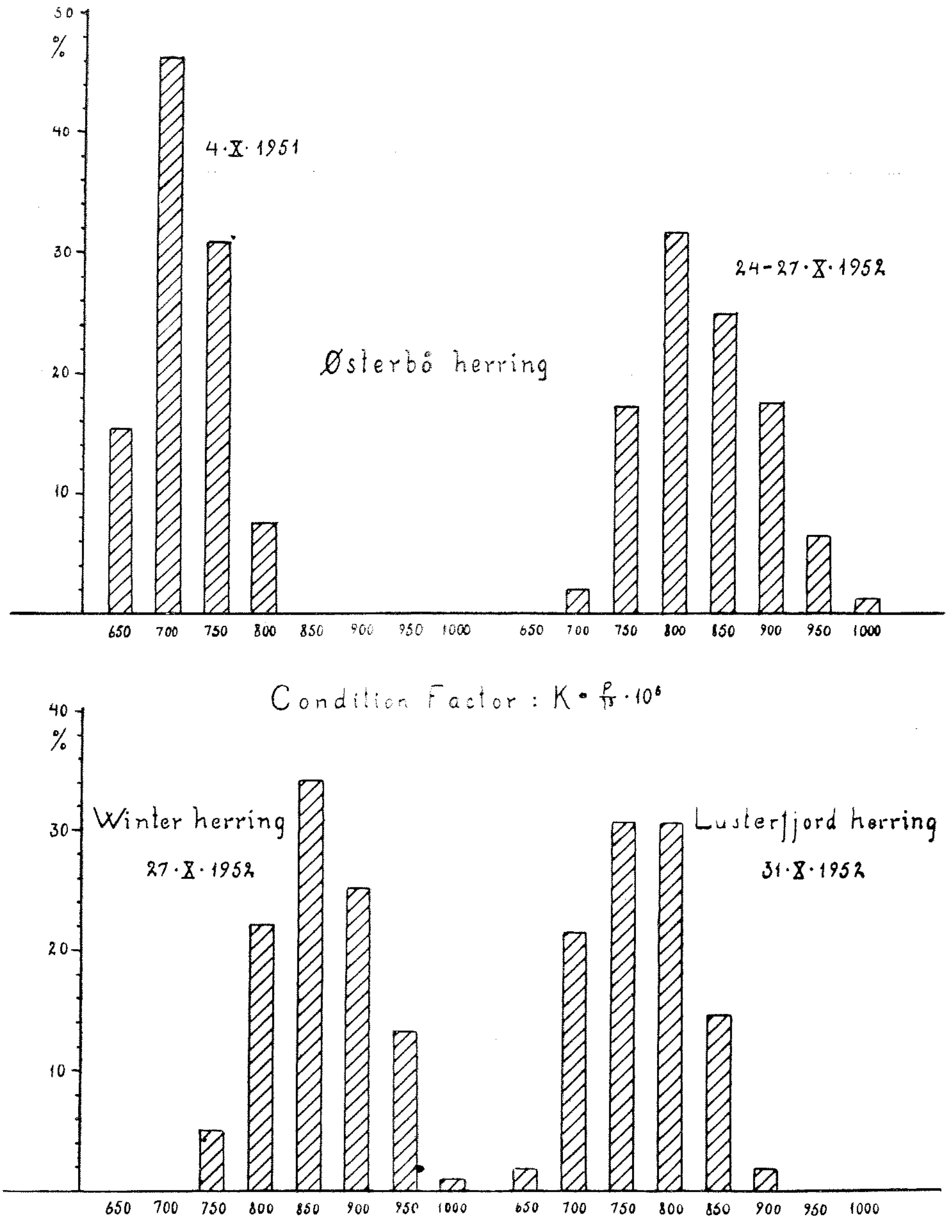

Fig. 14. The frequency distributions of K for the Østerbø herring, the Lusterfjord herring, and the Winter herring.

was dug about the year 1860, and since that time a herring tribe has taken residence in the lake. The tribe is thus at the most not fully 100 years old. In all probability it is derived from the Winter herring (the

Southern growth type), which it closely resembles. The differences are so slight that it is hardly justified to class the Østerbø herring as a «race».

To sum up:

a. The vertebral number in general (57.32± 0.10) is higher than for the Winter herring, but not much. The vertebral numbers of the year-classes are partly significantly different from those of the Winter herring, and partly not.

b) The mean lengths of the year-classes are in some cases smaller than for the Winter herring, in other cases larger. The mean length of the Østerbø herring in the autumn of 1952 was 31.58 cm ± 0.10 (composed of 5+ year-old and younger fish).

c) The mean weight was at the same time 255.6 gm ± 5.0. The different year-classes show similar relation to the Winter herring as stated for the length.

d) Growth analyses seem to indicate that the Østerbø herring normally grows better than the Winter herring. One of the year-classes was «marked».

e) All these differences, although small, furnish evidence towards establishing the Østerbø herring as a tribe of its own. So does also the fact that the samples show mature fish living in a well defined area on the Norwegian Coast when the nearest shoals of the Winter herring at the sampling time are located about the Faroes. Moreover, the stages of maturity indicate a somewhat later spawning than for the Winter herring. Local fishermen state that the spawning takes place in March.

f) The quality of the Østerbø herring appears to be excellent. The fat content sampled on the 27th October 1952 showed 18.8 % against 13.2 % for the Winter herring at the same date. Intestinal fat was also more plentiful.

One of the puzzling points about the Østerbø herring is that only young fish (5+ years and younger) have been found. As yet, no explanation can be offered.

Further, it seems strange that the 1947 year-class is «marked» in its third year while the 1948 year-class is not marked in its second year. Neither does the 1949 year-class show reduced growth in its first year. Yet the environment must be supposed to be the same for all groups in such a confined space. The explanation might be that different size groups have different requirements, for instance the plankton might have been qualitatively different in the three years.

The economical importance of the Østerbø herring is certainly not great. A few local fishermen take occasional catches for home consumption, preferably in summer. On the other hand, from a biological point of view it is of interest to investigate such local stocks in their niches and no doubt many can be found along the extensive Norwegian Coast with its numerous fjords.

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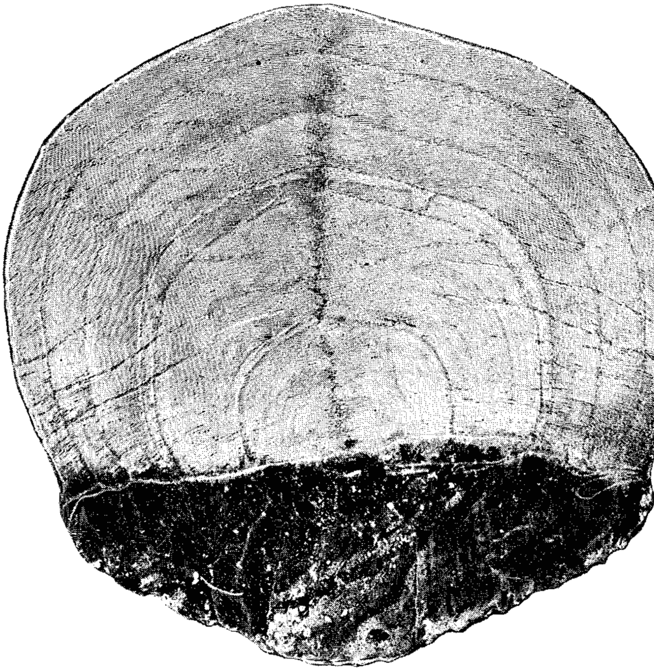
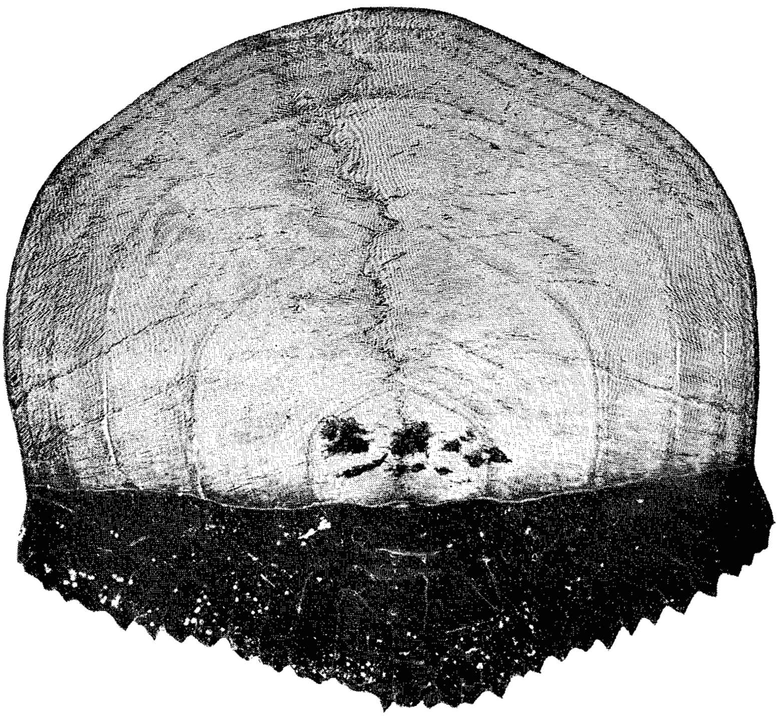


5 + year-old Østerbø herring (1947 year-class).



5 + year-old Winter herring (1947 year-class).