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The Cod Population of the Oslofjord.

by

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I. The Oslofjord.

The Oslofjord runs in a northerly direction from Ferder in the south towards Oslo (Fig. 1).

The fjord is - by nature - divided into two parts, the outer fjord - south of Drøbak, and the inner fjord - north of the same locality. The two parts are divided by a ridge at Drøbak. The sill depth is about 27 metres. North of this sill depths of 150 metres have been observed in the Vestfjord as well as in the Bonnefjord. Another sill is located at Nesodden.

South of Drøbak the fjord is deep and the circulation of the water good. North of Drøbak, however, the deeper water layers are often insufficiently aerated, owing to the presence of the two sills mentioned.

In the Bonnefjord, hydrogen sulphide may accumulate in the bottom layers. This was the case in the autumn 1950 when H_2S was observed from 75 metres down to the bottom (Beyer & Føyn 1951).

The most pronounced variations in temperature are found in the outer fjord.

In the inner fjord a strong pollution takes place. The effect of this will be discussed later.

II. Earlier Investigations.

The first detailed investigation of the cod in this fjord was carried out during the years 1936 - 38 by Professor, Dr. Johan T. Ruud at the Biological Laboratory, University of Oslo (Ruud 1939).

His investigations, as well as mine for the years 1939-51, are based on trap-caught cod, and were accomplished in order to form a necessary basis for a judgement of the effect of releasing cod fry in the fjord.

In addition some results obtained at this laboratory will also be considered. Samples of eggs and fry have been collected during the spawning period, and experimental fishing with a fine-meshed seine has taken place in the autumn. This is of great importance for the early detection of rich and poor year-classes.

Results of countings of vertebrae (Dannevig 1947) and measurements of scelerites (Dannevig 1949) will also be dealt with.

III. Material and Methods.

My own material cover 3,300 fish, collected from the inner Oslofjord during the years 1939-51. The samples have been received in spring and autumn, except for 1943, 1945, 1947 and 1950, for which years spring samples are lacking. Each sample contains about 100 fish.

Age determinations have been carried out by means of otoliths. As to these, we find that otoliths from cod caught in the inner fjord are characterized by many secondary zones, while otoliths from the outer fjord are clear with distinct transparent and opaque zones. This kind of otoliths is also found in the inner fjord. In order to ascertain whether my results were comparable to those of Ruud, his material has been reexamined. The conformity was very good, and my results thus comparable to his for the years 1936-38.

The zones in scales and otoliths are formed simultaneously. Transparent zones in otoliths and small sclerites in scales are laid down from July till October-November. During the rest of the year opaque zones and broad sclerites are conspicuous.

IV. Results of the Investigations.

a) Spawning etc. The spawning period of the cod lasts for several months, from January till May-June.

As to the distribution of the different stages of eggs, we find that inside Drøbak the eggs are exposed to a very high mortality. In the outer fjord the conditions are normal. Few eggs in advanced stages are found in the inner fjord. It is likely that some factors prevent a normal development of the eggs. As possible explanations may be suggested large quantities of planktonic animals, sprat, the effect of currents etc. More important perhaps, are the large concentrations of bacteria. Fig. 2 gives the number of bacteria for two cruises in the Oslofjord, respectively autumn 1952 and spring 1953. As will be seen, the majority of the bacteria are located in the upper 30-40 metres, i.e. in the same layers where the eggs are found. Apart from large concentrations at Tofteholmen in autumn 1952 - evidently due to the dumping of sewage from Oslo at that time - the concentration of bacteria is greater in the inner than in the outer fjord. It has earlier been considered at this laboratory that the population from the common sewers could be harmful for the development of eggs (Dannevig 1945, Løversen 1946).

The fishing experiments in the autumn show that the number of cod, whiting and pollack of the 0-group is considerably higher in the outer than in the inner fjord (Fig.3.)

The cod and the pollack run parallel, the same year-classes - viz., 1938 and 1945 - being prominent in both parts of the fjord. The whiting does not exhibit the same fluctuations in the strength of year-classes. Already at an age of half a year the number of cod per haul illustrates the different strength of the year-classes. As to the 1938 year-class this was also established in spring in the pelagic stage.

Hydrographical observations in the fjord 1946-1950, carried out from the Biological Laboratory, University of Oslo (Beyer & Føyn, 1951) - seem to indicate a correlation between the degree of aeration of the water masses and the strength of the year-classes of cod.

We do not know to what extent an immigration of small cod from waters south of Drøbak is taking place. Results of vertebrae countings and tagging experiments - supported by the special type of otoliths in the inner fjord - indicate, however, that the cod population of the inner fjord is mainly dependent upon the propagation in the same localities.

From 1892 till 1930 cod fry were released with short time intervals, except for the years 1905-1920 (Fig. 7), and many biologists considered this to be the reason for the good output of the fishery up to 1930. With our present knowledge to the statistics it is difficult to say anything definite about this point, although a certain correspondence seems to exist between number of fry released and the output of the fishery the subsequent 2-3 years. It is difficult to conclude anything as to the effect of the release in 1938-and 1949. About 120 millions of fry were released each year. The extraordinary rich natural spawning 1938 in the Oslofjord as in all other districts in the south-eastern parts of Norway, makes a calculation of the effect of the released fry impossible for this year. - Nor could we say anything as to the effect of the release in 1949. The apparent dominance of this year-class is not due to its abundance, but is more likely a consequence of the failure of the following one. The good output of the fishery in 1950 is to a large extent based upon the year-class 1948, and the low yield in 1951 (Fig. 7) also show that the 1949 year-class is not very abundant.

b) Characteristics of the Cod Population. Ruud (1939) distinguishes between two different types of otoliths - one with clear transparent and opaque zones, the other with more diffuse and many secondary zones. The first type is characteristic of other fjords in Southern Norway, the other type with secondary zones is peculiar to cod from the inner Oslofjord. According to Ruud fish with the latter type of otoliths have a lower number of vertebrae than fish with "normal" otoliths. Dannevig (1947) determined the average number of vertebrae for the 1938 year-class in the inner fjord, the outer fjord and the Skagerak, and found respectively 51,95 - 52,00 and 52,05 vertebrae. The figure for the inner Oslofjord is in good accordance with previous results obtained by Ruud.

As to the different parts of the fjord an increase in the number of vertebrae was stated from the inner Oslofjord outwards to Drøbak; from here on the number once more decreased.

Dannevig (1949) has examined scales of cod from different localities. In contrast to cod at Flødevigen and at Holmestrand (outer Oslofjord), scales of cod from the inner Oslofjord showed no distinct maxima and minima and they occurred with no regularity. Cod scales - like the otoliths - from the inner Oslofjord are characterized by the lack of well defined zones.

c) Migrations. It is evident that the cod in the inner fjord is peculiar to the locality. This idea is supported by the tagging experiments. Tagging of cod has been carried out by Ruud 1936-38 in the inner and outer fjord. The majority of the fish were recaptured in the vicinity of the marking place, and were not inclined to migrate in definite directions. Especially the cod from the inner fjord seemed to be very stationary. Only few individuals migrated from the inner to the outer fjord, or vice versa.

Earlier planned tagging experiments of small cod in order to ascertain whether any migration of small cod of the 0-group is taking place have not yet been carried out. The low number of vertebrae and the special type of otoliths, however, seems to deny an immigration of small codlings from the outer to the inner fjord.

d) Age Determinations. Fig. 4 illustrates the ate distribution in the autumn samples 1939-51. It will be seen that fish more than 4 years old are scarce, only 1,5% being older. Therefore it is difficult to get an idea of the strength of the year-classes by age determination. A comparison with the age distribution in the spring samples demonstrates, however, that the year-classes 1938 and 1945 - partially 1939 - are the most prominent, and those of 1940, 1941, 1946 and 1947 the most poor. The other year-classes are intermediate (hatched columns). As previously mentioned, the two rich year-classes brought themselves into notice at an age of half a year, the 1938 year-class in the pelagic stage already.

The figure shows the 1945 year-class to be dominant for a longer period than the year-class 1938. This is a consequence of the fact that the 1939 year-class is considerably richer than those two following the 1945 year-class, which for this reason will dominate for quite a long time in the samples.

Table I. Annual mortality rate (%). Autumn samples 1939-51.

Age-group	Number	Mortality rate (%)
I	815	45,4
II	445	74,4
III	114	81,6
IV	21	76,2
V	5	

Total annual mortality from one age-group to the next has been calculated. As will be seen from Table 1, the mortality rate is very high, about 80% for the grown-up cod. The low mortality from group I to group II is a consequence of the size limit of 25cm. (from 1947 30cm.), which permits the major part of the 1 1/2 year old fish to escape. According to tagging experiments the mortality due to fishing is estimated at 50-60% (Ruud 1939).

Age at maturity is shown in Fig. 5. At an age of 2 years 35% of the males and 29% of the females have ripe or ripening sex products. The corresponding figures for 3 year old fish are 80 and 69%. Among the older fish the few unripe individuals all belong to the 1945 year-class, which - as mentioned below - is characterized by slow growth. It is therefore reasonable to assume that normally all fish more than 3 years old have attained maturity.

Males mature at a lower age than the females. The length at maturity is also less for the males, which constitute the major part of the smaller fish with ripening sex products.

e) Growth. Fig. 6 illustrates the average length of cod of different ages, based upon the investigations of Ruud 1936-38 and my own values for the later years. The difference amounts to 2-4 cm. for each age-group. This is due to the exceptional slow growth of the 1945 year-class. Excluding this from the material I get values for the lengths close to those given by Ruud. The rich year-class 1938 does not show a similar retarded growth.

Average lengths of 1, 2, 3 and 4 year old fish are 20, 33, 41 and 49 cm.respectively.

The males have a slower growth than the females. The difference, which is most pronounced after maturity, is about 2 - 4cm. for each agegroup.

The largest length increment is taking place from spring till autumn. As has been shown for cod from the Skagerack Coast (Dannevig 1933), it is difficult to find any correspondence between width of the sclerites and growth of the fish. We regularly find narrow sclerites at the margin when the growth is at its best, and vice versa.

V. Comparison with other Waters.

It has been shown that the cod in the inner Oslofjord is very stationary. The growth of the cod is about the same as in other insulated fjords in Southern Norway, e.g. the Søndeledfjord. In the Skagerack and the open Topdalsfjord the growth is much better. The same is the case for cod from the Northern Kattegat. In the southern part of the Kattegat and the Baltic the growth is not so rapid.

The difference in growth between females and males has been observed among the spawners at this hatchery too, where females are about 3cm. longer than males of the same age (Sivertsen 1935).

Compared to other investigated Norwegian waters, the cod population of the inner fjord is subject to a heavy reduction, the value of the total annual mortality being about 80%. In the Søndeledfjord and the Topdalsfjord the annual mortality rate averages 60%, and a mortality of the same rate has been found among the spawners at this hatchery.

Maturity is attained at a very low age, about 30% of the fish having ripe or ripening sex products at an age of 2 years. On the Skagerack Coast the youngest ripe fish are 3 years old, and at an age of 4 - 5 years the larger part of the fish have attained maturity.

VI. Statistics.

Fig. 7 illustrates the supply of cod from the inner Oslofjord to the fish market during the years 1872-1951. Up to 1927 the yield was given in number of fish per year (2-3 small fish=1 "telletorsk"), for the subsequent years the weight is given.

The statistics have been improved for the later years, but are nor reliable. This is especially the case for the war years 1940-45, when more fish than usual were sold directly from fisherman to consumer. It is obvious, however, that the rich yearclasses have a bearing effect upon the yield. The peak of the curve in 1947 indicates the influence of the yearclass 1945, while the peak ir 1950 is due to two intermediate yearclasses - viz. 1948 and 1949, especially the former.

From 1929 the yield decreases rapidly. For two years only, 1947 and 1950, the annual yield is more than 40 Norwegian tons. Compared to the total annual yield of the Norwegian fjord-cod fishery, varying between 14.000 and 28.000 tons for the years 1938-51, the fishery in the inner Oslofjord is of no importance.

The unreliability of the statistics makes a calculation of the yield caused by the various yearclasses impossible.

VII. Concluding Remarks.

What can be done to secure a better yield of the fishery? First of all, a higher size limit should be introduced. A size limit of 35cm. would save the major part of the 1 1/2 and 2 years old fish, while now about 60% of the fish caught are of this age. A higher size limit will result in a higher stock of spawning cod. A higher yield would be achieved too, owing to the rapid increase in weight of the

small cod and the low value of the natural mortality. I mentioned that a higher size limit would increase the number of spawning cod. How this will affect the number of fry is uncertain on account of the bad conditions for development of the eggs and the heavy pollution of the inner fjord in spring. Sewage from Oslo is then dumped at Steilene and the growth of bacteria thus stimulated.

It is reasonable to assume that the large quantities of bacteria will affect the survival of fish eggs and larvae, but further experiments are needed to ascertain at what stage in development the fish are most subject to attacks by bacteria. If in the egg stage, a release of fry could be expedient in years when a sufficient aeration of the water has taken place. If fry are attacked too, the only way to improve the fishery is to reduce the content of bacteria. The solution of this problem is no easy task, but is certainly of great importance for the future fisheries in the inner fjord. First of all a control with the dumping of sewage in the fjord is desired.

Release of fry should be carried out in years only when the water is sufficiently aerated, and with shorter time intervals than has been the case for later years. Hydrographical observations for the years when fry have been released - as well as for the intervening years - together with collections of eggs and larvae, should give a fairly good material for investigations on the effect of releasing fry.

VIII. Summary.

The hydrographical conditions of the fjord are mentioned. Owing to the sills at Drøbak and Nesodden the water masses of the inner fjord are often insufficiently aerated.

In addition to my own material for the years 1939-51, consisting of spring and autumn samples, results from investigations carried out by Ruud 1936-38 and by different investigators at this laboratory are taken into consideration.

The distribution of the egg stages is quite different in the inner and outer fjord. In the inner fjord - north of Drøbak - few eggs in advanced stages are found. South of Drøbak the occurrence of the different egg stages is almost normal. The bad conditions for a successful development of the eggs in the inner fjord are ascribed to the high content of bacteria, especially in this part of the fjord in spring.

The strength of the yearclasses varies. The richer ones are those from 1938 and 1945, which were established at an age of half a year only, the former in the pelagic stage already.

The cod in the inner Oslofjord is characterized by a low number of vertebrae, a special type of otoliths and a very stationary habit.

Annual mortality averages 80%, a value considerably higher than in other fjords in Southern Norway. More than 60% of the fish is caught at an age of 1 1/2 and 2 years. This is a consequence of the low size limit - 30cm. from 1947.

The youngest fish with ripe sex products are 2 years old. Males attain maturity at a lower age and at a smaller size than the females.

Average lengths of the fish at an age of 1, 2, 3 and 4 years are 20, 33, 41 and 49cm. respectively, females being 2-4cm. longer than males of the same age. The growth is of the same rate as in other insulated fjords in Southern Norway, but slower than in open fjords and on the Skagerack Coast.

The yield of fishery has decreased alarmingly during the last 25 years. To obtain a higher yield the following possibilities have been discussed:

1. Raise of the size limit to 35cm.
2. Control with dumping of sewage in the fjord.
3. Release of fry.

IX. Literature.

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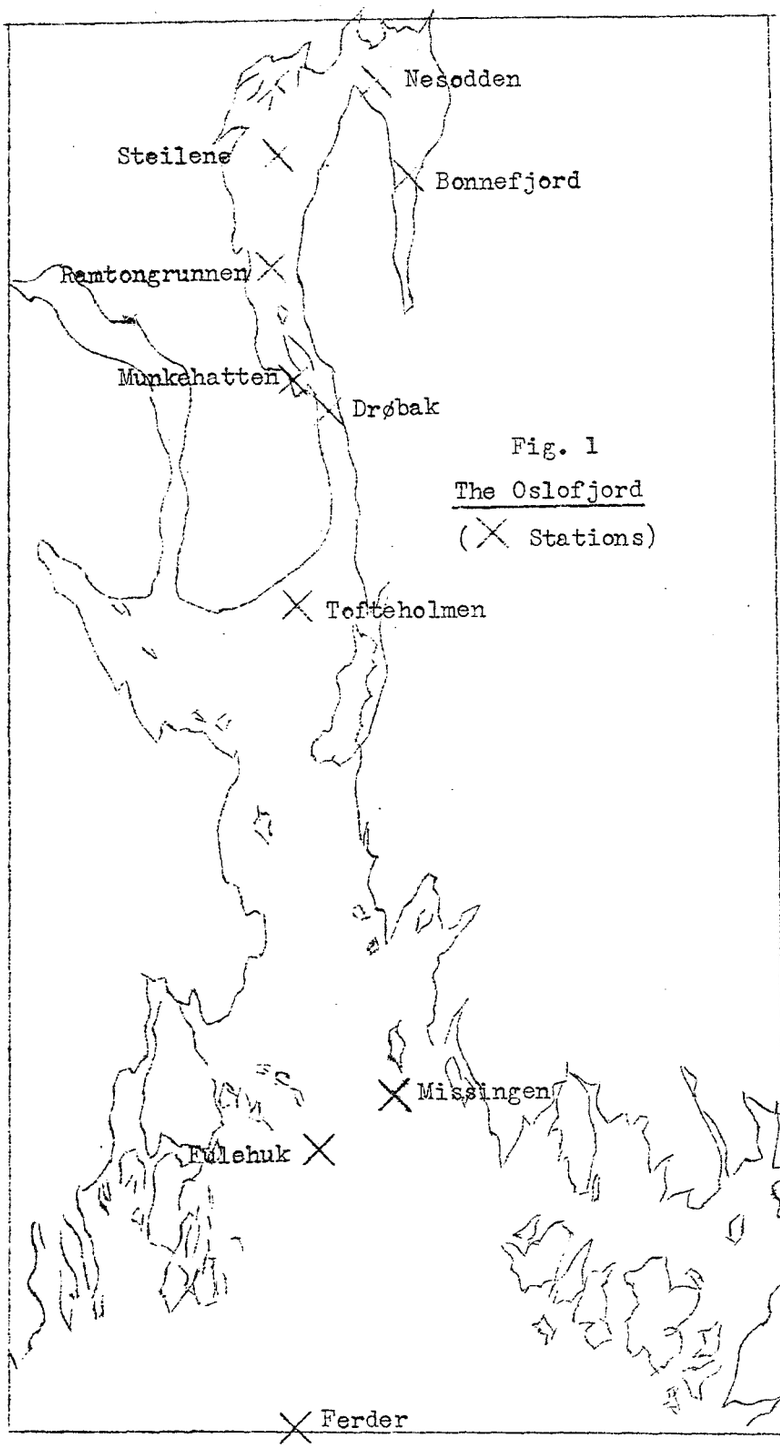
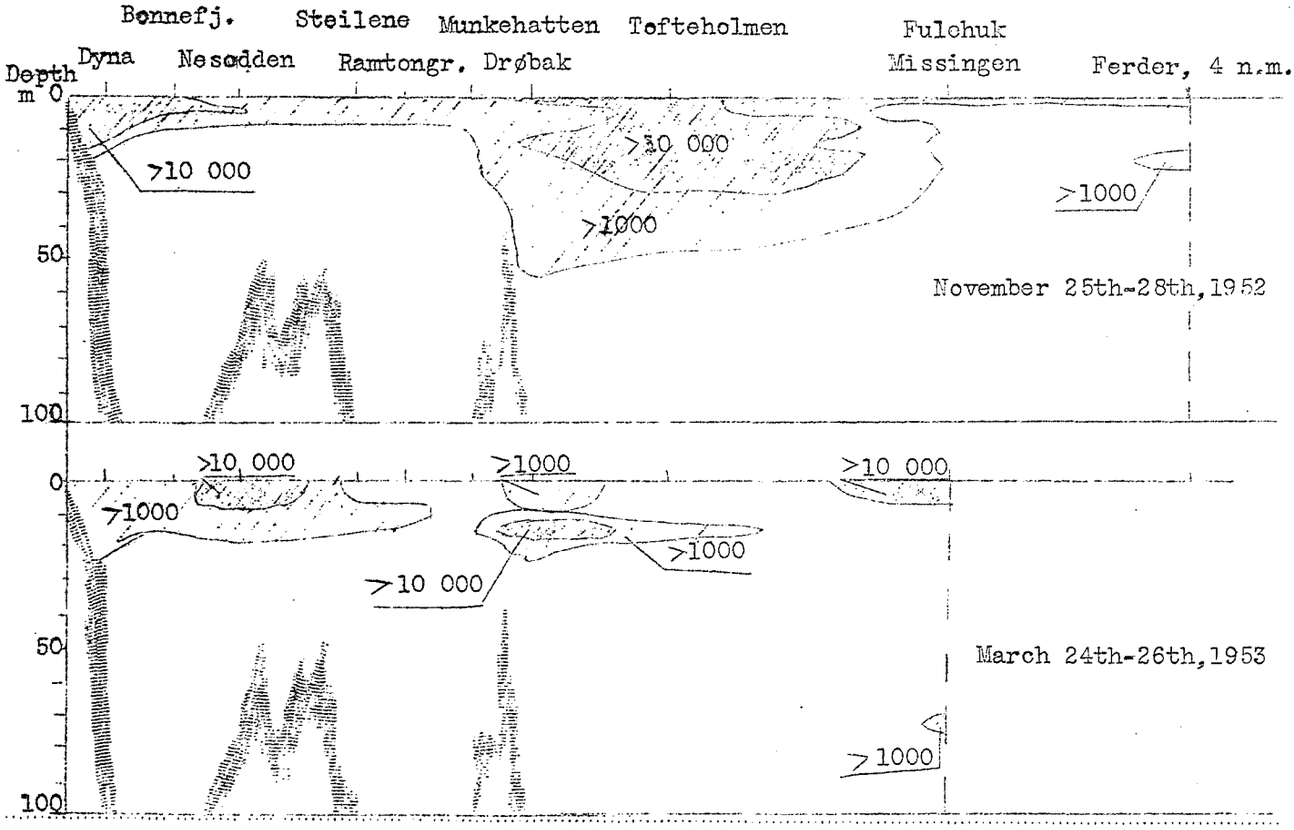


Fig. 1

The Oslofjord

(× Stations)

Fig. 2. THE OSLOFJORD, Bacteria, number/ml.



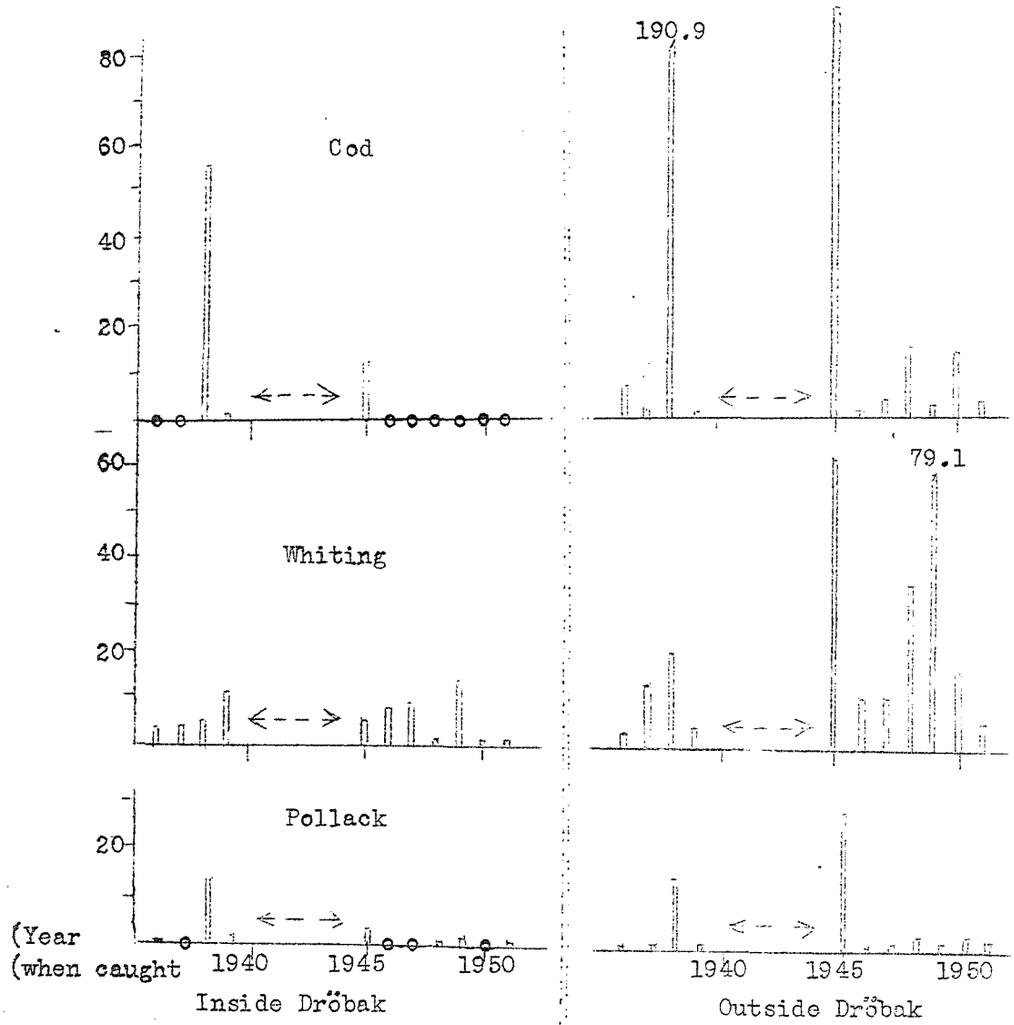


Fig. 3
THE OSLOFJORD,
Number of
yearlings
per haul

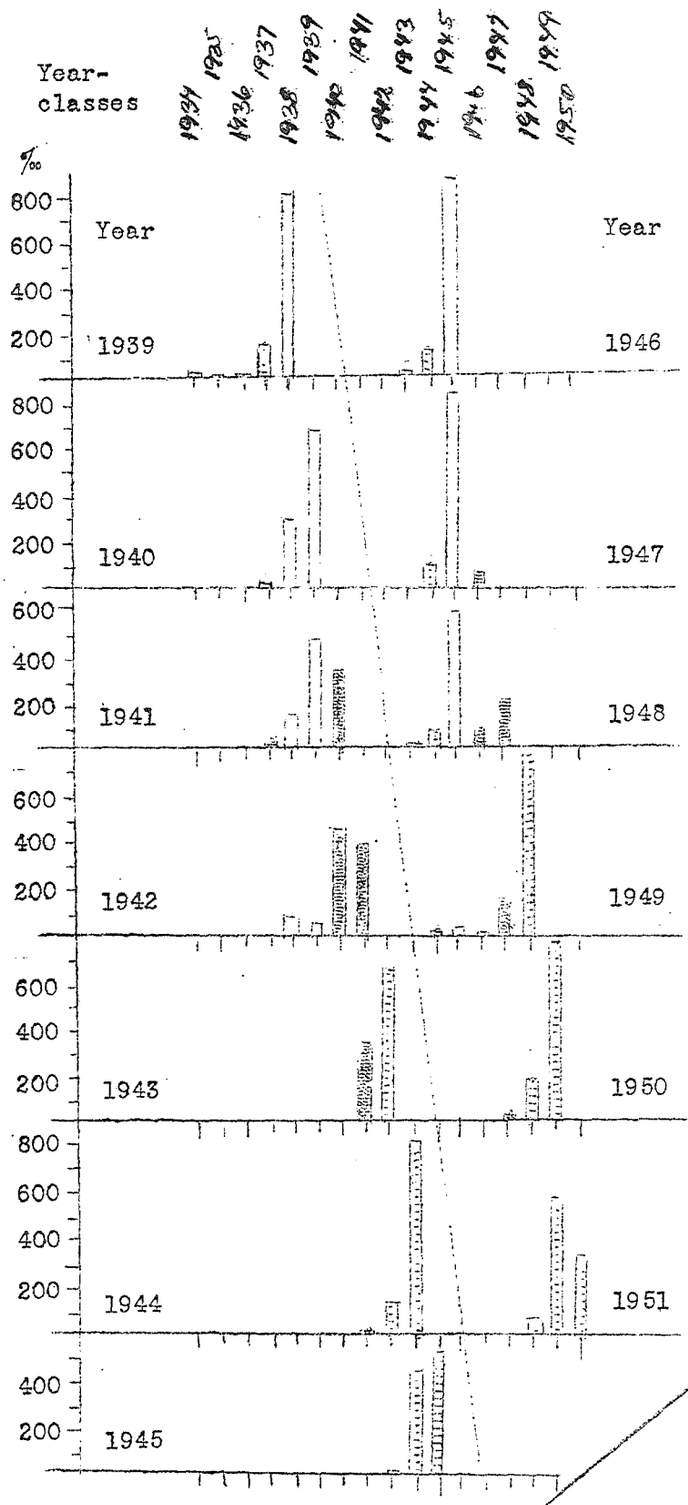


Fig. 4

Autumn samples 1939-1951.

Occurrence of Yearclasses.

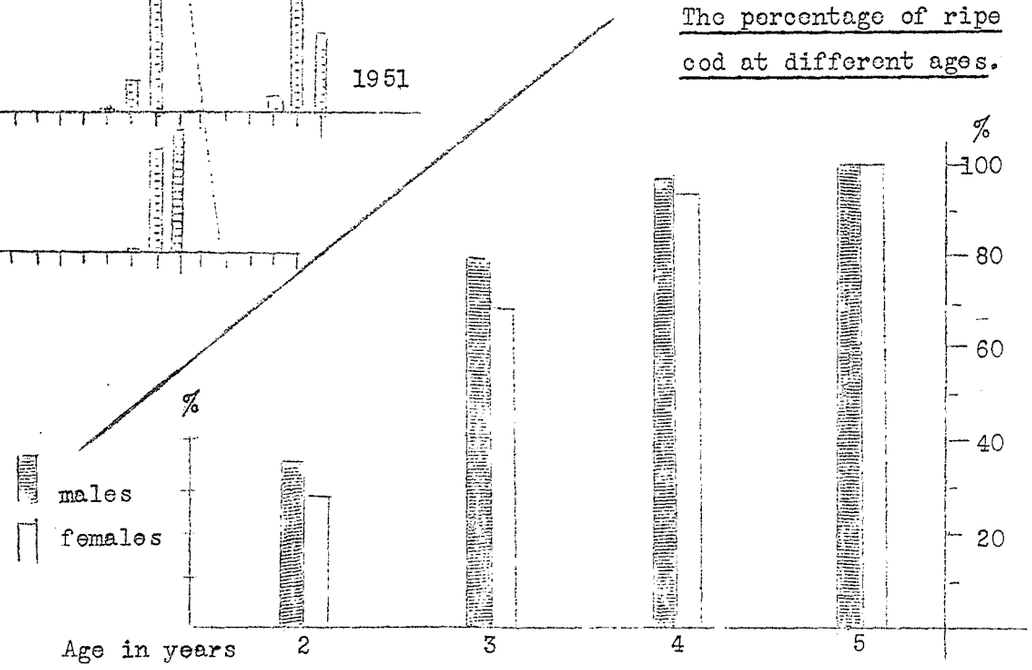


Fig. 5

The percentage of ripe cod at different ages.

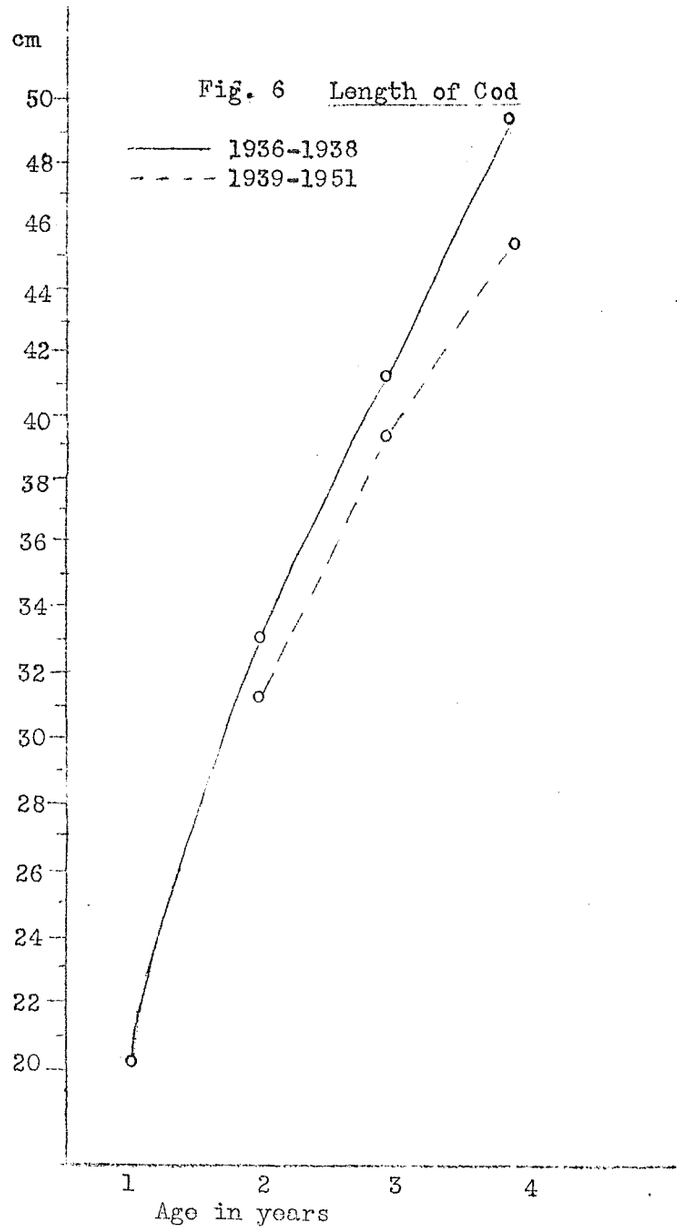


Fig. 6 Length of Cod

Fig.7 The Oslofjord inside Dröbak