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# The Propagation of the Common Food Fishes on the Norwegian Skager Rack Coast

## With Notes on the Hydrography

By

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The Flødevig Seafish Hatchery

The investigations
have been carried out with financial assistance from
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1940

A.s John Griegs Boktrykkeri, Bergen

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The detailed tables for hydrography, eggs and larvae will be deposited at Universitetsbiblioteket, Oslo, Fiskeridirektøren, Bergen, and the Flødevig Seafish Hatchery, Arendal.

# I. Preface.

The Flødevig Seafish Hatchery is situated on the Skager Rack coast of Norway in the vicinity of Arendal. The work which it undertakes comprises cod hatching, lobster rearing and oyster culture. In conjunction with this biological and hydrographical investigations are carried out in the neighbouring waters.

In this paper a resumé is given of the results of our investigations into hydrographic conditions on the Skager Rack Coast and the occurrence of fish eggs and larvae. In another paper similar problems in relation to the Oslo Fjord will be dealt with.

The sea investigations are regularly carried out by means of our motor cutter »Ossian Sars« under the leadership of Mr. R. LØVERSEN, technical assistant at the laboratory.

The material collected has been dealt with under my supervision at the laboratory attached to the hatchery by Messrs. E. SIVERTSEN mag. scient., G. DANNEVIG cand. mag., and N. BRUSLI stud. real., members of the scientific staff.

The necessary funds for the investigations at sea have been provided by Fiskeribedriftens Forskningsfond.

*Alf Dannevig.*

Flødevig Seafish Hatchery, July 1939.

# II. Earlier Investigations on the Skager Rack Coast.

Off the south coast of Norway a very intensive fishing industry is maintained both in the small fjords and inside the skerries as well as on the narrow coastal bank outside. During the winter ice may hinder fishing in the fjords, while outside the skerries operations may be checked by stormy weather. But, as moderate weather conditions generally prevail, fishing takes place in one locality or another on practically every working day all the year round. The types of fish of the greatest economic importance are cod, mackerel, herring, haddock, pollack and certain other gadidae and eel.

The population of this part of Norway is comparatively numerous and as the fish is brought direct to the consumer from the fishermen it commands a high price.

The question arises as to how the population of our common fishes can be maintained under these conditions. Since 1830 the local authorities have furnished the government with official reports on economic conditions in their districts, and even among the early reports reference is made to a decline in the fisheries on the south coast of Norway. Since 1876 official statistics have been compiled which indicate the variations in the important fisheries. Values are lacking, however, in respect of local fisheries.

The statistics show that the winter herring fisheries on the south coast yielded high values in respect of periods from about 1880 to 1895. Ten years later there was another good herring period, but after a few years the yield once more declined.

The mackerel fishery has increased mainly owing to the high development of the motor boat. The old mackerel fishery by means of land seines has, however, shown a definite drop during the same period.

The statistics furnish very little information concerning the fluctuations in the local fisheries of the more stationary types of fish. In the experience of the Norwegian fishermen the trend is in the direction of

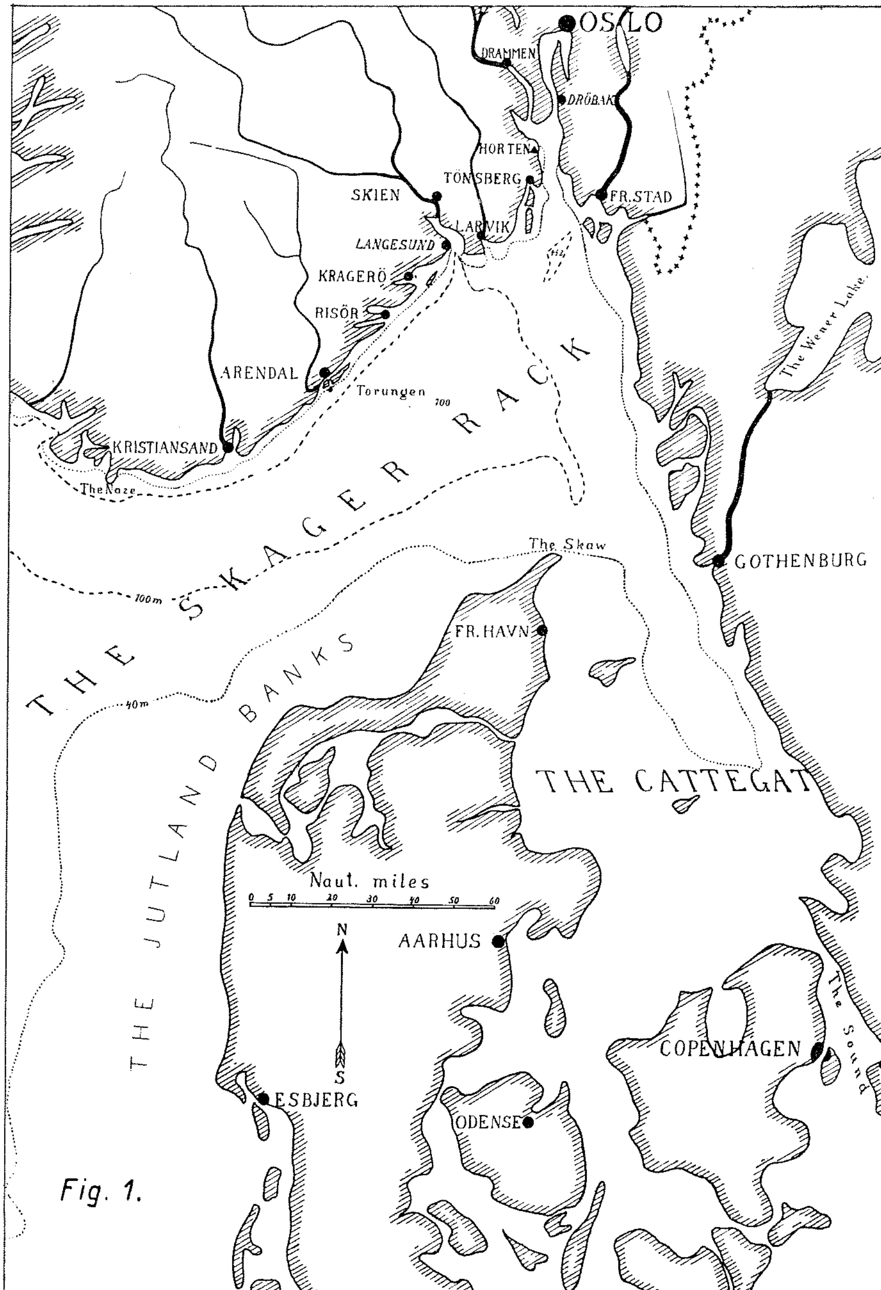

OSLO
DRAMMEN
DRÖBAK
HORTEN
TÖNSBERG
FR. STAD
SKIEN
LARVIK
LANGESUND
KRAGERÖ
RISÖR
ARENDAL
Torungen
100
KRISTIANSAND
The Noze
THE SKAGER RACK
100m
The Skaw
GOTHENBURG
The Wener Lake
FR. HAVN
40m
THE JUTLAND BANKS
THE CATTEGAT
Naut. miles
0 5 10 20 30 40 50 60
N
S
AARHUS
COPENHAGEN
The Sound
ESBJERG
ODENSE

Fig. 1.

decreasing catches from year to year. It is impossible, however, to confirm this by means of figures. In order to acquire information in regard to this a certain amount of experimental fishing has been undertaken from this station with ordinary fishing traps since 1921. Fig. 2 illustrates the result of the fishing per fishing gear per year. It is obvious that the cod caught per year is diminishing in all localities, particularly the fjords. In the case of coal fish and pollack there are great fluctuations but no signs of regularly declining values. This is quite reasonable. Tagging experiments have shown that the cod in the small fjords is a stationary form which is liable to be over-fished, whereas the coal fish and the pollack are in a high degree nomadic.

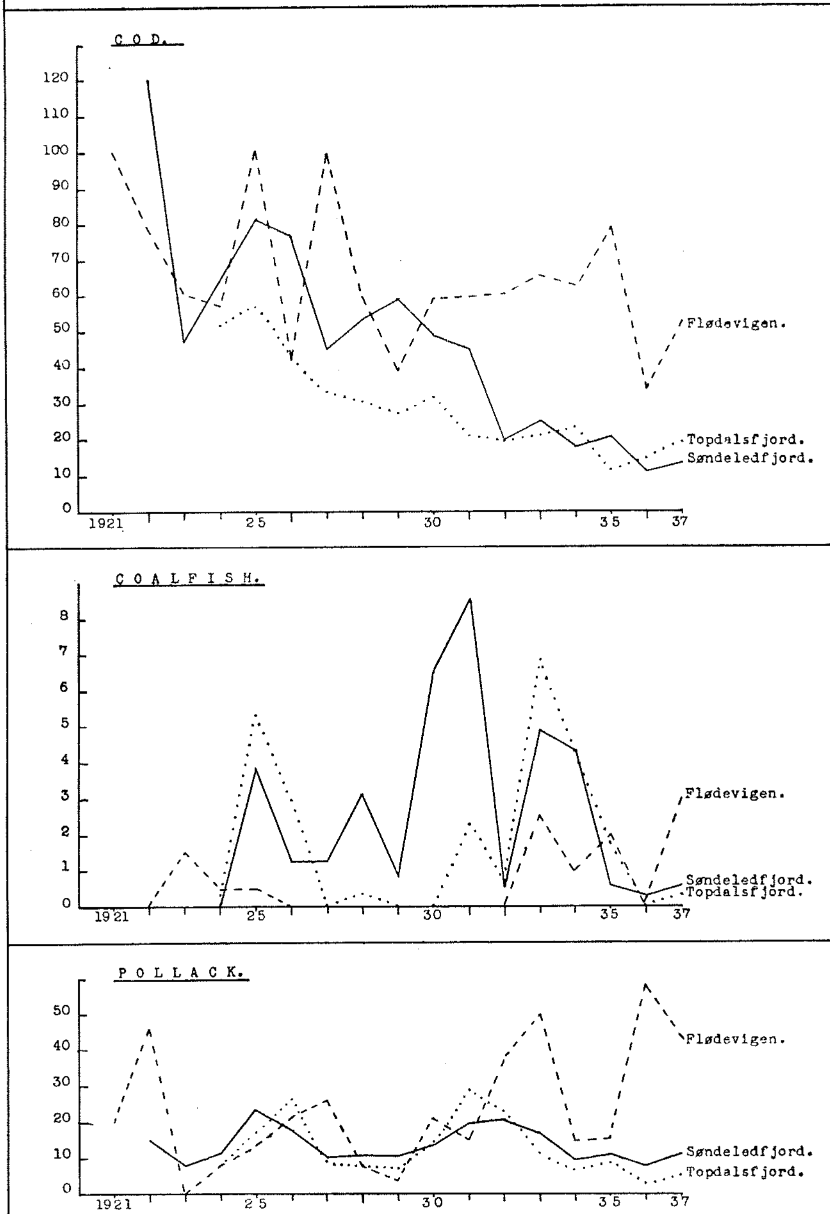
As, however, the fishing has increased in intensity the smaller catches of the individual fisherman or gear may be due to more fisherman or gear fishing the same population. It is not safe, therefore, to rely on the figures giving the fluctuations in the catches per year to illustrate the variation in the population.

Since 1903 some experimental fishing has been carried on with a small seine for young fish before the commencement of commercial fishing. During the years 1917—1938 the seine has been used in the same localities and as nearly as possible in the same month of every year. As will be seen from fig. 3 the catches vary greatly from year to year. Coal fish occur in small numbers during the whole of the period. The fluctuations in the catches of whiting are great, but there is nothing to indicate that the stock is on the decline. This may also be said of the pollack, although the mean for the latter half of the period is lower than that for the first half. The variations in this species are so great that a bigger material must be collected. In the case of the cod it will be observed that the good years become increasingly scarce and the poor years more frequent during the latter part of the period. As these figures represent the stock before fishing has actually commenced we must necessarily assume that it is the stock itself which is on the decline. The fairly good results of the experimental fishing in 1938 indicate, however, that the stock is sufficiently large to yield a fair number of young fish *in good brood years*. As will be described in another paper natural conditions this spring were extremely favourable for both the spawning of the cod, the hatching of the eggs, and the development of the young fish.

The experimental fishing has been carried on in the littoral regions only. It is reasonable to assume, however, that the fluctuations in the littoral fish population will accord with the variation of the entire population of the same year-class in the same district. Experimental trawling for the 0 group of cod (i. e. the brood of the year) in the deeper

FIG. 2. EXPERIMENTAL FISHING.

Number of fish per trap per year 1921 - 1937 .



waters of the Skager Rack coast has produced very poor results. We may therefore assume that the figures representing the annual catches of the 0 groups of Norwegian commercial fish are more useful for studying the fluctuation in the population than are the actual catches of the adult fish.

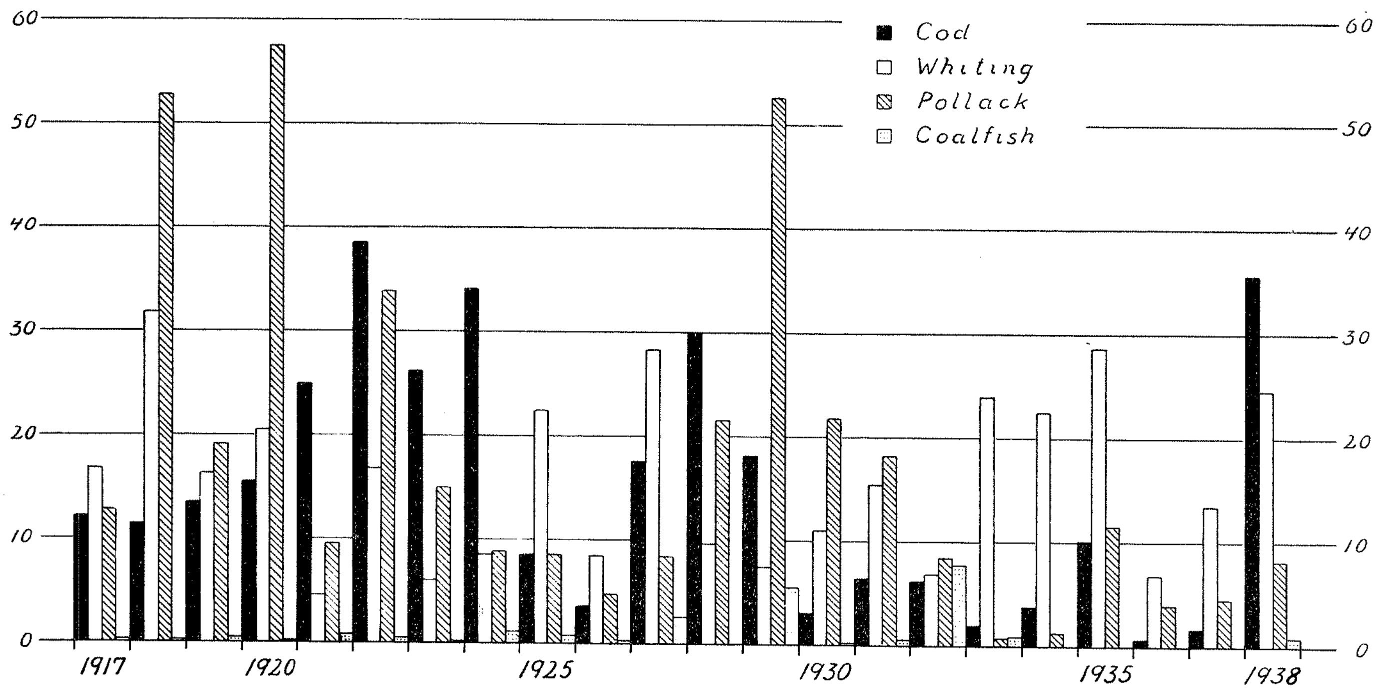
From a study of the values revealed in the statistics and the results of the experimental fishing, and with due regard to the experience of the fishermen themselves, it is evident that, on the Skager Rack coast of Norway, great fluctuations have taken place in the catches of the pelagic fish, the herring and mackerel. The catches of local cod have apparently declined and this is most certainly the case with regard to plaice. The latter is now rare on the coast and is of no significance at all for the fishery on this part of the Norwegian coast.

At an early date the variation in the fisheries was thought to be due to the effect of migration. Migration is certainly an important factor in connection with migratory fish, but an explanation of its cause is necessary. During the present century hydrographic and marine biological investigations have revealed that the different species of fish have their special optimum temperature and salinities, particularly during the spawning season. The fluctuation in the quantity of fish may therefore be explained by the variation in the physical conditions of the sea water off the different parts of the Norwegian coast.

In the final decade of last century P. T. CLEVE, G. EKMAN, JOHAN HJORT and OTTO PETTERSSON (1) studied hydrographic conditions during the great herring fisheries carried on in the years in question in the inner part of the Skager Rack. They discovered that the occurrence of the herring was intimately associated with the occurrence of the »bank« water, which has a salinity of 32 $^0/_{00}$ — 33 $^0/_{00}$ and a winter temperature which is relatively high, namely, about 4° C. This relation between the occurrence of the spawning herring and the physical character of the seawater in the Skager Rack has been fully confirmed by the investigation carried out from Flødevigen. The spawning herring do not occur if the relatively fresh and cold Baltic water is dominant along the coast. On the other hand, however, it is unlikely that the herring is restricted to the »bank« water; it also occurs in water of a higher salinity.

In 1923 A. C. JOHANSEN (2) recorded a great quantity of eggs and larvae of haddock in the Belts where this species does not normally occur. The young haddock grew large in these waters and in 1926 500 tons of full-grown fish were caught in this locality. The great quantity of haddock eggs and larvae occurred simultaneously with an extraordinary influx of salt Skager Rack water. The question of whether, in this case, the eggs and larvae were carried into the Belts

Fig. 3. The Occurrence of the 0-group Fishes in the Littoral Region.
The Catches per Haul with the Seine.



by the current, or whether the spawning of the haddock had taken place there in the salt water, was not resolved by the investigation.

In 1924 (DANNEVIG 3) the water in the Skager Rack was too cold for the spawning of the haddock. As, in that year, the Danish catch of haddock in the Skager Rack amounted to only $^1/_{10}$th of those of preceding years it is to be presumed that the full-grown haddock was to a great extent expelled from the Skager Rack by the cold water.

In 1932 ERIK M. POULSEN (4) recorded an unusual quantity of coalfish larvae in the Cattegat. At that time it was probable that the rare occurrence of coalfish larvae was due to the transport of eggs and larvae by the inflowing undercurrent.

It is thus evident that the theory of the fishermen that the fluctuations are due, in a great degree, to migration, active or passive, is correct; in any event as far as the more or less pelagic fish are concerned.

At the beginning of the present century the effect of the current and the migration of the fish also occupied a great part in the discussion on the more stationary fish.

In a book published in 1899 entitled »Fishing Experiments in Norwegian Fiords« (5) JOHAN HJORT and KNUT DAHL suggested that the population, e. g., of cod, in the southern fjords belonged to the open sea, in any event for a great part of its existence. This assumed non-local character of the fish population in the skerries naturally rendered local measures to preserve the population by means of restrictions as to size, limitation of fishing and the like, of doubtful value. This also applied to attempts to supplement the population by artificial hatching. It will therefore easily be understood that the assumed international character of the fish in the fjords and skerries was a problem of prime importance in the discussion of the most suitable means of preserving the fisheries in the fjords, particularly the cod fisheries.

The theory that the cod in the Norwegian fjords formed a part of the population of the Skager Rack and the North Sea was based by HJORT & DAHL on the following suppositions that:

1. The pelagic eggs and larvae from local spawning were carried out to sea by the surface current.

2. The young fish migrated in the autumn from the ocean into the fjords.

My father, G. M. DANNEVIG, late director of the Flødevig Seafish Hatchery, was of opinion, however, that the pelagic eggs and larvae of our common fish were too heavy to be carried away by the fresh surface current, and that the young fish of the 0 groups lived in, or near, the littoral region all the year round.

The combined fishing experiments of DAHL and G. M. DANNEVIG from 1903—1905 (6) proved that the theory of the total outward drift of the young larvae was not in accordance with conditions in the fjords. The young cod occurred there in good numbers throughout the whole of the year, and in 1904—1905 DAHL (7) proved by renewed pelagic fishing that the majority of the cod larvae was found 10—20 m below the surface in the fjords. He now advanced the idea of great transplantations of eggs and young by the currents in the intermediate layers.

The hydrographic measurements taken by DAHL reveal that great exchanges of water may take place between the fjord and the ocean. In DAHLS paper »The Problem of Sea Fish Hatching« (7) fig. 10, indicates that the water masses with a lower specific gravity than 1.021 have been carried out of the fjords in the last days of April. The results of the fishing with the egg net indicate, however, that the number of cod larvae per haul is greatest in the deeper layers which have evidently not taken part in the seaward transport.

When I was appointed director of the Flødevig Sea Fish Hatchery in 1911 I was most anxious to examine the occurrence of the different year classes of the cod, the amount of spawning and the development of the eggs, and the hydrographic conditions during hatching and maturing of the larvae.

In 1917 the first opportunity presented itself of investigating the occurrence of eggs and larvae in the fjords and neighbouring waters of the Skager Rack coast of Norway. The results are given in »Undersøkelser over den pelagiske egg og yngelbestand på Skagerakkysten våren 1917(8) (with an English Summary).

The localities investigated were in the neighbourhoods of Arendal and Risør. In the vicinity of Arendal a locality approximately one nautical mile off Torungen in the area of the Baltic current was investigated 8 times between March 16. and June 13. For the sake of comparison we also investigated Galtesund, the entrance to the Arendal fjord, almost simultaneously. The distance between the two localities is about 4 nautical miles. Table 35 in the paper in question gives a summary of the fishing experiments. There are great differences between the number of eggs and different species of larvae in the two localities. Some species occur only in one of the two localities and the relative quantity differs greatly. The larvae of the littoral fish are generally found in the skerries.

In the case of Risør the measurements of the oxygen content of the sea water (fig. 4) show that in the fjords the waters immediately below the surface layers were deficient in oxygen thus indicating that they were of a stationary nature. The differences found between the sea and the fjord renders it unlikely that great intermingling processes had occurred during the season.

The investigations were continued in 1924 on a greater scale (DANNEVIG 3). The winter of that year was very severe. On 29. desember 1923 the surface water of the Skager Rack had cooled to below zero. The daily observations at Flødevigen yielded the following average temperatures:

| | *January* | *February* | *March* |
|---|---|---|---|
| At the surface .......... | 0,0° C. | 0.4° C. | 0.0° C. |
| At the 1 metre level .... | 0.3° C. | 1.0° C. | 0.4° C. |

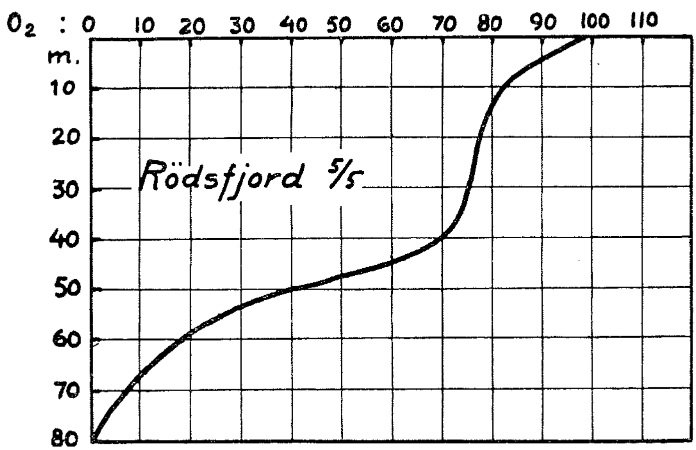



Fig. 4. The percentage of oxygen in the Rödsfjord 5. May 1917.

During the most severe part of the winter dead fish were found along the coast and it is likely that most species retired from the areas covered by the cold current and withdrew to deeper parts where the temperature was higher. In the depth of the Skager Rack temperatures were never found below 4° C. and in the fjords with a barrier at the entrance the bottom layers regularly had a temperature of 5°—6° C.

Fig. 5 shows that in the Frier Fjord in the middle of April the temperature was nearly 6° C. at the 20 metre level and 2.1° C. outside the coast. As the temperatures in the intermediate and deep layers of the fjord are very constant during the winter the temperature differences have been much greater during the winter when the temperature outside the coast was near to zero.

In the Skager Rack it was not only the surface layers which turned colder than usual. This was also the case with the bottom layers. During the late winter the temperature in the deeper layers is usually about

6° C. but in this particular winter it was as low as 4°C. Thus, the haddock, for example, which prefers a water temperature of 6°—7° C when spawning, apparently deserted the Skager Rack in such numbers that its absence was severely felt by the Danish seine fishermen. The Danish Director of Fisheries informed me that the yield of the Danish haddock fisheries in 1924 amounted to only $^1/_{10}$ of that of the two preceding years.

Briefly, the hydrographic measurements revealed great differences between the temperature outside the coast and that in the fjords. The latter were reservoirs of temperate waters at a time when the cold

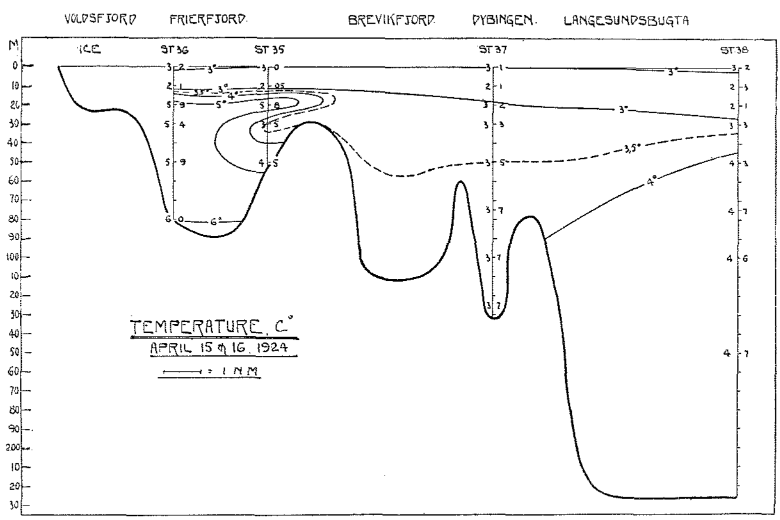



Fig. 5.

Baltic current swept along the coast, and in them the common fish could find suitable temperatures for their spawning processes.

Fishing with the egg net disclosed some spawning before the onset of the cold period. The eggs and larvae disappeared, however, when the temperature dropped, and spawning ceased. This was in full accord with the results attained at the hatchery. The spawning of the cod may be stopped altogether if low temperatures set in, even in the middle of the normal spawning season. Vide figs. 40—43. DANNEVIG (3). When the temperature rose in the spring spawning recommenced but the occurrence of larvae was low.

Taking these results in conjunction with earlier pelagic fishing it is likely that a cold period will be followed by poor catches of fry. If the chief spawning period is followed by rising temperatures the catches of fry will be relatively good.

In 1930 Poulsen (9) showed that in Danish waters in 1923—1928 there seemed to be a parallelism between the occurrence of salt, and comparatively warm, water and relatively large numbers of pelagic cod fry. Moreover, O. Sund (10) has found in respect of a series of years some parallelism between the amount of snow and rich yearklasses of skrei (the Lofoten cod). The quantity of snow is here used as an illustration of the meteorological conditions.

As a result of the investigations carried out in Norway under the leadership of Hjort it was demonstrated in the first decade of the present century that the variation in the stocks of fish was capable of being caused by great numerical fluctuations in the different year-classes. Both in the case of the Norwegian spring herring and of the skrei some year-classes appeared to be far more abundant than others.

In 1913 Professor H. H. Gran at the International Fishery Investigation Council suggested that the cause of the fluctuation in the numerical strength of the different year-classes might be ascribed to the variation in food convenient to the newly-hatched larvae.

This theory is supported by our rearing experiments with cod fry. The quantity and quality of the food is of prime importance. Our experiments have confirmed that the cod larvae will consume plant plancton as well as small animals and larvae. Plant plancton, however, is probably not a suitable food for the larvae. It will serve to sustain life but the general condition improves considerably if sufficient animal larvae are present. In one case, 1909, (Dannevig 11) the result of a rearing experiment was exceptionally good. In that year mollusc larvae were abundant in the rearing pound. In nature the hatching of the larvae suitable for the very young cod is governed by the temperature of the sea. If the temperature in the early spring is on the upward grade spawning and hatching will take place at an increasing rate. If it drops, however, the spawning processes will stop and the hatching will be retarded. On the days succeeding a fall in temperature the food supply of the fish larvae hatched in a previous warm period will stop. This phenomenon may be one of the causes of the scarcity of fish larvae after a fall in the temperature of the sea. On the other hand an increasing rise in temperature will enormously enrich the food supply.

If the temperature of the sea is high enough in the early winter to permit the spawning of the food animals the light will nevertheless be too poor for the plant plancton and there will thus be a dearth of suitable food for these animals.

By means of experiments I have illustrated the effect of light on cod, particularly the larvae (Dannevig 12). It proved that a certain amount of light was necessary to the well-being of the larvae. In dark or foggy weather they turned pale and sank to the bottom, but the light of an electric lamp was sufficient to restore them. The effect of light, however, is not restricted to larvae alone, the behaviour of the eggs is also to a high degree influenced by the amount of light to which they are exposed. This can frequently be observed in the hatching apparatus (G. M. DANNEVIG 13 and ALF DANNEVIG 14). If the weather becomes foggy the specific gravity of the eggs will increase and the eggs will sink in the sea water whereas normally they remain at the surface. The normal specific gravity of cod eggs is 1.021 at 4° C.

If the temperature during hatching is relatively low, say 2°—3° C., the hatching process will be prolonged and the eggs will become covered with small algae. This is specially obvious in the hatching apparatus, but it has also been found to be the case with eggs taken in our pelagic trawlings. Experience tends to show that eggs with a coating of algae or bacteria turn heavy and will sink in ordinary sea water. This thus enables them to escape our trawling gear. It will therefore be understood that physical factors are of the utmost importance to the plant and animal life of the sea, including the fish larvae.

It is moreover evident that meteorological conditions and the physics of the sea water are governed by the influence of the sun and moon. This, therefore, brings us to the final result that the cause of the fluctuation in the fisheries is of a cosmic nature.

The magnitude of the fish population, however, is not dependent on the propagation of the stock alone. It is also greatly influenced by destructive forces and among these is the intervention of man. This paper, however, will only deal with the propagation of the most common types of fish, particularly the pelagic fish eggs and larvae, and the contemporary hydrographic conditions. A study of the occurrence in nature of fish eggs and larvae may be of interest in itself, and this is more especially the case in relation to the problem of the culture of sea fish.

Before discussing the fish eggs and larvae taken in 1934—1937 a few remarks must be made on the hydrography of the waters of the Skager Rack coast in general and the conditions of the sea water in each year in particular.

# III. The Hydrography of the Coastal Waters.

From fig. 1 page 8 it will be observed that the waters of the Skager Rack are very deep. On the Jutland side there is a broad coastal bank of a dept of less than 40 metres. On the Norwegian side the banks are very narrow, but there are numerous skerries and small fjords. There are no big fjords, however, apart from the Oslo Fjord, and this will be discussed in a separate paper.

The general features of the system of currents in the Skager Rack are well known. There is the Jutland current which carries North Sea water along the west coast of Jutland. At the Skaw this approaches the comparatively fresh current which emanates from the Baltic. Part of the Jutland current proceeds as a submarine current into the Cattegat and another part turns north and mixes to some extent with the Baltic current.

The volume of the Baltic current varies considerably with the melting of the snow and the downpour in the Baltic districts. According to WITTING (15) the quantity of water which flows out from the Baltic in a year amounts to 480 km$^3$. The greatest quantity is in the spring and autumn and at these seasons the salinity of the Baltic current must be expected to be relatively low. A similar state of affairs must therefore be expected along the Skager Rack coast of Norway, but as will subsequently be shown offshore winds may prevent the Baltic current from approaching the coast.

The Baltic current runs along the west coast of Sweden to near to the mouth of the Oslo Fjord where it turns to the west and follows the Skager Rack coast of Norway as a coastal current in a westward direction and on to the north of Norway. As the current passes along the coast it mixes with underlying salt water and the salt water on its left. On its right, however, it will receive a constant supply of fresh water from the Norwegian rivers. We must therefore expect an increasing salinity from the shore and outwards.

Owing to the rotation of the Earth the current will, in ordinary circumstances, keep close to the land and will here give rise to eddies among the skerries and shallows, and as the friction between the current and the skerries is much greater than that between the current and Skager Rack water outside the speed of the current on the shore side will be retarded. The current will also tend to rotate around its longitudinal axis. It is thus reasonable to assume that the water masses will here and there find an opportunity of running close to the shore, a factor of great interest to the young fish which are carried along with it.

Hydrographic conditions in the vicinity of the Skager Rack coast of Norway vary considerably. They vary according to the salinity of the Baltic current and the quantity of fresh water carried out by the rivers. Moreover, the wind exercises considerable influence. On days of strong shore winds from the north and west the entire surface water is driven away from the coast. A high salinity at the surface near the coast will then be found and a lower further out, in other words opposite conditions to those which usually prevail.

This state of affairs is illustrated in the salinity measurements at 0 metre taken on 10. April 1924:

| At Flødevigen | 1 n. m. off Torungen. | 5—6 n. m. off Torungen |
|---|---|---|
| 33.03 ‰ | 32.29 ‰ | 31.29 ‰ |

In such circumstances the temperature also will vary very much. The following observations taken at Flødevigen at 1 metre illustrate how this may differ from day to day.

| Date | Wind | Temperatur C.° | Salinity ‰ |
|---|---|---|---|
| July 25. 1934 ........ | Light S. breeze | 19.9 | 26.20 |
| „ 26. „ ........ | NW. „ | 17.4 | 28.12 |
| „ 27. „ ........ | „ „ | 12.8 | 32 09 |
| „ 6. 1936 ........ | „ „ | 12.7 | 31.40 |
| „ 7. „ ........ | SE. „ | 17.6 | 24.89 |
| „ 8. „ ........ | E. „ | 18.9 | 22.10 |
| Feb. 4. 1939 ........ | Light SSW. „ | 1.6 | 25.45 |
| „ 5. „ ........ | „ | — | — |
| „ 6. „ ........ | „ WSW. „ | 6.3 | 33.23 |

With southerly and easterly winds the brackish surface water will remain close to the land. Hence, the temperature of the sea water will be low in winter and high in summer. Northerly and westerly winds will carry the surface water of low salinity away from the coast. Salinity will therefore be high and temperature comparatively low in summer and high in winter.

Thus the variation in the direction of the wind may give rise to great fluctuations in salinities and the temperature of the sea surface from day to day, and if a special type of wind prevails during the season great variations may occur from year to year. During the winter of 1936 and 1937 cold easterly winds prevailed and the sea was cold. In 1934, 1935 and 1938 there were westerly winds during the winter and comparatively high temperatures in the sea.

In the fjords there is usually some inflow of fresh water from inland. The fresh water which is thus emptied into the fjords gives rise to a surface current regularly running outwards. As the fresh water mixes with the salt and carries a small quantity of it out of the fjord it follows that there must be a replacement by a very slow ingress of salt water in the intermediate layers. This phenomenon can often be studied in a narrow fjord. The medusae are carried by the submarine current and accumulate in great quantities just outside the mouth of the river. This will also be the case with other plancton forms. Thus a comparatively rich fauna is regularly to be found near the rivers. On coasts with big tides there must be a strong in- and outgoing current in the fjords. On this coast however, there are practically no tides. The fuctuations in the water level are caused by the wind. PETTERSSON (16) has shown, however, that the tides are present beneath the brackish water layers, but the tidal waves are diminished by the latter and are not visible at the surface.

Near the bottom there are almost stagnant water masses in all the Norwegian fjords. In stormy weather, however, heavy salt water may flow into the fjords and replace the old layers. Internal waves also — O. PETTERSSON (17) — may occasionally play an important rôle in the renewal of the »bottom water« of the fjords. The seasons in which these great submarine waves, or strong wind currents, occur are particularly the late autumn and early winter.

The movements of the water masses can, of course, be studied by direct current observations. In the Skager Rack fjords, however, the movements are very slow and the weak tides will, to a great extent carry the same watermasses inwards in the fjords and again seawards. Another method of studying the renewal of the fjord water is to observe the characteristics of the water masses in and outside the fjords. If the water masses are homogeneous as regards temperature, salinity or oxygen content it is reasonable to assume that some measure of mixing has, or may have, taken place. If there are differences in one respect or another we must assume that the water masses have been sufficiently long in the locality to take on a special character.

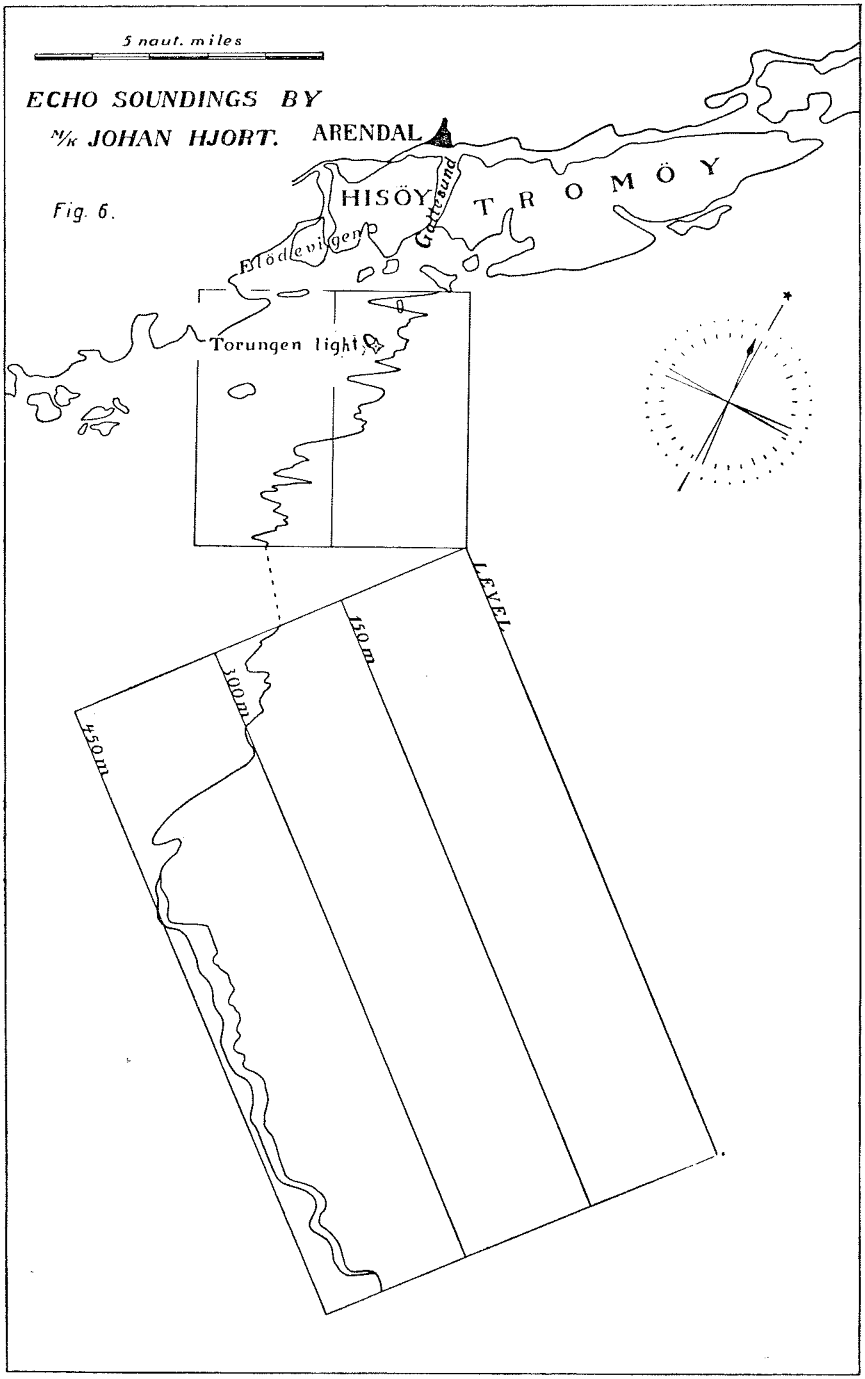

5 naut. miles
ECHO SOUNDINGS BY
M/K JOHAN HJORT.
ARENDAL
HISÖY
TROMÖY
Galtesund
Flödevigen
Torungen light
LEVEL
150 m
300 m
450 m

Fig. 6.

In order to furnish some idea of hydrographic conditions during the period of fishing with pelagic nets some figures will be shown specifying the main features of the waters in question.

## A. THE COASTAL WATERS NEAR ARENDAL.

Fig. 6 illustrates the topography of the waters examined and the configuration of the bottom obtained by echo soundings from the motor cutter »Johan Hjort«. It will be observed that near the coast the depth varies considerably.

Hydrographic measurements are taken in these waters all the year round, the temperature at the surface is measured every day at Torungen Light and at Flødevig Seafish Hatchery both specific gravity and temperature are controlled. Fig. 7. shows the average temperatures of the sea water 1 metre below the surface at Flødevigen.

Figs. 8—13 show the hydrographic conditions in the open sea and give the results of 8 cruises during the year 1937. In the middle of February the temperature is in the neighbourhood of 0° C. at the surface whereas at only a few metres below it is 2° C. On 8. March the cold water has augmented considerably; 16 days later the temperature is about the same.

It is of particular interest to note temperatures of 4°—6° C. in the intermediate layers during the coldest part of the winter. On 28. April the surface layers are warmed down to 20 metres. The lowest temperatures occur between 20 and 30 metres below the surface, namely, less than 4° C. In the neighbourhood of 100 metres the temperature is 5.5° C. which is the lowest observed that year in the deeper layers. On 24. June there is 10° C. or more down to about 20 metres. It will be observed that the isotherm of 7° C. has a depression 5 nautical miles outside of Torungen. It is here located at about 80 metres. At 14 nautical miles it lies at 20 metres. This is manifested even more clearly by the measurements taken on 28. July. This indicates a great volume of warmer water near the coast. In the central part of the Skager Rack the temperature is relatively low.

The possible explanation of this phenomenon may be that this is the natural Skager Rack water which still retains its winter temperature, or that it is water emanating from the north. In view of measurements taken by the Institute of Oceanography at the Directorate of Fisheries in Bergen the latter explanation is hardly feasible. It must, therefore, be assumed that the cold water masses found are of a stationary character.

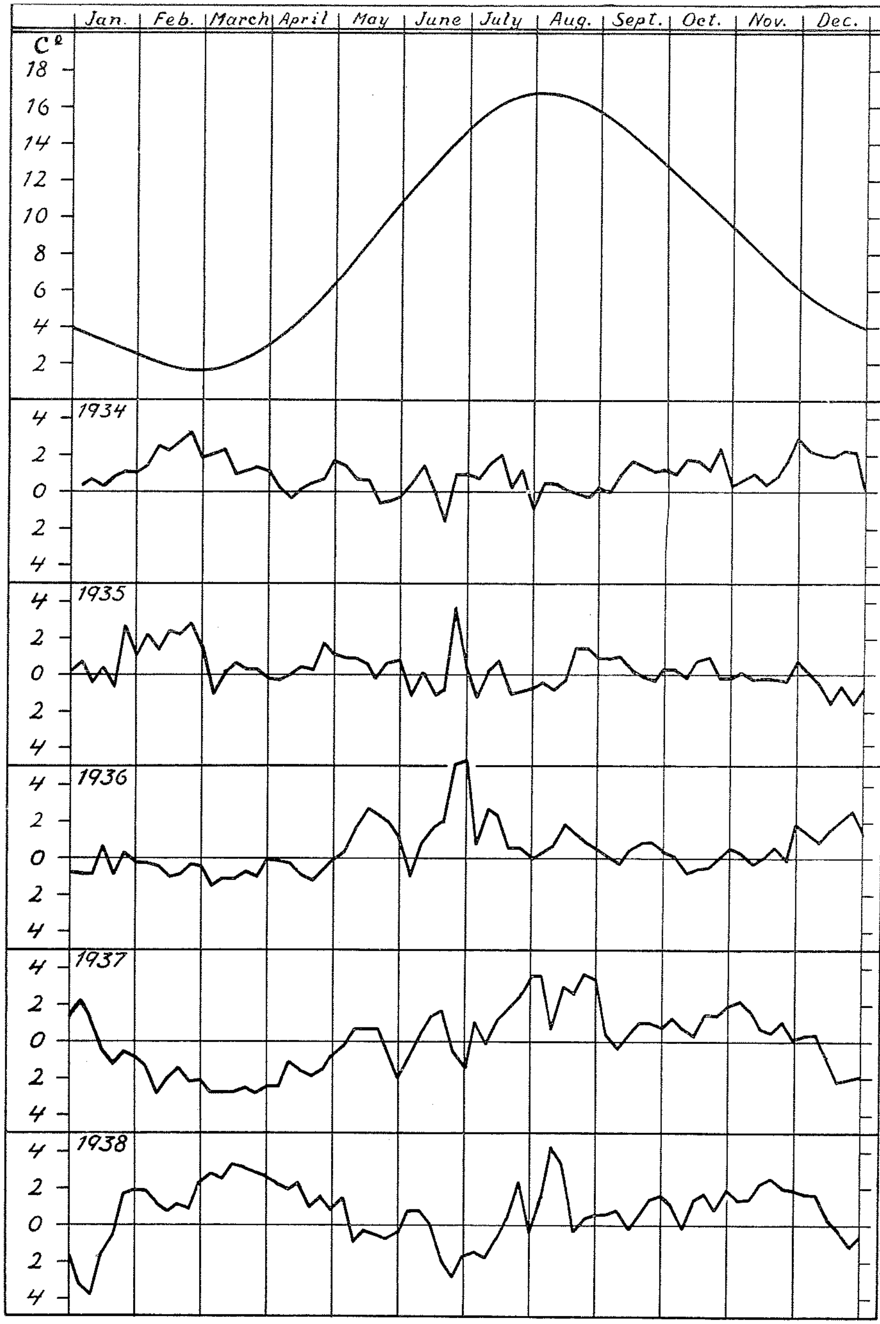



Fig. 7. The upper line represents the average temperature of the seawater 1 metre below the surface at Flødevigen 1919—1938.
The lower lines represent the divergences for 5 days from the average for the years 1934 – 1938.

Late in September the surface layers have cooled. The intermediate layers, 50—100 metres, have now reached their highest temperatures. On 22. November winter conditions have commenced. The surface has now cooled to such an extent that its temperature is lower than that at 20—40 metres where the temperature is highest.

It will be seen from the 1937 measurements that the temperature of the surface layers varies between 0° C. and 19° C. in conformity with summer and winter atmospheres. At 50 metres it varies between 5° C. and 13° C. The lowest temperature occurs in the late winter and the highest in the early part of the autumn. At 100 metres the temperature only varies between 5.5° C. and 8° C., the latter reading being for the autumn.

In comparatively warm winters the temperature at the surface will not fall below 3° C. but when the winter is specially severe great volumes of the upper layers may have temperatures below 0° C. The deeper layers may also vary from winter to winter to a slight extent according to the character of the winter. During the cold winter of 1924 the temperature in all parts of the Skager Rack was as low as 4° C.

The variations in salinity are set forth in figs. 10 and 11. In the spring, from February 16. to April 28., there is a good quantity of water in the upper layers with a salinity below 30 $^0/_{00}$ particularly on 8. March and 28. April. In June and July these layers are very thin and in September and Nowember they are absent.

From the figure it will be observed that, in some cases, there is water of a low salinity near the coast and salter water further out. In other cases the salinity of the surface layer is highest near the coast, vide figs. for June and September. As regards 24. June the meteorological notes for the previous days show strong westerly and northerly winds. These had also been the prevailing wind directions in the days prior to 28. September. As already mentioned it is the strong winds which give rise to these special features.

The depth at which North Sea water of 34 $^0/_{00}$ is to be found varies between 10 and 70 metres, thus indicating that great vertical variations may occur. Accordingly there were also very great variations in the volume of the coastal water.

Water of Atlantic origin of 35 $^0/_{00}$ and more occurs, according to the 1937 observations, in February and March at a depth of 150—300 metres. In April and June Atlantic water was not found by our measurements. In July it is seen to be situated at a depth of 100 metres, in September at 70—100 metres and in Nowember at about 50 metres. This conforms to the general concensus of opinion on the Skager Rack. The great influxes of Atlantic water occur in the late autumn.

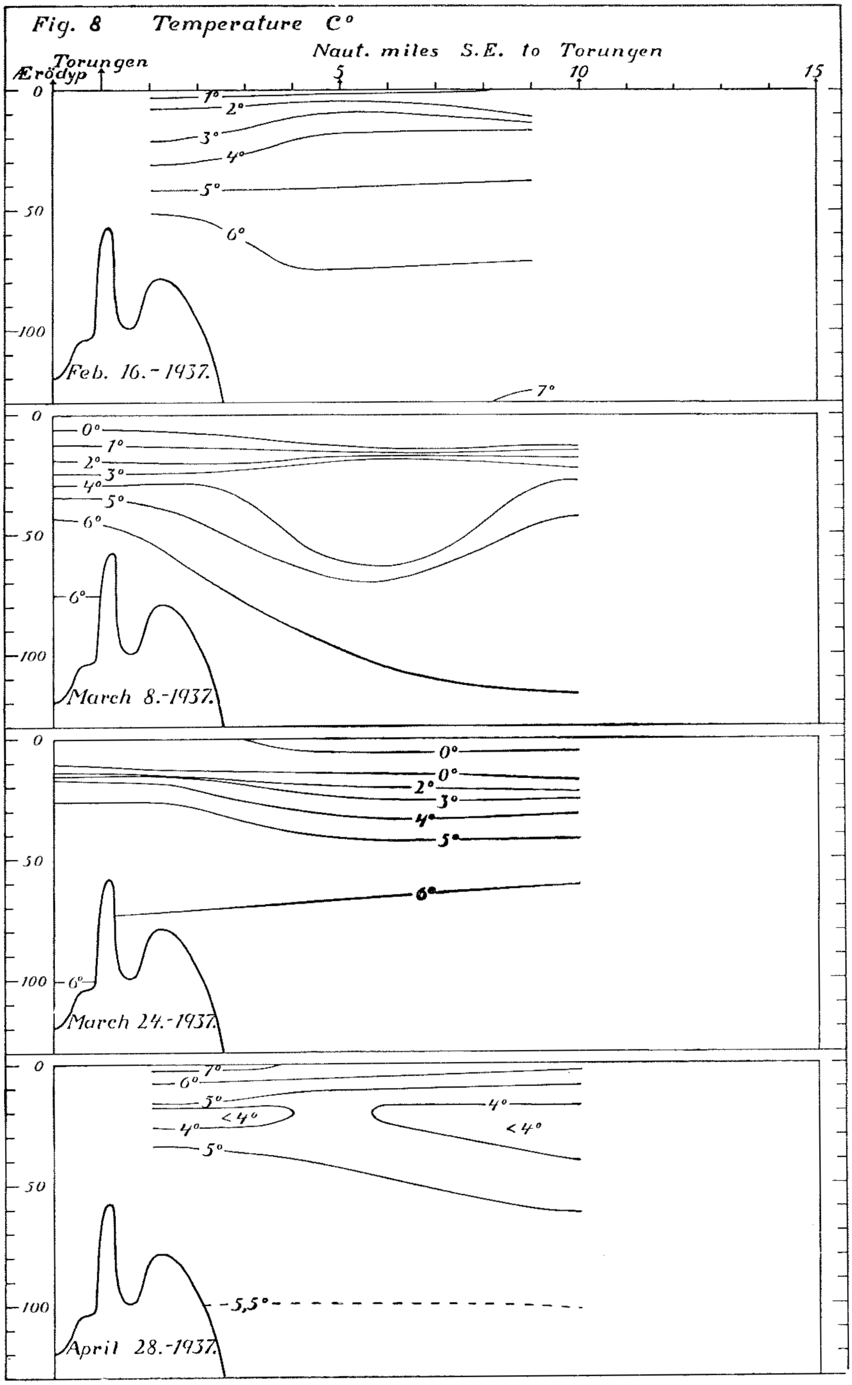


Fig. 8 Temperature C°
Naut. miles S.E. to Torungen
Ærödyp
Torungen
5
10
15
0
50
100
1°
2°
3°
4°
5°
6°
7°
Feb. 16.-1937.
0°
1°
2°
3°
4°
5°
6°
6°
March 8.-1937.
0°
0°
2°
3°
4°
5°
6°
6°
March 24.-1937.
7°
6°
5°
< 4°
4°
5°
4°
< 4°
5,5°
April 28.-1937.

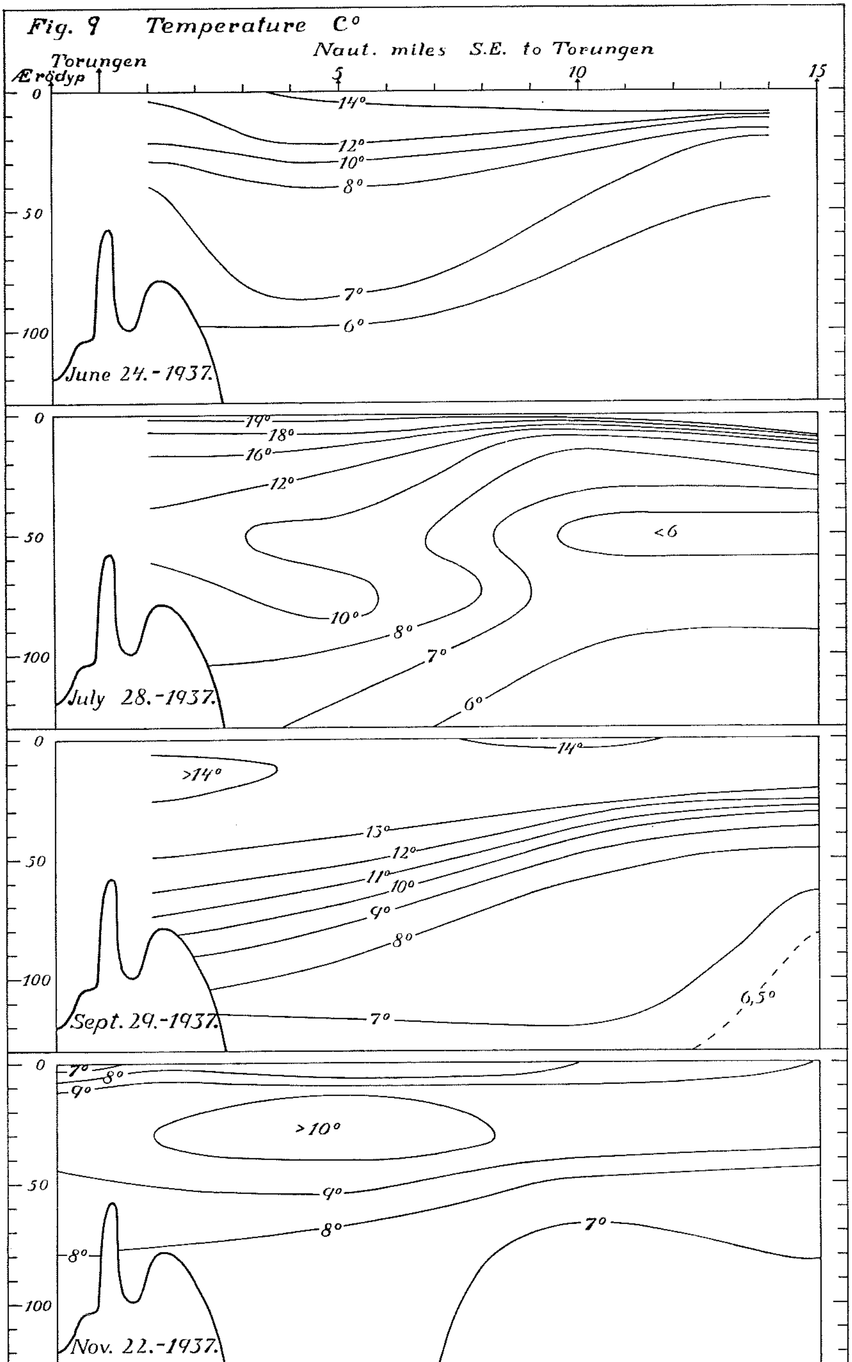


Fig. 9 Temperature C°
Naut. miles S.E. to Torungen
Torungen
Ærødyp
0
5
10
15
50
100
14°
12°
10°
8°
7°
6°
June 24.-1937.
19°
18°
16°
12°
<6
10°
8°
7°
6°
July 28.-1937.
14°
>14°
13°
12°
11°
10°
9°
8°
7°
6,5°
Sept. 29.-1937.
7°
8°
9°
>10°
9°
8°
7°
8°
Nov. 22.-1937.

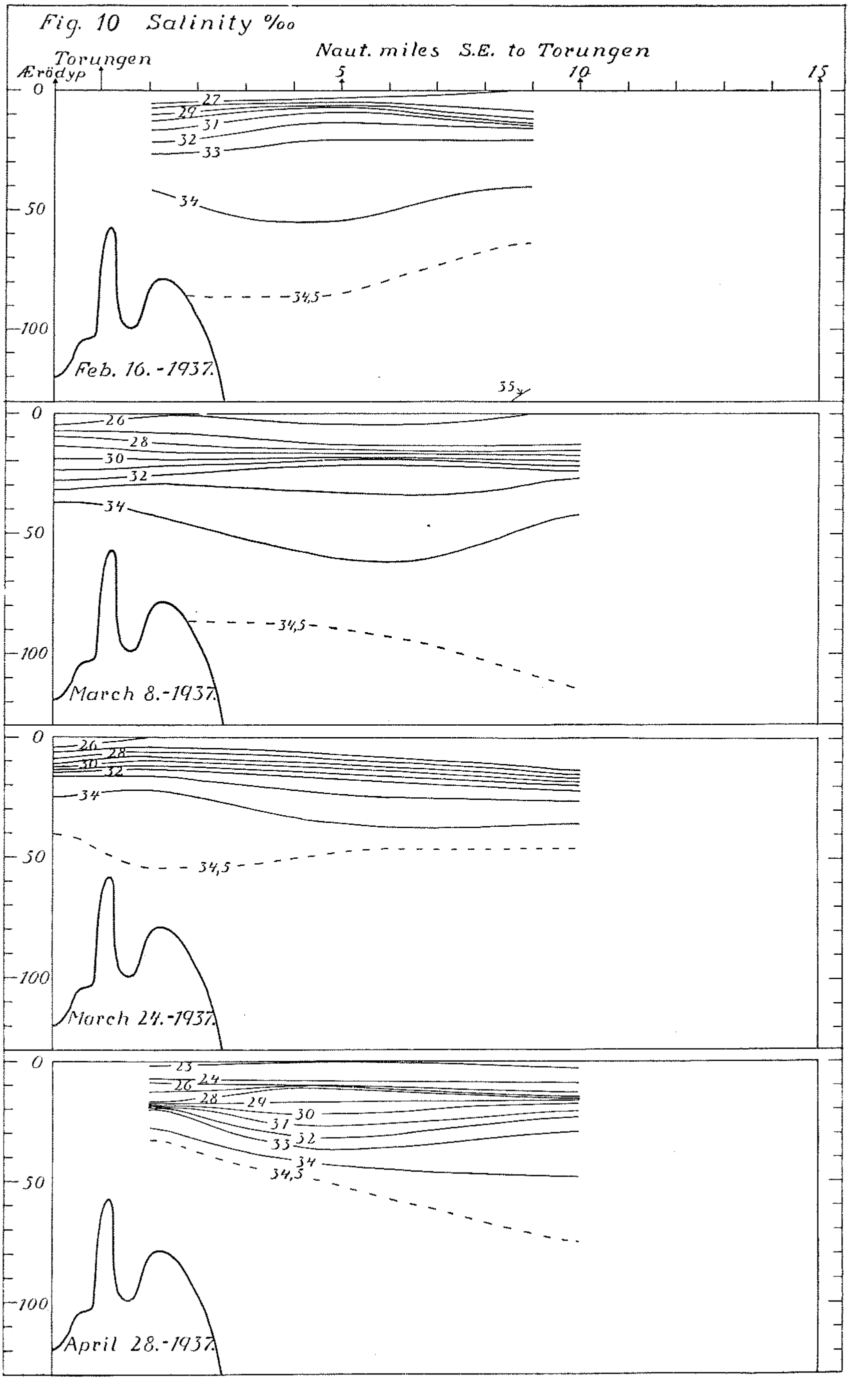


Fig. 10 Salinity ‰
Torungen
Ærödyp
Naut. miles S.E. to Torungen
0
5
10
15
50
100
27
29
31
32
33
34
34,5
35
Feb. 16.-1937.
26
28
30
32
34
34,5
March 8.-1937.
26
28
30
32
34
34,5
March 24.-1937.
25
24
26
28
29
30
31
32
33
34
34,5
April 28.-1937.

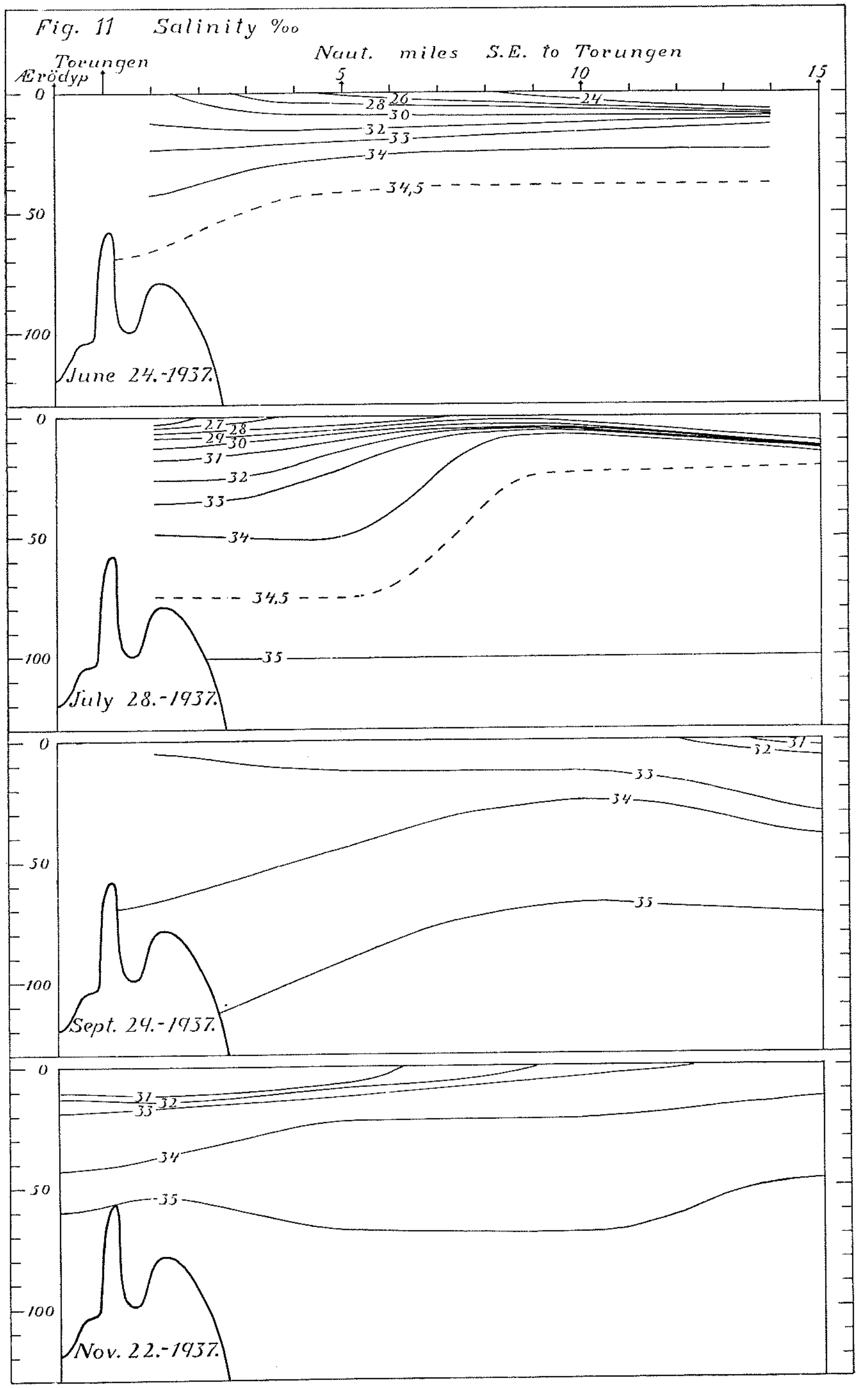


Fig. 11 Salinity ‰
Naut. miles S.E. to Torungen
Torungen
Ærödyp
5
10
15
0
50
100
26
28
30
32
33
34
34,5
24
June 24.-1937.
27
28
29
30
31
32
33
34
34,5
35
July 28.-1937.
31
32
33
34
35
Sept. 24.-1937.
31
32
33
34
35
Nov. 22.-1937.

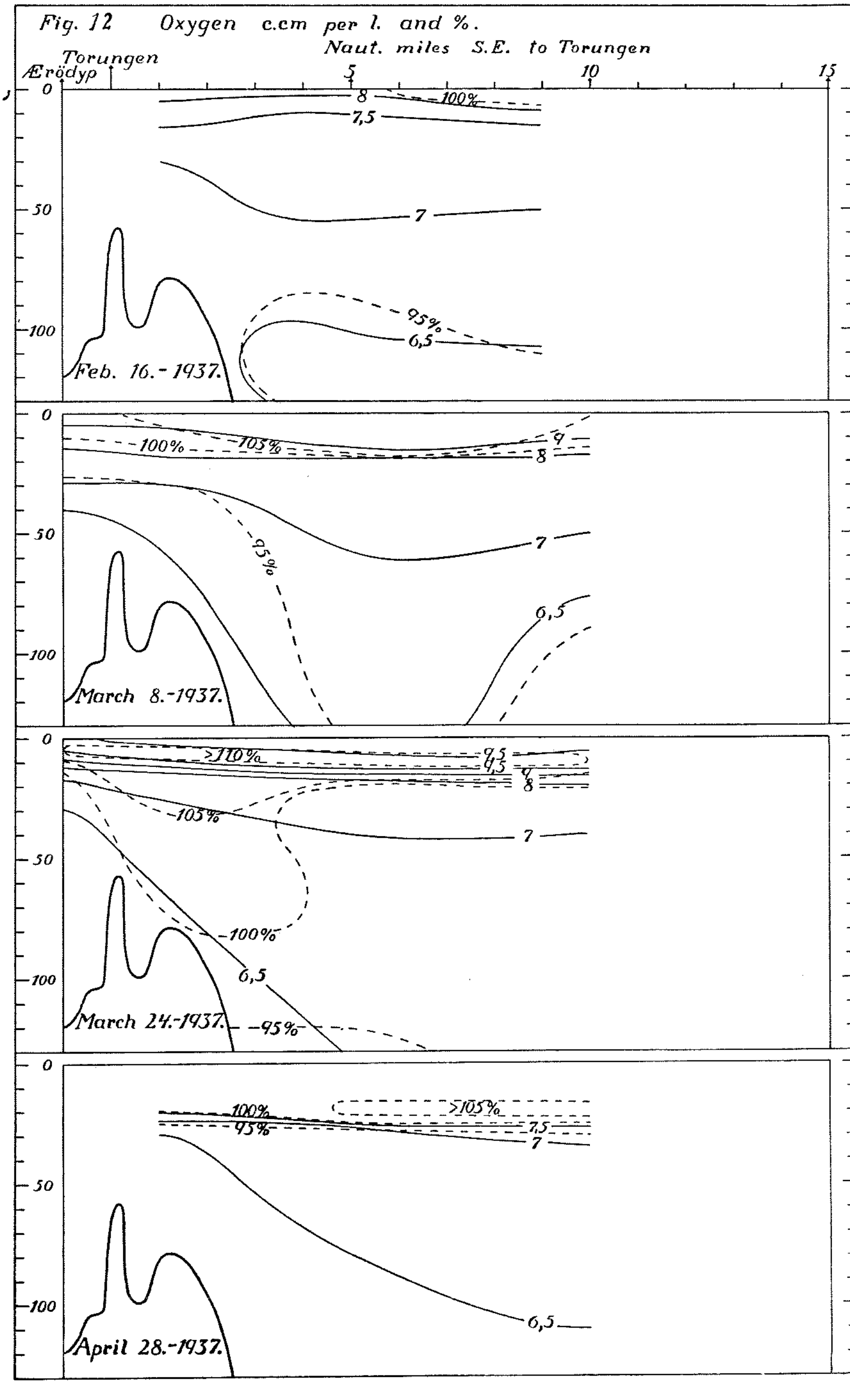


Fig. 12 Oxygen c.cm per l. and %.
Naut. miles S.E. to Torungen
Torungen
Ærödyp
0
5
10
15
50
100
8
100%
7,5
7
95%
6,5
Feb. 16.-1937.
105%
9
March 8.-1937.
>110%
9,5
105%
March 24.-1937.
>105%
April 28.-1937.

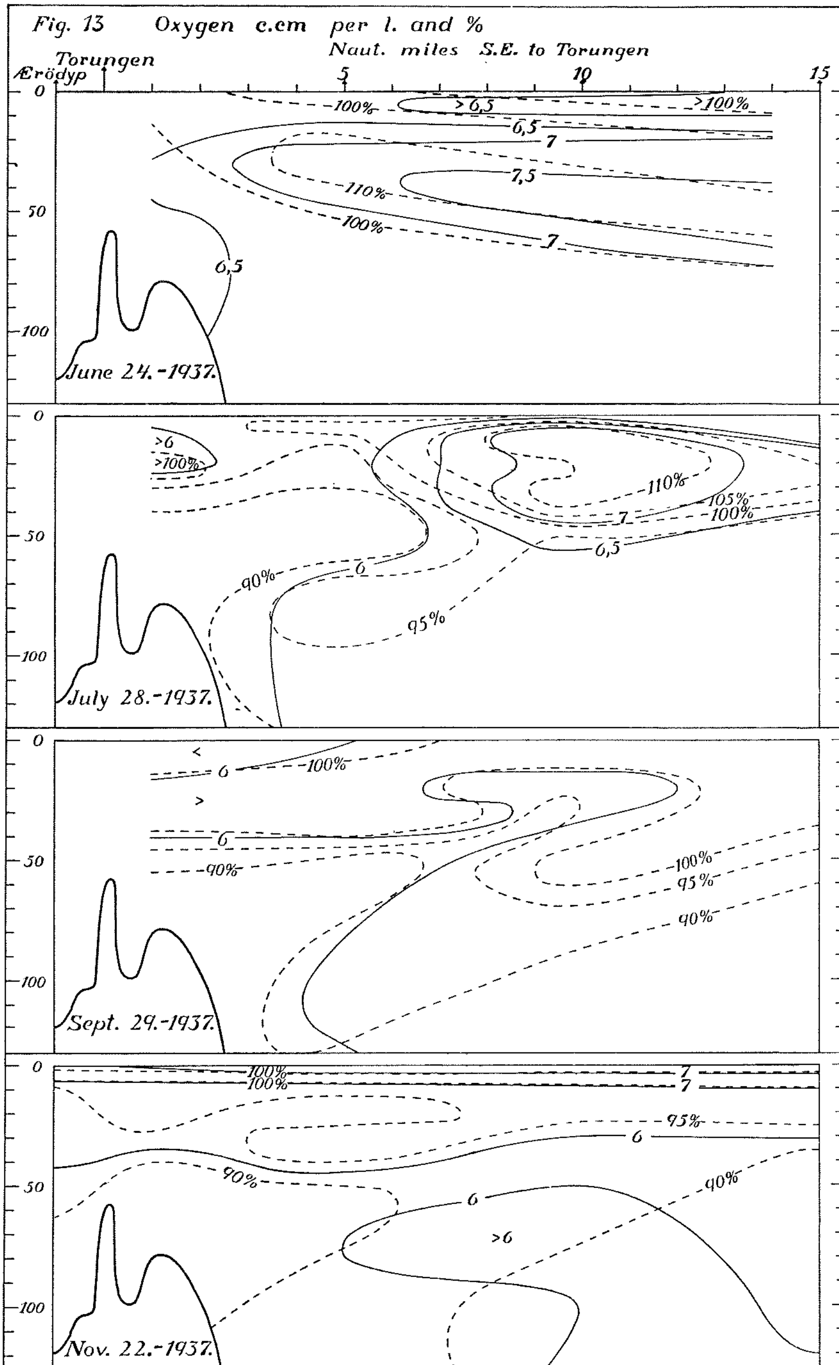


Fig. 13 Oxygen c.cm per l. and %
Naut. miles S.E. to Torungen
Torungen
Ærödyp
0
5
10
15
50
100
100%
>6,5
>100%
6,5
7
7,5
110%
100%
7
6,5
June 24.-1937.
>6
>100%
110%
105%
100%
7
6,5
90%
6
95%
July 28.-1937.
<
6
100%
>
6
90%
100%
95%
90%
Sept. 29.-1937.
100%
100%
7
7
95%
6
90%
6
>6
90%
Nov. 22.-1937.

Figs. 12 and 13 illustrate the oxygen content of the sea water and the percentage of saturation. In the upper layers the highest percentage of oxygen is found in March at the time of the greatest plancton production. It is also interesting to note the high content of oxygen at 10 nautical miles on 28. July. This may probably be the result of a high production of phytoplancton in the area where waters of different origin meet.

Furthermore, the measurements of oxygen indicate that the sea water is well-ventilated to a depth of at least 300 metres. Measurements from even deeper layers are seldom taken as this is of minor interest to our investigations. As it is known that the oxygen in the sea water emanates from the atmosphere and from the photosynthesis of the phytoplancton in the upper layers it follows that the deep layers in the Skager Rack are in communication with the surface layers of the open sea.

The figures here quoted from our 1937 measurements will illustrate the hydrographic conditions on the Skager Rack coast of Norway. As previously mentioned, however, there may be great variation in the details from day to day and the meteorological character of the year may give rise to great divergences.

Consideration must now be given to the small fjords investigated, which belong to the landlocked type. A description of these waters in general is given by KÅRE MÜNSTER STRØM, 1936, in his paper »Landlocked Waters« (18). Observations from the fjords here dealt with will be found in the paper in question.

## B. THE WATERS NEAR KRISTIANSAND.

Situated on the southern part of the Skager Rack coast of Norway is the Kristiansand Fjord which runs into the Topdals Fjord (fig. 14). Outside the skerries there is a narrow coastal bank with depths to a little more than 150 metres. Near Oksø Light a deep narrow channel runs into Kristiansand Fjord. This channel forms further in a submarine basin with a depth of 280 metres. The deep parts run close to the town. From the north-eastern part of the Kristiansand Fjord the Topdals Fjord cuts its way into the country district. The entrance at Søm is narrow and shallow with a maximum depth of less than 40 metres. Inside there is a submarine basin, the outer basin of the Topdals Fjord near Hånes, the depth being approximately 70 metres. In the middle of the fjord the Topdal River empties itself with great quantities of fresh water, and the deposits from the river have here built up a second barrier which is only 30 metres deep. Further in is the inner basin of

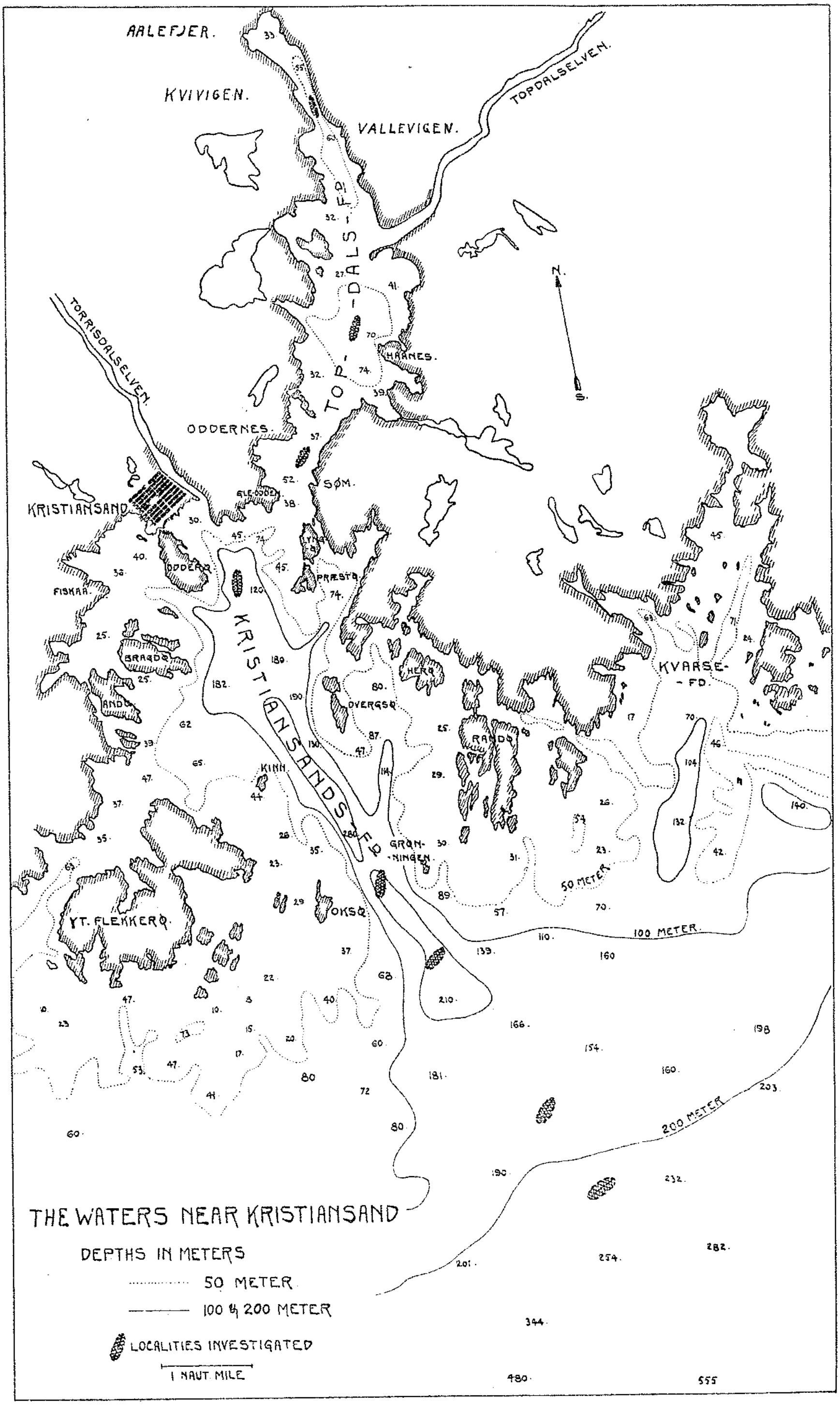

AALEFJER.
KVIVIGEN.
VALLEVIGEN.
TOPDALSELVEN.
TOP-DALS-FD.
TORRISDALSELVEN.
HAANES.
ODDERNES.
SØM.
KRISTIANSAND
ODDERØ
FISKAA.
BRAADØ
PRÆSTØ
KRISTIANSANDS-FD.
HERØ
OVERGSØ
RANDØ
KVARSE-FD.
KINN.
GRØNNINGEN.
OKSØ
YT. FLEKKERØ
50 METER
100 METER
200 METER
THE WATERS NEAR KRISTIANSAND
DEPTHS IN METERS
50 METER
100 & 200 METER
LOCALITIES INVESTIGATED
1 NAUT. MILE

Fig. 14.

the Topdal Fjord in the vicinity of Kvivigen with depths of about 70 metres. See also fig. 17. From the coast to the inner part of the Topdals Fjord the distance is about 9 nautical miles.

These fjords are typical of the Skager Rack coast of Norway. The coastal bank and the skerries form a barrier to the open sea. Inside the skerries there are one or more submarine basins.

Topography, naturally, plays an important part in the hydrography. The depths of the thresholds and the narrowness of the sounds towards the sea are especially of fundamental importance. In this respect there are on the Norwegian coast all types of fjords, from those which are open to those which are entirely landlocked with salt water in the deeper layers only.

The normal hydrographic conditions in the Kristiansand and Topdals Fjord emerge from fig. 15, tab. 1 and figs. 16 & 17. In these use has been made of observations from 1924 to 1937. On account of ice only a few observations are taken during the winter months.

Fig. 15 shows the variation of the temperature at different depths according to the season. The water is warmest near the surface in all localities in July and August. At 10 metres the highest temperatures occur in August, at 20 metres in September and October. At a depth of 40 metres the seasonal variation is only about 1° C. in the inner basin, about 4° C. in the outer basin, and in the Kristiansand Fjord 7°—8° C. At a depth of 60 metres the variation in the inner basin is only a few tenths of a degree; in the outer basin it amounts to about 1° C. In the Kristiansand Fjord there are seasonal variations of nearly 7° C. at a depth of 50 metres and it is possible that even at depths of 75, 100 and 150 metres the temperature is seasonal in character, but here the regularity is evidently disturbed by other factors, possibly the influxes of water from outside.

It is evident that the summer temperature requires several months to penetrate to the deeper layers and retardment is greatest in the innermost basin. In the fjords, where the water is more or less stagnant, and where the differences in salinity between the top and intermediate layers are great, no vertical circulation can take place. The divergences in temperature can here only be transmitted by leading or week convection currents, both very slow processes. In the open fjords the deep layers may be exchanged with water from outside and the temperature thereby influenced.

The range of temperatures observed at a depth of 50 metres irrespective of the seasons is set forth in figure 16. From 1924 to 1937 the temperature in the inner basin only varied from about 5.0° C. to 7.7° C. In the outer basin it ranged between 5.0° C. and 8.5° C., and in the Kristiansand Fjord between 5.0° C. and 15.0° C.

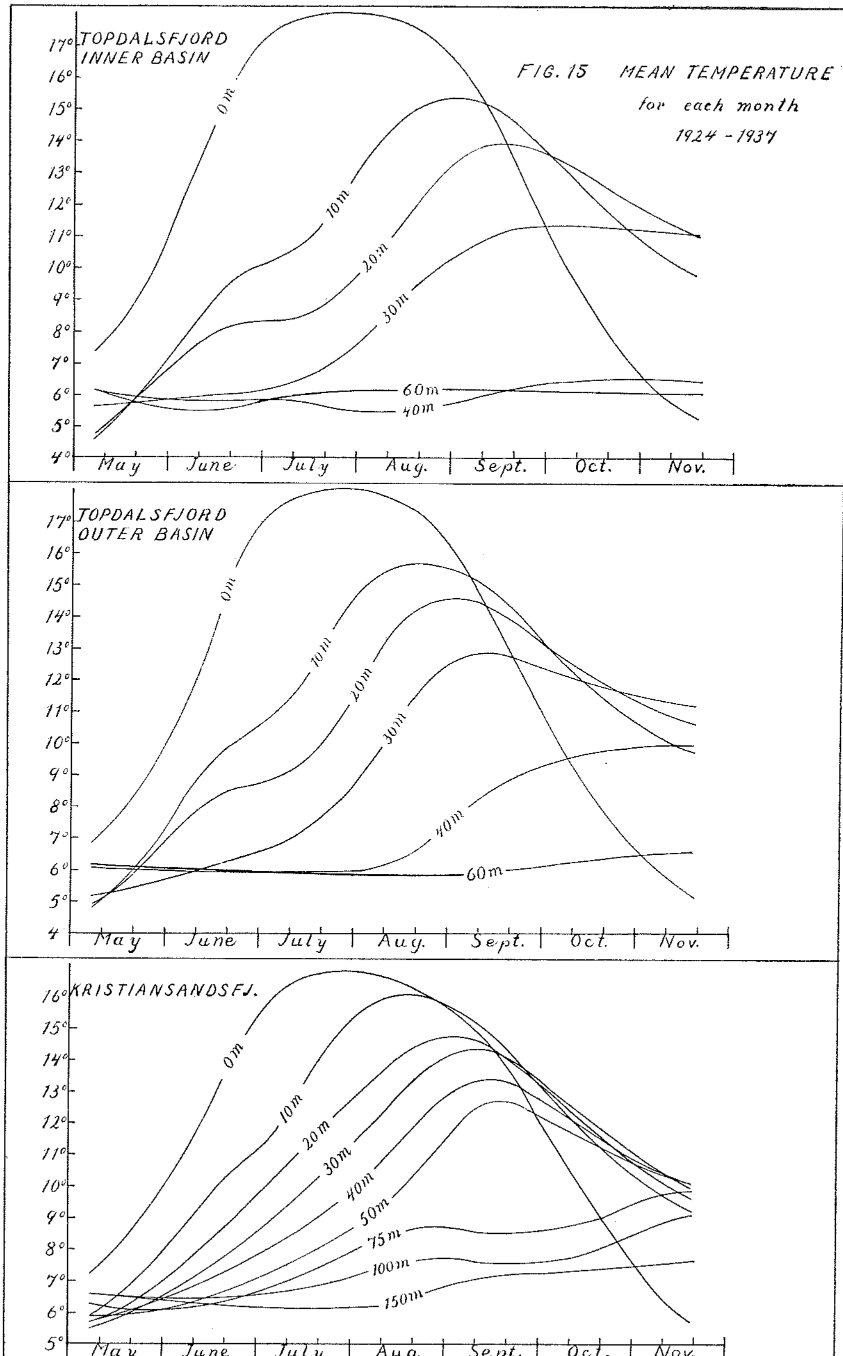


FIG. 15 MEAN TEMPERATURE
for each month
1924 - 1937
TOPDALSFJORD
INNER BASIN
0m
10m
20m
30m
60m
40m
TOPDALSFJORD
OUTER BASIN
0m
10m
20m
30m
40m
60m
KRISTIANSANDSFJ.
0m
10m
20m
30m
40m
50m
75m
100m
150m
17°
16°
15°
14°
13°
12°
11°
10°
9°
8°
7°
6°
5°
4°
May
June
July
Aug.
Sept.
Oct.
Nov.

*The Salinities in the Topdalfjord and the Kristiansandfjord found by our measurements in the years 1924—1937.*

TABLE 1. A. TOPDALSFJORD, INNER BASIN.

| Depth in metres | S ‰ | | | | | | | | | Observa-tions |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0–10 | 10–25 | 25–30 | 30–32 | 32–33 | 33–34 | 34–34 5 | 34 5–35 | 35–35.5 | |
| 0 | 22 | 12 | 4 | 1 | | 1 | | | | 40 |
| 10 | | | 18 | 15 | 4 | 4 | 2 | | | 43 |
| 20 | | | 4 | 15 | 10 | 10 | 2 | | | 41 |
| 30 | | | | 2 | 3 | 29 | 9 | | | 43 |
| 50 | | | | | | 2 | 28 | 11 | | 41 |
| 60 | | | | | | 1 | 27 | 11 | | 39 |

B. TOPDALSFJORD, OUTER BASIN.

| Depth in metres | S ‰ | | | | | | | | | Observa-tions |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0–10 | 10–25 | 25–30 | 30–32 | 32–33 | 33–34 | 34–34.5 | 34.5–35 | 35–35.5 | |
| 0 | 21 | 20 | 3 | 1 | | | | | | 45 |
| 10 | | | 14 | 18 | 7 | 5 | 2 | | | 46 |
| 20 | | | 2 | 17 | 12 | 11 | 2 | 1 | | 45 |
| 30 | | | | 1 | 6 | 30 | 6 | 1 | | 44 |
| 50 | | | | | | 2 | 28 | 12 | 1 | 43 |
| 60 | | | | | | 1 | 25 | 18 | 1 | 45 |

C. KRISTIANSANDSFJORD (ODDERØ).

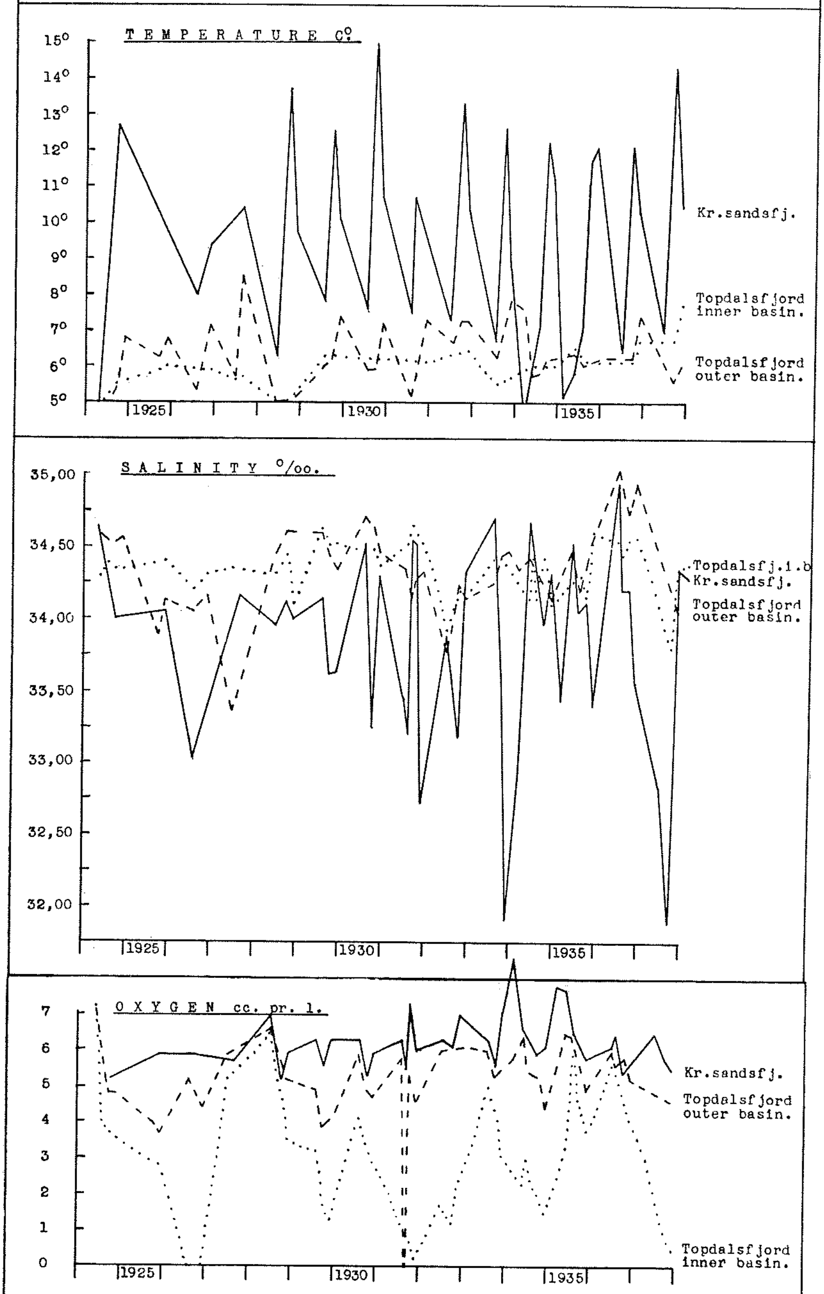
| Depth in metres | S ‰ | | | | | | | | | Observa-tions |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0–10 | 10–25 | 25–30 | 30–32 | 32–33 | 33–34 | 34–34.5 | 34.5–35 | 35–35.5 | |
| 0 | 11 | 28 | 2 | | | | | | | 41 |
| 10 | | 1 | 13 | 15 | 8 | 6 | 1 | | | 44 |
| 20 | | | 4 | 11 | 18 | 7 | 3 | 1 | | 44 |
| 30 | | | | 9 | 13 | 14 | 5 | 2 | | 43 |
| 50 | | | | 2 | 3 | 15 | 15 | 8 | | 43 |
| 75 | | | | | 1 | 6 | 11 | 19 | 2 | 39 |
| 100 | | | | | | 2 | 14 | 16 | 9 | 41 |
| 150 | | | | | | 1 | 2 | 15 | 13 | 31 |

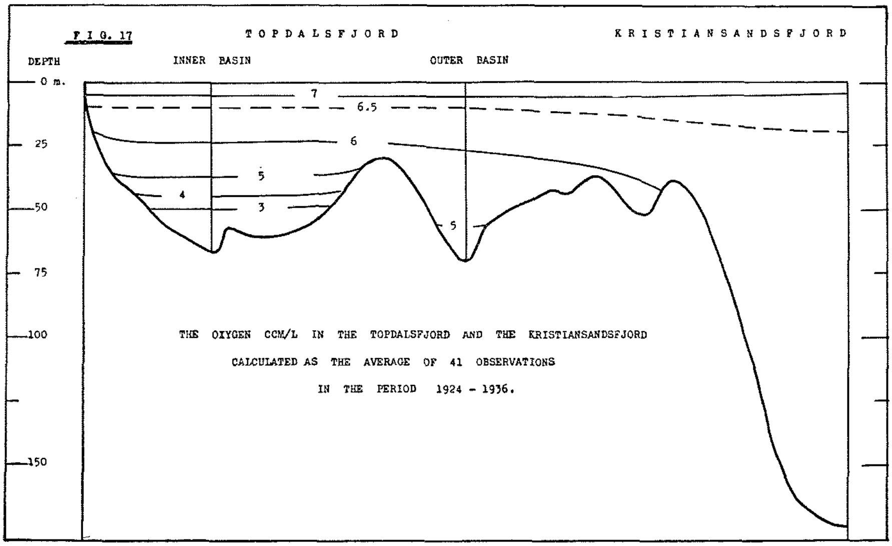
The salinity of the fjords of course also varies in some degree with the seasons. When the snow melts in the spring great masses of water from the inland districts are emptied into the rivers, and in the early autumn there is liable to be a period with a heavy rainfall. The advent of these water masses naturally influences the salinity of the surface layer of the fjords. When the rainfall is small and the wind is offshore the salinity of the fjord may rise considerably. These variations naturally have the greatest influence on the plant and animal life of the fjord. A survey is therefore given in table 1. of the occurrence of the different types of water according to salinity. Sufficient observations are not available, however, to illustrate the variation in salinity from month to month. As regards surface water it will be seen that in 22 out of 40 observations in the *inner* basin a salinity of less than 10 $^0/_{00}$ was recorded. In the *outer* basin the corresponding figures were 21 out of 45 and in the Kristiansand Fjord 11 out of 41. Here water of 10 $^0/_{00}$—25 $^0/_{00}$ is predominant. It is very interesting to note, however, that the highest salinity near the surface — 33.86 $^0/_{00}$, was found in the inner part of the Topdals Fjord on 18. November 1930. The strong shore winds which had prevailed according to our observations during the preceding three weeks had carried the fresh water layers out of the fjord. At the mouth of the river there will naturally always be some fresh water at the surface. From the same table it will be seen that the variation in salinity becomes less towards the deeper layers. Figure 16 illustrates the variations in salinity observed at 50 metres. At this depth the variation is naturally greatest in the Kristiansand Fjord. In the Topdals Fjord the water at the depth in question is practically stationary.

As regards the volume of oxygen there may be some seasonal variations in the upper layers. These are caused by the variation in the photosynthesis of the phytoplancton. Sufficient material is not available, however, for a discussion of this question. In the surface layers there is always a sufficiency of oxygen, but in the deeper layers production of oxygen is very slow and there is no seasonal variation. The diagram in fig. 17 shows the average content of oxygen. It will be observed that the surface and intermediate layers are well aerated. In the Kristiansand Fjord the deeper layers are well aerated but in the inner part of the Topdals Fjord the average quantity of oxygen found is too small for many of our fish.

With one exception the Topdals Fjord has been examined every year from 1924 to 1937 in the month of September. The results will be found in fig. 18. The content of oxygen is quite regular down to a depth of 30 metres but beyond this there are great variations owing to

FIG. 16. The variation in oxygen, temperature and salinity in Topdalsfjord and Kristiansandsfjord at a depth of 50 meters 1924 - 1937.





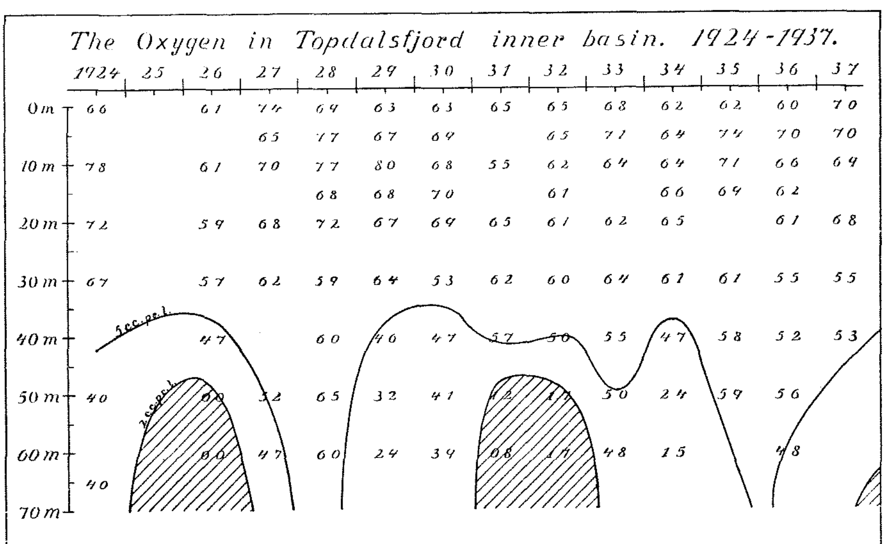
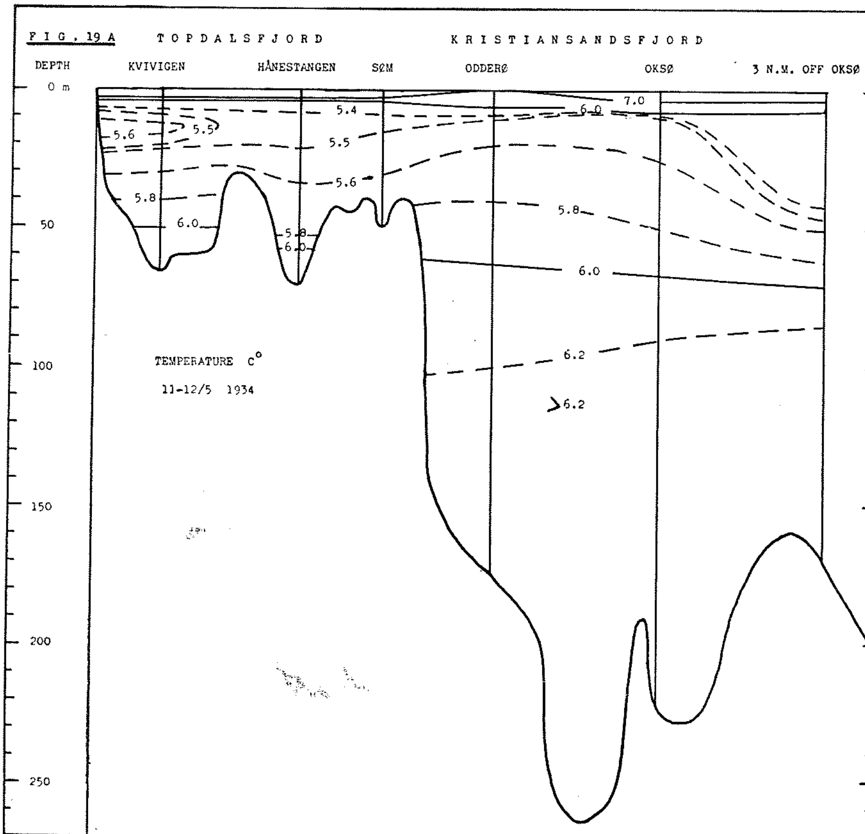




Fig. 18. The values given represent the observations made in the month of September in the years 1924—1937. Oxygen ccm l.




the stagnation or »age« of the water. At a depth of 60 metres it will be seen that, in the case of two periods, 1925—1926 and 1931—1932, the water has been nearly depleted of oxygen. In 1928 the water has been renewed right down to the bottom.

Fig. 16 shows the content of oxygen at a depth of 50 metres for all observations. In the Kristiansand Fjord it varies from 5.2 to 8.5 ccm $O_2$/l. In the outer basin of the Topdals Fjord it varies regularly between 4 and 6.5 ccm $O_2$/l. and in the inner basin from 0—7.2 ccm. Fig. 16 also shows that a renewal of the bottom waters has taken place in 1924, 1927 and 1928, partially in 1930, and in 1933, 1935 and 1936.

To illustrate hydrographic conditions during the investigations the results obtained on the cruise of 11.—12. May 1934 are given (fig. 19 a. b. c.). Near the surface there is relatively warm water, particularly in the Topdals Fjord, with a temperature at Søm of 11.5° C. In the layers at about 10—20 metres there is a minimum temperature of less than 6° C. There are no great differences between the various localities.

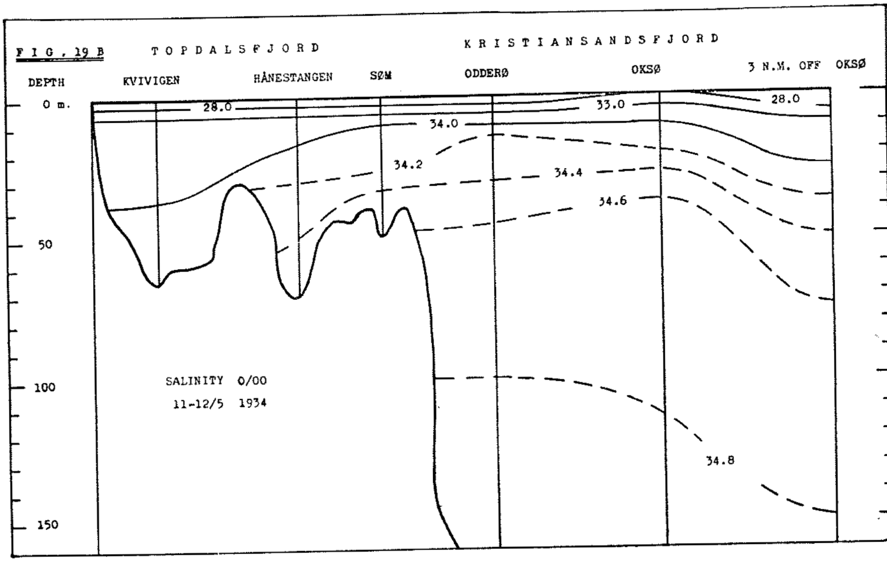


FIG. 19 B
TOPDALSFJORD
KRISTIANSANDSFJORD
DEPTH
KVIVIGEN
HÅNESTANGEN
SØM
ODDERØ
OKSØ
3 N.M. OFF OKSØ
0 m.
50
100
150
28.0
33.0
28.0
34.0
34.2
34.4
34.6
34.8
SALINITY 0/00
11-12/5 1934

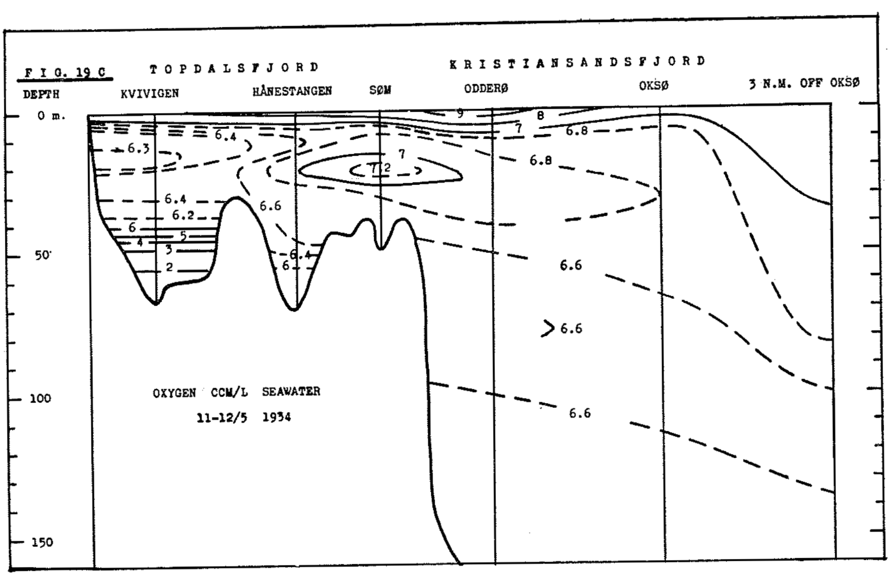


FIG. 19 C
TOPDALSFJORD
KRISTIANSANDSFJORD
DEPTH
KVIVIGEN
HÅNESTANGEN
SØM
ODDERØ
OKSØ
3 N.M. OFF OKSØ
0 m.
50
100
150
9
8
7
6.8
6.4
6.3
7
7.2
6.8
6.4
6.6
6.2
6
5
4
3
2
6.4
6
6.6
6.6
6.6
OXYGEN CCM/L SEAWATER
11-12/5 1934

In the Topdals Fjord and the inner part of the Kristiansand Fjord the water is almost fresh at the surface. In the inner basin, water masses of a salinity between 33 $^0/_{00}$ and 34.2 $^0/_{00}$ are absolutely predominant. This type of water is also conspicuous at the outer station. but is of minor significance in the Kristiansand Fjord.

It is evident from fig. 19 c that there is a great deficiency of oxygen in the deeper parts of the inner basin. The greatest volume of oxygen per litre of sea water is found at the entrance to the Topdals Fjord where the water from this fjord is mixed with that from the more open Kristiansand Fjord. Such mixing is regularly followed by an abundance of phytoplancton which in turn produces the oxygen.

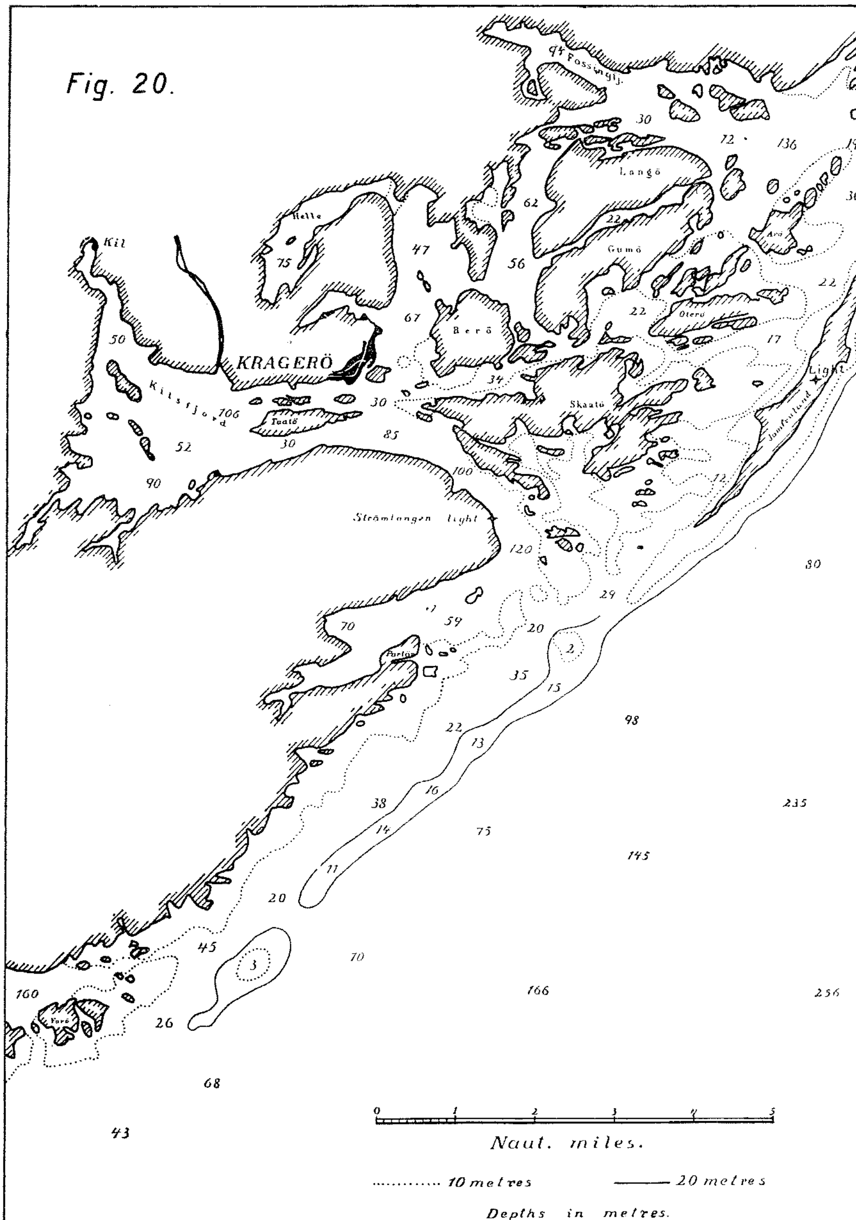
## C. THE WATERS NEAR KRAGERØ.

Something must also be said with regard to the hydrography of the waters in the vicinity of Kragerø. Fig. 20 shows that outside Jomfruland there is a narrow coastal bank. The bottom then falls off towards the great depths of the Skager Rack. Jomfruland is part of an old moraine running to the east and west in long banks with shallow waters. Inside Jomfruland there is a complicated system of fjords. In the main fjord running from the Skager Rack towards the town of Kragerø there are submarine basins on the inside of the Jomfruland barrier with depths of more than 120 metres. At Tåtø the fjord, now 30 metres deep, makes its way through a narrow entrance into the Kils Fjord, a basin with a depth of about 90 metres (vide fig. 24).

Kils Fjord has been examined each year since 1924 at the beginning of September. Fig. 21. shows the average sea temperature and minimum and maximum values observed in the month of September from 1924 to 1937. Complete series for the whole of the year are not available. It will be seen that the temperature is very low from a depth of 30 metres right down to the bottom at a season when the sea-temperature should be at its highest. (Vide fig. 15).

From fig. 22 an idea is obtained as to the variations in salinity in the season in question. In some years the isohaline of 30 $^0/_{00}$ is only a few metres from the surface, in others it is found at a depth of nearly 25 metres. The great variations in the salinity of the surface layers of the fjord have an adverse influence on plant and animal life. The isohaline of 33 $^0/_{00}$ lies between 18 and 40 metres. The salinity at 60 and 80 metres has remained unchanged in all years. It varies only from 33.3 $^0/_{00}$ to 33.9 $^0/_{00}$. It is interesting to note that, in contrast to the Topdals Fjord

Fig. 20.




The Waters Near Kragerö

where the salinity of the deeper parts is regularly more than 34 $^0/_{00}$, water is never found here with a salinity as high as 34 $^0/_{00}$.

Fig. 23 shows the variation in the quantity of oxygen for the same series of years. The water is well saturated with oxygen to a depth of about 30 metres. In the deeper layers the variation is considerable. The bottom layers may for years be contaminated by sulphuric hydrogen. It will be seen that the water here was renewed in 1928, 1930 and 1933, precisely the years in which the bottom layers were renewed in the Topdals Fjord. This, naturally, was to be expected. The renewal of water in the fjords is caused by great submarine waves in the ocean.

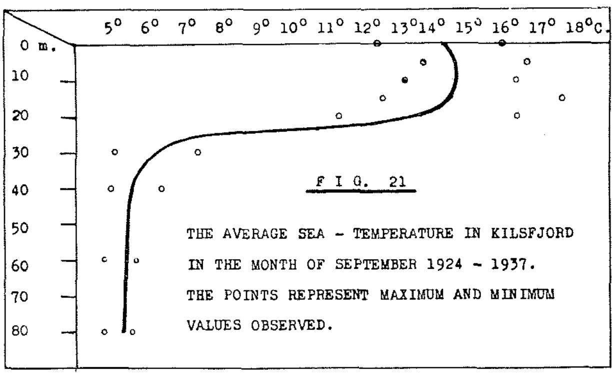



FIG. 21

THE AVERAGE SEA - TEMPERATURE IN KILSFJORD IN THE MONTH OF SEPTEMBER 1924 - 1937. THE POINTS REPRESENT MAXIMUM AND MINIMUM VALUES OBSERVED.

It is clear, however, that the Kils Fjord is more isolated than the Topdals Fjord as contaminated water occurs there more frequently.

The renewal of the bottom layers is of great significance in relation to the occurrence of fish and other animal life in the fjords. In years in which there is a deficiency of oxygen in the bottom layers no animal life can exist there. When the old water is replaced by new conditions of life become good.

In order to illustrate the hydrography of the waters in the season when fish larvae generally occur in the greatest quantities figs. 24 a, b and c are reproduced from our observations of 7.—9. May 1935.

The temperature near the surface ranges from 8 to 11.5° C. (fig. 24 a). At about 10 metres below the surface it is reminiscent of winter conditions. In the Kils Fjord the lowest temperature is recorded at 10 metres, outside Jomfruland at 40 metres.

The isohalines (fig. 24 b) show water of a low salinity everywhere near the surface. The fjord basins are filled with water of a salinity of about 33.5 $^0/_{00}$. At the same depth outside the coast there is water of about 34 $^0/_{00}$.

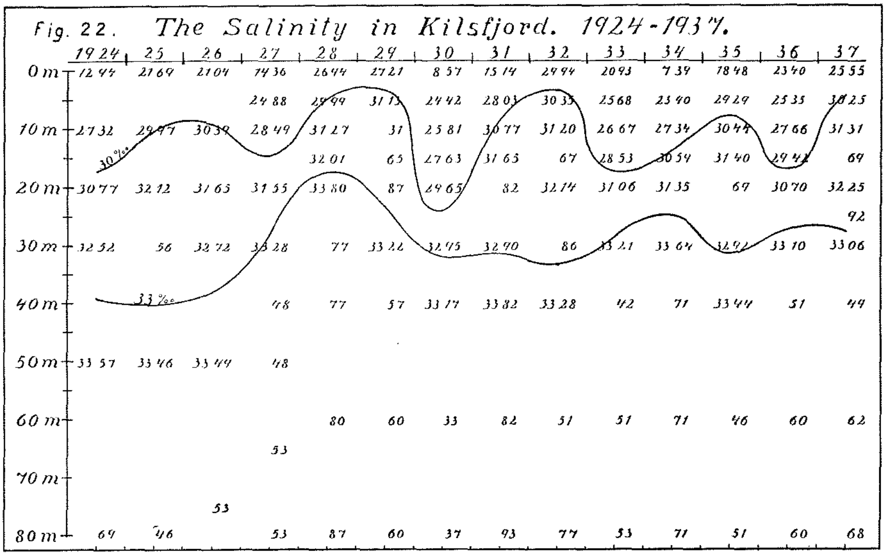



Fig. 22. The Salinity in Kilsfjord. 1924-1937.

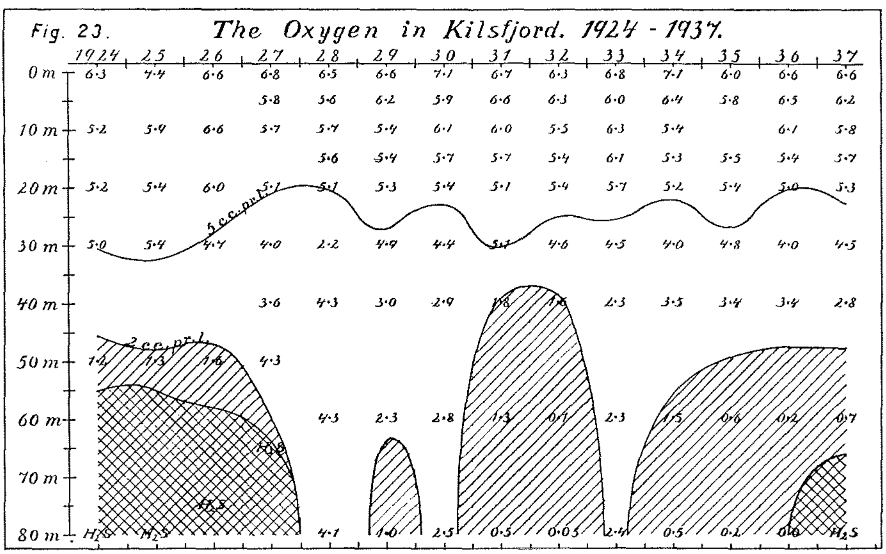



Fig. 23. The Oxygen in Kilsfjord. 1924 - 1937.

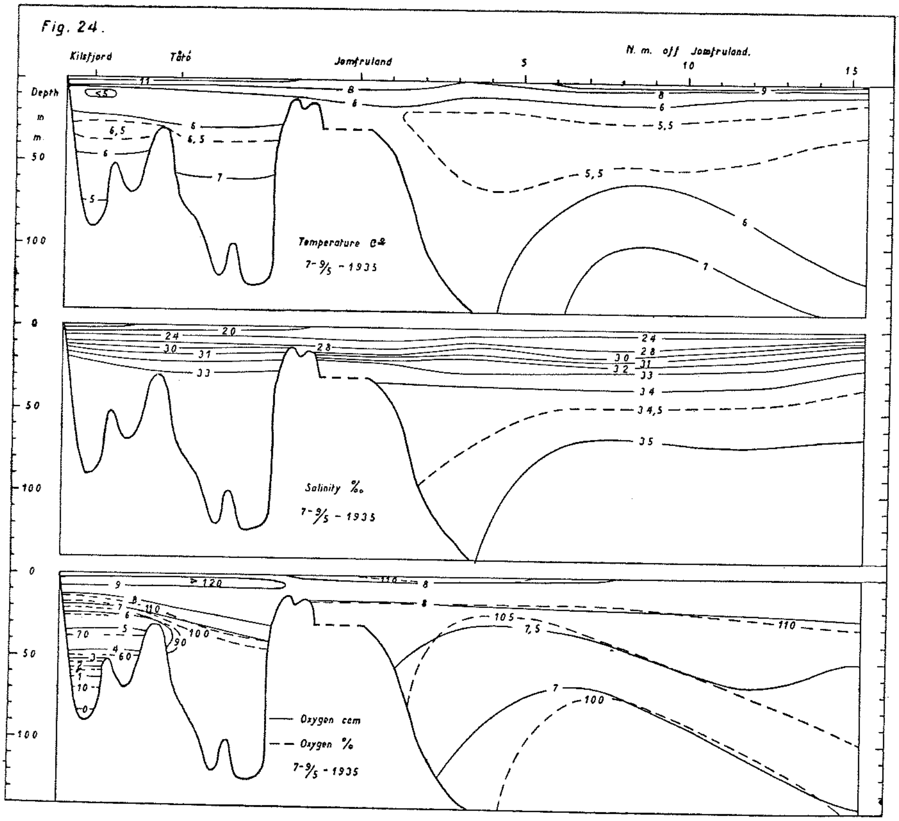



Fig. 24 reveals that the basin of the Kils Fjord is filled with water with a small oxygen content. This is »old« water. Outside the coast the water is well ventilated to the greatest depth examined.

# IV. Fish Eggs and Larvae Collected.

## METHODS.

All our common food fish have pelagic larvae and most of them pelagic eggs. The most prominent species having demersal eggs is the herring. The collection of fish eggs and larvae can therefore be undertaken by pelagic trawling. For taking the eggs and newly-hatched larvae an egg net is used. This has a diameter of 1 metre and a total length of 2.5 metres, 1.6 metres of which is made of silk net No. 0 x x x and the foremost part of thin canvas. The silk net is just fine enough to retain the smallest fish eggs while permitting most of the ordinary plancton material to escape through the meshes. In an outstanding diatomace plancton season filtration, however, may be severely reduced. The filtering ability of the egg net is therefore bound to vary and its efficiency as a fishing implement for larvae and eggs is influenced by the quantities of plancton in general. A strict comparison between catches with regard to numbers found cannot be made but the main figures will undoubtedly be revealed. In the ordinary way the egg net is used horizontally at depths of 0, 10, 20, 30, 50 and 70 metres below the surface, the net being held in position by the trawl wire and a buoy line. A third line from the ship holds the buoy vertically over the net, vide DANNEVIG 1930 (3). The egg net is towed for 10 minutes. In previous investigations the net has been closed by a messenger before being hauled to the surface, but as the closing mechanism is not always reliable it has been omitted in the present investigations. By means of vertical hauls it was demonstrated that the quantities of fish eggs and larvae caught by raising the net were insignificant in comparison with the catches made by horizontal hauls.

For the larger eggs and fry a young-fish net (larvae net) is used, which has a diameter of 2 metres and a total length of 4.75 metres. The forepart of the net is made of ordinary netting with 5 mm square meshes. The narrow end is made of silk netting No. 0000xxx. The filtering ability of the young-fish net is not hampered by ordinary plancton. In a few cases, however, great masses of ctenophores and medusae may hinder filtration to a considerable extent. It is the regular practice to work the young-fish net for periods of 20 minutes at depths of 10, 30 and 70 metres.

By means of fishing for eggs and larvae we have endeavoured to collect information as to their geographical distribution and the water layers in which they occur, and also in regard to the season for spawning and hatching.

The collections of eggs are preserved in a mixture of formaline, glycerine and sea water in the following proportions:

| | |
|---|---|
| Formaline (40 %) ...... | 3 |
| Glycerine .............. | 1 |
| Water.................. | 2 |

This mixture is added to the plancton samples in the proportion 1 : 10. The glycerine enables the eggs to retain a greater degree of transparency than would be the case if formaline alone were used. At the laboratory the samples are sorted under a low power lense and fish eggs and larvae are placed in separate tubes. Identification of the fish eggs is often difficult and in some cases impossible. This is particularly the case with eggs before the embryo has attained its characteristic shape and pigmentation. The eggs, however, may be sorted into two different groups, namely, those *with* distinct oildrop and those *without* oildrop, this feature being, in general, characteristic of the different families. Moreover, the diameter of the eggs is of systematic interest. From table IX A in DANNEVIG 1930 (3) page 132 it will be seen that these characteristics are capable of providing some information in regard to the species in question. When the embryos are fullgrown most of the eggs may be identified as to species. This is also the case with the larvae.

In dealing with the egg material we have therefore noted the diameter of the eggs and any especial features which may be found. The degree of development is also noted in order to mark whether we are dealing with newly spawned eggs or with older stages. This, of course, is of great importance in dealing with the reduction in number of eggs.

To persons particularly interested in the problems dealt with in this paper all details will be made available at this station.

It will easily be understood that to print all the details is out of question in view of the magnitude of our observationes. The material dealt with here has been collected by 520 hauls with the nets and each haul is capable of yielding hundreds of eggs and larvae of nearly all the species which occur in these waters. The hydrographical data consists

*Cod Fry Liberated on the Skager Rack Coast of Norway 1934—37.*
*(Figures in millions of Cod Fry).*

TABLE 2.

| District | 1934 | 1935 | 1936 | 1937 |
|---|---|---|---|---|
| Horten .................. | 10.0 | 10.3 | | |
| Tønsberg—Langesund .... | 84.8 | 84.3 | | |
| Near Kragerø ............ | 64.0 | 68.8 | | |
| Lyngør—Grimstad ........ | 49.2 | 35.9 | 97.7 | 3.0 |
| Grimstad—Kristiansand .. | 7.8 | 4.5 | 15.5 | |
| Near Kristiansand ........ | 10.0 | 10.2 | | |
| West of Kristiansand .... | | | 12.2 | |
| Total | 225.8 | 214.0 | 125.4 | 3.0 |

of about 2000 observations of temperature, salinity and oxygen. The chief results are given below for each series of stations in the form of graphical figures. The main hydrographic conditions are stated and the quantity of eggs at each depth at each station down to 30 metres. The catches in the hauls from 50 and 70 metres yield only a few eggs and larvae of the common fish, but we here find larvae and eggs of deep sea forms. Those hauls are omitted from our figures. Owing to the shallowness of the waters they have not been completed in all cases.

As previously mentioned the diameter of the eggs is of some systematic interest. In the graphs the diameter of the eggs will normally be given when a sufficient quantity occurs. Eggs with oildrops are illustrated by a broken line, those without by a complete line. After having discussed the graphs the different species will be studied in detail.

In the discussion English names will be used for the most common species. In order to avoid misunderstanding the scientific designations are as follows:

Cod = *Gadus callarias L.*, Haddock = *G. aeglefinus L.*, Whiting = *G. merlangus L.*, Pollack = *G. pollachius L.*, Coalfish = *G. virens L.*, Torsk = *Brosmius brosme (Asc.)*, Herring = *Clupea harengus L.*, Sprat = *Cl. sprattus L.*, Mackerel = *Scomber scombrus L.*, Flounder = *Pleuronectes flesus L.*, Dab = *Pl. limanda L.*, Plaice = *Pl. platessa L.*, Long rough Dab = *Drepanopsetta platessoides (O. Fabr.)*.

It will be remembered that the curves showing the hydrographic data were all placed with the shore side to the left. The same system is followed in dealing with the eggs and larvae. By arranging the material in this manner the study of the occurrence of fish eggs and larvae is simplified, and as the chief hydrographic results are set forth in the same figures the correlation may be investigated.

In discussing the material of eggs and larvae collected it should be borne in mind that in some cases cod larvae have been liberated from the Flødevig Sea Fish Hatchery. This may have affected the number of larvae caught. Table 2.

## A. THE WATERS NEAR ARENDAL.

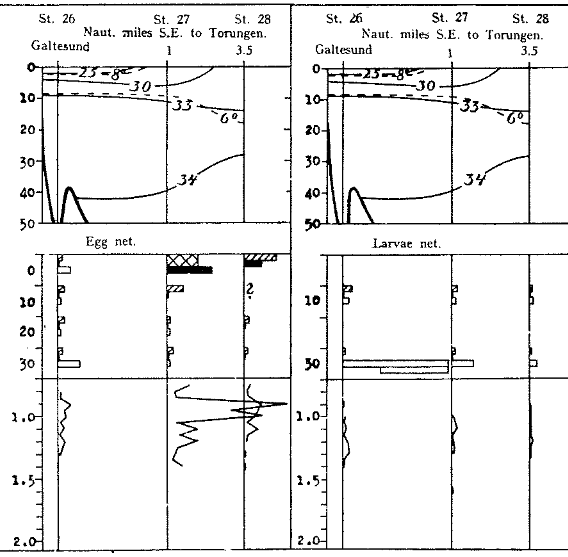
In 1917 and 1924 these waters were investigated more regularly (DANNEVIG 8 and 3). In 1934 only one cruise was made, in 1935 five, in 1936 three and in 1937 two.

In 1934 the waters from Galtesund to 4 nautical miles S.E. of Torungen were examined on 18. to 19. May, fig. 25. The surface layers had acquired a temperature of approximately $8^0$ C. Close to the land salinity was low, less than 25 $^0/_{00}$. A glance at the figure and the detailed tables shows that eggs without oildrop occur in great quantities near the surface at the intermediate station 1 nautical mile off Torungen. The diameter of the eggs varies between 0.9 mm and 1.3 mm, and it is the sprat eggs which predominate. A few eggs of this size also occur at Galtesund and others 3 nautical miles off Torungen. There is also an occurrence of a good quantity of eggs with oildrop at the intermediate station which probably belong to *Onos sp.* Some eggs with oildrop at the inmost and outermost stations appear to belong to the mackerel. At the outmost station, at a depth of 70 metres, 2 eggs of 3.1 mm and 3.2 mm in diameter were found. These belong to the *Argentina silus*. The eggs of *Callionymus lyra* occur at all stations, also some Gadidae eggs, but these have not been identified as regards species. In the case of larvae these occurred most numerously in Galtesund at a depth of 30 metres. The most numerous were *Cyclogaster montagui*, the flounder, cod, dab and several other species.

In 1935 the first hauls with the egg net were undertaken on 18. and 25. February, fig. 26. The temperature at 10 metres was about $4^0$C. and salinity was high nearly up to the surface. The inmost station yielded some eggs without oildrop. The diameter of the eggs was approximately 0.9, 1.35 and 1.7 mm. The small eggs could not be identified but the medium-sized group consisted of cod-haddock eggs. Those species cannot be distinguished in the early stages. Among the larger eggs were some of the plaice while the remainder were from the long rough dab. The outermost station yielded very few eggs. No larvae occurred at the inmost station. At the outermost there were some *Ammodytes tobianus*.

Fig. 25.

18. to 19. of May 1934.



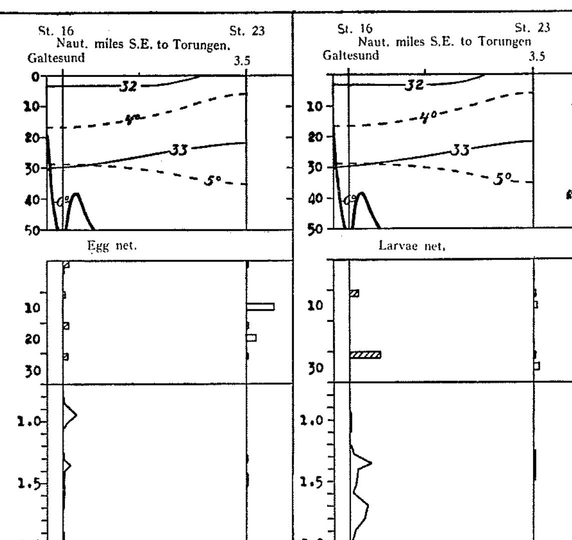

50 eggs without oilgl.
500 » » »
50 » with »
2 larvae.

Occurrence of eggs according to diameter.

——without oilgl.

Fig. 26.

18th of February and 25th of February 1935



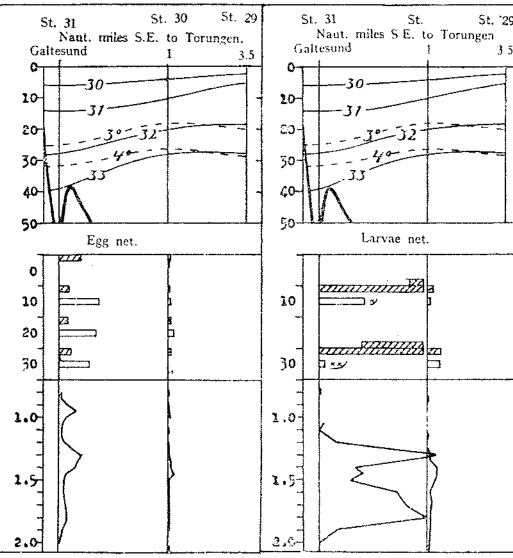

50 eggs without oilgl.
50 » with
2 larvae.

Occurrence of eggs according to diameter.

without oilgl.

Fig. 27.

11th of March 1935.




▨ 50 eggs without oilgl.
■ 50 » with »
□ 2 larvae.

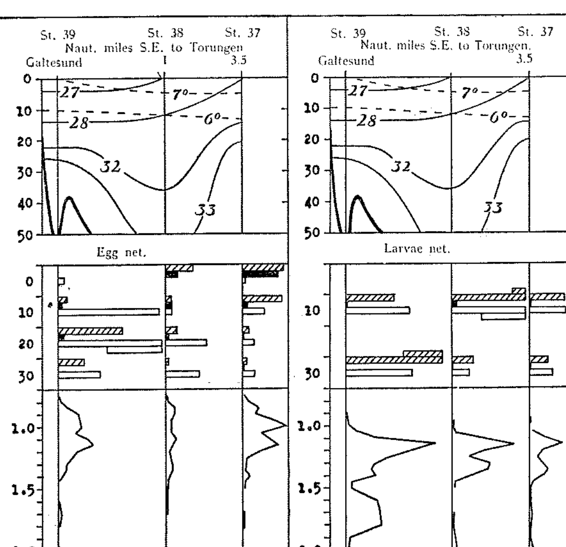
Occurrence of eggs according to diameter.

—— without oilgl.

*) +98 Ammodytes tobianus
**) +20 » »

Fig. 28.

24th of April 1935.




▨ 50 eggs without oilgl.
■ 50 » with »
□ 5 larvae.

Occurrence of eggs according to diameter.

—— without oilgl.

On 11. March (fig. 27) the water was colder, less than 3$^0$ C. down to 20 metres. Salinity was about 30 $^0/_{00}$ in the uppermost layers. From the innermost station we have a few eggs without oildrop approximately 0.9, 1.3 and 1.8 mm in diameter. Among the small eggs we have the flounder, among the medium-sized the cod and among the larger 19 plaice eggs, while the remainder were the eggs of the long rough dab. Eggs with oildrops are practically absent. The larvae, mainly *Ammodytes tobianus* and some *Cottus sp.*, occur particularly at the inmost station.

On 24. April (fig. 28) the water was about 6$^0$ C. down to 10 metres. Salinity was low near the coast. Eggs without oildrop were numerous at 20 metres in the Galtesund and in the upper hauls outside the coast. In the catches in the egg net most of the eggs were small, about 1 mm. Eggs of the *callionymus* , sprat eggs and some *Gadidae* were taken. In the larvae net there was a fair number of larger eggs, particularly from Galtesund, namely cod, haddock, long rough dab and a single plaice egg. There were many larvae, particularly of the herring, at the two inmost stations. Cod occurred at all stations, also haddock. The latter was most numerous at the outermost station.

On 10.—11. May (figs. 29 a and b) the surface temperature exceeded 9$^0$ C. and salinity was below 25 $^0/_{00}$. Eggs without oildrop occurred at all stations except the outermost. In the egg net catches *Callionymus*, sprat and small *Gadidae* eggs were found. In the larvae net there were *Gadidae* eggs (cod identified) and long rough dab. At 4 and 8 nautical miles a good quantity of torsk eggs (*Brosmius brosme*) was taken. The larvae were most numerous at the intermediate stations, cod, haddock and dab occurring most frequently, while at the inmost station there were also some herring larvae. An inspection of the figure and the detailed tables reveals the interesting fact that the greatest number of larvae and the greatest number of species were found just outside the coast.

On 27.—28. June (figs. 30 a and b) the temperature was more than 15$^0$ C. near the surface. Salinity was low down to about 15 metres. At 1.5 nautical miles there was a big quantity of small eggs without oildrop pertaining to *Callionymus lyra*, the dab, sprat and a few *Cadus sp.*, furthermore, some eggs of the cod—haddock group, but these were most numerous at the inmost station in the collection in the great net. A few mackerel eggs were also identified, chiefly at the inmost stations. It is interesting to note that the mackerel eggs occurred particularly at stations with relatively high temperatures, vide isotherm of 11$^0$ C. According to the tables the mackerel were most numerous outside Torungen up to a distance of 12 nautical miles. At 8—12 nautical miles there were enormous quantities of sprat-larvae. They occurred at all

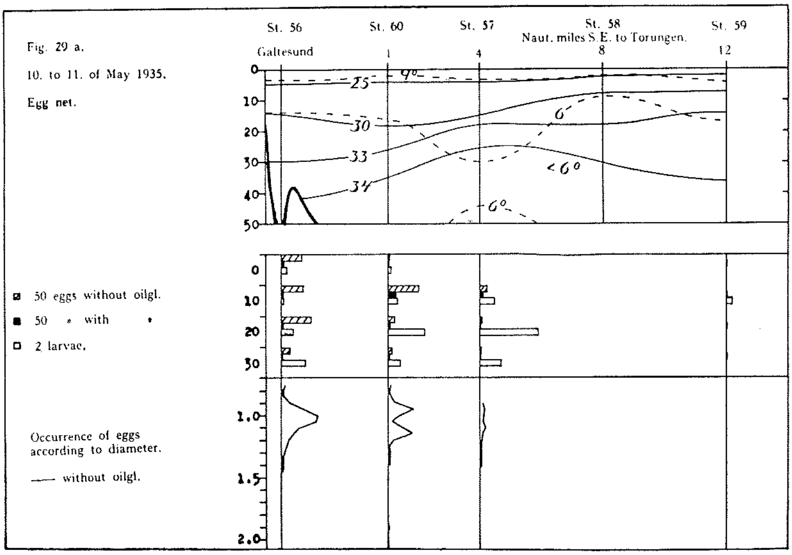


Fig. 29 a.
10. to 11. of May 1935.
Egg net.
St. 56
St. 60
St. 57
St. 58
St. 59
Naut. miles S. E. to Torungen.
Galtesund
50 eggs without oilgl.
50 " with "
2 larvae.
Occurrence of eggs according to diameter.
—— without oilgl.

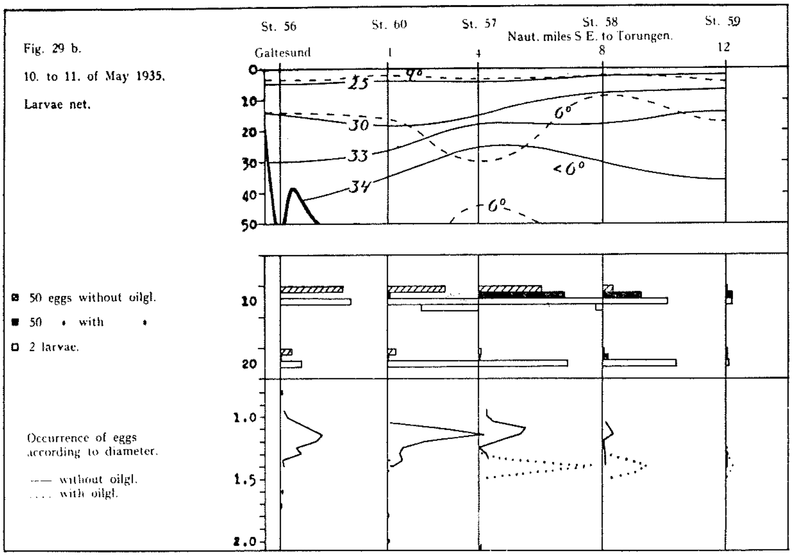


Fig. 29 b.
10. to 11. of May 1935.
Larvae net.
St. 56
St. 60
St. 57
St. 58
St. 59
Naut. miles S. E. to Torungen.
Galtesund
50 eggs without oilgl.
50 " with "
2 larvae.
Occurrence of eggs according to diameter.
—— without oilgl.
.... with oilgl.

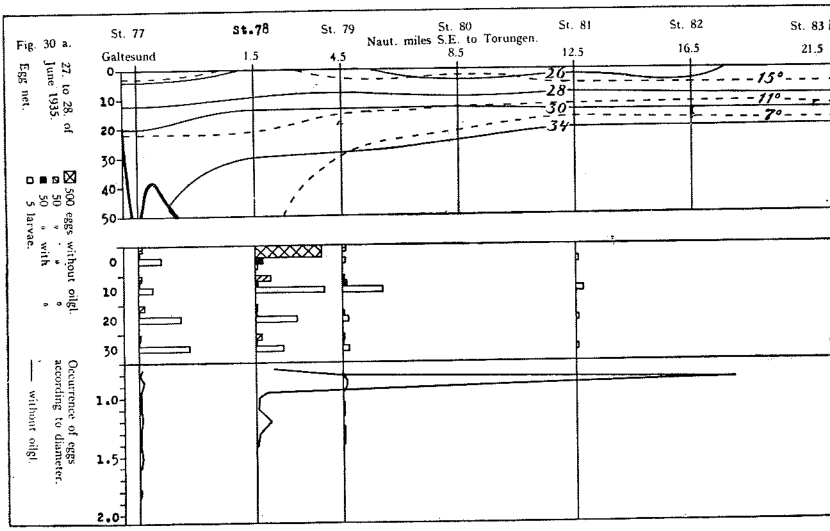



Fig. 30 a.

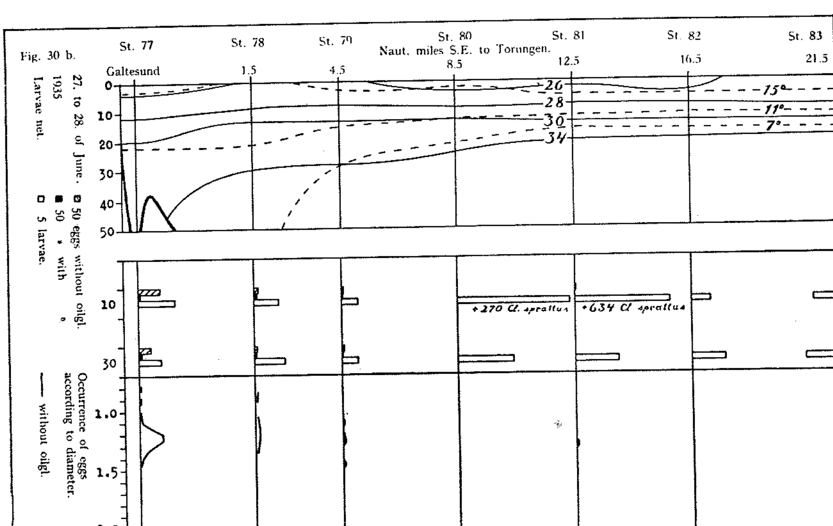



Fig. 30 b.

stations in small numbers. Many other species occurred especially at the intermediate stations.

In 1936 the investigations commenced on 16. January. The temperature near the surface was $3^0$ C. but at 30 metres it was approximately $7^0$ C. No eggs or larvae were caught at distances of 1 and 5 nautical miles from the coast. The temperature was high enough for spawning by most of the fish but the spawning season had not commenced. It is, of course, not only the temperature of the sea water which governs the spawning. It is presumed that the spring spawners will not spawn as a general rule until the temperature has passed a minimum value.

It is possible that lack of light plays a great part. In many cases we have found great numbers of eggs in fjords immediately after the snow and ice has melted. At that precise period conditions for the penetration of light improve.

On 15. May (figs. 31 a and b) more than $12^0$ C. was recorded near the surface, and salinity was low. In the Galtesund fair numbers of eggs without oildrop were caught, including small Gadidae eggs, while the cod—haddock group was well-represented. They were not sufficiently developed, however, to permit of identification. There were a few larvae, mainly haddock and cod, chiefly at the outlying stations.

The final cruise in 1936 took place on 17.—18. June (figs. 32 a and b). The temperature was about the same as in May, except at the actual surface, where $16^0$ C. was recorded in some places. Salinity near the surface was comparatively low, especially at the outermost station. Eggs without oildrop occurred in great quantities from Galtesund to 5 nautical miles off the coast. The small sizes were those of the dab and sprat, the medium sizes were evidently *Gadidae* and *Pleuronectidae*. Eggs with oildrop are mostly those of the mackerel and were very common 10 nautical miles off the coast. Some *Macrurus* eggs were also identified. The egg net yielded enormous quantities of small mackerel larvae and also some sprat larvae. Moreover, a good quantity of other fish larvae was taken, mainly summer spawners, including *Labridae*. The spring spawners were almost absent.

The winter of 1937 was very cold and spawning was retarded. On 28.—29. April (figs. 33 a and b) approximately $6^0$ C. near the surface was recorded and the salinity of the water was low. Great numbers of eggs without oildrop occurred everywhere, especially at 20 and 30 metres. This was very remarkable as the eggs usually occur at 0 and 10 metres (vide DANNEVIG 8). In this case the density of the upper layers was too low for the eggs. The cod and rough dab were identified but other species undoubtedly occurred. The eggs with oildrop were numerous

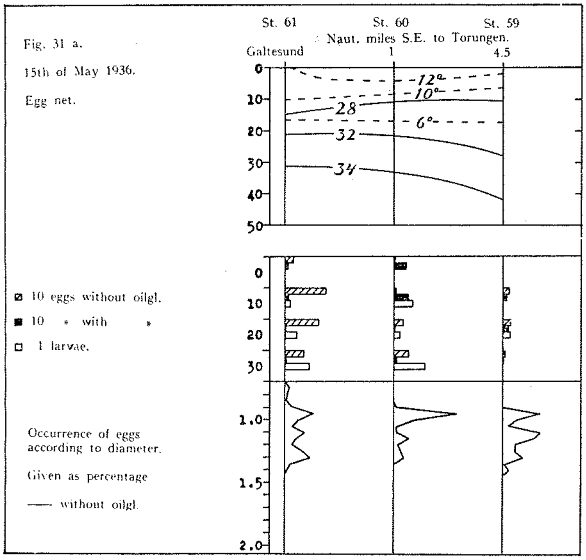


Fig. 31 a.
15th of May 1936.
Egg net.
St. 61
St. 60
St. 59
Naut. miles S.E. to Torungen.
Galtesund
1
4.5
0
10
20
30
40
50
12°
10°
28
6°
32
34
10 eggs without oilgl.
10 » with »
1 larvae.
1.0
1.5
2.0
Occurrence of eggs according to diameter.
Given as percentage
—— without oilgl.

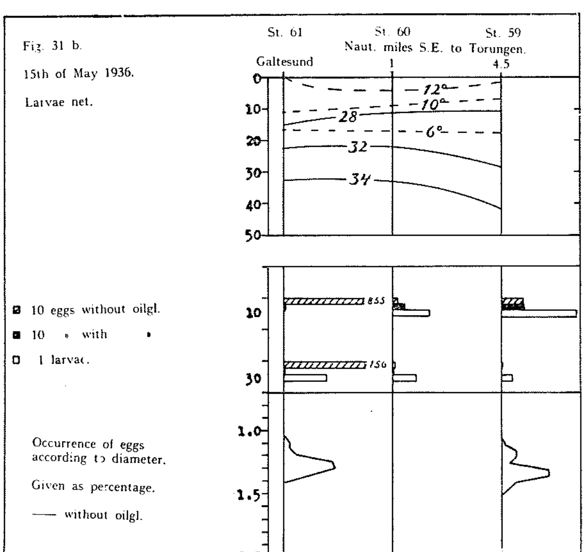


Fig. 31 b.
15th of May 1936.
Larvae net.
St. 61
St. 60
St. 59
Naut. miles S.E. to Torungen.
Galtesund
1
4.5
0
10
20
30
40
50
12°
10°
28
6°
32
34
10 eggs without oilgl.
10 » with »
1 larvae.
855
156
1.0
1.5
2.0
Occurrence of eggs according to diameter.
Given as percentage.
—— without oilgl.

Fig. 32 a.

17. to 18. of June 1936

Egg net.

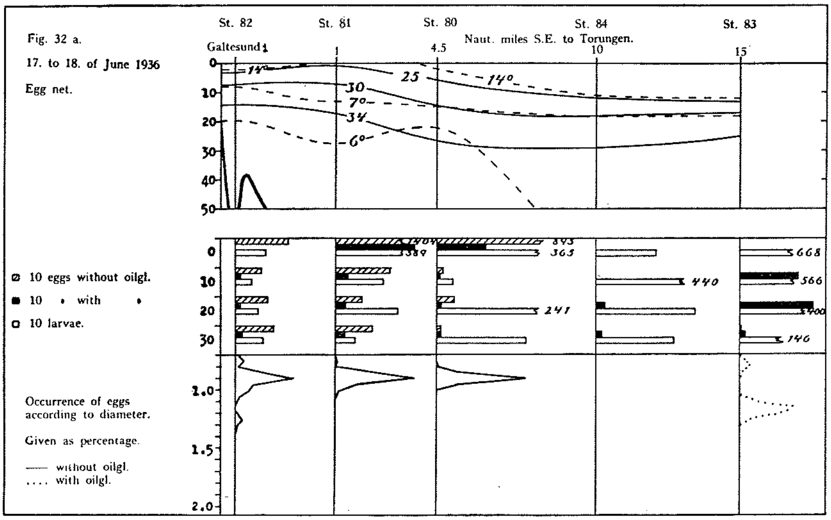
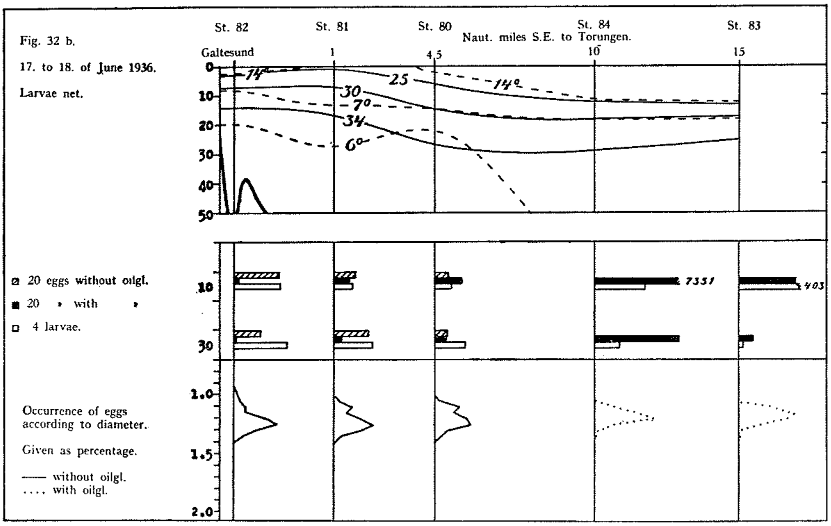



Fig. 32 b.

17. to 18. of June 1936.

Larvae net.



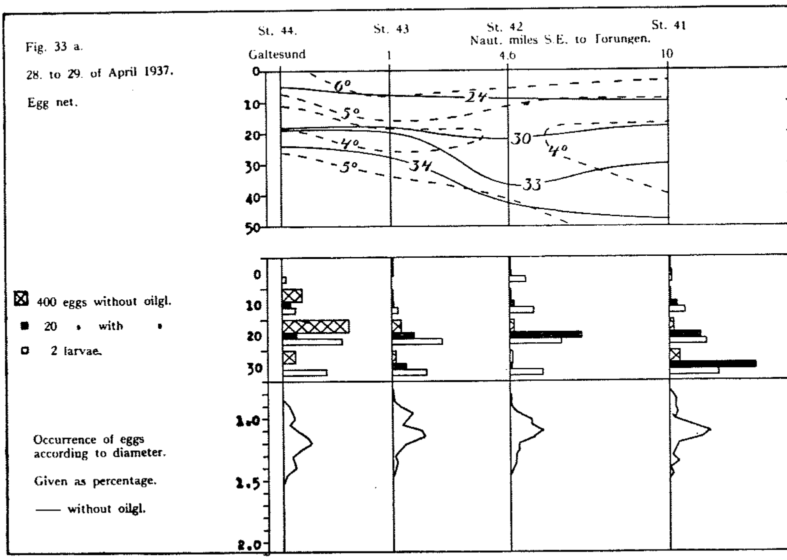


Fig. 33 a.
28. to 29. of April 1937.
Egg net.
St. 44.
St. 43
St. 42
St. 41
Naut. miles S.E. to Torungen.
Galtesund
1
4.6
10
400 eggs without oilgl.
20 » with »
2 larvae.
Occurrence of eggs according to diameter.
Given as percentage.
—— without oilgl.

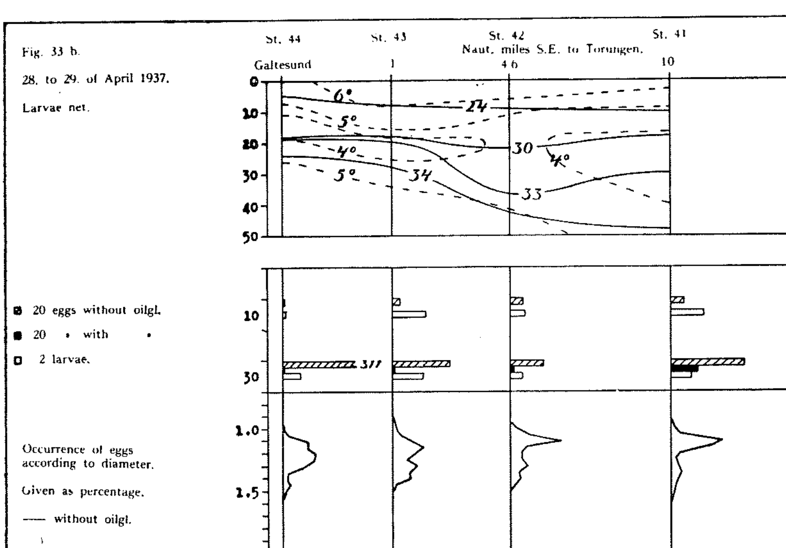


Fig. 33 b.
28. to 29. of April 1937.
Larvae net.
St. 44
St. 43
St. 42
St. 41
Naut. miles S.E. to Torungen.
Galtesund
1
4.6
10
20 eggs without oilgl.
20 » with »
2 larvae.
311
Occurrence of eggs according to diameter.
Given as percentage.
—— without oilgl.

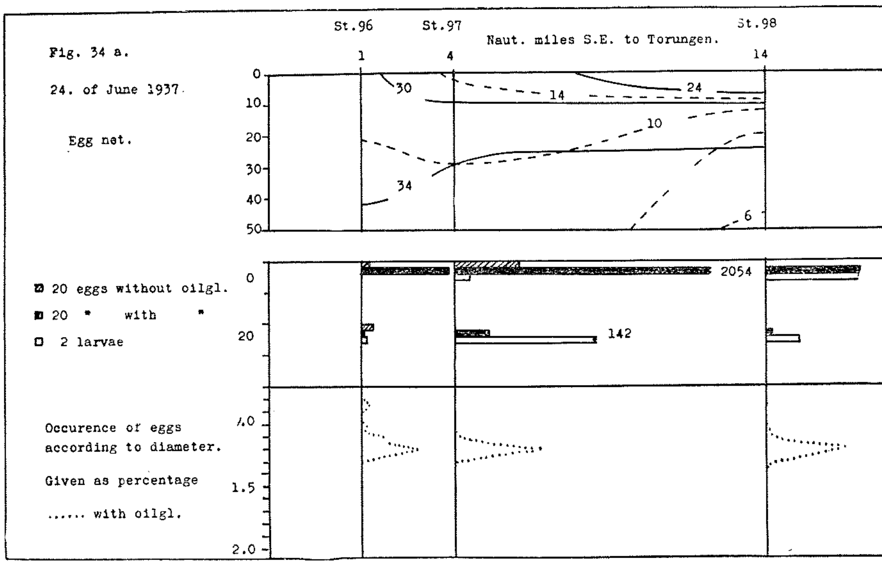


Fig. 34 a.
24. of June 1937.
Egg net.
St.96
St.97
St.98
Naut. miles S.E. to Torungen.
1
4
14
0
10
20
30
40
50
30
14
24
10
34
6
20 eggs without oilgl.
20 " with "
2 larvae
0
20
2054
142
Occurence of eggs according to diameter.
Given as percentage
...... with oilgl.
1.0
1.5
2.0

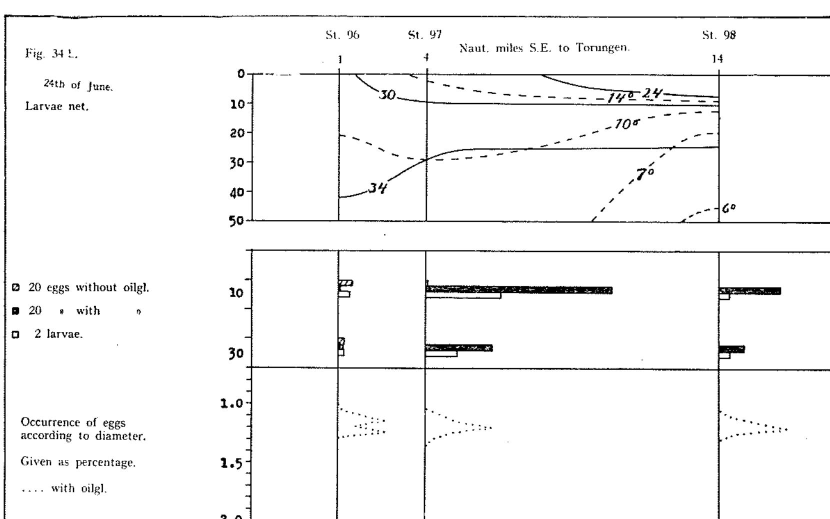


Fig. 34 b.
24th of June.
Larvae net.
St. 96
St. 97
St. 98
Naut. miles S.E. to Torungen.
1
4
14
0
10
20
30
40
50
30
14°
24
10°
34
7°
6°
20 eggs without oilgl.
20 " with "
2 larvae.
10
30
Occurrence of eggs according to diameter.
Given as percentage.
.... with oilgl.
1.0
1.5
2.0

at the outermost station. In this case *Onos* and torsk eggs were identified. Comparatively few larvae were collected.

On 24. June there was a warm and comparatively fresh surface layer at the outermost stations (figs. 34 a and b). Eggs without oildrop occurred in small numbers at the inmost stations; with oildrop they were plentiful, particularly at the intermediate station. These were mackerel eggs. A few *Macrurus* eggs were found and at the outermost station two eggs of the *Argentina silus* were secured. The larvae caught were mainly sprat, mackerel and whiting.

## B. THE WATERS NEAR KRISTIANSAND.

During the cold winter of 1924 these waters were examined for the first time (DANNEVIG 3). On 11.—12. May 1934 hydrographic measurements were taken, and pelagic trawlings carried out, in the Topdals Fjord and outwards to 3 nautical miles S. E. of Oksø. It will be observed (figs. 35 a and b) that in the fjord there is a brackish layer near the surface. This is not present near Oksø, but is again found at a distance of 3 nautical miles, presumably in the area of the Baltic current. The temperature is about $7^0$ C. near the surface and $5.5^0$ C. in the intermediate layers. Fig. 35 a illustrates the catches of eggs and larvae in the egg net. Only 3 stations were examined with the nets, however. A maximum of eggs without oildrop was obtained at the inmost station and near the surface. Values declined outwards and downwards. The diameter of most of the eggs was less than 1.0 mm and the detailed tables show that the eggs here obtained belonged to *Callionymus lyra* and *Pleuronectes sp.* At the outermost station one cod egg was identified and the eggs measuring about 1.1 mm were probably those of a gadid. Eggs with oildrop occurred at Oksø mainly near to the surface. The measurements showed a diameter of approximately 0.8 mm in most cases and *Onos cimbrius* was identified. Other *Onos sp.* probably occurred, however. There were also a few eggs with a greater diameter which were not identified. At a depth of 30 metres at Søm a dozen cod larvae were found. The catches of eggs with the larvae net (fig. 35 b) were small but a good quantity of larvae was taken at Søm. Out of a total of 94 larvae 90 were cod larvae. It will be observed that the great quantity of larvae was caught at a depth of 10 metres, immediately below the brackish layers. In the year in question cod fry from the Seafish Hatchery had been liberated in the fjord near Søm.

The same waters were examined in 1935 from 26. to 27. February (figs. 36 a and b). Owing to ice the Topdals Fjord was not examined.

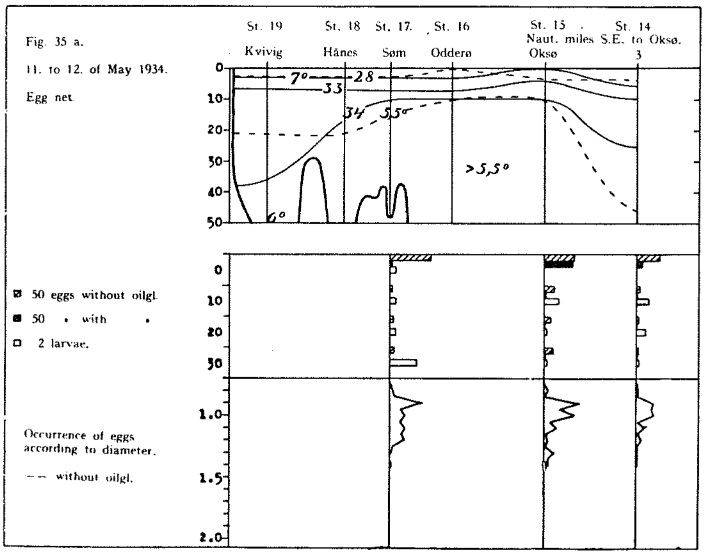


Fig. 35 a.
11. to 12. of May 1934.
Egg net.
St. 19 Kvivig
St. 18 Hånes
St. 17 Søm
St. 16 Oddere
St. 15 Oksø
St. 14 3
Naut. miles S.E. to Oksø.
7°
28
33
34
5,5°
>5,5°
6°
50 eggs without oilgl.
50 » with »
2 larvae.
Occurrence of eggs according to diameter.
— — without oilgl.
0
10
20
30
40
50
1.0
1.5
2.0

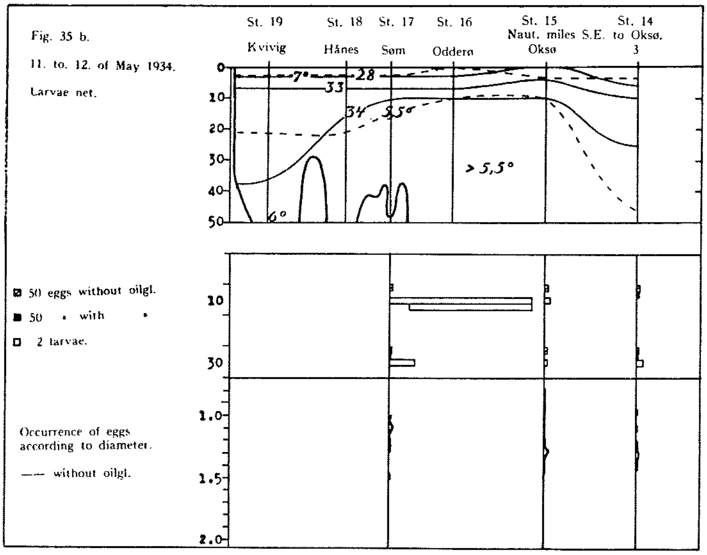


Fig. 35 b.
11. to. 12. of May 1934.
Larvae net.
St. 19 Kvivig
St. 18 Hånes
St. 17 Søm
St. 16 Oddere
St. 15 Oksø
St. 14 3
Naut. miles S.E. to Oksø.
7°
28
33
34
5,5°
> 5,5°
6°
50 eggs without oilgl.
50 » with »
2 larvae.
Occurrence of eggs according to diameter.
— — without oilgl.
0
10
20
30
40
50
1.0
1.5
2.0

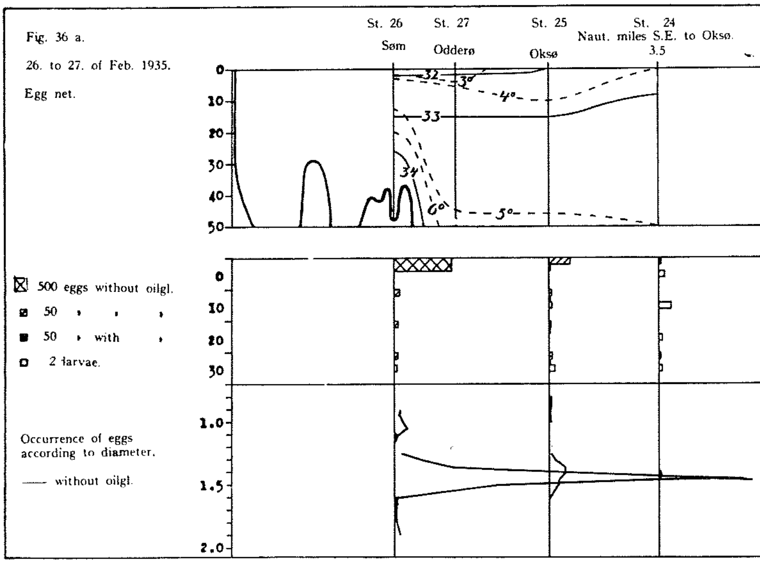



Fig. 36 a. 26. to 27. of Feb. 1935. Egg net.

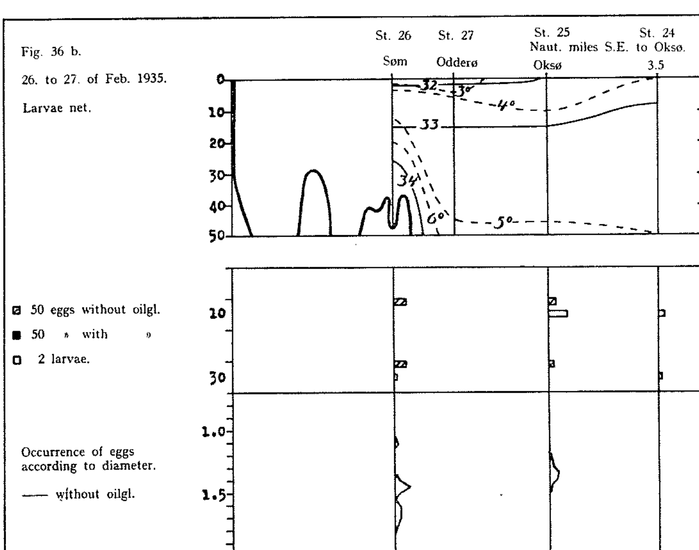



Fig. 36 b. 26. to 27. of Feb. 1935. Larvae net.

The uppermost 10 metres had a temperature of approximately of $3^0$—$4^0$ C. and the salinity was less than 33 $^0/_{00}$. The isohalines and isotherms were considerably depressed on leaving the Topdals Fjord. The water in this fjord is obviously warmer and more salt than that at corresponding depths in the Kristiansand fjord. At the entrance to the Topdals Fjord the egg net yielded in a surface haul more than 2,500 eggs of the cod—haddock group. At the other station only a few eggs were obtained. In the deeper hauls the catches were everywhere small. This was also the case with the larvae net. In all very few larvae were caught.

From 2.—4. May these waters were re-examined (figs. 37 a and b). In the uppermost layers the temperature was now $6^0$—$7^0$ C. and the salinity less than 31 $^0/_{00}$. At the innermost station great quantities of eggs without oildrops were caught in the egg net 20—30 metres below the surface. These were sprat eggs with a diameter of about 1.0 mm. At the other stations only a few eggs without oildrop were found and among these were some from the cod, haddock, long rough dab and *Callionymus*. The sprat had obviously spawned very intensively in the inner part of the fjord. The larvae net catches were largest near Oksø, from the vicinity of which eggs with a diameter of 1.1—1.4 mm were taken. None of them has been identified. Similar sizes occurred at the other stations where cod and haddock were identified. The eggs of the long rough dab occurred everywhere. At the outermost station some eggs were identified as cod eggs. Both the egg net and the larvae net yielded fair numbers of larvae at all places, the herring, cod and haddock being most abundant.

In 1937 only one cruise was made with the special object of ascertaining the spawning of the mackerel (figs. 38 a and b). It will be observed that great quantities of eggs with oildrop and of a diameter of 1.2 mm occurred everywhere, particularly near the surface. These were mackerel eggs. A good number of eggs without oildrop also occurred at the inmost station. The diameter of these was approximately 0.9 mm and they were probably sprat and dab. At the stations near Oksø the great majority of the larvae were sprat larvae, which were found especially at a depth of 20 metres. It will be noted that at the intermediate station mackerel and sprat larvae occurred in about equal quantities whereas at the outermost station the mackerel was in the ascendent. Whiting larvae were found in good numbers, but declining outwards.

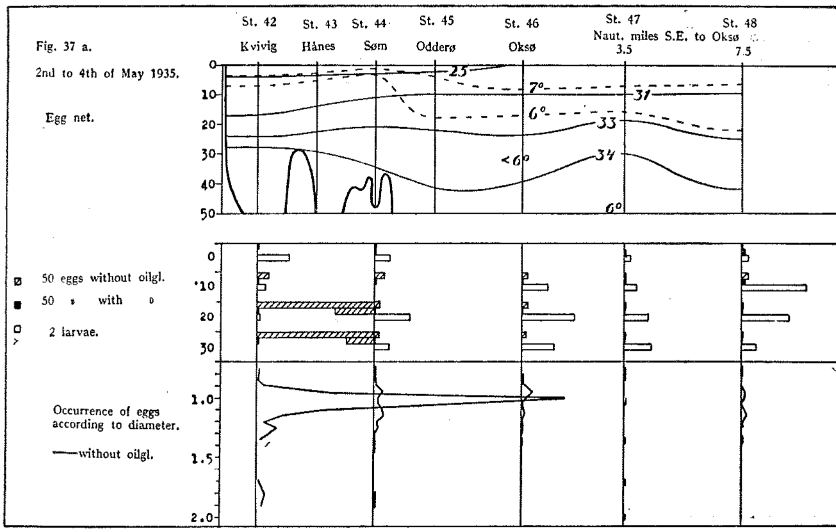


Fig. 37 a.
2nd to 4th of May 1935.
Egg net.
St. 42 Kvivig
St. 43 Hånes
St. 44 Søm
St. 45 Oddernø
St. 46 Oksø
St. 47 Naut. miles S.E. to Oksø 3.5
St. 48 7.5
50 eggs without oilgl.
50 » with »
2 larvae.
Occurrence of eggs according to diameter.
—without oilgl.

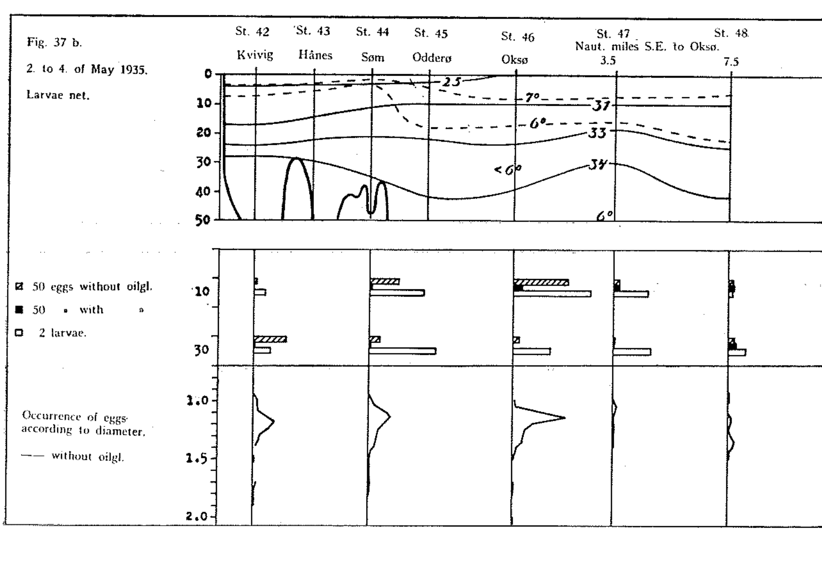


Fig. 37 b.
2. to 4. of May 1935.
Larvae net.
St. 42 Kvivig
St. 43 Hånes
St. 44 Søm
St. 45 Oddernø
St. 46 Oksø
St. 47 Naut. miles S.E. to Oksø. 3.5
St. 48 7.5
50 eggs without oilgl.
50 » with »
2 larvae.
Occurrence of eggs according to diameter.
— without oilgl.

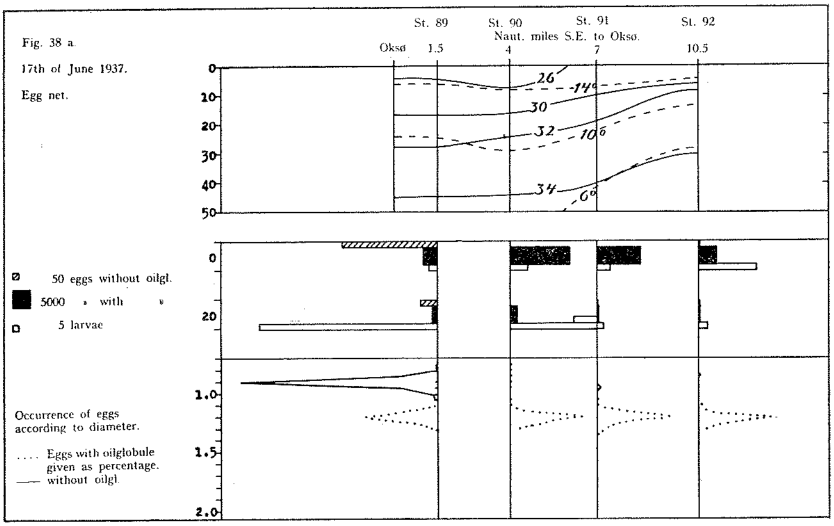


Fig. 38 a.
17th of June 1937.
Egg net.
St. 89
St. 90
St. 91
St. 92
Naut. miles S.E. to Oksø.
Oksø
1.5
4
7
10.5
0
10
20
30
40
50
26
14°
30
32
10°
34
6°
0
20
50 eggs without oilgl.
5000 » with »
5 larvae
1.0
1.5
2.0
Occurrence of eggs according to diameter.
.... Eggs with oilglobule given as percentage.
—— without oilgl.

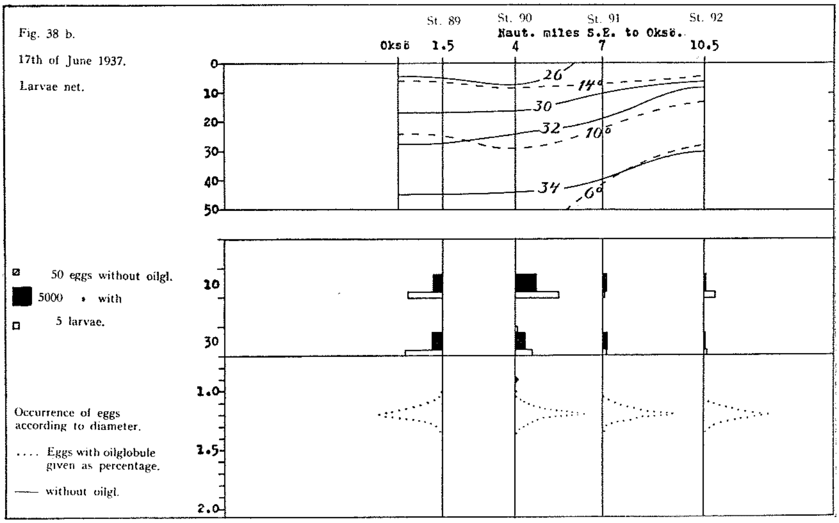


Fig. 38 b.
17th of June 1937.
Larvae net.
St. 89
St. 90
St. 91
St. 92
Naut. miles S.E. to Oksö.
Oksö
1.5
4
7
10.5
0
10
20
30
40
50
26
14°
30
32
10°
34
6°
10
30
50 eggs without oilgl.
5000 » with
5 larvae.
1.0
1.5
2.0
Occurrence of eggs according to diameter.
.... Eggs with oilglobule given as percentage.
—— without oilgl.

## C. THE WATERS NEAR KRAGERØ.

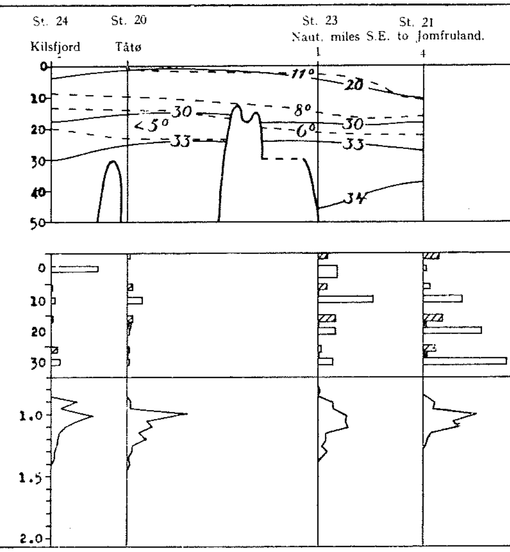
These waters were investigated from 14. to 16. May 1934 (figs. 39 a and b). The temperature near the surface was about 11° C. At 10 metres 8° C. was found in the fjord and at 17 metres outside of Jomfruland. Down to approximately 18 metres the salinity of the surface layers was less than 30 ‰. In the egg net collections there were a few eggs without oildrop taken at the outermost stations. The eggs here were mainly 1.0 mm and 1.1 mm in diameter. Both sprat and Gadidae eggs were identified. The former also occurred at the inmost station and among the larger eggs from this station there were a few cod with developed embryos. Owing to the larger meshes in the larvae net the small eggs are not retained in the collections made with it. But it contained a good quantity with diameters ranging from 1.0 mm to 1.5 mm, particularly from 2 nautical miles off Jomfruland. Eggs of a diameter of 1.1 and 1.3 mm were especially conspicuous, the smaller size being apparently Gadidae, with short and thick embryos. Among the larger size both cod and haddock were identified. This was remarkable in view of the late date. From the detailed tables it emerges that the sprat eggs were most abundant near the surface. The cod group did not occur so near the surface but were most plentiful at depths of 20 and 30 metres. On comparing the hydrography it is interesting to note that the sprat eggs occurred in the warmer and fresher layers, the cod in the colder and more salt. This is in conformity with the nature of these species. In the egg net larvae occurred in good quantities, particularly at the outermost stations. A good number was also obtained in the larvae net just outside of the Kils Fjord. A glance at the detailed tables shows the larvae at the inmost station to be mostly cod. In the Kils Fjord some millions of cod fry had been liberated a few weeks previously. At the outermost station a good quantity of dab and Norway pout was found.

In 1935 these waters were examined on 19. to 21. February. As will be seen from the isotherms (figs. 40 a and b) the water outside the coast was very cold, the surface temperature being just over 3° C. At 34 metres the temperature was 4° C. In the fjord there was more than 6° C. from about 5 metres. The isohaline of 33 ‰ was situated in the vicinity of 20 metres in the fjord, while outside the coast it was at a depth of more than 40 metres. Fishing with the egg net in the fjord yielded a fair number of eggs without oildrop, particularly close to the surface. The egg measurements show that eggs of different diameter occurred. There were some small eggs of about 0.9 mm, especially at 0 and 10 metres. The cod—haddock group occurred at the same depths, and there were some larger eggs of approximately 1.9 mm, particularly

Fig. 39 a.

14. to 16. of May 1934.

Egg net.




50 eggs without oilgl.
50 » with »
20 larvae
2 »

Occurrence of eggs according to diameter.

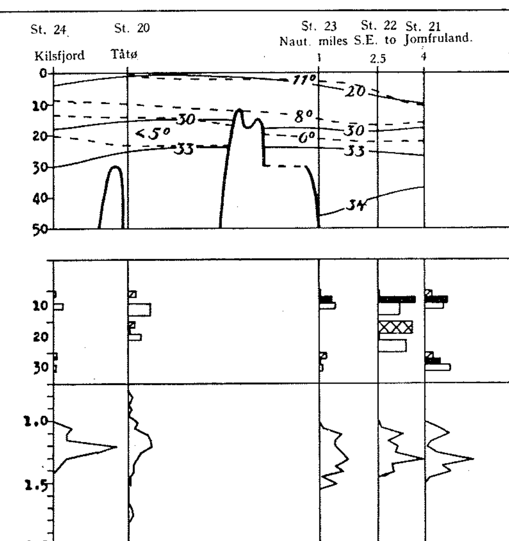
Given as percentage.

—— without oilgl.

Fig. 39 b.

14. to 16. of May 1934.

Larvae net.




500 eggs without oilgl.
50 » » »
50 » with »
20 larvae
2 »

Occurrence of eggs according to diameter.

Given as percentage.

—— without oilgl.

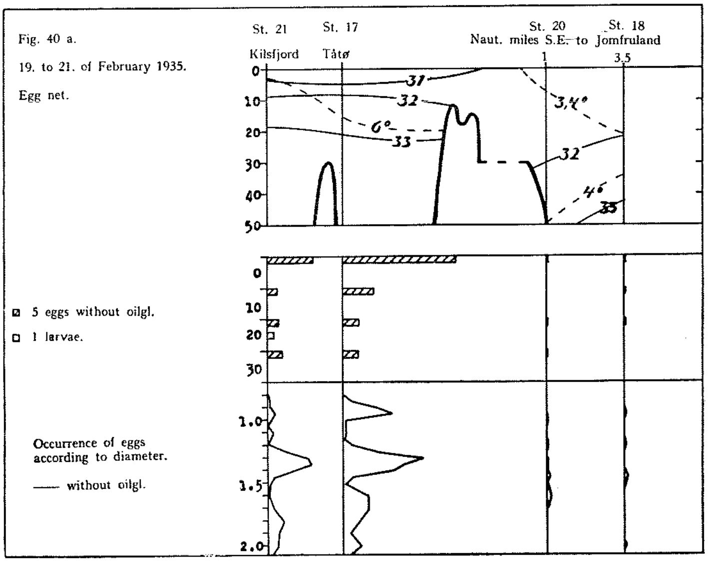


Fig. 40 a.
19. to 21. of February 1935.
Egg net.
St. 21
Kilsfjord
St. 17
Tåtø
St. 20
St. 18
Naut. miles S.E. to Jomfruland
1
3.5
0
10
20
30
40
50
37
32
6°
33
3,4°
32
4°
33
5 eggs without oilgl.
1 larvae.
0
10
20
30
Occurrence of eggs according to diameter.
—— without oilgl.
1.0
1.5
2.0

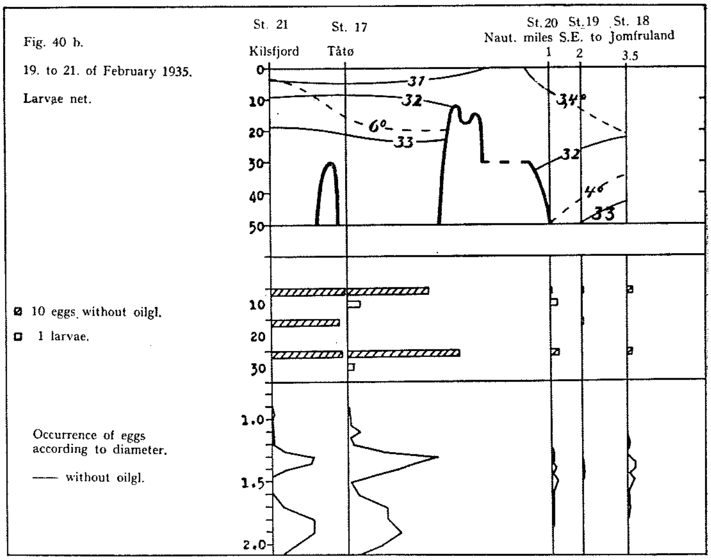



Fig. 40 b.
19. to 21. of February 1935.
Larvae net.
St. 21
Kilsfjord
St. 17
Tåtø
St. 20
St. 19
St. 18
Naut. miles S.E. to Jomfruland
1
2
3.5
0
10
20
30
40
50
37
32
6°
33
3,4°
32
4°
33
10 eggs without oilgl.
1 larvae.
10
20
30
Occurrence of eggs according to diameter.
—— without oilgl.
1.0
1.5
2.0

at 20 and 30 metres; these were the eggs of the long rough dab. The great net also yielded from the fjord a fair number of eggs without oildrop, but the smallest size of eggs was lacking and those of the cod—haddock group and the long rough dab were predominant. Very few larvae occurred and these only from winter spawners. This cruise presented a very interesting example of the correlation between an optimum sea temperature and a fair number of eggs. The eggs occurred only in the fjord where there was a temperature of about 6° C. and there was practically none outside of Jomfruland where the temperature was approximately 3°—4° C.

From 7.—9. May a re-examination of these waters was carried out (figs. 41 a and b). There were no great differences between the temperatures and salinities of the waters inside the fjord and outside of Jomfruland. A study of the diagram of the catches in the egg net reveals great differences in the eggs and larvae taken in the different areas. In the fjord eggs without oildrop and of a diameter of approximately 1.0 mm, mainly sprat eggs, were predominant at 10 and 20 metres. Outside the coast these eggs were scarce, but some occurred 15.5 nautical miles off Jomfruland. Eggs with oil globules (*Onos sp.*) were numerous at a distance of 1—4 miles. In the larvae net a fair quantity of eggs was found, especially in the fjord at Tåtø. In two hauls more than 1000 eggs of different species were taken here. Cod eggs were identified at most of the stations. In contradistinction to the eggs the larvae were most numerous just outside the coast, and there was a maximum between 1 and 8 n. m. outside Jomfruland. The larvae net especially yielded fine collections of young cod, young haddock and dab. This cruise provides a good illustration of the manner in which the community of eggs and larvae may vary from one locality to another.

In 1937 the waters near Kragerø were examined from 31. May to 2. June (figs. 42 a and b). The temperature was about 12° C. near the surface and in the deeper layers below 6° C. The salinity of the surface layers was less than 24 ‰. The egg net everywhere yielded a fair number of eggs without oildrop which to a great extent were sprat eggs. Eggs with oildrop, namely, mackerel eggs, occurred most numerously outside the coast. Eggs taken in the larvae net in the fjord were without oildrop. Near the coast both kinds occur while further out the latter were predominant. Eggs without oildrop come partly from the sprat while those with oildrop are chiefly mackerel. This alternation between sprat eggs near the coast and mackerel eggs further out was also remarked in the waters near Kristiansand (vide page 64). From a study of the detailed tables it is apparent that the eggs were generally most numerous at depth of 10 metres in the fjord, but near to the surface outside the

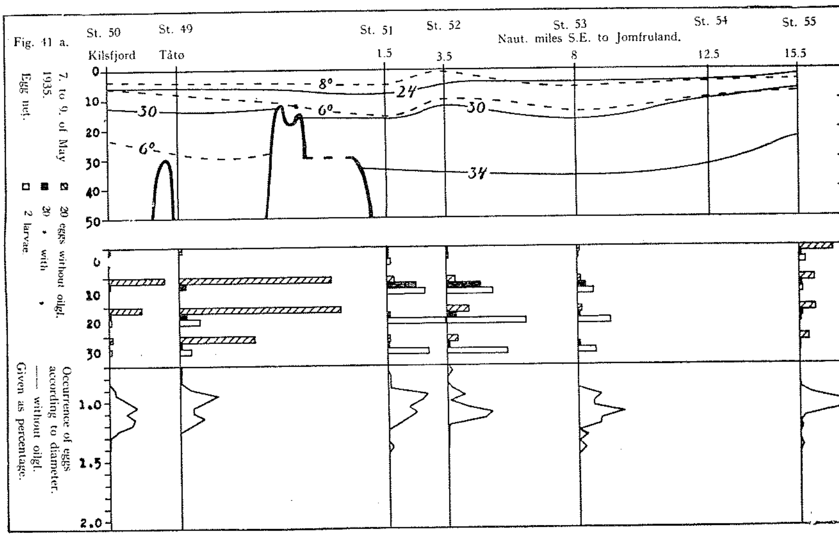


Fig. 41 a. 7. to 9. of May 1935. Egg net.

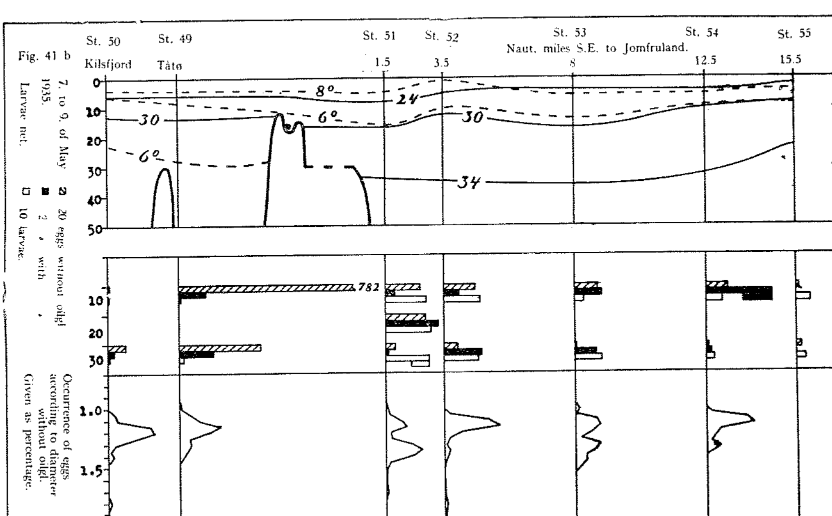
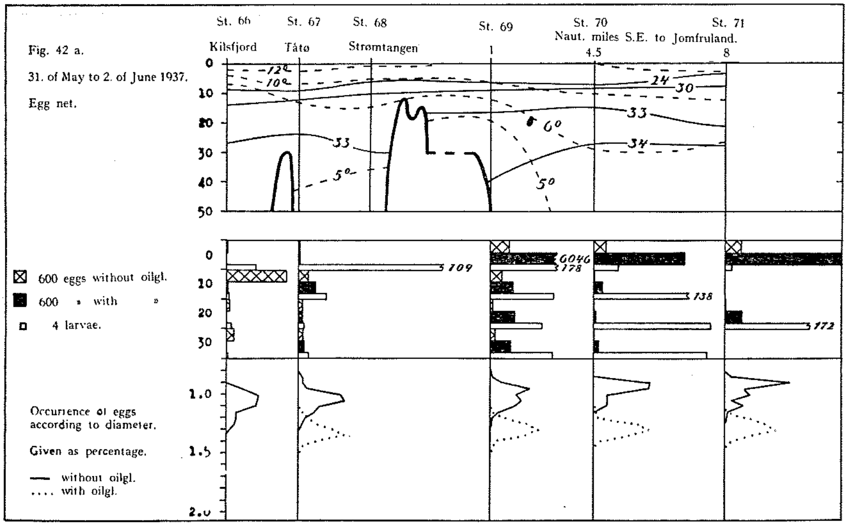
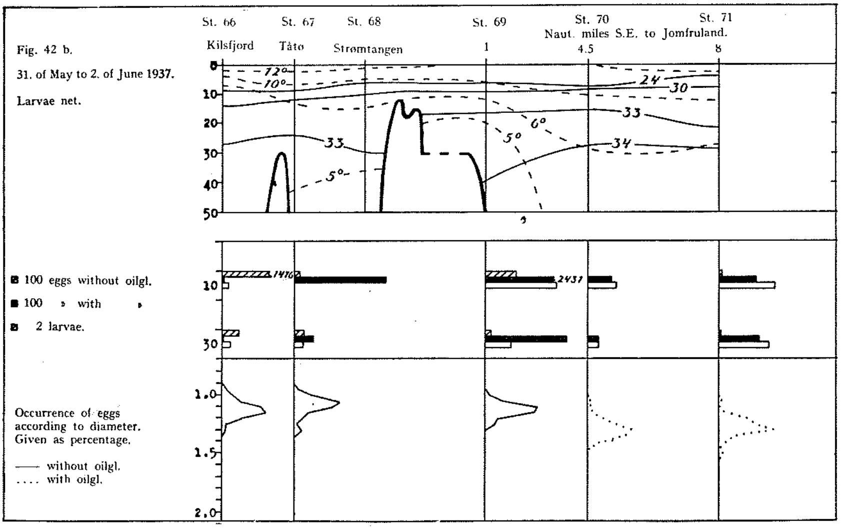


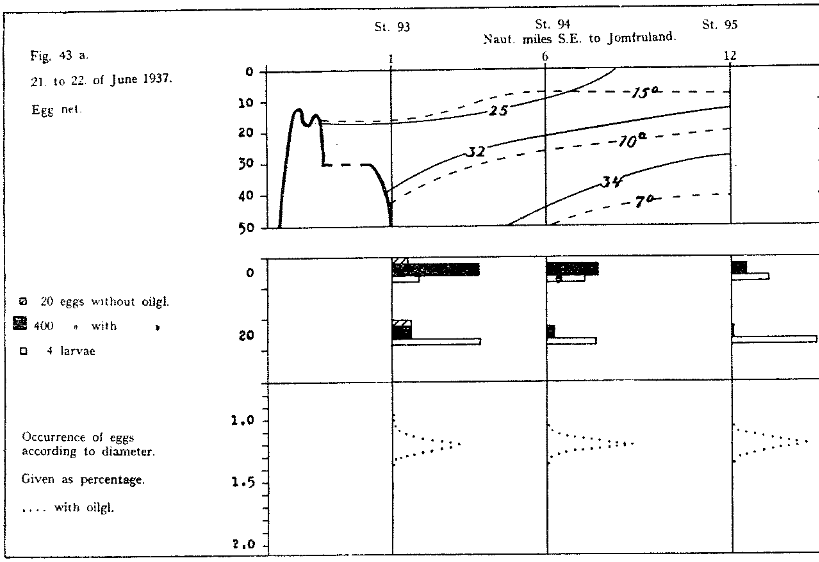
Fig. 41 b. 7. to 9. of May 1935. Larvae net.

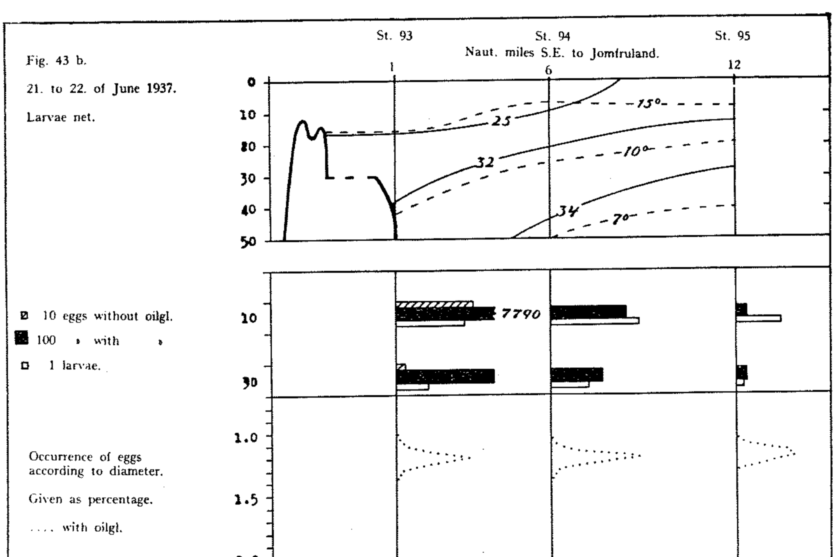


St. 66
St. 67
St. 68
St. 69
St. 70
St. 71
Naut. miles S.E. to Jomfruland.
Kilsfjord
Tåtø
Strømtangen
1
4.5
8
Fig. 42 a.
31. of May to 2. of June 1937.
Egg net.
600 eggs without oilgl.
600 » with »
4 larvae.
Occurrence of eggs according to diameter.
Given as percentage.
—— without oilgl.
.... with oilgl.
709
6046
178
738
772

St. 66
St. 67
St. 68
St. 69
St. 70
St. 71
Naut. miles S.E. to Jomfruland.
Kilsfjord
Tåtø
Strømtangen
1
4.5
8
Fig. 42 b.
31. of May to 2. of June 1937.
Larvae net.
100 eggs without oilgl.
100 » with »
2 larvae.
Occurrence of eggs according to diameter.
Given as percentage.
—— without oilgl.
.... with oilgl.
1476
2431


St. 93
St. 94
St. 95
Naut. miles S.E. to Jomfruland.
Fig. 43 a.
21. to 22. of June 1937.
Egg net.
1
6
12
0
10
20
30
40
50
15°
25
32
10°
34
7°
20 eggs without oilgl.
400 » with »
4 larvae
0
20
Occurrence of eggs according to diameter.
Given as percentage.
.... with oilgl.
1.0
1.5
2.0


St. 93
St. 94
St. 95
Naut. miles S.E. to Jomfruland.
Fig. 43 b.
21. to 22. of June 1937.
Larvae net.
1
6
12
0
10
20
30
40
50
15°
25
32
10°
34
7°
10 eggs without oilgl.
100 » with »
1 larvae.
10
30
7790
Occurrence of eggs according to diameter.
Given as percentage.
.... with oilgl.
1.0
1.5
2.0

coast. In the fjord there was a thin layer of fresh water which prevented the eggs from coming to the surface. In this particular case the egg net provided a great quantity of sprat larvae while off Jomfruland the dab occurred in good numbers. As the detailed tables show the sprat larvae occurred in the surface haul catches, the dab larvae evidently prefering deeper water. The larvae net yielded, from the outer stations especially, some larvae of different species. The small sprat and dab larvae passed through the meshes of this gear.

On 21. to 22. June an examination was made of the waters outside Jomfruland. Summer temperatures now ruled in the sea (fig. 43 a and b) more than 15° C. being recorded at the surface. The water near the coast had a salinity of less than $25^0/_{00}$. Both the egg net and the larvae net yielded a quantity of eggs without oildrop at the innermost station. At the same place, however, great quantities of mackerel eggs were obtained, the number declining in an outward direction. Some of the larger eggs with oildrop were *Macrurus sp.* In the egg net in particular fine catches of young mackerel and sprat larvae were obtained.

## D. SPECIES OBSERVED.

It is difficult to classify the data collected on the cruises mentioned in the previous pages, and we must confine ourselves to a brief reference to the most prominent species, endeavouring to throw some light on the season at which spawning commences and when pelagic larvae occur. Mention will also be made of the occurrence of eggs and larvae in relation to the waters in question. In a subsequent paper I hope to return to various points of biological interest. The results of the investigations in 1917 and 1924 are included.

Figs. 44 a and b illustrate the occurrence of *cod and haddock eggs and larvae* identified in the waters near Arendal. The eggs without oildrop with a diameter of 1.25 to 1.50 mm belong mostly to the cod or haddock. In the early stages those species can not be distinguished. In the figures they are indicated by numbers. The eggs of the cod and haddock group occurred during all cruises except in January 1936. In the month of February a few eggs were found and in March and April there were a good number in Galtesund. In May and June some eggs of the cod—haddock group were also found, particularly in Galtesund. We may thus assume that the spawning of the cod and haddock generally occurs here in March and April.

The figure also demonstrates that the cod—haddock group of newly-spawned eggs is most aboundant in Galtesund and 1—2 nautical miles off Torungen, thus indicating the vicinity of spawning places. Cod eggs (in late stages) occur nearly everywhere, except at the outermost stations. Haddock eggs (in late stages) are comparatively scarce, but in April 1935 they occurred in numbers from 1—2 nautical miles off Torungen. Cod larvae occurred from April to the middle of June, and most abundantly in May. The greatest quantities were generally caught near the coast and declined in number outwards. Haddock larvae occurred in good quantities in April and May outside Torungen and, similar to the cod, were scarce at the outermost stations. The haddock was almost non-existent in Galtesund.

In fig. 45 will be found the results for cod and haddock near Kristiansand. It is difficult to express a definite opinion in regard to the spawning season owing to paucity of investigations. But it will be seen from the figures that the cod-haddock group occurred both at the close of February and at the beginning of April 1924, on each occasion at the entrance to the Topdals Fjord, with declining numbers outward. In May 1924 the number of eggs had dropped. A few cod eggs were identified at the utmost stations and some haddock eggs at the outermost.

Cod larvae were most numerous at Søm and haddock occurred only in the vicinity of Oksø.

On 11.—12. May 1934 few eggs were obtained, but a great number of cod larvae at the inmost station. As previously mentioned cod fry had been liberated in the fjord near Søm in the year in question.

In February 1935 large quantities of newly-spawned eggs were caught at the inmost station. In May of the same year eggs were scarce but there were fair numbers of cod larvae at Søm and Oksø. Some haddock eggs in late stages — and larvae — occurred at the outermost stations. In June 1937 there was an absence of cod—haddock eggs from the waters examined.

Fig. 46 sets forth the total result in respect of the collection of cod and haddock eggs and larvae from the vicinity of Kragerø. A maximum of cod and haddock eggs occurred from the fjord itself and outwards to 2 nautical miles off the coast. Cod fry occurred in large numbers from Tåtø to about 8 nautical miles outside the coast.

In May 1934 cod fry were most numerous in the fjord and in May 1935 just outside the coast but the number decreased in an outward direction. In both years cod larvae were liberated in the fjords. Haddock fry occurred almost exclusively outside the coast. It seems evident from the figure that the greatest numbers of cod—haddock eggs are likely to occur from February to May. The greatest numbers of cod and haddock larvae occur late in April or in May. It is worth noting that in the month of June only a few eggs and larvae are to be caught. This is of particular interest as it has been assumed by DAHL that the littoral stock of young cod in the fjord may be augmented by pelagic fry during the summer.

Finally, in all the waters examined both eggs and larvae of cod occurred in the greatest quantities in the fjords or very near to the coast Haddock eggs and larvae occur more especially outside the coast and at a greater distance from the shore.

In figs 47 a, b, 48 and 49 the results in respect of the occurrence of *sprat larvae* have been summarized. Owing to the fact that it is difficult, in some cases, to identify sprat eggs numbers of eggs are not quoted. In the waters examined the eggs and larvae occur especially in May and June. In one case, namely, May 1935, a large quantity of eggs was found in the inner basin of the Topdals Fjord. In the middle of June 1937 great quantities of eggs were found 1.5 nautical miles outside of Oksø. In a previous paper (DANNEVIG 3) mention was made of the fact that the eggs and larvae of this species were found as early as the middle of April in the Frier Fjord, near Langesund. The early spawning of the sprat in the Norwegian Skager Rack fjords has previously been remarked by DAHL, 1906 (6) and SUND 1910 (19). The observations made tend to show that the sprat spawning season may occur in the fjord basins as early as the middle of April. The chief spawning season outside the coast is at least one month later.

As the eggs of *the herring* are demersal the time of spawning cannot be ascertained by pelagic trawling. The occurrence of herring larvae in the years 1917 and 1924 is quoted in the paper already referred to (DANNEVIG 3). In the years here dealt with the herring larvae occurred particularly in April—May and at the beginning of June, and were almost exclusively found in the fjords or near the coast. (Figs. 47 a, b, 48 and 49).

*Mackerel* eggs do not occur in great quantities until June (figs. 47 a, b, 48 and 49). Larvae are then also found in abundance and from the figs. it is evident that they are numerous from the coast and outwards, as far as our investigations go to show. This conforms to the spawning habits of the mackerel which is a pelagic fish which spawns near the surface in the open sea. The herring is also a pelagic fish but since its eggs are demersal spawning takes place close to the shore, or in comparatively shallow water where the larvae are also found.

*Whiting* larvae and young fish (figs. 47 a, b, 48 and 49) are caught in April—May and June and the pelagic stages of this fish undoubtedly cover the summer and autumn. They are found at all places, from the fjords to far out in the Skager Rack, possibly in greater numbers comparatively speaking from the coast outwards to a distance of 6 nautical miles.

As regards *flat fish* the larvae of the *long rough dab* are found from the skerries and out to the limit of our investigations, and most numerously in the skerries (Galtesund) to a distance of 3 nautical miles off the coast. The *flounder* occurs in comparatively great numbers in Galtesund and some few specimens are also found outside the coast. The *dab* is numerous preferably outside the coast.

It is evident that some species occur in nearly all areas investigated. Others are more specific in their distribution. On the basis of a summary of the detailed tables we find that the following species occur numerically in the fjord, the skerries and the waters just outside the coast:

TABLE 3.

| | The fjords | | The skerries | The coastal waters |
|---|---|---|---|---|
| Near Arendal ...... | | | Galtesund<br>32 (5) | 1—1.5 n.m. off Torungen<br>31 (9) |
| Near Kristiansand.. | Topdalsfjord (Søm)<br>11 (2) | | Oksø<br>12 (3) | 1—1.5 n.m. off Oksø<br>12 (6) |
| Near Kragerø .... | Kilsfjord<br>6 (0) | Tåtø<br>14 (3) | | 1—2 n.m. off Jomfruland<br>22 (11) |

The number of species found is lowest in the actual fjord. This is particularly pronounced in the waters adjacent to Kragerø where the species regularly augment outwards. As previously mentioned the variation in salinity in the fjord is so great as to make it a restricting factor in respect of the species which can live and propagate in the waters. The numbers in brackets represent numbers of species peculiar to the station in relation to the other stations investigated in the same area It will be seen in the coastal waters we find relatively numerous species which do not occur in the skerries or in the fjord.

F I G. 44 a. THE WATERS NEAR ARENDAL.

Cod eggs identified 1= □, larvae 1= ■. Haddock eggs identified 1= ▧, larvae 1= ▨.

The ciphers represent number of eggs between 1.2 and 1.5 mm. (cod and haddock).

Calculated per haul.

Egg net worked at 0 - 10 - 20 - 30 metres. Larvae net at 0 - 30 metres.

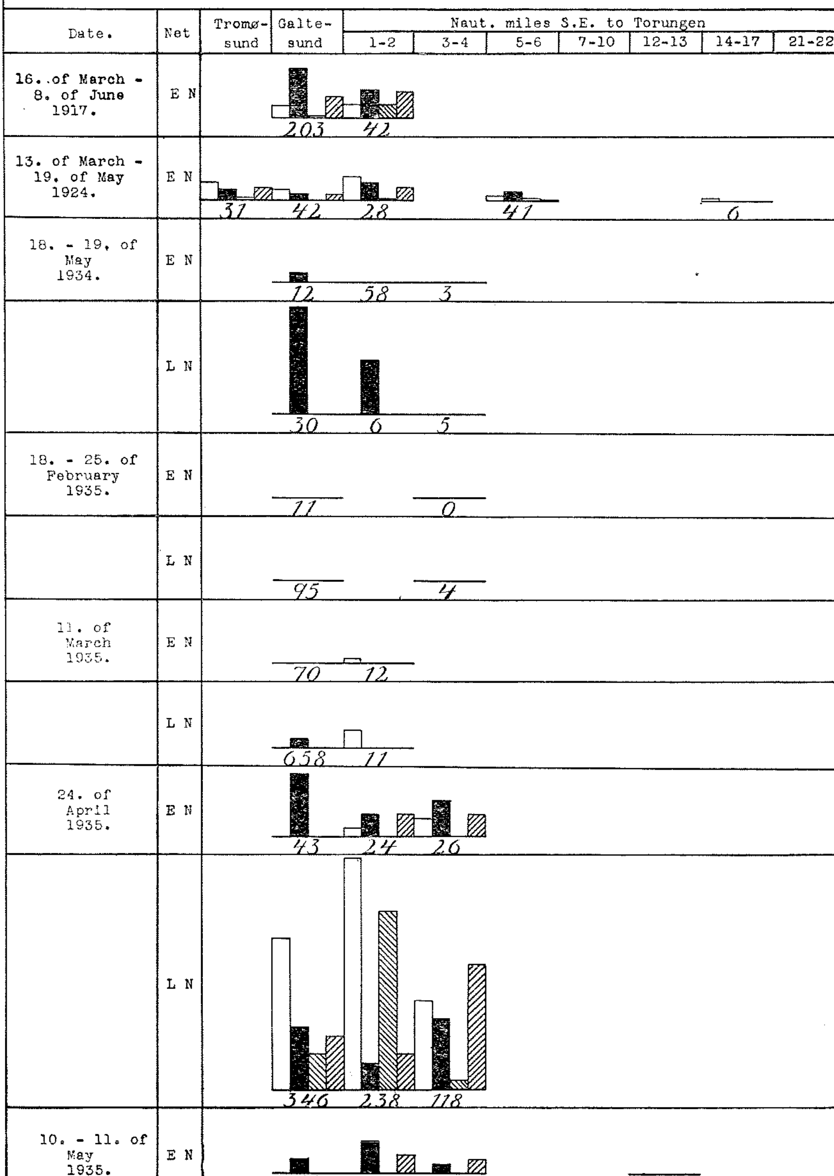


FIG. 44 b. THE WATERS NEAR ARENDAL continued.

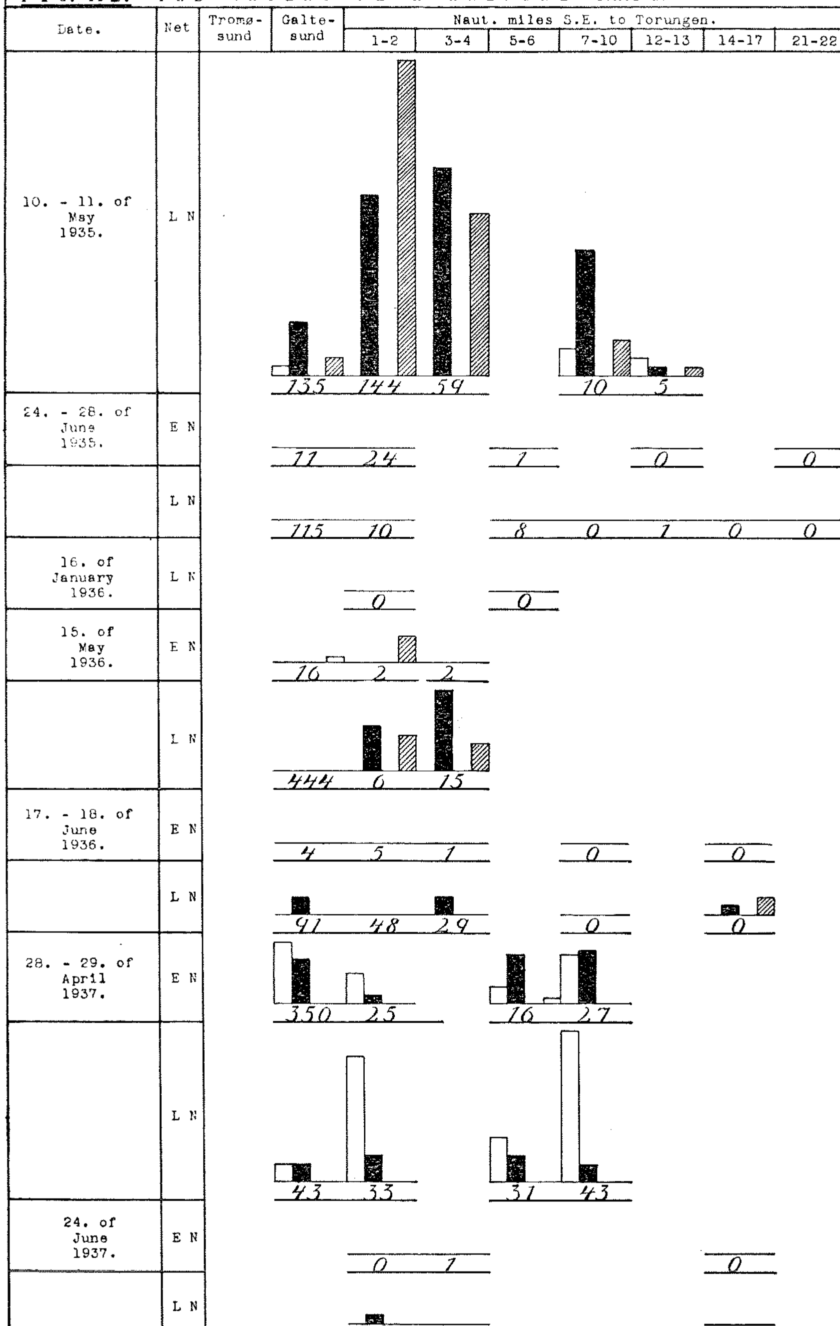


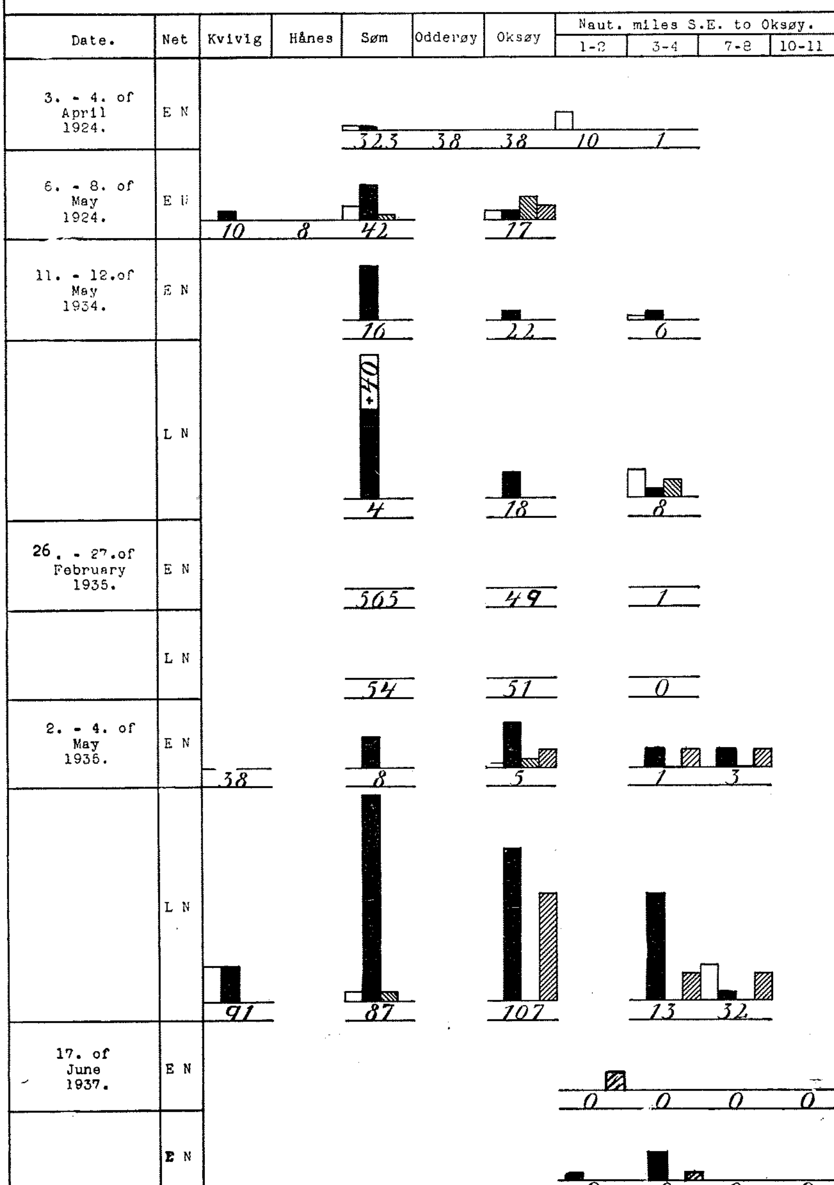
**FIG. 45.** THE WATERS NEAR KRISTIANSAND

Cod eggs identified 1= □, larvae 1= ■. Haddock eggs identified 1= ▧, larvae 1= ▨

The ciphers represent number of eggs between 1.2 and 1.5 mm. (cod and haddock).

Calculated per haul.

Egg net worked at 0 - 10 - 20 - 30 metres. Larvae net at 10 - 30 metres.



F I G. 46. T H E W A T E R S N E A R K R A G E R Ø.

Cod eggs identified 1= ☐, larvae 1= ■. Haddock eggs identified 1= ▧, larvae 1= ▨.

The ciphers represent number of eggs between 1.2 and 1.5 mm. (cod and haddock).

Calculated per haul.

Egg net worked at 0 - 10 - 20 - 30 metres. Larvae net at 10 - 30 metres.

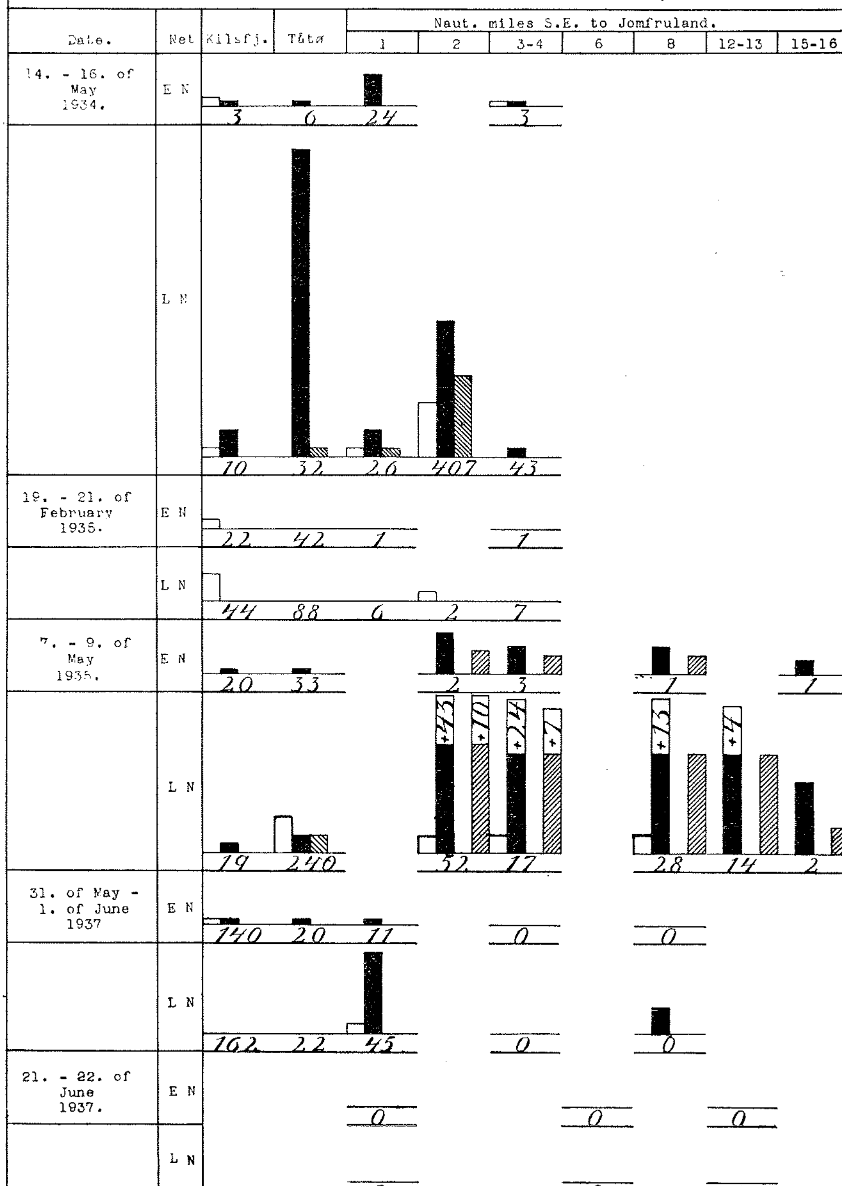


FIG. 47 a. THE WATERS NEAR ARENDAL.

Larvae.

Sprat 1= □. Herring 1= ■. Mackerel 1= ▨. Whiting 1= ▧.

Calculated per haul.

Egg net worked at 0 - 10 - 20 - 30 metres. Larvae net at 10 - 30 metres

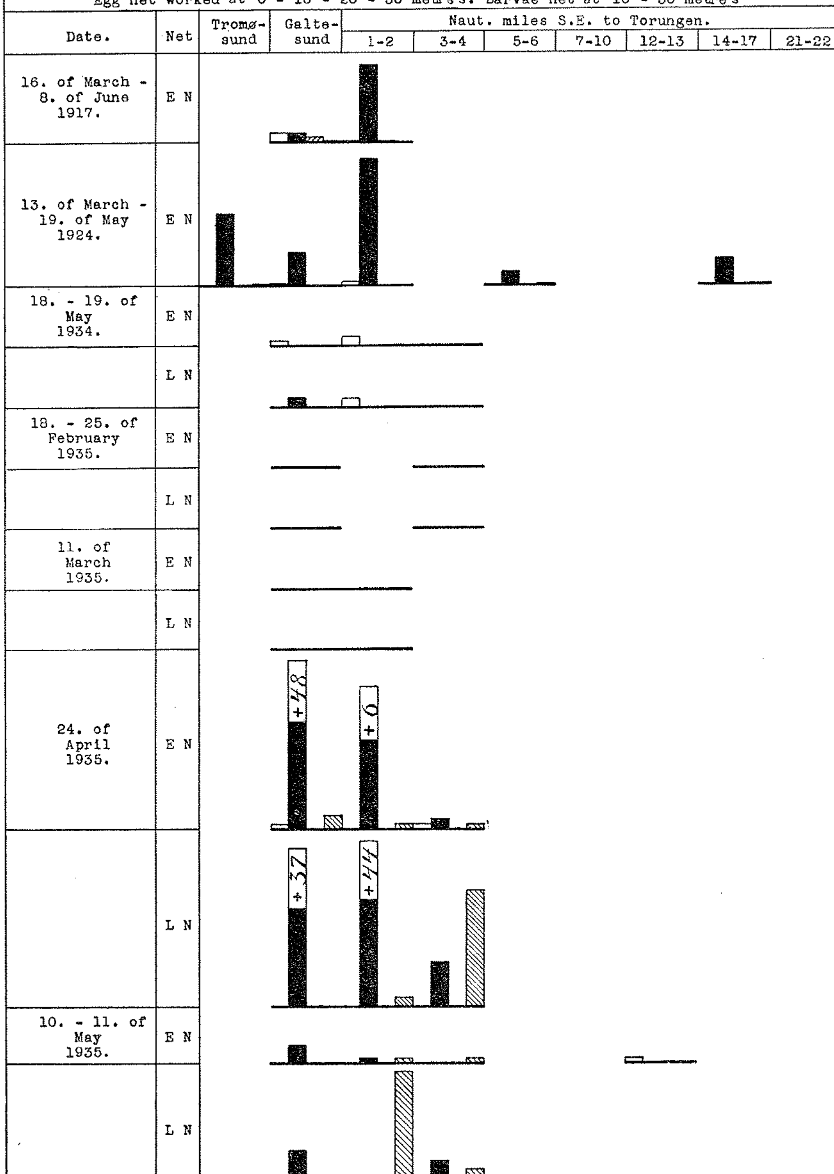


FIG. 47 b. THE WATERS NEAR ARENDAL continued.

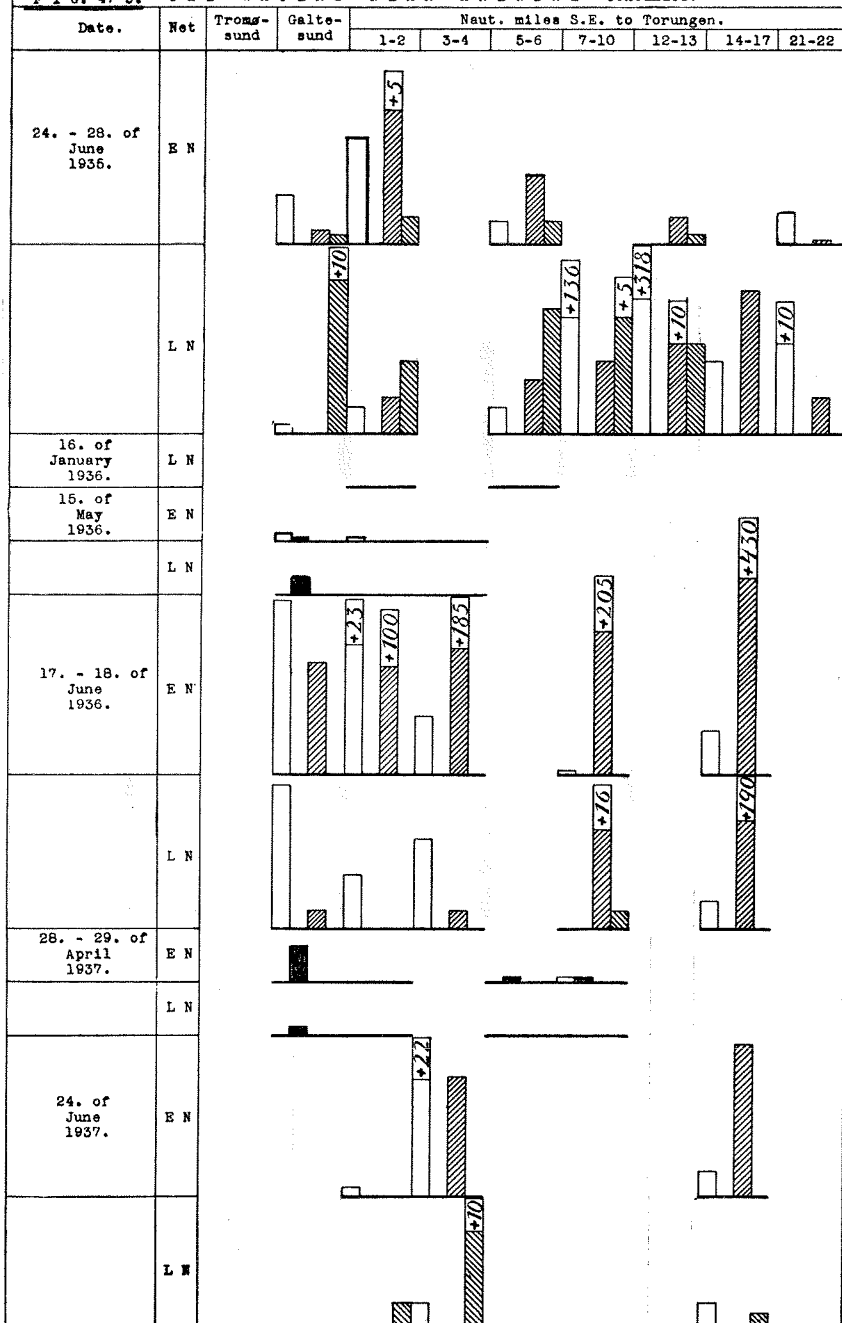


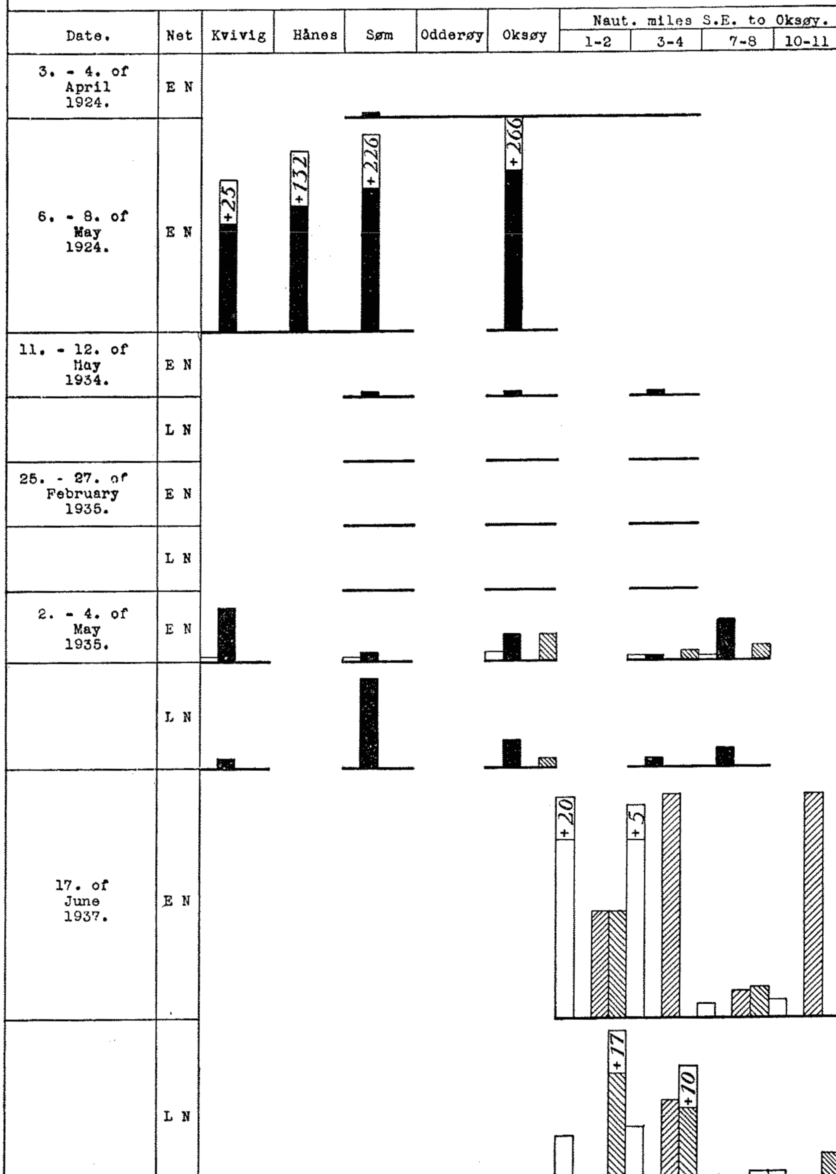
FIG. 48. THE WATERS NEAR KRISTIANSAND.

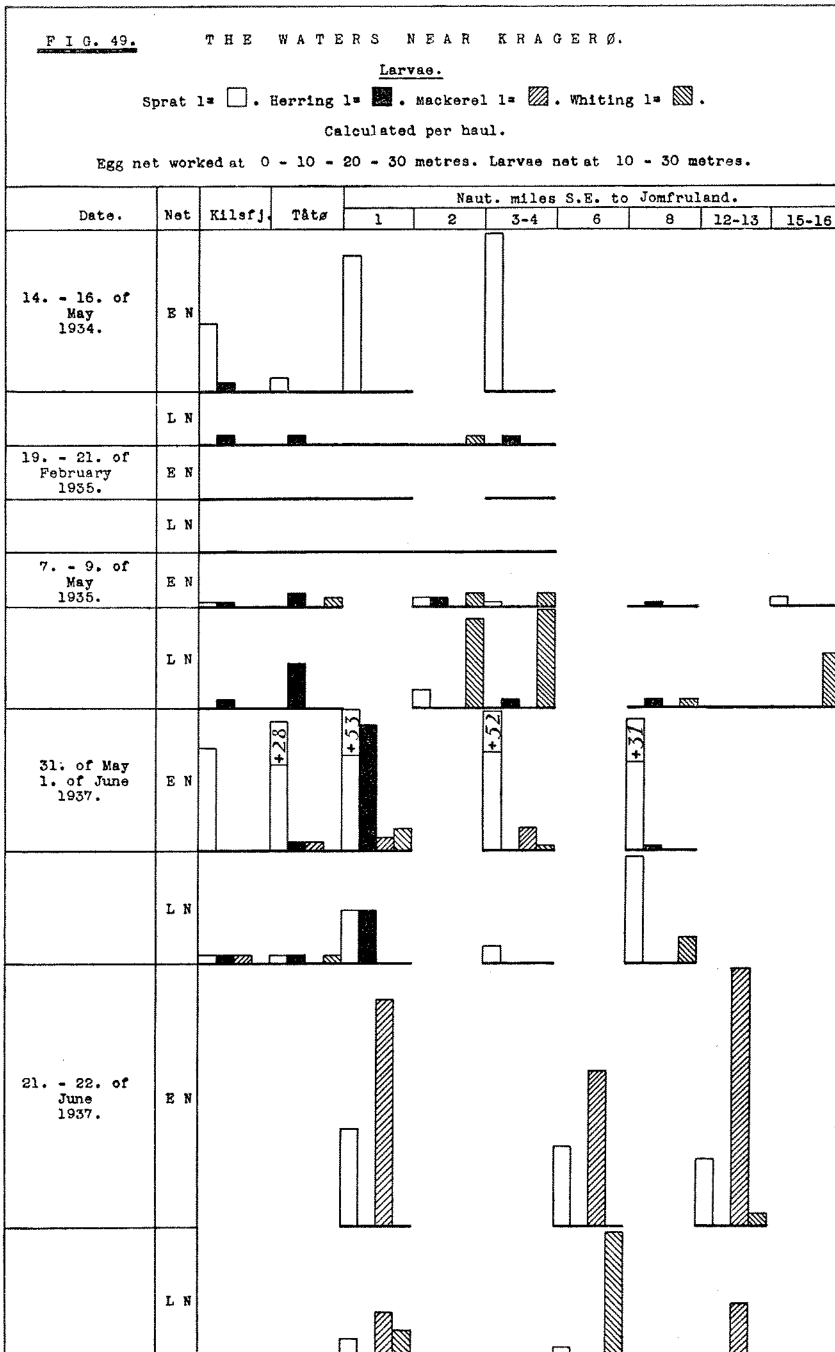
Larvae.

Sprat 1= □. Herring 1= ■. Mackerel 1= ▨. Whiting 1= ▧.

Calculated per haul.

Egg net worked at 0 - 10 - 20 - 30 metres. Larvae net at 10 - 30 metres.




F I G. 49.
T H E W A T E R S N E A R K R A G E R Ø.
Larvae.
Sprat 1= . Herring 1= . Mackerel 1= . Whiting 1= .
Calculated per haul.
Egg net worked at 0 - 10 - 20 - 30 metres. Larvae net at 10 - 30 metres.
Date.
Net
Kilsfj.
Tåtø
Naut. miles S.E. to Jomfruland.
1
2
3-4
6
8
12-13
15-16
14. - 16. of May 1934.
E N
L N
19. - 21. of February 1935.
E N
L N
7. - 9. of May 1935.
E N
L N
31. of May 1. of June 1937.
E N
+28
+53
+52
+37
L N
21. - 22. of June 1937.
E N
L N

# V. Summary.


The Skager Rack coast of Norway is characterized by narrow coastal banks, a well developed system of skerries and small fjords. Intensive fishing is carried on, mackerel, herring, cod and some other Gadidoid fish, etc., being of special importance.

Fishing statistics from years back reveal the occurrence of great fluctuations in the herring fisheries. Mackerel fishing has increased while the output of the cod fisheries is undoubtedly declining.

There is no doubt that the fluctuation in the herring fisheries is, in a high degree, caused by the variation in hydrographic conditions. The increase in the mackerel fisheries on the other hand is obviously a result of the high standard of development of motor craft and fishing gear while the decline in output of the cod fisheries is attributed to fishing on too intensive a scale, as fishing experiments tend to show.

It is commonly assumed that there may be great variations in the result of the spawning of the different species. In order to comprehend the fluctuation in the output of the fisheries it is therefore of importance to study the conditions under which fish eggs and larvae develope in the different years. Investigations having a bearing on this point have previously been undertaken on this coast by KNUT DAHL in 1904 and 1905 (6) and by me in 1917 (8) and 1924 (3).

DAHL found great quantities of fish eggs and larvae in the fjords and advanced the suggestion of possible great interchanges between the fjords and the open sea of fish eggs and larvae by means of currents.

My investigations in 1917 showed that the content of oxygen in the fjord at the intermediate and deep water layers was much lower than out at sea. It was not reasonable therefore to assume that great interchanges of water masses took place as a matter of course, and the collection of fish eggs and larvae demonstrated some difference between skerries and open sea both as regards species and comparative numbers. In the skerries there was a fauna of eggs and larvae differing from that of the fjord and the sea just a few miles outside.

The investigations in 1924 demonstrated the effect of a cold period in the middle of the spawning season of the spring spawners. The eggs disappeared from the waters. The influence of the cold water, however, was more restricted to the open sea. In the fjords there were reservoirs of water of a sufficiently high temperature. When the ice melted here a good quantity of eggs was found to be present, and when the temperature of the sea outside the coast and in the skerries increased fish eggs and larvae were again found, but only in small numbers.

A tentative suggestion was made to the effect that a cold period in the middle of the spawning process was detrimental to the eggs spawned and the larvae hatched and it was assumed that the best spawning and hatching results would be obtained if the temperature of the sea during the early winter prevented spawning. When the temperature subsequently rose conditions would be good for hatching and development of the larvae.

In all years since 1917 regular hydrographic observations have been made, both near the coast and in the fjords. Outside the coast both salinity and temperature in the surface and intermediate layers vary greatly according to the meteorological conditions obtaining during the year. Easterly winds in winter and spring bring comparatively fresh and cold water near the coast. Spawning will not, therefore, take place and the spawners will seek warmer water layers. Westerly winds bring higher temperatures and salinities in their train, conditions well-suited for the spawning, hatching and development of the brood. The last mentioned process, however, is entirely dependent on the food available. Directly and indirectly the larvae feed on the phytoplancton and as the latter is very dependent on the light it is of great importance that hatching of the larvae should not take place until reproduction of the phytoplancton has commenced.

In the fjords the investigations have shown that the variations in the hydrography of the deeper layers are insignificant. Except in special circumstances, between which there may be intervals of many years, no renewal of the waters takes place here. For this reason the quantity of oxygen dissolved in the bottom layers will be consumed by the life processes of animals and plants and by the oxydizing of organic matter. Thus for a time the bottom layers may be unfit for animal life. The intermediate layers of the fjords are also very stationary and the quantity of oxygen here may vary in quite a different manner to that of the water outside. Here, however, the quantities are never so low as to render the waters unsuitable for animal life.

The material dealt with in this paper was collected in 1934, 1935, 1936 and 1937 — from the waters outside the coast, the skerries and the fjords near Arendal, Kristiansand and Kragerø. The results arrived at in 1917 and 1924 are referred to.

The figs. illustrating the occurrences of the different species show that the eggs and larvae of cod are found most abundantly in the fjord, the skerries and close outside the coast. The highest numbers of larvae caught in the Topdals fjord (11.—12. May 1934) and Kragerø Fjord (14.—16 May 1934) occurred, however, as already mentioned, some weeks after millions of cod fry had been liberated in these fjords.

Haddock larvae are most numerous some miles further from the coast.

Sprat larvae occur both in the fjords and in the open sea. Spawning appears to commence about one month earlier in the fjords than outside the coast.

Herring larvae are most abundant in the skerries.

Mackerel larvae occur almost exclusively outside the coast. Few hauls have been made in the fjords, however, during the mackerel spawning period.

The results already attained in 1917 (DANNEVIG 8), namely, that each area of water, fjords, skerries and open sea, has its own special communities of fish eggs and larvae, are confirmed by the present investigations. Cod and herring are coastal forms both as to spawning and larvae. Haddock larvae are most prominent further out. This, undoubtedly, accords with the more oceanic character of the haddock as compared with the more littoral cod on this coast. The sprat and mackerel are pelagic forms. The former spawns both in the fjords and the open sea.

A study of the detailed tables brings to light other differences between the fjord and the skerries. A number of species only occur in the open sea or in the skerries. In the most isolated waters investigated, namely, those of the Kils Fjord, only a few species are present. The special hydrographic conditions in the fjords will only permit a restricted number of species to live and propagate in the fjord.

Such a distribution cannot take place if the waters in question interchange to a great extent and when a few species do occur in nearly all areas investigated they must be regarded as representatives of species with a wide spawning area.

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