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Observations on the Cod and Cod Fisheries of Lofoten

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by

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Age, length, and growth studies, tagging experiments etc. undertaken on cod in Norwegian and Arctic waters have shown that there are many reasons for regarding the cod of the Barents Sea, and the spawning cod which every year appear on the Lofoten banks, as belonging to one population,

The Arcto-Norwegian Stock of Cod, or sherter, The Arctic Cod.

It seems on the other hand justified to place the cod occurring all the year round in the Norwegian fjords, and on the coastal banks, in another separate group, The Coastal Cod. Even if the cod of the coast consist of numerous populations, stocks, races, types, or whatever sub-groups there may be found, the cod belonging to the coastal waters show some common features which tie them together. However, our knowledge of the biology of this group of cod is little compared with the information we possess of the Arctic Cod.

Since 1913 we have taken yearly length measurements of the cod from Lofoten, and we are thereby able to follow the fluctuations in length distribution of the mature part of the Arctic Cod - the Skrei - through a period of 40 years. Since 1932 when age determinations by means of the otoliths were taken up we have an uninterrupted series of observations of the age distribution of the skrei through a period of 20 years.

In our studies of the Arctic Cod the official fisheries statistics have been of fundamental value. As from 1860 we know the number of cod taken every year in Lofoten, and also the number of fishermen engaged in the fisheries. Accordingly we also know how fortunate or unfortunate the Lofoten fishermen have been over a period of 90 years.

From 1883 onwards we know the average gutted weight of the Lofoten cod, this being still another valuable series of observations of the size of the spawning skrei through 70 years.

The illustrations will, in a striking manner, show the fluctuations in the cod fisheries of Lofoten, and also the variations in the size, length, and age of the cod.

The Age Distribution, Figure 1.

From age determinations on scales we have certain information on the year-classes before the period covered by the otolith readings. 1904, 1912, and 1915 are mentioned as good brood-years. The age determinations by means of the otoliths have shown outstanding year-classes born in 1917, 1918, 1919, 1929, 1930, and 1937.

The Length Distribution, Figure 2.

The length measurements show the years in which the spawning stock has been renewed. As the recruit spawners appear in greater abundance in their 8th. year we can, with some certainty, point out those year-classes which cause the renewal. The results of the age determinations support the conclusions which we draw from the length measurements. From the length measurements alone it should be justified to point out the years 1904-1906, and 1912 as good brood years.

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Figures 3 and 4 show the deviations for each year from a long time average distribution of length and age respectively.

As will be discussed later we have found fluctuations both in growth rate and in rate of maturity. - The average size of the 10 years old cod is not always the same, and the average spawning age of a year-class will also fluctuate. The average frequency distributions for length and age will thus be affected and broadened.

Figure 4 showing the yearly deviations of each single year-class from the long time average age distribution gives the impression that some promising year-classes are fading out early, whilst others show an increasing frequency as the time goes by. This, however, may not only be due to accelerated or retarded rate of maturity but may also be caused by the varying strength of the concurrent year-classes.

The Yearly Total Yield of the Lofoten Cod Fishery 1860-1953.

Figure 5. The fluctuations in the number of cod caught in Lofoten indicate fluctuations of varying duration.

a. Long time fluctuations: Catches above average from about 1875-1899, below average from 1900 - 1925, and again above average from 1926 - 1950.

b. Short time fluctuations: The catches show an increasing tendency over a couple of years followed by a decrease in the next 3 to 5 years.

c. Unregular yearly fluctuations: The increasing or decreasing tendency of the catches seems to be "disturbed" by factors which in the particular season affect the fishing activity + or +.

Speaking of the last period, when we can find support in the age and length investigations; we find that the good catches in 1945-47 were mainly due to the 1937 year-class.
The year-classes 1929-30 gave the good catches in 1940, and the 1917-18 and 19 year-classes are responsible for the catches in 1926 - 1930.

As there seems to be a close connection between the number of cod taken and the numerical strength of the year-classes in the period 1925-1950 it seems justified to suppose that there has been a relatively poor reproduction of the stock in the years 1890-1915, but a relatively rich reproduction in the period 1865 - 1890. Perhaps we could point out 1887, 1882, 1878 and 1872 or a preceding or subsequent year as good brood-years in this past period.

Number of Fish Per Man Per Season.

From the number of cod caught and the number of fishermen taking part in the Lofoten fishery each year we can calculate the number of cod per man per season, Figure 6.

The average catch is about 900 fishes, but as will be seen there are great fluctuations. In this diagram we are using smoothed data both regarding fish and fishermen to remove the "disturbing" factors.

The good catches in the years 1925 to 1930 are based on the rich year-classes 1917, 18, and 19. The year-classes born in 1928-30 are responsible for the increase of the catches in the late thirties, and the record catch in 1946 is mostly due to the 1937 year-class.

Turning to the more distant years, we could perhaps ascribe the increasing catches from 1892 onwards to the year-classes born about 1885. Furthermore year-classes from about 1878 could have increased the catches as from 1884. And we could perhaps ascribe the good catches in the years 1866-1880 to good year-classes born within the period 1862-1872.

The Gutted Weight of the Lofoten Cod, 1883-1953.

The average gutted weight of the Lofoten cod is given in the official statistics, and the values we have plotted in figure 7. The diagram shows fluctuations of a conspicuous regularity.

In the period from which we have age and length determinations we have found that decreasing average weight coincides with the appearance and dominance of young spawners belonging to rich year-classes, and that the average weight and length increase when the renewal is poor.

As the fluctuations occurring in this period seem closely connected with the abundance of the year-classes entering the stock (and not produced by varying fishing intensity) we may assume that a substantial renewal of the spawning stock has taken place in the years 1889, 1894, 1900, 1909, 1917, and 1924, pointing to good brood-years in 1882, 1887, 1892, 1900, 1909, 1918, or any neighbouring year.

Note: The shifting tendency which occurs every 8th. or 9th. year may be caused by a density regulating factor.

The Yield of the Various Year-Classes.

Our age and length investigations being based on catches from long lines neither show the correct picture of the spawning stock proper nor the composition of the catches taken by nets or purse seines. Table 1, therefore, only gives the yield of the various year-classes taken by long lines.

Questions Concerning the Geographical Distribution of the Cod Populations.

As mentioned above it seems justified to divide the cod occurring in Norwegian waters in two main groups, The Arctic Cod and the Coastal Cod, of which the latter may comprise numerous local subgroups.

The following table gives some features which may serve as a means of indentification of the two groups.

	The Arctic Cod.	The Coastal Cod.
Geographical distribution	In the Barents Sea all year round and at the Norwegian coast from Finnmark to Møre Nov. to June.	The entire Norwegian coast in the fjords and on the coastal banks all the year round.
Body shape	slender	heavy
Vertebrae	53.5o - 80	52.oo - 52.8o
Bones in the skull	thin (primitive)	thick (developed)
Otoliths:		
Form	plane	twisted
Structure	terse	diffuse
Fracture	easily broken in the middle	easily broken near the ends
Growth rate:		
Immature	ca. 10 cm per year	
Mature	1 - 3 cm per year	
Maturity	6 - 14 years	3 - 7 years
Duration of life	up to 30 years	up to 17 years
Spawning grounds	Norw. Coast from W. Finnmark to Møre	the entire coast
Migrations	Long	?

Questions Concerning Changes in the Cod Populations.

Changes in Growth Rate. In figure 8 we have plotted the mean value of the average lengths of age groups 8 - 13 years. The diagram shows the fluctuations in length of cod of equal age during the last 21 years.

At the same age the cod in 1936 and in 1951 were about 8 cm longer than in 1932 and in 1944. These fluctuations in growth rate seem to correspond with the density of the stock. In the years 1932-1936 the stock consisted of remains of the year-classes born in 1917-19. But from 1936 the 29 and 30 year-classes being 7 and 6 years respectively start to join the mature stocks.
The density of the stock is obviously increased by these two year-classes and increases even more when the very strong 37 year-class makes its appearance.

As the fish grow the demand of each single fish for space and food adds up until mortality and the poor recruitment in the years 38 to 41 have reduced the stock to a lower level. Then the growth rates start climbing again reaching the peak in 1951.

From this year decreasing growth rate may indicate increasing density, or poorer food conditions, or both.

Changes in Age of Maturity.

By means of the spawning zones in the otoliths it is possible to determine the age at the first spawning and the changes in the rate of maturity.

In figures 9 and 10 we have chosen the abundance of first time spawners of each age group as a means of demonstrating the changes in the age of maturity.

If a year-class have matured early the percentage of first time spawners will be low at a more advanced age and vice versa.

It is interesting to note that the year-classes which constituted the spawning stock in the years 1932-1938 all have been influenced by a factor causing an accelerated maturity. Between the seasons 1938-39 there is a sudden change, all year-classes react simultaneously on a factor causing a retarded rate of maturity and since then only slight changes have taken place.

What happened in the summer of 1938 in the Barents Sea ?

Rate of Mortality.

A calculation of the total mortality of the cod can be undertaken by means of the method used by Einar Lea on the herring, based upon the frequencies on the age groups and starting from an age of which the year-classes dos not receive any more first time spawners. In the case of the cod a year-class may receive new spawners 14 years old and at that age a year-class is mostly worn down, and only a very small part of the age material can be used in the calculations.
If we introduce spawning classes instead of year-classes we can base our calculations on the entire age samples. Such calculations are carried out for 5 successive periods on the basis of age material from long line catches in Lofoten.

		Females		Males	
		Surv.	Mort.	Surv.	Mort.
1st. period	1932-36	0.53	0.47	0.54	0.46
2nd. "	1936-40	0.60	0.40	0.59	0.41
3rd. "	1940-45	0.49	0.51	0.48	0.52
4th. "	1944-48	0.48	0.52	0.48	0.52
5th. "	1948-52	0.52	0.48	0.52	0.48

The coefficients of mortality seem not to have changed very much.

The Relative Strength of the Year-Classes.

The study of the purse seine catches from Lofoten has shown that long line catches dos not give a true picture of the age composition. Calculations based on line samples will accordingly not be correct and will not pass for real stock.

When using the age composition of the line samples as a basis for a calculation of the relative strength of the year- classes we have to bear in mind that our results are not exact. It may perhaps be possible later to introduce corrections.

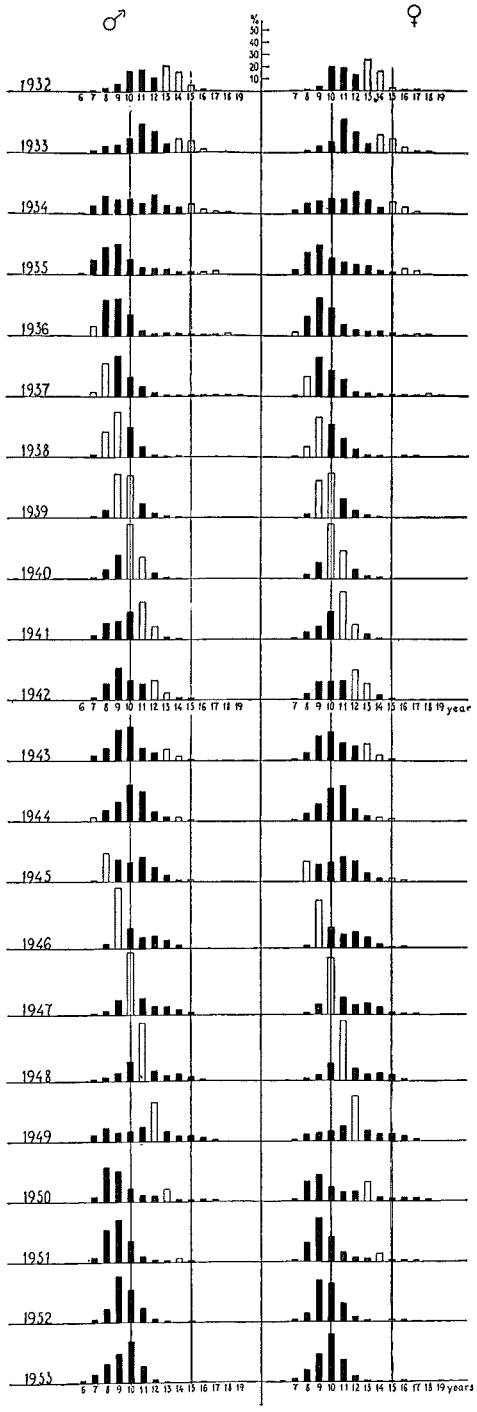
Table II gives the relative strength of the year-classes based on a 19 year average composition.

Table II.

Year-classes	1939	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24
Females	0.3	0.5	2.3	0.8	1.7	1.1	1.1	0.7	0.8	1.8	1.6	1.2	1.1	0.9	0.4	0.4
Males	0.3	0.5	2.4	1.0	0.7	1.2	1.3	0.8	0.8	1.8	1.5	1.1	0.9	0.7	0.4	0.3

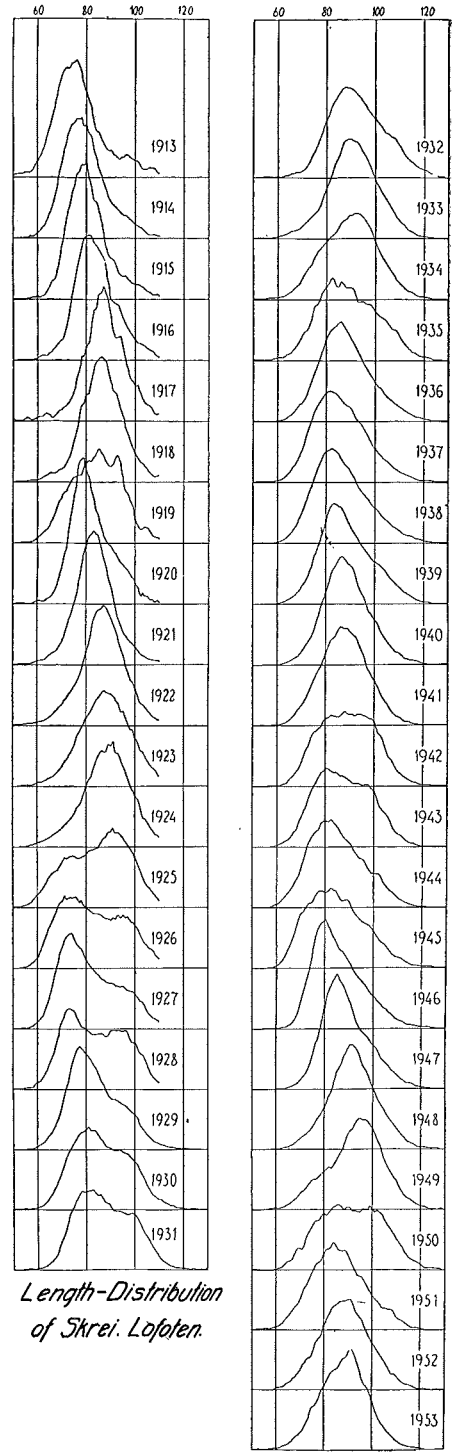
The Yield of the Various Year-Classes.

	1945	1944	1943	1942	1941	1940	1939	1938	1937	1936	1935	1934	1933	1932	1931	1930	1929	1928	1927	1926	1925	1924	1923	1922	1921	1920	1919	1918	1917	1916	1915
7	0.1	0.1	0.2	0.2	0.1	0.08	0.02	0.04	0.27	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.3	0.3	0.27	0.06	0.02										
8		0.3	0.8	1.3	0.5	0.2	0.4	0.4	1.7	0.85	0.7	0.9	0.9	0.5	0.6	1.3	2.0	1.2	0.7	0.62	0.22	0.15									
9			1.1	1.4	1.5	0.45	0.5	1.7	6.3	1.4	1.7	1.9	2.0	1.3	1.6	4.3	3.4	3.1	1.8	0.9	0.61	0.38	0.38								
10				1.0	0.8	0.72	0.5	1.2	8.5	2.5	1.4	3.2	2.1	1.6	2.3	4.6	4.75	2.5	1.8	1.2	0.5	0.7	0.63	1.63							
11					0.43	0.3	0.42	0.75	4.2	2.4	1.6	1.8	2.6	1.1	1.5	3.6	2.2	1.9	1.3	1.1	0.43	0.3	0.6	1.61	1.60						
12						0.1	0.1	0.42	2.1	0.9	1.3	1.8	1.3	1.1	0.9	2.2	1.2	0.7	0.7	0.5	0.3	0.2	0.25	0.92	1.07	1.06					
13							0.03	0.1	0.83	0.53	0.4	1.4	1.2	0.6	0.5	1.0	1.1	0.4	0.2	0.3	0.1	0.2	0.17	0.22	0.51	0.48	1.95				
14								0.02	0.2	0.2	0.32	0.5	0.9	0.5	0.2	0.4	0.4	0.4	0.1	0.1	0.2	0.1	0.1	0.16	0.09	0.27	0.84	1.48			
15									0.04	0.05	0.2	0.34	0.4	0.3	0.1	0.2	0.2	0.1	0.17	0.03	0.03	0.1	0.03	0.1	0.09	0.07	0.48	0.65	0.33		
16										0.02	0.04	0.2	0.24	0.1	0.15	0.1	0.1	0.1	0.01	0.04	0.01	0.01	0.03	0.1	0.1	0.02	0.14	0.24	0.23	0.07	
17											0.01	0.04	0.2	0.09	0.06	0.14	0.1	0.04	0.02	-	0.03	0.01	0.02	0.1	0.1	0.1	0.06	0.1	0.08	0.04	0.04
	0.1	0.4	2.1	3.9	3.33	1.85	1.97	4.63	24.14	9.05	7.87	12.28	11.94	7.29	8.01	18.04	15.75	10.74	7.07	4.85	2.45	2.15	2.21	4.84	3.56	2.02	3.47	2.47	0.64	0.11	0.04



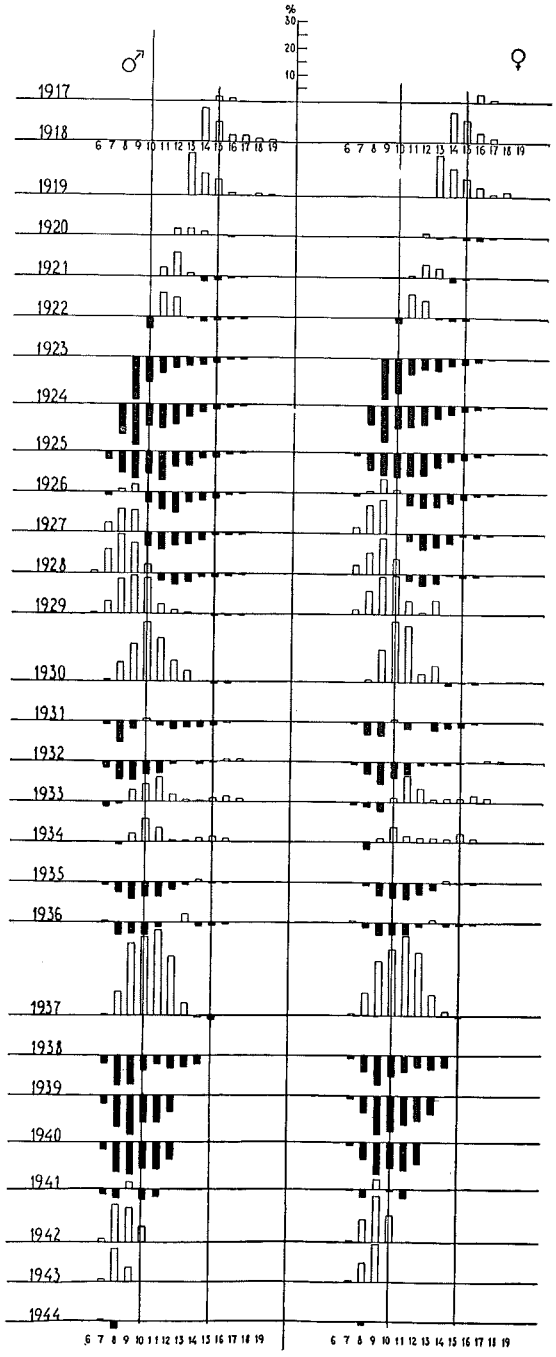
Age-Distribution of Skrei. Lofoten.

Fig. 1.



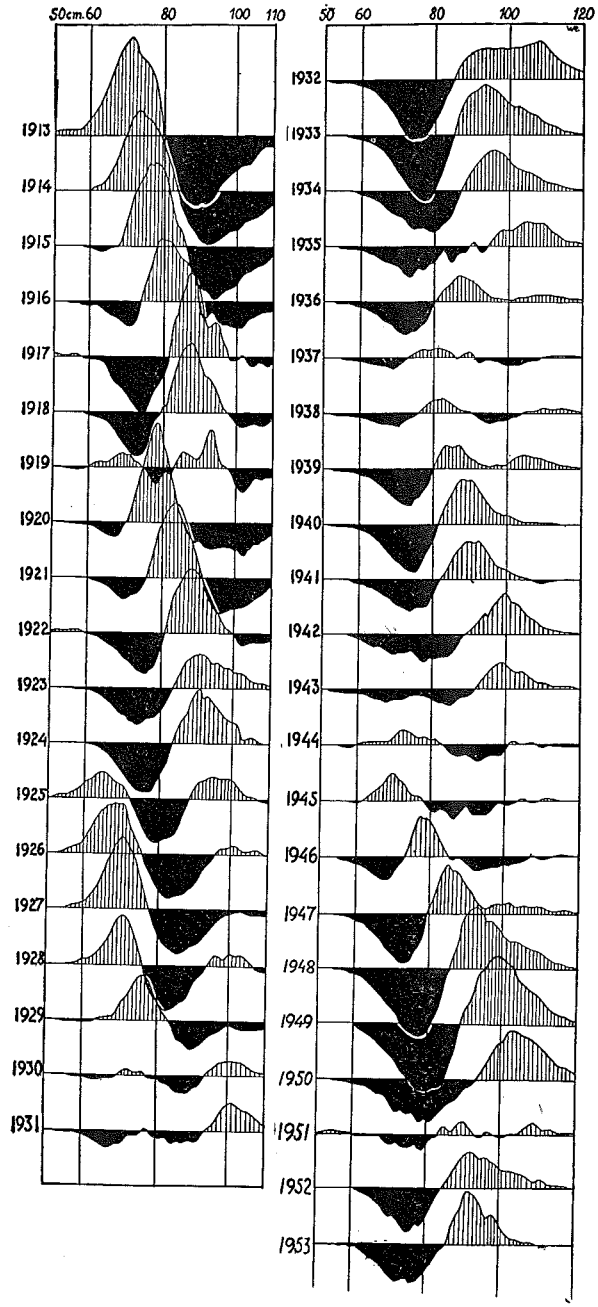
Length-Distribution of Skrei. Lofoten.

Fig. 2.



Yearly Deviations from the Average Age-Distribution. Skrei. Lofoten.

Fig. 3.



Yearly Deviations from the Average Length Distribution. Skrei. Lofoten.

Fig. 4.

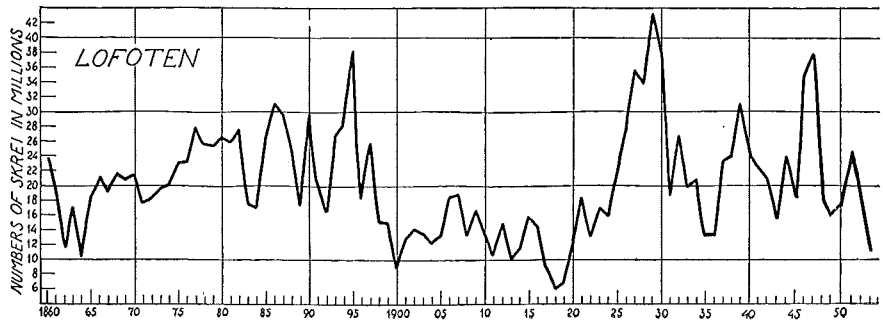


Fig. 5

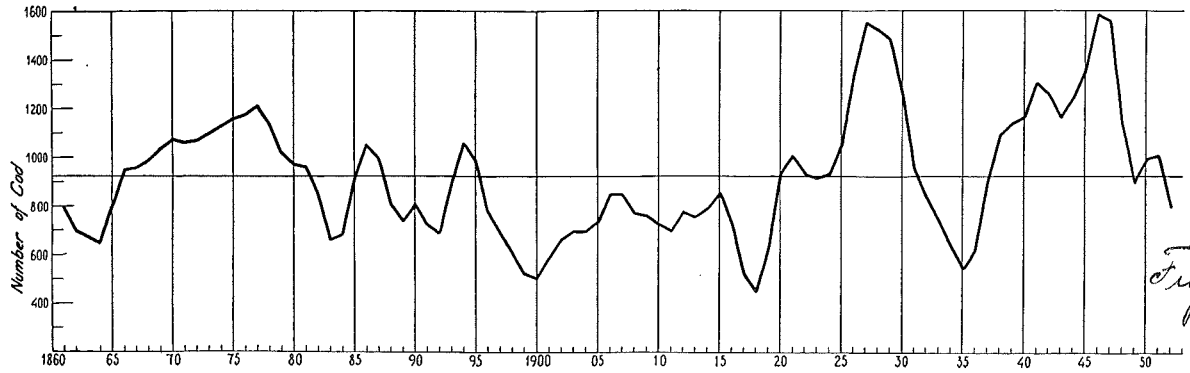


Fig. 6

Catch per Man per Season. Skrei. Lofoten.

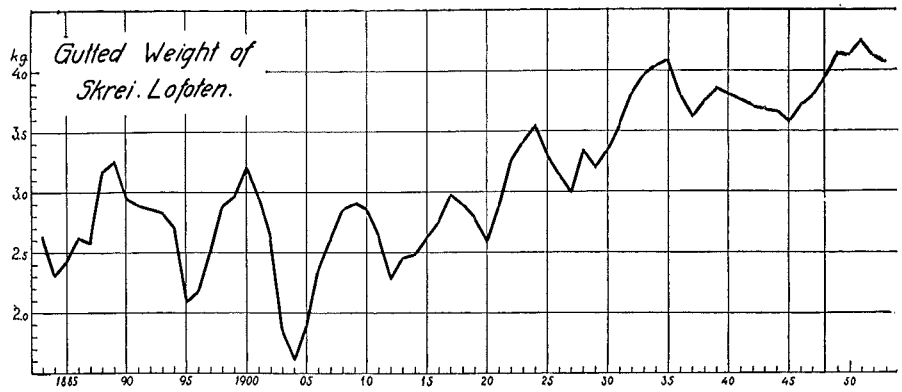


Fig. 7

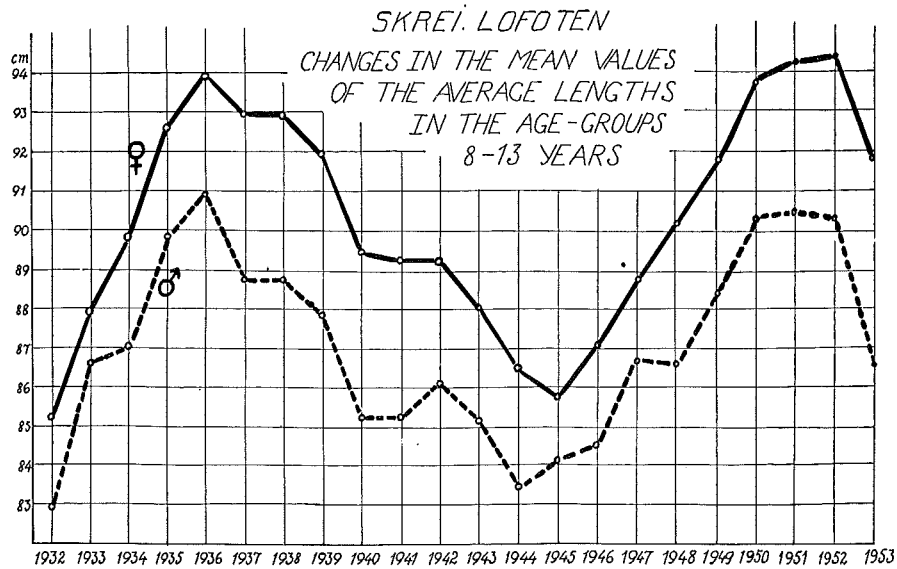


Fig. 8

Skrei. Lofoten.

% ♂ Percentage of Recruit-Spawners in the Various Age-Groups

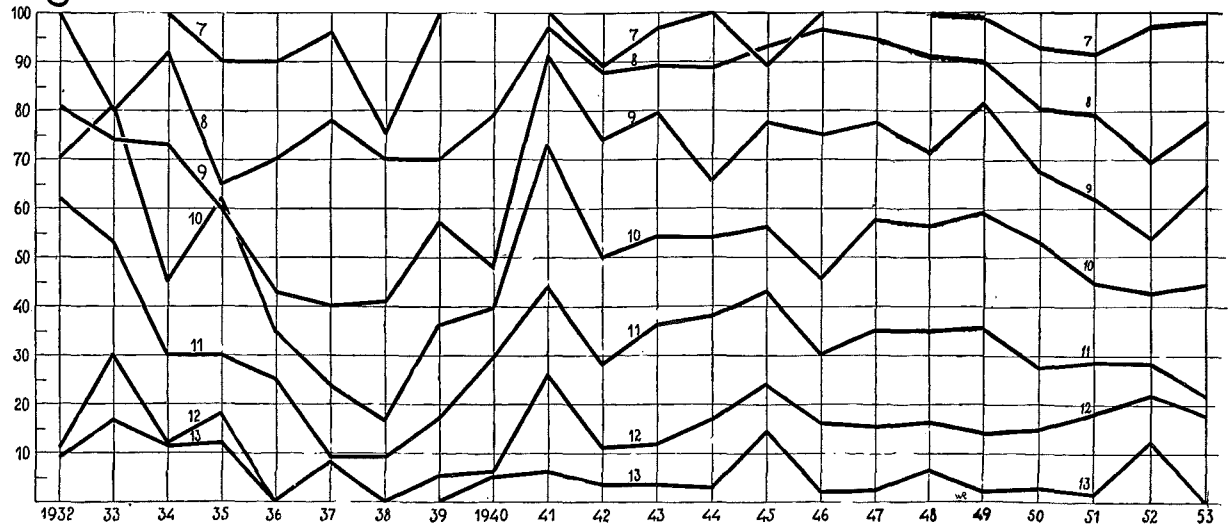


Fig. 9.

Skrei Lofoten

% ♀ Percentage of Recruit-Spawners in the Various Age-Groups

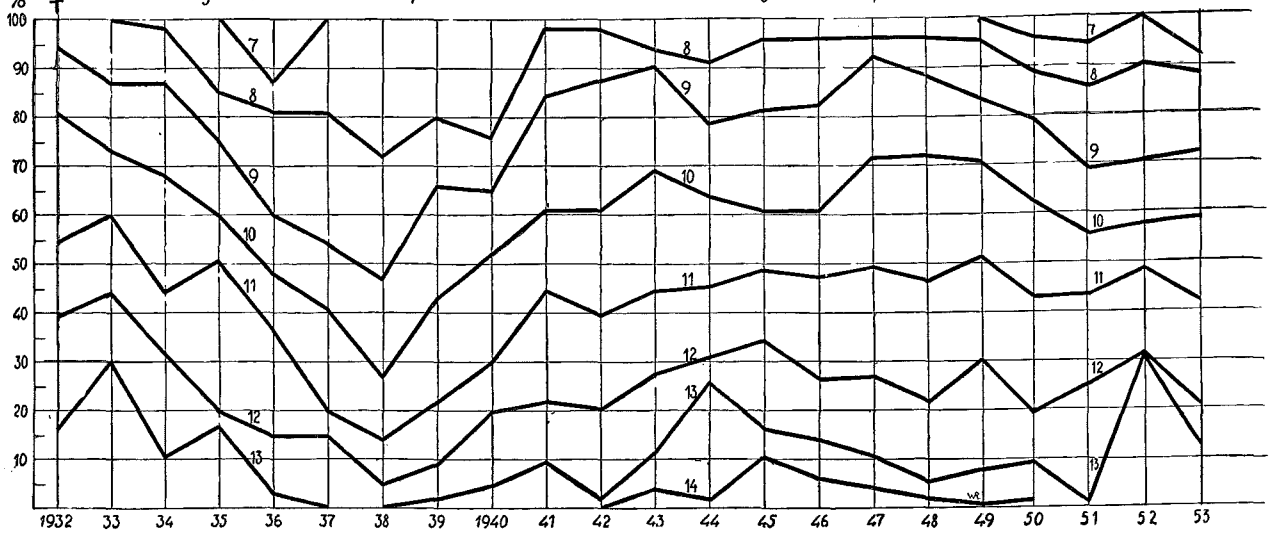


Fig. 10.