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The Spawning Zone in Cod Otoliths and Prognosis of Stock

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In a preliminary paper "The Otoliths of the Cod",[1]) and in another entitled "The Cod Otolith as a Guide to Race, Sexual Development and Mortality"[2]) a connection was suggested between the occurence of a certain particular type of growth zones in the otoliths and the sexual activity of the cod.

The whole of the large otolithmaterial collected during the Norwegian Cod fisheries in 1932—33—34, and a portion of that from 1935 has now been worked up, and this continued investigation along the lines described in the two papers cited above, support and consolidate the conclusions arrived at upon the 1932/33 material.

The stock of "skrei" or spawning cod is now apparently entering upon a period of powerful expansion as two or three good yearclasses are in evidence, it is therefore important to use the opportunity of observing the recruitment of the spawning stock from these rich yearclasses, and a detailed description of material and laboratory methods has therefore been postponed.

In the two papers cited above it was moreover pointed out that the assumption of a definite zone type as spawning zones, led to the conclusion that the recruitment and mortality of the stock might be described by means of a definite formula.

If the increase and decrease of the stock followed such a rule it would be possible to calculate the expected age distribution from that of the last year.

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[1]) Fiskeridir. Skr. vol. IV No. 3 1933.

[2]) Rapp. et Procés-Verbaux. Vol. LXXXVIII. 1934.

Assumptions and methods of calculation.

Assuming the peculiar outer zones in some otoliths to be spawning zones, the yearclasses of the skrei which have formed the stock in the period investigated seem to have entered maturity according to a definite rule, a scale composed of the "maturing factor" for each year group.

Thus from the relative number of the 6 years old first-spawners we should be able to compute the relative number of the first-spawners 7 years old the following year, and so on constructing the agecomposition of the first-spawners for each age-group in the next year.

The yearly mortality of the stock of skrei has been found to amount to about 40 %. The yearclasses of a given stock should appear the ensuing year on the spawning banks one year older, but according to the mortality-rate, with $^6/_{10}$ of their numerical strength in the previous year.

Fig. 1 shows the method of computation.

The individual fish of the sample are entered according to age and number of spawning zones. To illustrate: taking the 1934 collection; this contained 7 specimens 6 years old, 58 of 7 years, and 114 of 8 years old. Six of the 8 years old fishes had one spawning-zone, indicating a maturity-age of 7 years; 108 had no complete spawning-zones and are therefore considered as first-spawners. Of 12 year old fish there were 176, 39 of which had no complete spawning-zones, 85 had one, 44 two, 6 three, 1 four and 1 had five spawning-zones.

The yearclass 1926 (8 years old) is represented in the sample with 108 specimens of first spawners. In 1935 this yearclass will, according to theory, again send a number of first spawners (now 9 years old) and this number will be proportional to the number of first spawners in 1934 (108), and this ratio, $\frac{N_9}{N_8}$, is found to be 2.8. (See Fig. 1, red figures) according to which the relative number of 9 year old first spawners should amount to 303 in 1935.

The yearly mortality rate being 40 %, the 108 eight years old first-spawners, the relative number of second-time-spawners 9 years old, should the following year appear reduced to 65 specimens ($108 \cdot 0.6 = 65$).

In this manner we can treat all the different components of the collection, and get the relative frequency of the various yearclasses one year in advance.

Maturing Factors			$\frac{N_7}{N_6} = 5.5$	$\frac{N_8}{N_7} = 4.4$	$\frac{N_9}{N_8} = 2.8$	$\frac{N_{10}}{N_9} = 1.8$	$\frac{N_{11}}{N_{10}} = 1.1$	$\frac{N_{12}}{N_{11}} = 0.67$	$\frac{N_{13}}{N_{12}} = 0.49$	$\frac{N_{14}}{N_{13}} = 0.28$	$\frac{N_{15}}{N_{14}} = 0.17$		Observed Distribution 1934		Calculated Distribution 1935	
Age at First Spawning		6	7	8	9	10	11	12	13	14	15			%		%
Age-Groups	6	**7**											7	0·7		
	7	4	**58** 38										58	5·7	42	2·8
	8		**6** 35	$\boxed{\textbf{108}}$ 255									114	11·3	290	19·5
	9		4	**24** 65	**93** 303								117	11·6	372	24·9
	10		**1**	**11** 14	**41** 56	**68** 168							121	12·0	238	15·9
	11			**2** 7	**14** 25	**54** 41	**42** 75						112	11.1	148	9·9
	12		**1**	**1** 1	**6** 8	**44** 33	**85** 25	**39** 28					176	17·3	95	6·4
	13			**4**	**5** 4	**10** 27	**29** 51	**26** 24	**10** 17				84	8·3	123	8·2
	14		**3**	**2** 2	**5** 3	**8** 6	**10** 17	**13** 16	**10** 6	**2** 3			53	5·2	53	3·7
	15		**4** 2	**9** 1	**12** 3	**16** 5	**14** 6	**19** 8	**9** 6	**8** 1			91	9·0	32	2·1
	16		2	5	**3** 7	**9** 10	**8** 8	**12** 11	**9** 5	**3** 5	**1**		45	4·4	53	3·7
	17				**4** 2	**3** 5	**4** 5	**3** 7	**4** 5	**3** 2	**1**		22	2·2	26	1·7
	18				2	**3** 2	**1** 2	**1** 2	2	2			5	0·5	12	0·8
	19					**3** 2	**1** 1	**1**					5	0·5	3	0·2
	20					2	1			**1**			1	0·1	3	0·2
	21							**1**					1	0·1		
													1012	100·0	1490	100·0

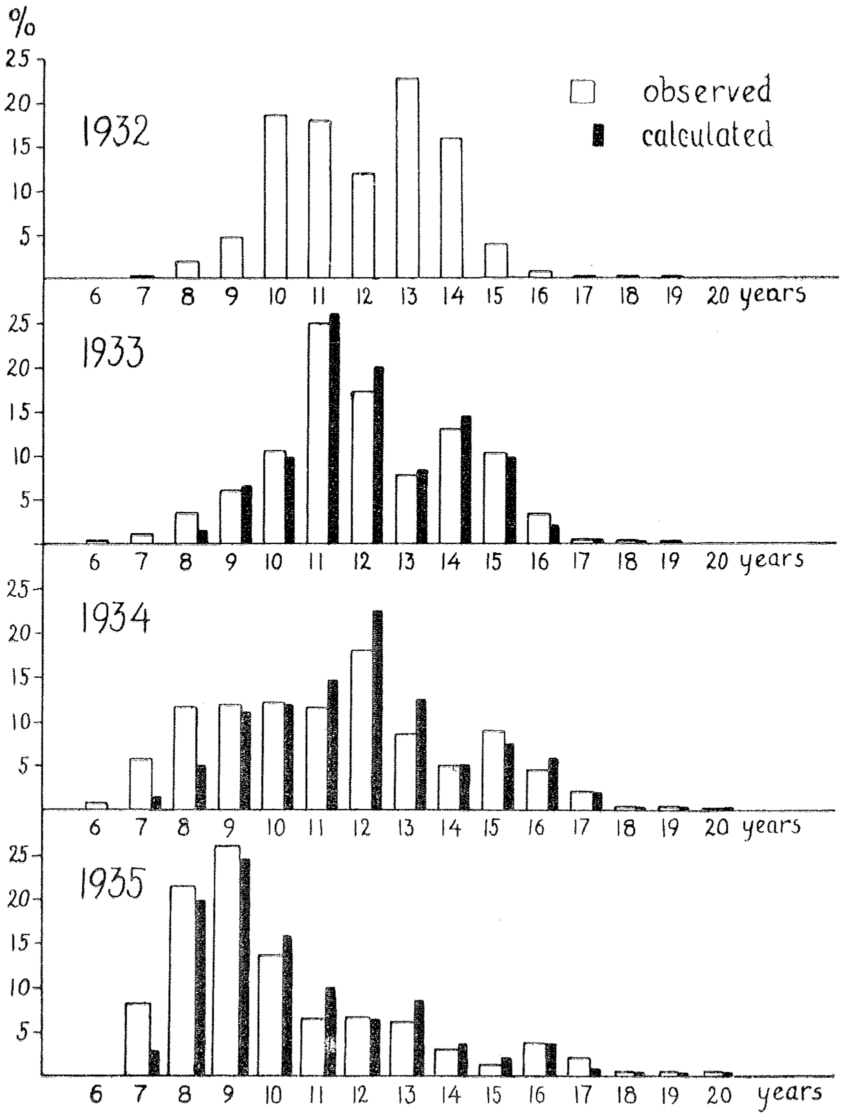

Fig 2. The observed and the calculated Age-composition of the Skrei.
(1932 — 800 specimens, 1933 — 900, 1934 — 1200, 1935 — 1000).

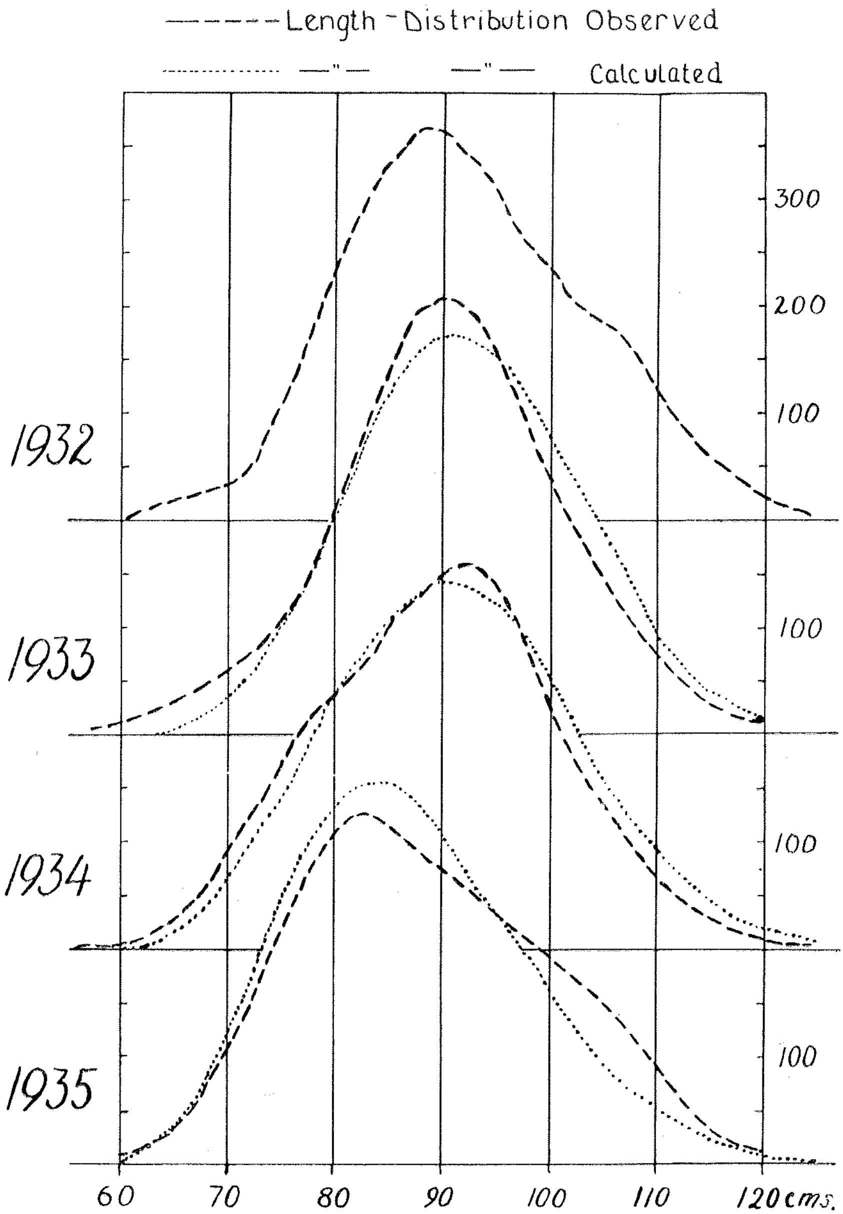

Fig 3. The observed and the calculated Length-distribution of the Skrei.

We notice however, that as our two operations:

1. computing the tribute of expected first-spawners of each age group
2. applying the mortality coefficient (40 %)

were applied upon on a sample consisting of about 1000 (1012) specimens, the expected relative number for the next year will be 1490.

This increase in number is due solely to an increase in number of first-spawners and indicates a total increase of the spawning stock by about 33 % as compared to that of the previous year.

Working up the otolith material on the hypothesis that the very narrow, clear, evenly wide, outer zones correspond to years of spawning, definite numerical regularities may be formulated regarding the recruitment of the skrei stock with new spawners and also regarding the mortality of the stock.

These rules might be numerically expressed by a system of factors, and we should therefore be able, given an observed stock, with aid of these factors to follow it theoretically exactly to its next stage of development, bearing in mind the possibility of the skrei of various yearclasses migrating to different or special spawning-grounds.

If therefore observed age compositions fit with the above hypothesis, we have an indirect proof of the validity of our supposition — that the peculiar outer zones in the otoliths are formed after maturity.

Fig. 2 shows the observed age-compositions of the skrei during the years 1932—1935, compared with the calculated distributions for the corresponding year. With the exception of the computation "1932 into 1933" the calculations were completed before the commencement of the fishery seasons in question.

The high degree of similarity between the observed and the computed age distributions afford the required evidence of a correct interpretation of these peculiar zones.

Based upon the known size-distribution of each age group of spawners, the expected size distribution may be computed and compared to the subsequently observed size distribution. This is shown in fig. 3.

As it may be considered as *being* of interest to know the age and size distributions to be expected in the catch of next year (1936) we have decided to publish the relevant calculations at the present moment (december 1935).

In fig. 4 and 5 the calculated distribution of age and length of the 1936 stock is shown.

The average length of the cod in 1936 should be approximately 85 cm and the average weight (gutted) 3,25 kg.

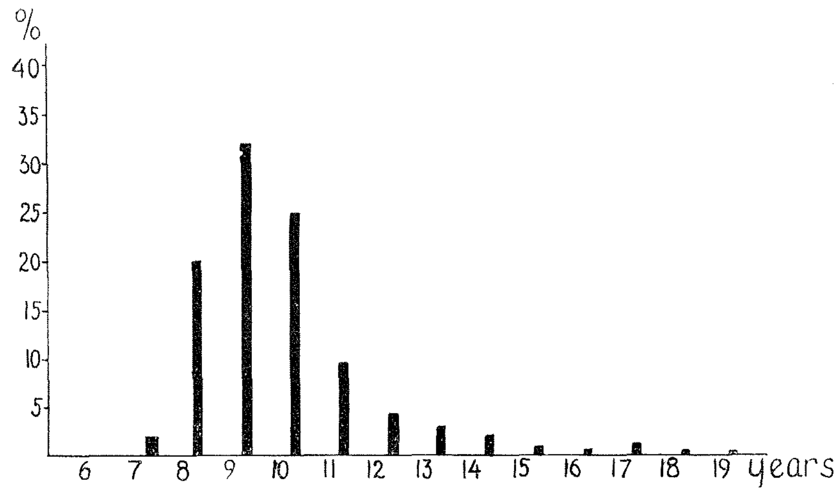

Fig 4. The calculated Age-distribution of the Skrei 1936.

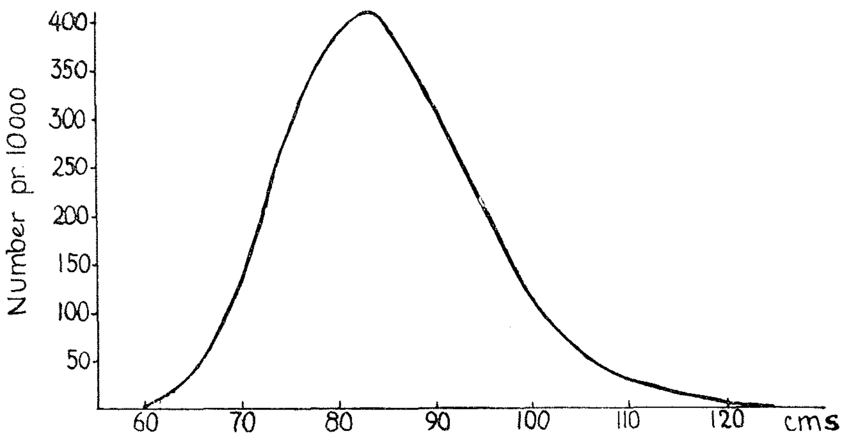

fig 5. The calculated Length-distribution of the Skrei 1936.

According to the length-distribution we can give the following % distribution of weight gutted:

Length-groups....	58–67	68—77	78—87	88—97	98—107	108	cm
Average weight........	1·25	1·8	2·75	4·0	5·3	6·7	kg
Frequency......	2·1	22·5	39·0	25·0	9·0	2·5	%

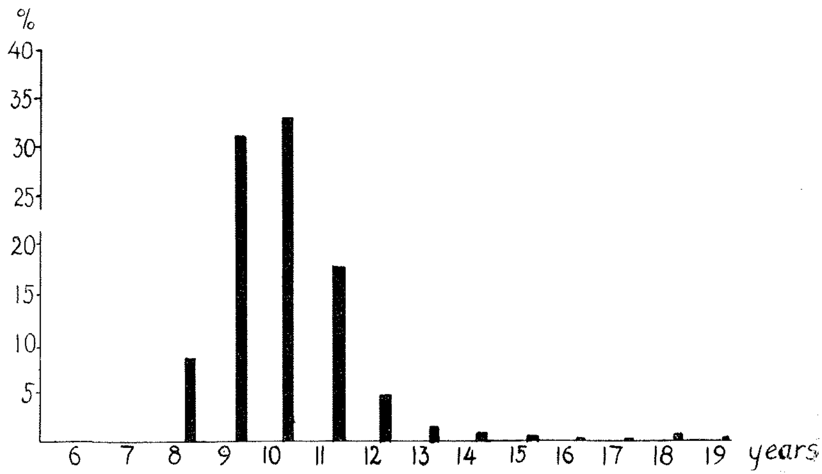

Fig 6. The calculated Age-distribution of the Skrei 1937.

Also the probable age-distribution of the stock in 1937 is forecasted (fig. 6), the predictions being based on the *calculations* for 1936. A prediction for this length of time is, however, uncertain partly owing to the uncertainty of the value of the maturing-factors and partly to the restricted material at disposal.

By a calculation of the stock one year in advance we have no clues for the computation of the relative number of 6 year old spawners, and by calculation 2 years in advance this is the case also for the spawners 7 years old. Therefore the percentages of the expected age-distributions given, will be influenced by these "unknown" age-groups.

As, however, the skrei are recruited from the shoals of "loddetorsk" immature Finmark Cod, definite information on the agecomposition of this immature stage would furnish an excellent control of the observed relative representation of the year groups 6—8among the skrei.

The relatively very small representation of such young matured fish, in the samples under investigation form the weak point in our calcu lations because the high maturing-factors to be applied to these small numbers, introduces a relatively large uncertainty. This might, however, be remedied by drawing the loddetorsk into the purview of the investigation.

If the representation of the 4th and 5th year groups among the loddetorsk be known, the problem should not be insuperable of predicting the size distribution of the skrei two or three years later.