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The Propagation of Our Common Fishes During the Cold Winter 1924

Investigations on the Norwegian Skagerrack Coast

By

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A.S JOHN GRIEGS BOKTRYKKERI · BERGEN

Contents.

[1]) The tables B., C, D. will not be printed. Typed copies may be acquired by applying to the Director of Fisheries, Bergen, or to the Flødevig Sea-Fish Hatchery, Arendal.

I. Preface.

The winter 1923—1924 was extraordinarily severe, and as the cold period began in December, the surface water of the Skagerrack was cooled down to below zero as early as the 29th of December. On that day, the temperature of the sea at the Flødevig Sea-Fish Hatchery near Arendal at 0 *m*. was ÷ 0°.1 C. The daily observations in January 1924 gave a mean of ÷ 0°.2 C. at the surface and + 0°.3 C. at 1 m. depth.

Under those conditions, I feared that the hatching season would be a failure. It would be impossible to secure living cod for the hatchery. On the other hand, I was eager to ascertain the influence of the cold water on the propagation of some of our principal fishes, especially the cod. Therefore, on the 19th of February I suggested to the Director of Fisheries that the hatching work should be discontinued that season, and that some of the money granted to the Hatchery should be employed in the investigations above mentioned.

The Director of Fisheries and the Royal Department for Commerce, Fisheries etc. consented to my application, and on the 14th of March the allowance was given.

As the spawning time of our Gadidae may begin in January, the investigations ought to have started at the beginning of the New-year — but according to the circumstances referred to they were not begun until the middle of March. Some hydrographical stations were taken during January and February, but owing to the heavy cold, the drifting ice at the coast and the ice of the fjords, the investigations could not be carried out according to a regular plan. We had very often to take the chance whenever we had it.

The ice in the fjords did not melt until April and May—thus those waters could not be investigated so well as the waters outside the skjærgaard.

The investigations referred to here were meant to give a picture of the hydrographical conditions of the watermasses, especially the temperature, during winter and spring and to ascertain the relative quantity of fish-eggs and larvae in the watermasses exploited. Special investigations on the occurrence of the spawning fishes could not be carried on — but some material of a more accidental character as to the influence of the low temperatures upon the grown fishes, has been collected.

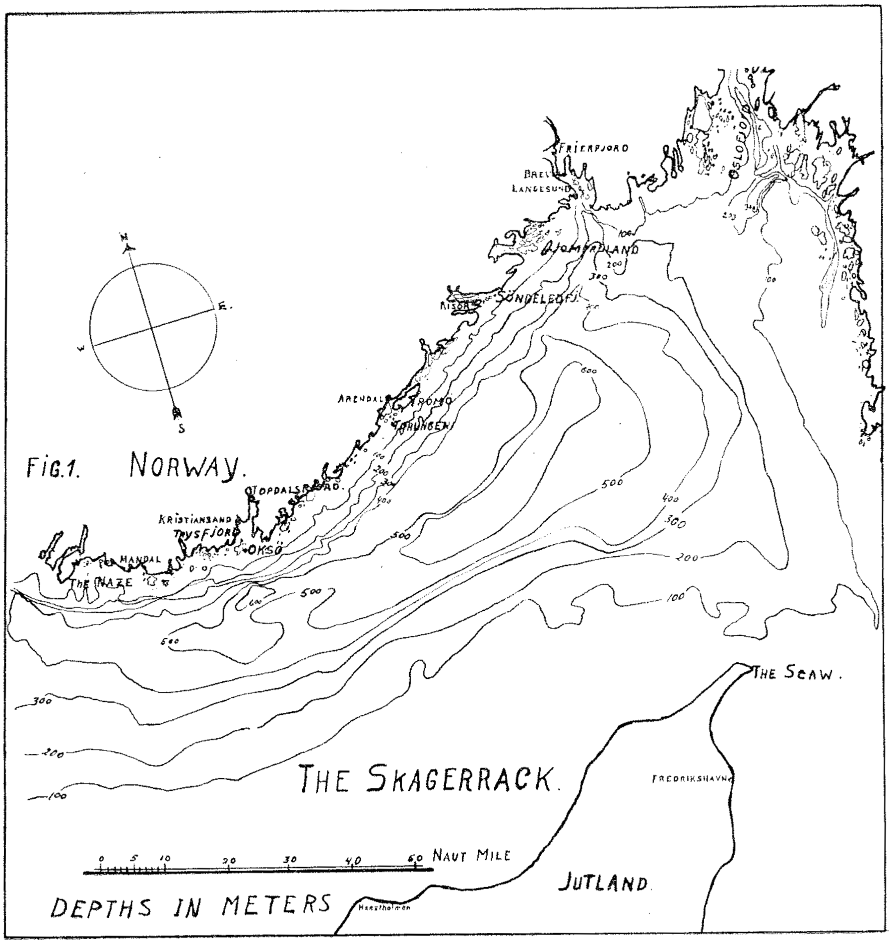
When discussing the results of the investigations, it would have been of importance to know how things are in an ordinary and mild winter on this coast — but of this we do not know much. Therefore I must generally confine myself to discuss the problem on the basis of the different temperatures found in the waters exploited.

In an extraordinarily cold winter the seawater will be very cold, and disturbances in the normal occurrence of the fishes will naturally be ascribed to the temperature. It must, however, be remembered that the low sea-temperatures are not the sole effect of a cold winter. The direction of the winds will to a great extent be opposite to that of a mild winter, and the winds act upon the currents — and the wet. Since the chief factor to determine the wind is the pressure of the air, we may just as well find a correlation between the occurrence of fish and the pressure of the air, the directions of the wind—or the precipitation.

As will be shown later, however, we must assume that the temperature is the direct — and chief acting factor — as to the spawning of the fishes. A close examination of that question, however, cannot be given here, it must be solved by experiments.

The areas investigated are situated on the Norwegian Skagerrack coast between Langesund and Mandal. The most prominent area is near Arendal where the Tromøsund, the Galtesund and the Skagerrack are exploited several times — at different distances from land 1—5—10—15 nautical miles from the Light-house of Store Torungen.[1] The

[1]) Instead of "Store Torungen" the shorter form Torungen is used later in the text, in the tables and figures. The bearings are always compass bearings.



Tromøsund and Galtesund, Fig. 8 page 22, are to be regarded as typical skjærgaard waters. The stations in the Skagerrack near land in relatively shallow water are representative of the coast waters, and the outermost stations over the great depth of the Skagerrack are characteristic of the open sea.

At Langesund, Fig. 21 page 47, the investigations proceed from the open bay, Langesundsbugta — through Dybingen, a narrow but deep sound, into the Brevik fjord, also deep. From there to the right into the Eidangerfjord and to the left into the isolated Frierfjord and Voldsfjord.

At Kristiansand, Fig. 30 page 62, the investigations proceed from the open sea through the deep Kristiansandsfjord into the Topdalsfjord —

with a threshold of moderate depth at the entrance but with deeper basins inside.

The Trysfjord Fig. 36 page 73, to the west of Kristiansand, represents the isolated fjords — the entrance is very narrow and shallow. In the inner part the water near the bottom is stagnant and poisoned by sulphurated hydrogen.

On one occasion a cruise was taken across the deep Skagerrack off Kristiansand to the banks 28 n. m. to the S. E. of the Light of Oxen, in order to ascertain the temperatures of the sea-water.

On the 19th of May the investigations were suspended, the money at disposal had come to an end.

The Flødevig Sea-Fish Hatchery, November 1926.

Alf Dannevig.

II. Methods and Gear employed.

The investigations were carried on from the motorcutter „Ossian Sars“ belonging to the Flødevig Sea-Fish Hatchery.

The vessel is equipped with a hand-winch with a steel wire 400 m. long and 3 mm. of diameter, an Ekmans reversing water-bottle with a Richter reversing thermometer from Vereinigte Fabriken für Laboratorien Bedarf, Berlin. Surface thermometers from Schmidt und Vossberg.

The salinity of the water samples from the cruises is always determined by titration of the quantity of chlor, the quantity of oxygen by the method of Winkler. Some of the samples have been determined at the Geofysical Institute, Bergen, the majority, however, at the laboratory of the Hatchery.

To ascertain the quantity of pelagic fish eggs and larvae a plankton net 1 m. in diameter and 2.5 m. long is used. The part near the ring is made of thin canvas 90 cm. long, the rest of Swiss silknet no. 0 (= French silknet no. 40). This net, 15 meshes pr. 10 mm. is fine enough to retain the pelagic fish eggs in question and so open that it permits quantities of the small pelagic algae to escape. In this way the net is not clogged so quickly as if a net with finer meshes is used. At the Hatchery, the egg-collector is construtced of the same sort of silknet, and through a surface of ca. 1.9 square meter there will in an hour pass about 25—30 tons of sea-water. The egg-collector is ordinarily cleaned once in 24 hours. Only when the diatomes (especially. *Chaetoceras* sp). is abundant, the collector will be clogged in an hour or two. This happens very seldom (a day or two) each spring, especially when the salinity is low. The water for the Hatchery is lifted from a depth of 15 meters.

When the haul is made, most of the water is permitted to run off. The plancton bucket at the end of the net is loosened and emptied in wide glass-bottles as used for jams, with a capacity of 500—2000 cm.^{3}. The bucket is replaced, the net washed, and the rest of the plancton also filled into the glass-bottle. A mixture of Formalin and Glycerine (half and half) is added to the sea-water in ratio 1: 10, the shrewing lid is put on the glass, and the bottle turned a few times to make the preservative mix well with the water of the sample. Glycerine is added to the Formalin to keep the fish eggs more transparent.

When dealing with fish larvae it is of importance that the glasses are large enough to prevent the young from becoming deformed. When some hundred samples are taken within a narrow space of time, however, this fact cannot be given the attention it ought to have.

As soon as possible the plancton is sorted, first in a black, then in a white disk as used for development of photographic plates. The fish eggs and larvae are taken care of — the rest of the plancton is put away for later examinations if such are wanted.

In this case my assisstant has sorted the plancton, but all the samples are corrected by myself. Thus the whole plancton masses have passed four times under close observation.

The plancton is examined with a needle without using any magnifying power, but in bright light. The fish eggs and larvae found are put in small glasses and a mixture of formalin-glyserine to sea-water in the same ratio as the fixing fluid is filled on.

When the fish eggs and larvae are to be examined some are filled into a chamber on an objectglass made for this purpose. A frame of caoutchouc 3 mm. high has been attached to an object glass by Canada balsam, and the space inside, 35 $\times$ 17 mm. divided lengthwise in 4 sections by 3 glass pins 1 mm. thick. In this way the portion of eggs and larvae can easily be examined in the microscope, without any risk of noting the same egg twice.

All the eggs are counted, the diameter and degree of development of each egg is noted, and also the species to which it belongs if this is evident. The degree of development is noted in order to give some idea whether we have to deal with newly spawned eggs or eggs of older stages.

Three stages are distinguished:

I. The germinal disc

II. Embryo stretched

III. Embryo with pigmented eyes.

It ought to be remembered, however, that the eggs of many species are hatched before the eyes get any pigment. The larvae are all determined as to species with a few exceptions, and the length noted to the nearest m. m.

It would have been of great interest to have the eggs determined as to species as well, but this is a matter of great difficulty, and impossible when dealing with preserved material. On the other hand, when attention is given to the diameters of the eggs in question, to the eggs determined with far developed embryoes, or with characteristic features, and to the young larvae in the material at hand, we have a very good basis for forming an opinion of the species to which the majority of the eggs belong.

The diameter of the fish eggs that may commonly be found at the Skagerrack coast during winter and spring, and the more precise time of occurrence are available from the accompanying table A page 132 compiled from E. Ehrenbaum: Eier und Larven von Fischen.

The hauls with the egg net are all horizontal. The net is allowed to sink with the point first to the depth wanted. It is stopped there by a buoy with a line of the length equal to the depth required. The boat goes slowly forward and the wire runs over a meter wheel. By the aid of another line the buoy carrying the egg net at the depth wanted is kept at a constant distance from the boat, and on a diagram the length of the trawl-wire is read, and the winch stopped when the length required has been given out.

The diagram will show the arrangement.

When the length of wire has run out and is tightened by the speed of the boat, the line from the buoy to the eggnet is a perpendicular. And as the angle between the line from the ship to the buoy and from the ship to the eggnet is very small, the distance between ship and buoy being relatively great, the eggnet will be carried away at the depth wanted — or at least very nearly so. The duration of the haul is always reckoned from the time when the winch line is out at its proper length, and is carried on for 10 minutes. When time is up, the vessel is turned 180°, the wire is taken in slowly as the vessel advances, and when near the buoy, a messenger is sent down and the egg-net is shut. The shutting mecanismus being lost, the stations 43 to 65 are filled without shutting the net, and this is taken open to the surface.

At each station, normally horizontal hauls are made at 0—10—20—30—50—70 m. below the surface, except of course, where the water is too shallow.

The method is not correct — when lowered, the egg-net may catch some eggs and larvae, and when towed it may be lifted a little from its proper place. Experiments have shown that when the surface layers are rich, but the deeper layers nearly free from eggs and larvae, a haul

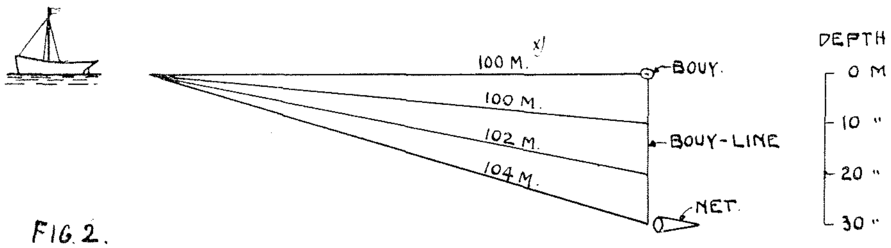


FIG. 2.

The distance between ship and bouy is kept konstant at 100 meters when fishing down to 30 meters. When deaper a distance of 150 meters is used.

of 0 minutes in the deep will give just the same results as a haul of 10 minutes, the catch indicates the error of the haul. The very small catches at the great depths must therefore be looked upon with scepticism. Not so with the relatively greater catches, however. The weather is of great importance, rough sea and strong winds will make the vessel very difficult to manage in a proper way, and as the facility of filtration of the net is affected by the phytoplancton, the fishing power of the net will vary.

As it is impossible to state the inaccuracy in the different areas, in different depths and at different times of the single hauls it will not be justifiable to claim quantitative correctness of the hauls—except with regard to the ratio in which the different species occur in the catches. On the other hand, however, I am of opinion that the methods reveal to us the characteristic features of the distribution of fish eggs and larvae in the waters examined. The incorrectness of the method will in the long run not be able to disguise the facts.

III. The Waters of the Norwegian Skagerrack-coast.

Before dealing with the different localities investigated it may be of interest to say a few words of the character of the waters of the Norwegian Skagerrack coast — especially the part between Langesund and the Naze.

In the southern part of our country the skjærgaard consists of numerous islands, rather small, often uninhabited, with some greater islands here and there. The islands are separated by sounds and channels, generally of a very moderate depth — 50 meters of water are seldom found, — 100 meters in the greater fjords and in their communications with the ocean. Often, however, the depth of the fjord is interrupted by the skjærgaard. Thus submarine basins are formed separated from the depth of the open sea. Outside the skjærgaard there are quite narrow shallows and banks, often formed by the deposits of the glaciers of old days. The great depth of the Skagerrack, the Norwegian channel, here approaches the shore. The sketch fig. 3 will show this better than many words.

The waters of the fjords are characterized by a more or less fresh surface layer — the temperature of which varies within wide limits — from 0 to 20° C. or more. The fjordbasins, however, are always filled with water of high salinity, often higher than the salinity of the sea outside the skjærgaard at the depth considered. This condition of things may be ascribed to the great submarine waves of very salt and heavy water coming in from the great ocean (see Literature 2—32—33). The wave is pressed against the coast and fills up all basins and fjords to a very high level. When the wave withdraws, the basins of the fjords and skjærgaard will retain the heavy salt water to the level of the threshold to the sea. The water of these basins will be more or less stagnant, as the renewal of the water only takes place whenever a

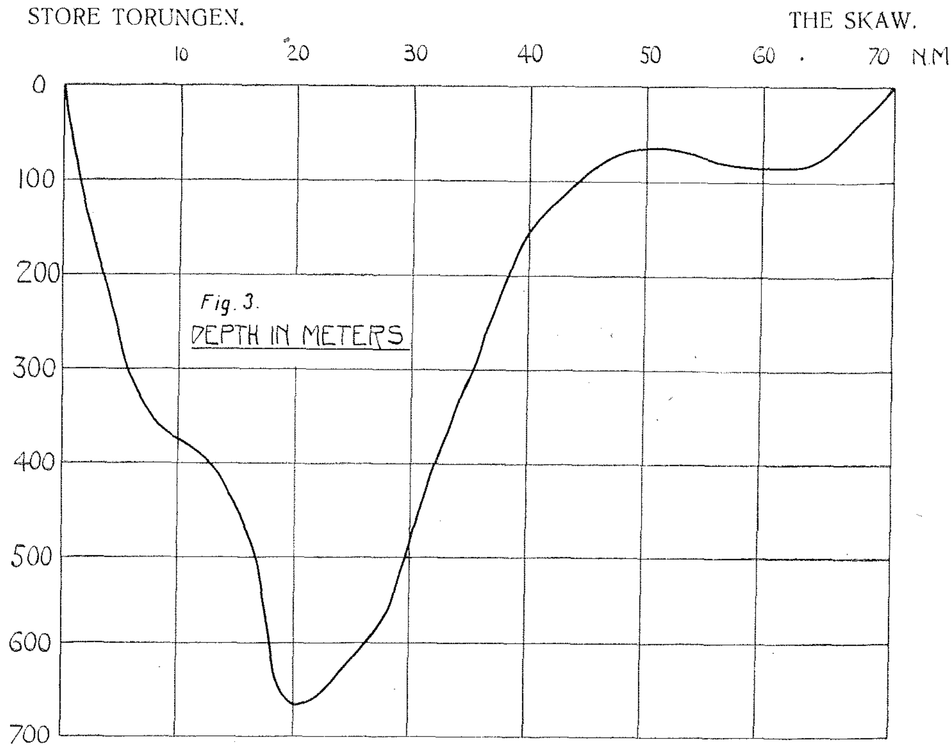


Fig. 3.
DEPTH IN METERS

new wave proceeds. And as these submarine waves usually occur in the late autumn and early winter, a year or two may pass without any renewal. As the temperature of the oceanic water of the submarine waves varies but little, the temperature of the deep basins will keep nearly constant from year to year, because the sp. gravity of the bottom layers is too great to permit any mixing with the top layers.

Outside the skjærgaard, we have the Baltic current running along the coast towards the S. W. The water here comes from the Baltic. It is nearly fresh when leaving the Sound, but is mixed with the underlying salt water and the Jutland current coming up from the south along the west coast of Jutland.

The character of the water of the Baltic current off the Norwegian Skagerrack coast varies according to the seasons. It is very cold during the winter, temperatures below zero are observed when the weather is very cold — and the current can under extraordinary circumstances carry along drifting ice. In the summer it is relatively warm.

The salinity of the current varies according to the quantity of water poured into the Baltic by the rivers, but is always less than the native Skagerrack water, the limits between them may be placed at about 32 ‰.

As the Baltic current is fresher than the underlying seawater, it will be of a less specific gravity. When in summer the surface layers are considerably warmed, this will augment the difference of the sp. g. between the layers, and the current will tend to spread wide out over the underlying heavy water. On the contrary, in the winter, the low temperature acts against the freshness of the surface layers, and the current becomes narrow but deeper.

The hydrographers teach us that streaming water on our latitudes will have a tendency to turn to the right — this will impell the Baltic current to keep close ashore. And still more, the current will have a rotation around its longitudinal axis, the tendency to the right being greater at the top than near the bottom of the current. The movement of the current will be that of a screw. (Literature 37).

This fact is of great interest to us when dealing with pelagic fish eggs and larvae. Due to the nature of the current the young of our bottom fishes carried along by the current will have a chance to come into the vicinity of the coast. In this way the skjærgaard and the shallows outside it will act as a filter. As the current proceeds the young fishes with an instinct of seeking the bottom will be left behind along the coast. The fishes of a more pelagic nature, however, will be carried away mile after mile.

At the Flødevig Sea-Fish Hatchery observations of the specific gravity and the temperature at the surface and 1. m. below are taken each week day, during the hatching seasons also on Sundays — and also in the water pipe bringing the water from 15 m. below the surface.

The fig. 4 shows the temperature, and the salinity of the sea-water 1. m. below the surface from Dec. 1st 1923 to June 1st 1924. The reason for not using the observations of the very surface water is to avoid the influence of a little rill running into the sea in the neighbourhood of the Hatchery.

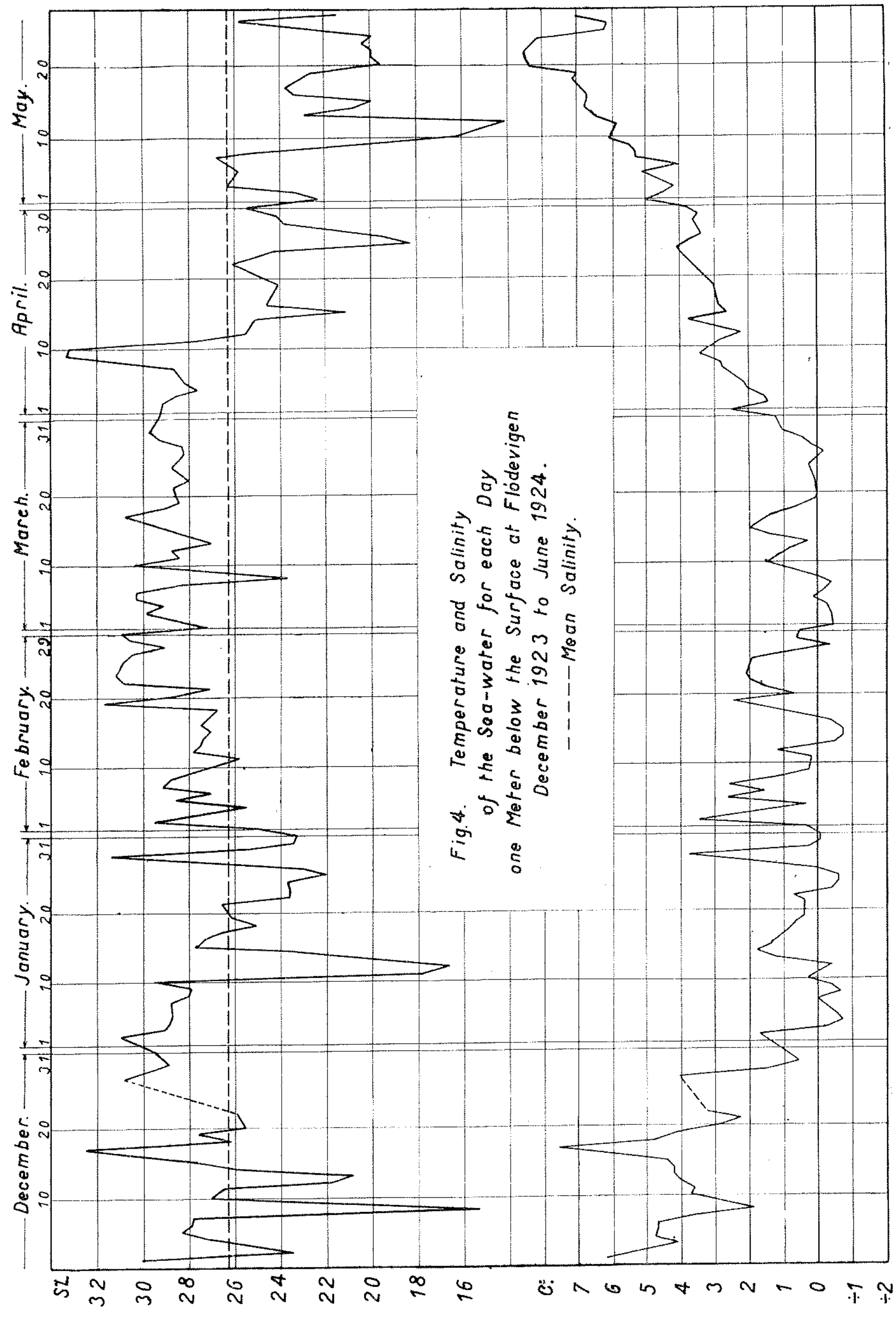


Fig. 4. Temperature and Salinity of the Sea-water for each Day one Meter below the Surface at Flødevigen December 1923 to June 1924.
– – – – Mean Salinity.

The Flødevig is situated near the coast, but as there are some islands outside, it may be representative of the open skjærgaard — thus it resembles very much the localities exploited at Narestø and Galtesund.

The temperature and salinity varies very much during the winter, often from day to day. It is obvious that during the winter the variations in temperature and salinity follow each other. When the salinity is high the temperature is high — and vice versa. The very low temperatures, one degree below zero, or more, are not found in the brackish water, but in water with a moderate salinity. When spring approaches, and the surface water is heated more than the intermediate layers, we have the opposite condition of things: the variations will be opposite to each other, high salinity and low temperatures will correspond.

The daily fluctuations both in temperature and salinity at the coast are to a grèat extent controlled by the wind and the pressure of the air. (Literature 16 & 32.) It is a well known fact that when in our waters the wind is blowing out from land it will carry out the brackish layers near the top, the further the stronger the wind is. When the wind ceases the brackish water will come back again, in a way controlled by the hydrographical conditions, and the rotation of the earth.

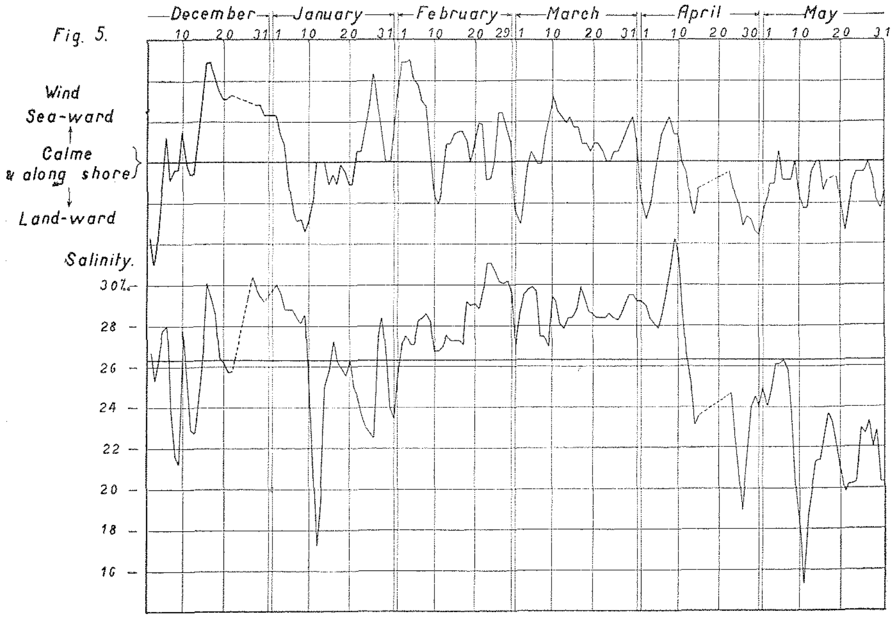
At the Hatchery the direction of the wind is noted twice a day, and when comparing the direction of the wind and the conditions of the sea, we should have full conformity in the fluctuations. Mostly this is the case — but the irregularity found shows that other causes may have a great influence. The wind at the Hatchery may be of a local nature — and opposite to the wind acting on the Skagerrack and the North Sea a. s. o.

In the fig. 5 I have illustrated the salinity and the direction of the wind at Flødevigen. The uppermost line represents the direction and the strength of the wind according to its direction towards or from the coast.

The coast is running from N. E. to S. W.

The directions of wind along shore are put = 0. The wind perpendicular to the coast line has the value 2—3 according to ist strength, the N. W. positive, the S. E. negative. The wind passing

Fig. 5.



the coastline at 45 degrees has the value 1—2 according to strength — W. and N. has a positive value, E. and S. a negative. The value of the observations at 9 a. m. and 2 p. m. are added. Thus the wind blowing against the coast has a negative value, the wind with the directions off the coast a positive one.

In order to reduce the effect of local causes the values are smoothened by counting a running mean value for three days for both wind and salinity. Although the method must be deemed a very rough one, it will be evident that there is a great conformity between the two lines.

The hydrographical conditions at the coast in the area of the Baltic current one to two n. m. off Torungen during the winter 1924 is illustrated by the fig. 6 & 7. The series of observations are few, but may be sufficient to reveal the general character of the waters. On the 24th of January the first observations are taken. We have temperatures below zero from the surface more than 10 meters down, and the salinity is very low, less than 25 ‰. At 50 m., however, we still have more than 6° C, and the salinity is more than 34 ‰. As the winter proceeds the temperature at the surface varies but little. On the 9th of February it is 0.5° — but some days afterwards we again have temperatures below zero, and to a depth of about 15 meters.

At the end of the first week of April a temperature of 2° is attained, on the 30th 3°.8, but from that date the temperature is rising quickly. Not so in the deeper layers. At 60 meters we have temperatures as low as 3°.1 on the 10th of April, on the 19th of May only 4°.4 at the same depth.

During April we have water of a very homogeneous temperature and salinity from surface to at least 60 m. It is the time of the chan-

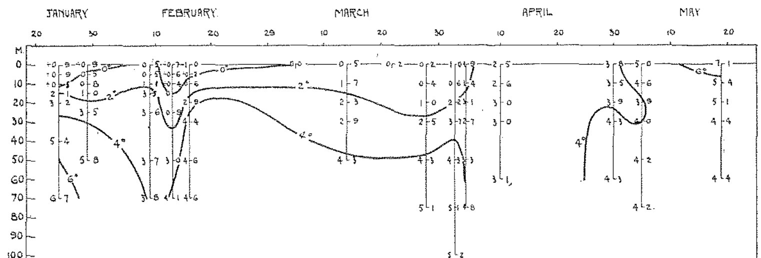


FIG. 6. TEMPERATURE

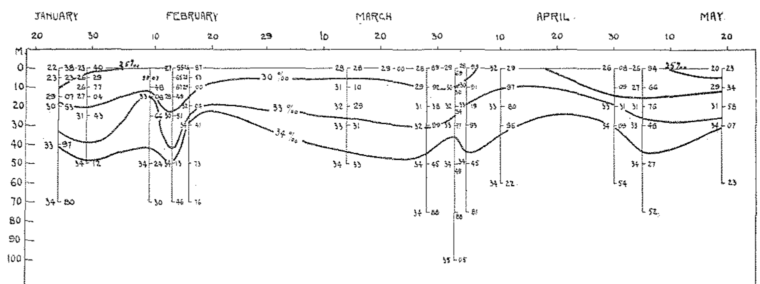


FIG. 7. SALINITY

ging of the seasons in the sea. We leave the winter conditions — when the water has its lower temperature at the surface, its higher at the deep — and through a time of equal temperatures we pass to the summer conditions: A warm surface, and cold deeper layers.

The isohalines show that on the 10th of April we have a maximum of salinity at the surface. It may be, however, that these conditions to some degree may be the results of extraordinary circumstances. On the 10th of April we have the following salinities at the surface.

At Flødevigen .... 0 m. 33.03 ‰
- — .... 1 - 33.15 ‰
1 n. m. off Torungen .... 0 - 32.29 ‰
4—5 n. m. off do. .... 0 - 31.29 ‰

The salinity is highest near land just opposite to what it ought to be. It is evident that a submarine wave has pressed against the coast and driven the coast water out to sea, or it may be the effect of the land-wind prevailing at that time.

It will be observed that the illustrations given to the hydrographical conditions of the waters are from the cold winter 1924. Only in the case of the surface temperatures at Torungen, I am able to give details from a number of years — those temperatures have been recorded by the Meteorological Institute in Oslo, since 1874. (22 & 45).

In table E I have compiled the material, giving the mean temperatures of each month for the different years.

In the text table I have given the average temperatures for each month during the period 1874—1923 — fifty years. And for the sake of comparison, the temperatures of 1922—1924.

	Month.												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
1874/1923	2.5	1.5	1.4	3.7	8.2	12.6	15.4	15.6	13.7	10.5	7.0	4.4	8.0
1922	3.7	÷0.9	1.3	3.0	6.5	11.8	14.3	14.9	13.3	8.9	6.7	5.0	7.4
1923	3.8	1.6	0.4	3.5	7.2	10.2	13.9	14.3	12.5	10.3	7.1	2.7	7.3
1924	÷0.1	0.1	0.1	2.5	6.1	11.2	14.1	15.5	14.3	11.4	8.2	6.6	7.5

It is evident that the sea temperature from Dec. 1923 to July 1924 is below normal — and this cold period follows upon two years with relatively cold sea-water, as shown by the medium of the year.

The table E shows that in 1924 for the first time since 1874, we have a monthly mean for January below zero. But in February this happened 8 years and in March 9 years.

The details will be apt to show that the winter 1923—1924 is a severe one — the temperature deficiency is apparent for half a year — but the low temperatures attained have often been surpassed in earlier severe winters.

IV. Material collected.

A. The Waters near Arendal.

As mentioned in the preface, the waters explored near Arendal stretch from the Tromøsund, a typical skjærgaard water, through the Galtesund, out to the coast and from there out over the great depth of the Skagerrack.

The Tromøsund is a sound inside of the Tromø. It is 7 naut. miles long and in some places very narrow, one hundred meters or two, but with some great basins of a moderate depth. A little to the west of Arendal the Nidelv pours in quantities of fresh water, and a part of this passes out the Tromøsund. The rest goes out the Galtesund.

The depth of the sound is sketched on the figures of temperature and salinity. The bottom line represents the approximate deep line according to the drafts. On the figures the distances between the stations are put down equal to the shortest sea-line between the localities exploited — although the directions between them may vary.

At the east end of the sound we have a basin at Narestø. It is situated close to the entrance of the sound and is open to the sea, at least to a depth of 40 meters.

In the middle of the sound, at Salterød, we have another basin. The depth here is 40 meters. The hydrographical measurements, especially of the quantity of oxygen, show that the water is sound to the very bottom.

Then we have a basin in the harbour of Arendal, also of a moderate depth. To the south it is connected with the sea by the Galtesund.

The waters of Narestø, Salterød and Galtesund have been explored several times. These three stations may represent the skjærgaard.

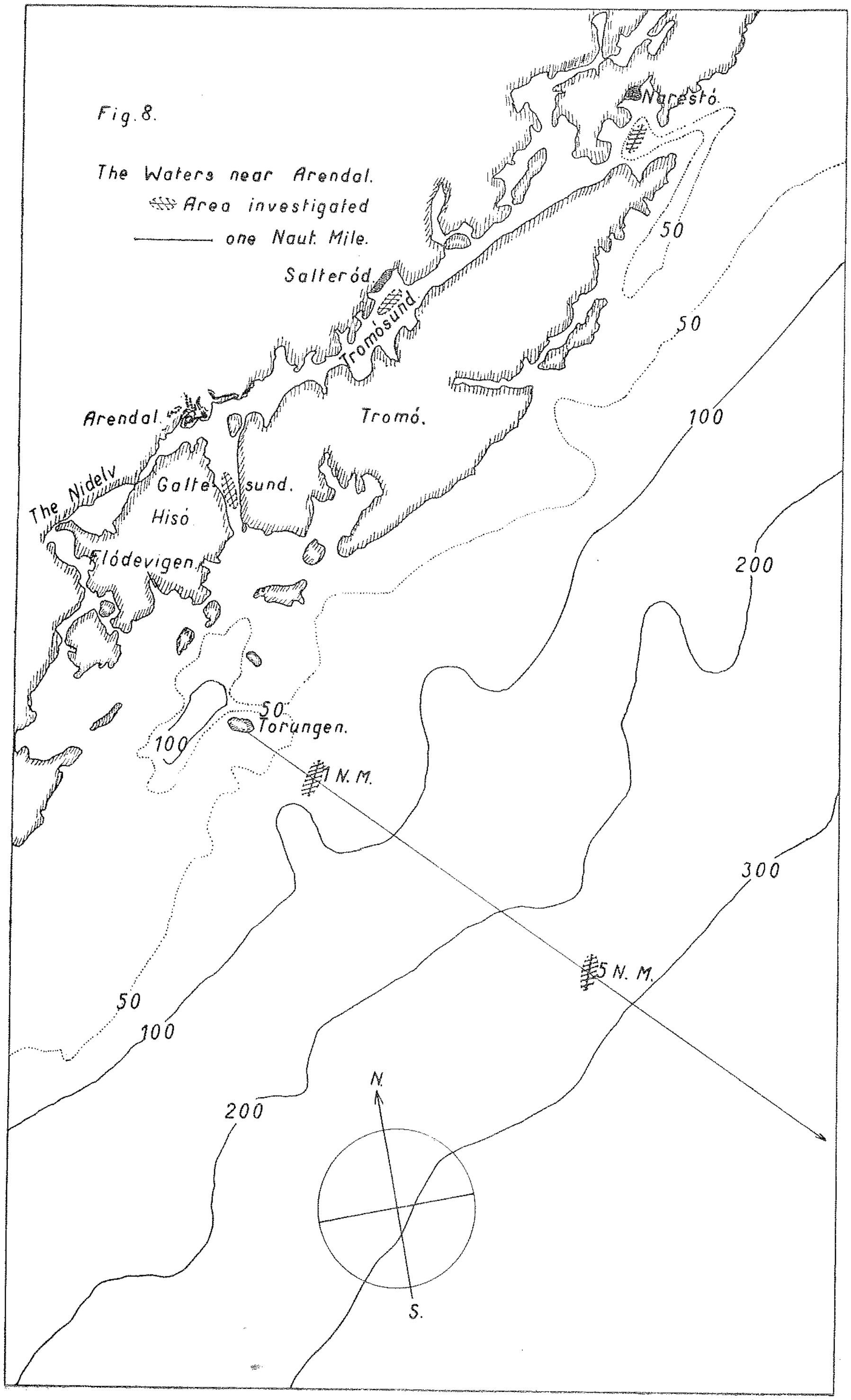


Fig. 8.
The Waters near Arendal.
Area investigated
one Naut. Mile.
Narestö.
Salteröd.
Tromösund
Arendal.
Tromö.
The Nidelv
Galte
sund.
Hisö
Flödevigen.
Torungen.
1 N. M.
5 N. M.
50
100
200
300
N.
S.

From the Galtesund the depth rapidly increases. Inside the island of Store Torungen we find a depth of 100 meters or more — but outside Store Torungen the bottom raises once more, and here we find a quite narrow "bank" of a depth of 70 meters or less. To the east this bank is connected with the shallow water outside Tromøen.

On this "bank" about 1 n. m. off Torungen we have our coast stations. This locality is situated within the normal area of the Baltic current.

From here sea-ward the bottom falls off rapidly. At 4 to 5 n. m. off Torungen we have a depth of more than 200 meters. This locality has been explored several times, and also the waters fourteen to fifteen n. m. S. E. of Torungen. Here we find a depth of nearly 450 meters.

From the following survey it will be seen that the same locality has been examined different times, and more of the localities at the same date. In this way, we may be able to study the variations in plancton and hydrography as we proceed from one locality to another. On the other hand — when studying the results from the same localities at different dates we may be able to study the changes brought about by time.

The Galtesund and the waters outside Torungen (1 & 5 n. m.) were explored for the first time on March 13th & 14th. Due to the ice, the Tromøsund could not be explored until April 9th.

The fig. 9. & 10. reveal to us the hydrographical conditions at the beginning of the investigations. A layer of very cold water covers the sea from the Galtesund out to 5 n. m. off Torungen. The isotherm of 3° is situated near 20 meters at the inner and outer station. In the middle, however, it is bent down to more than 30 meters, indicating that the relatively cold water here has its maximum of volume. The bottom temperature in Galtesund is 3.5°, at the other stations presumably more than 4°.

The salinity is low. The Baltic water, less than 32‰, goes down to 15 to 20 meters, and at the very surface we have water with a salinity as low as nearly 25 ‰ in the Galtesund. At the outer stations, water of more than 34 ‰ covers the bottom.

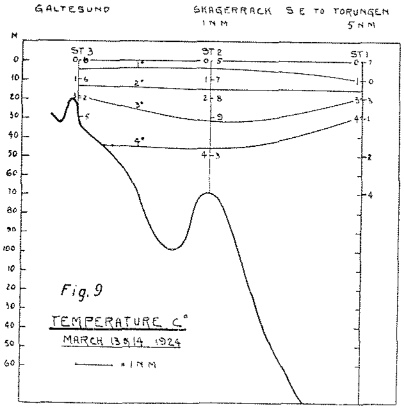


Fig. 9
TEMPERATURE C°
MARCH 13 & 14. 1924

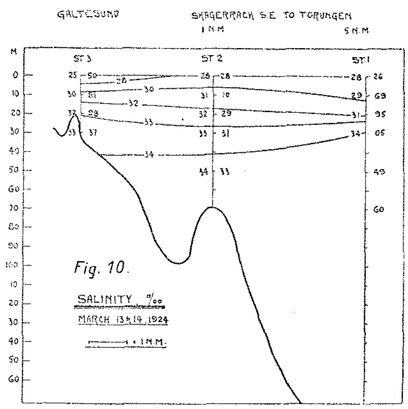


Fig. 10.
SALINITY ‰
MARCH 13 & 14 1924

Table 1. The size & number of eggs. Eggs with oil globule in ( ).
March 13th. & 14th.

Diam. mm.	Galtesund Station 3 4 hauls	1 n. m. Station 2 5 hauls	5 n. m. Station 1 6 hauls
0.8	2		(2)
0.9	16	5	4 (12)
1.0	10		19
1.1	6		12
1.2	54	8	24
1.3	152	76	167
1.4	145	103	238
1.5	20	32	176
1.6	3	1	8
1.7	10	2	2
1 8		3	
1.9	2		1
2.0	1	1	
	421	231	651 (14)

The following species are identified:

Station 1. 1.5 mm. *Gadus callarias.*
„ 2. 1.3—1.5 „ *Gadus callarias.*
1.7 mm. or more = *Drepanopsetta platessoides.*
„ 3. 1.4—1.5 mm. *Gadus callarias.*
1.6 mm. or more = *Drepanopsetta platessoides.*

On the 13th & 14th of March hauls were made with the egg-net at 0—10—20—30 meters below the surface at all stations.[1]) At station 2 also at 50 meters, at station 1 at 50 and 70 meters.

The results were:

Number of eggs. Eggs with oil-globule in ( ).
March 13th & 14th.[2])

Depth	Galtesund Station 3	1 n. m. Station 2	5 n. m. Station 1
0 m.	332	68	608 (13)
10 —	74	90	18
20 —	3	38	11
30 —	12	32	1
50 —		3	4
70 —			9 (1)
	421	231	651 (14)

At the intermediate station the quantity of eggs is at a minimum, and here we find the eggs at a greater depth than at the two other stations. At station 3 and at station 1 the maximum is near the surface, the maximum at station 2 is at 10 meters. I can find no reasonable explanation to this. The depth of the station is intermediate to the two others and the differences in salinity and temperature are insignificant.

It being impossible to distinguish the eggs of the different species, a close examination of the total number of eggs at each station is of little value — except as an illustration of the richness of the waters. But when in some cases a sorting as to species is possible, a comparison may be made, care being taken as to the error of the method.

The majority of the eggs, Table 1 pag. 24 belongs according to their size to the cod or shellfish (1.2—1.6 mm. of diameter). It is of interest to note that at station 3 (Galtesund) the maximum is at 1.3 mm. in the Skagerrack at 1.4 mm. indicating that there is reason to believe that the eggs in the two places are not of the same origin. The cod eggs outside the coast may be somewhat larger than the cod eggs from

[1]) The site of the stations see figures of temperature and salinity. The tables and figures are always arranged with landside to the left.

[2]) In this and in the following concurring tables 0 indicates that haul has been made — but no capture.

Table) 2.* Larvae.

Station & Date	Depth	*Ammodytes*	*Gadus callarias*	Total
3 14/3	0			
	10	1		1
	20			
	30			
		1		1
2 14/3	0			
	10	4	1	5
	20	3	1	4
	30	5		5
	50			
		12	2	14
1 13/3	0			
	10	1	1	2
	20	1		1
	30	1		1
	50	1		1
	70			
		4	1	5

*) In this and the following concurring tables hauls are made at the depth stated. The larvae are put down as they appear in the hauls from land outwards.

the Galtesund — or there may be a greater contingent of shellfish eggs, these being some tenths of a mm. greater. All eggs identified, however, belong to *Gadus callarias.*

At station 3 we also find eggs about 0.9—1.0 mm., probably belonging to *Pleuronectes limanda* or *Pl. flesus.* The eggs near 1.0 mm. at 5 n. m. probably belong to small *Gadidae.* The eggs at 1.7 mm. or more belong to *Drepanopsetta platessoides,* they are easely distinguishable by the great perivitelline space.

The eggs with oildrop are characteristic for the outer station and belong to the genus *Onos.*

The few larvae caught have been compiled in table 2.

The results of these hauls are interesting. We find quite a number of eggs and some larvae in water with temperatur less than one degree, and many of the eggs are in advanced stages as shown by the detailed tables IX B. This indicates that the temperature found is not detrimental to the eggs — but of course, the time of development is prolonged at this low temperatures.

The fact, however, that eggs and larvae are found in the very cold water tells nothing about the temperature at which the eggs have been spawned. Noting the temperatures near the bottom, however, it is reasonable to assume that the "spawning temperature" may have been about 4 degrees. The majority of fishes that spawn at this time are bottom fishes. The pelagical eggs then float up until the water layer is found were the specific gravity is just the same as that of the egg — or to the surface.

As to the specific gravity of the eggs of the different species, we know very little. In the case of the cod the specific gravity of the eggs at a temperature of 5.4 C. varies practically between 1.019 and 1.022 (Dahl og Dannevig: 3).

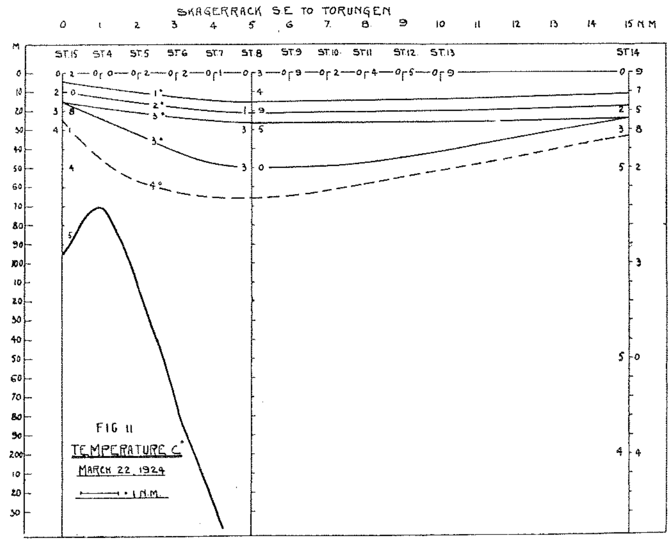
In the Hatchery it is a well known fact, however, that the eggs and larvae will sink in water of a still higher specific gravity if the temperature is rising to 10°, or falling to 0°. I am of opinion that this is caused by a physiological process, which tends to withdraw the eggs from water not suitable to their development. Another cause of augmenting the sp. g. is the masses of diatomacea and bacteria often growing on the eggs.

On the 22nd of March a cruise was made from Torungen over the deep part of the Skagerrack to 15 n. m. S. E. off Torungen. On this occasion a number of surface hauls were made, and the temperature and a water sample taken at the surface. More complete hydrographical stations were taken 3/10 n. m. to the N. E. of Torungen and 5 & 15 n. m. to the S. E. (Fig. 11 and 12). The temperature was below 1° at the surface — but at Torungen it rose quickly downwards. Here 4° will be found near 25 m. at 15 n. m. near 35 m., at 5 n. m., however, this temperature was not found till 50 m. (the deepest measurement).

In the table 3. pag. 29 we find the results of the eggfishing. It seems to be somewhat irregular. The highest number of eggs is found in the most shallow place. The presence of quantities of drifting algae indicate that here we have a ripple where eggs may accumulate. Minimum of eggs is found at station 14, 15 n. m. off Torungen, in the deepest water. In the journal it is noted that here the water at the surface was very transparent.

The size of the eggs is very homogeneous. The majority accumulates around the cod group 1.2—1.6 mm. with a little portion near 1.0 mm. probably belonging to small *Gadidae*. This group is slightly augmenting towards station 13 at 10 n. m.

Eggs with oil-globule are very rare, at station 13, 10 n. m. off Torungen there is, however, quite a small quantity, most of the eggs probably belonging to *Onos*. At station 13 & 14 also occurs an egg certainly belonging to *Brosmius*. Only 1 larvae is found, a cod 5 mm. long with resorbed yolcksack, at station 6, 0 m.


SKAGERRACK S.E. TO TORUNGEN
FIG 11
TEMPERATURE C°
MARCH 22. 1924
= 1 N.M.

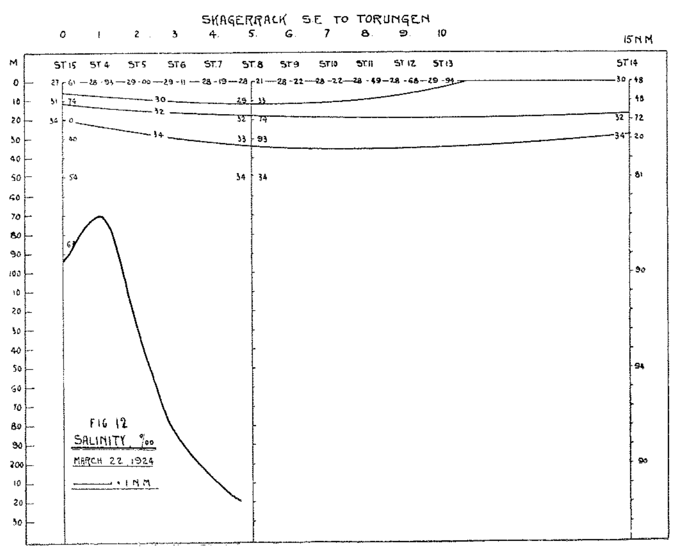

SKAGERRACK S.E. TO TORUNGEN
FIG 12
SALINITY ‰
MARCH 22. 1924
= 1 N.M.

Table 3. The size & number of eggs. Eggs with oil-globule in ( ).
March 22nd. Surface hauls S. E. of Torungen (the distance in nautical miles).

Dist.:	3/10 N.E.*)	1	2	3	4	5	6	7	8	9	10	15
Diam. m/m.	St. 15	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St. 10	St. 11	St. 12	St. 13	St. 14
0.8	1		(1)		(3)	(2)	(3)	(4)	(4)	(1)	(20)	(4)
0.9		1 (3)	(1)	(2)	(3)	(7)	2 (2)	(1)	(4)		1(20)	(3)
1.0	1	2	1	3	4	5	6	4	4 (1)	7	18	
1.1	1	3	2		1	3	1	3	2	2	3(1)	
1.2	3	9	3	8	10	20	13	10	3	1	10	1
1.3	35	77	21	61	32	98	70	66	53	37	98	3
1.4	23	132	30	85	31	99	69	85	97	62	118(1)	1
1.5	8	114	17	18	13	33	31	21	31	24	53	1 (1)
1.6		2		1	1	2	1				3	
1.7							1				7	
	72	340 (3)	74 (2)	176 (2)	92 (6)	260 (9)	194 (5)	189 (5)	190 (9)	133 (1)	311(42)	6 (8)

*) 3/10 n. m. to the N. E. of Torungen.

The following species are identified:

Station 4.	1.0	mm.	*Gadus virens?*
	1.5	„	*Gadus callarias.*
„ 5.	1.4—1.5	„	*Gadus callarias.*
„ 6.	1.4	„	*Gadus callarias.*
„ 7.	1.5	„	*Gadus callarias.*
„ 9.	1.3—1.5	„	*Gadus callarias.*
„ 10.	1.5	„	*Gadus callarias.*
„ 13.	1.6—1.7	„	*Pleuronectes platessa?*
	(1.4)	„	*Brosmius brosme?*
„ 14.	(1.5)	„	*Brosmius brosme?*

The results of the cruise may be summed up that fish eggs at that date are common near the surface out to 10 n. m. off Torungen. At 15 n. m. they are practically absent.

On the 28th & 29th of March, we have one station in the Galtesund and three in the Skagerrack at 1.4, 5 and 14 n. m. S. E. off Torungen. (Fig. 13 and 14).

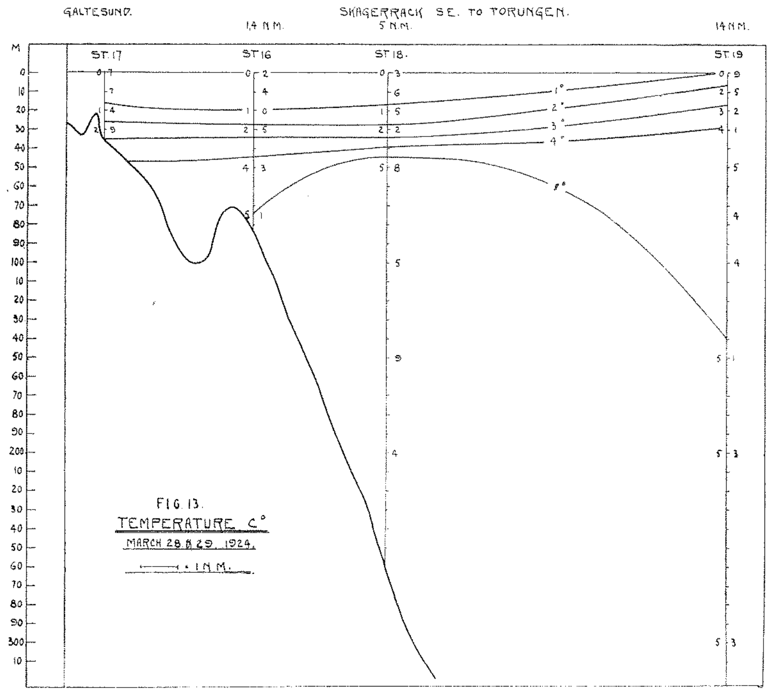


FIG. 13.
TEMPERATURE C°
MARCH 28 & 29. 1924.
= 1 N.M.

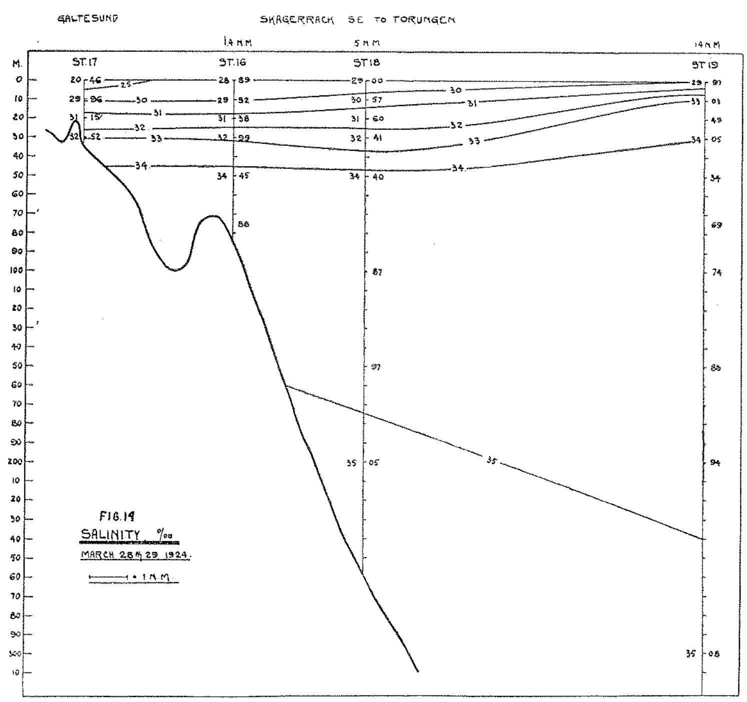


FIG. 14
SALINITY ‰
MARCH 28 & 29 1924.
= 1 N.M.

Table 4. The size & number of eggs. Eggs with oil-globule in ( ).
March 28th & 29th.

Dia.n. mm.	Galtesund Station 17 4 hauls	1 n. m. Station 16 6 hauls	5. n. m. Station 18 6 hauls	14 n. m. Station 19 2 hauls
0.8	1		(5)	
0.9	42	(1)	1	1 (1)
1.0	11	3	1	
1.1	4			
1.2	7	6	6	1
1.3	14	27	34	6
1.4	40	32	29	1
1.5	24	2	8	1
1.6	3			(1)
1.7	14			
1.8	21		1	
1.9	10	1		
2.0	8		1	
3.0			(1)	
	199	71 (1)	81 (6)	10 (2)

The following species are identified:

Station 16.	1.0	mm.	Short & plump embryo.
	1.4	„	*Gadus callarias.*
	1.9	„	*Drepanopsetta platessoides.*
„ 17.	0.9	„	*Pleuronectes flesus?*
	1.4	„	*Gadus callarias.*
	1.7—2.0	„	*Drepanopsetta platessoides.*
„ 18.	1.4—1.5	„	*Gadus callarias.*
	1.8	„	*Pleuronectes platessa.*
	2.0	„	*Drepanopsetta platessoides.*
	(3.0)	„	*Argentina silus.*
„ 19.	(1.6)	„	*Brosmius.*

We have a stratum of cold water less than 1° C. covering the sea, at station 16 down to 20 meters, but the isotherms for 2, 3 and 4° are situated close to each other. The bottom temperature in the Galtesund is $<$ 3° but on the other station $>$ 5°. A wave of warm water $>$ 5° is rising up to 45 m. below the surface at 5 n. m., but falls off on both sides. The salinity has not altered much since the measurements on March 22nd.

Number of eggs. Eggs with oil-globule in ( ).

March 28th & 29th.

Depth	Galtesund Station 17	1 n. m. Station 16	5 n. m. Station 18	14 n. m. Station 19
0 m.	75	30 (1)	54 (4)	10 (1)
10 —	11	24	11 (1)	0 (1)
20 —	39	10	7	
30 —	83	2	5	
50 —		3	4 (1)	
70 —		2	0	
	199	71 (1)	81 (6)	10 (2)

Table 5. Larvae.

Station & Date	Depth	*Ammodytes*	*Gadus callarias*	Total
17 29/3	0			
	10	1	1	2
	20			
	30	1		1
		2	1	3
16 28/3	0			
	10	2		2
	20			
	30			
	50	1		1
	70			
		3		3
18 29/3	0			
	10			
	20	1		1
	30			
	50			
	70			
		1		1

The catches are very small when compared to the results of the fishing on March 13th & 14th and 22nd. The majority of the eggs are found at the surface except in Galtesund, here we have one maximum near the surface, and one near the bottom.

From the detailed table IX B it will be seen that the maximum of eggs near the surface in the Galtesund is of sizes 1.3—1.5 mm; ɔ: the cod group, the maximum near the bottom, however, of sizes 0.9 = *Pl. limanda & Pl. flesus*, and 1.8 = *Dreponopsetta*. The occurrence of eggs at different depths shows that the specific gravity of the eggs is different. In this case it may be of interest that Capt. G. M. Dannevig in his notes from the Hatchery has put down the eggs of *Pl. flesus* with a sp. g. of 1.025. The analysis of the water samples from the station in question (17) shows that the specific gravity is the following:

	σ_t		σ_t
0 m.	16.43	20 m.	24.94
10 ,, ...	24.04	30 ,, ...	25.93

It will be natural to find the cod eggs with a normal sp. g. of 1.019—22 between 0 and 10 meters and the eggs of *Pl. flesus* near 20 m. below the surface.

On the stations in Skagerrack those eggs occur but very sparingly — here the cod group is prevailing — and, as in the Galtesund, near the surface. In the Skagerrack we have some eggs with oil belonging to the *Onos*, *Brosmius* and *Argentina*.

The number of larvae is small.

On April 9th the Tromøsund was investigated for the first time — the ice had disappeared.

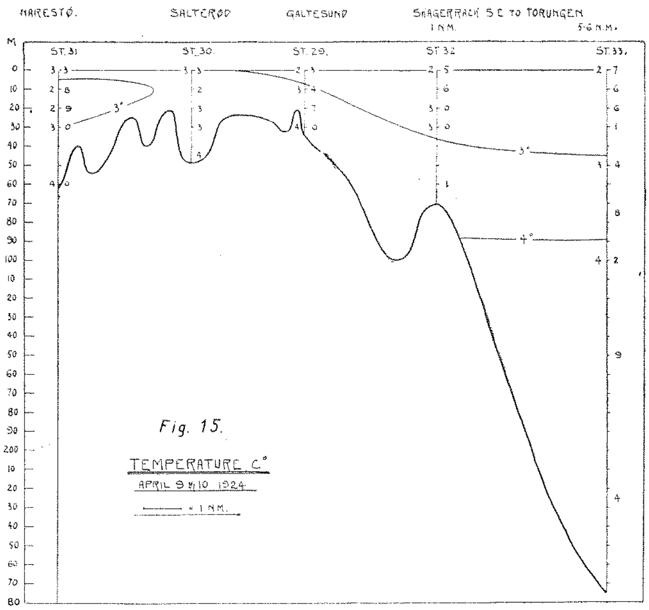
In the eastern part, at Narestø, we had station 31, in the middle of the sound, at Salterød, station 30, and in the Galtesund station 29. The next day we had stations at 1 and 5 à 6 naut. miles S. E. of Torungen.

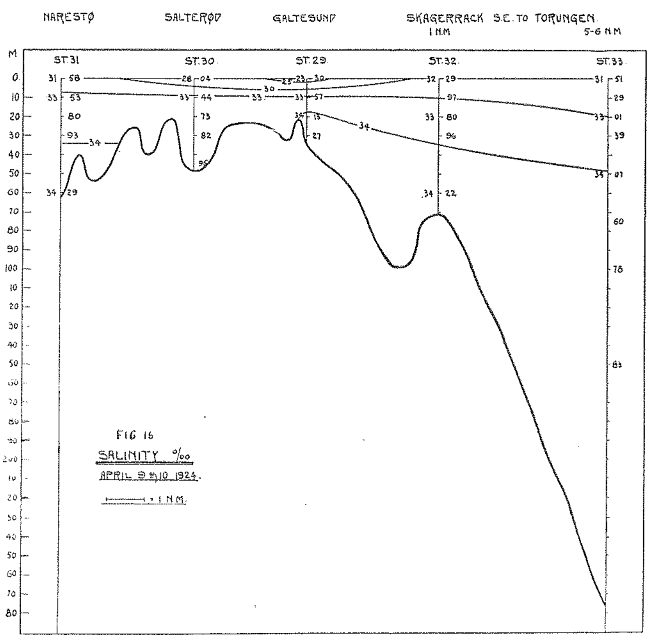
From the fig. 15 it will be seen that the temperature is very homogeneous in the whole area, the water less than 2° has disappeared. — On the other hand the water between 2.5° and 4° has a considerable extension and the water of more than 5 degrees is absent.

From the isohalines fig. 16 it is obvious that the water at the coast (station 32) is salt to the very surface — water of a salinity less than 32 ‰ is absent although it filled up the upper 30 meters 10 days previously. The absence of water less than 32 ‰ at this station may be of a somewhat adventitious character. When looking at the figures of the isohalines of the sea water at Flødevigen fig. 4 page 16 it is obvious that the state of things was abnormal at this date, the salinity being extraordinarily high. In chapter III I have metioned this phenomenon, and consider it as the result of a submarine wave, or the influence of the wind.

In the Tromøsund and Galtesund the surface has a low salinity, the water of 34 ‰ has not forced its way into the sound at that date — it ougth to be remembered that the observations are not quite coeval.

From the table we may see the results of the egg fishing.


NARESTØ.
SALTERØD
GALTESUND
SKAGERRACK S.E. TO TORUNGEN
1 N.M.
5-6 N.M.
ST. 31
ST. 30
ST. 29
ST. 32
ST. 33
3°
4°
Fig. 15.
TEMPERATURE C°
APRIL 9 & 10 1924.
= 1 N.M.


NARESTØ
SALTERØD
GALTESUND
SKAGERRACK S.E. TO TORUNGEN
1 N.M
5-6 N.M
ST. 31
ST. 30
ST. 29
ST. 32
ST. 33
34
FIG 16
SALINITY ‰
APRIL 9 & 10 1924.
= 1 N.M.

Number of eggs. Eggs with oil-globule in ( ).
April 9th & 10th.

Depth	Narestø Station 31	Salterød Station 30	Galtesund Station 29	1 n. m. Station 32	5 n. m. Station 33
0 m.	335 (7)	131	160 (1)	68 (4)	5 (2)
10 —	35	50	111	6	10 (1)
20 —	24	25	205	8	13
30 —	18	39	1	7	3
50 —				3	0
70 —					4
	412 (7)	245	477 (1)	92 (4)	35 (3)

Table 6. The size & number of eggs. Eggs with oil-globule in ( ).
April 9th & 10th.

Diam. mm.	Narestø Station 31 4 hauls	Salterød Station 30 4 hauls	Galtesund Station 29 4 hauls	1 n. m. Station 32 5 hauls	5 à 6 n. m. Station 33 6 hauls
0.8	52 (7)	26	28 (1)	3 (3)	
0.9	76	71	146	13 (1)	3 (1)
1.0	36	21	87	6	5
1.1	25	13	22	2	1
1.2	121	50	64	15	3
1.3	52	23	35	27	5
1.4	7	4	18	17	4 (1)
1.5	2	6	3	1	8 (1)
1.6	13	14	16		1
1.7	10	12	32	3	
1.8	12	3	17	2	1
1.9	6	2	7		1
2.0			2	3	3
	412 (7)	245 (0)	477 (1)	92 (4)	35 (3)

The following species are identified:

Station 29. 0.8—1.2 mm. Probably *Pl. limanda & flesus.*
1.4 „ *G. callarias.*
1.6—2.0 „ *Drepanopsetta.*
„ 30. 1.4—2.1 „ *Drepanopsetta.*
„ 31. 1.6—1.9 „ *Drepanopsetta.*
„ 32. 1.4 „ *G. callarias.*
1.7—2.0 „ *Drepanopsetta.*
„ 33. 1.8—2.0 „ *Drepanopsetta.*

Table 7. Larvae.

Station & Date	Depth	*Ammodytes*	*Cottus bubalis*	*Agonus cataphractus*	*Drepanop-setta*	*Pleuronectes flesus*	*Clupea harengus*	Total
31 9/4	0	1						1
	10	2	2					4
	20	2						2
	30	4		1				5
		9	2	1				12
30 9/4	0	1						1
	10				1			1
	20		1					1
	30							
		1	1		1			3
29 9/4								1
	0					1		7
	10	7						6
	20	5	1					1
	30	1						
		13	1			1		15
32 10/4	0							0
	10						1	1
	20						1	1
	30							0
	50							0
							2	2
33 10/4	0							
	10							
	20							
	30							
	50							
	70							
								0

At Narestø station 31, and Galtesund station 29, the catches are quite rich, but poor in the Skagerrack. There may be some reason to believe that this condititon of things is brought about by the extraordinary hydrographical conditions just referred to — the surface layers may have been driven out carrying eggs and larvae out to sea. As will be shown later another explanation may also be justified.

Station 29, Galtesund, is of interest as we find maximum of eggs at 20 m. just the same as we found on the 28th of March in the same place (station 17). And the explanation is the same, we have here a quantity of eggs of 0.9 mm., *Pl. flesus,* and 1.6 and more, *Drepanopsetta.* At the surface the cod group 1.2—1.5 is more prominent.

At the skjærgaard stations 29—31 are caught some larvae of *Ammodytes*, some *Cottidae,* 1 *Pl. flesus,* 1 *Drepanopsetta* and 1 *Agonus cataphractus,* all belonging to our skjærgaard fishes. At station 32, at the coast, 2 individuals of *Clupea harengus* are secured.

The waters, Tromøsund—Galtesund, were explored on the 24th of April. Fig. 17 and 18, Table 8 and 9. The temperature is augmenting at the surface, but in the deeper layers temperatures between 3 and 3.5 degrees are prevailing. The water of low salinity $<$ 30 ‰ has attained a great volume caused by the melting of snow and ice inland.

The catch of fisheggs is the following:

Number of eggs. Eggs with oil-globule in ( ).

April 24th.

Depth	Naresto Station 40	Salterød Station 41	Galtesund Station 39
0 m.	53 (4)	1	30
10 —	38	58 (1)	35 (2)
20 —	57	319	111 (2)
30 —	74	457	76
	222 (4)	835 (1)	252 (4)

At Salterød, in the middle of the sound, we now have a great maximum of eggs — and characteristic enough, at 30 m. It is once more the *P. limanda* — *P. flesus* type of eggs which occurs in the deeper layers, vide the detailed table IX B. It seems that the time of spawning of those specimens has been later at this station.

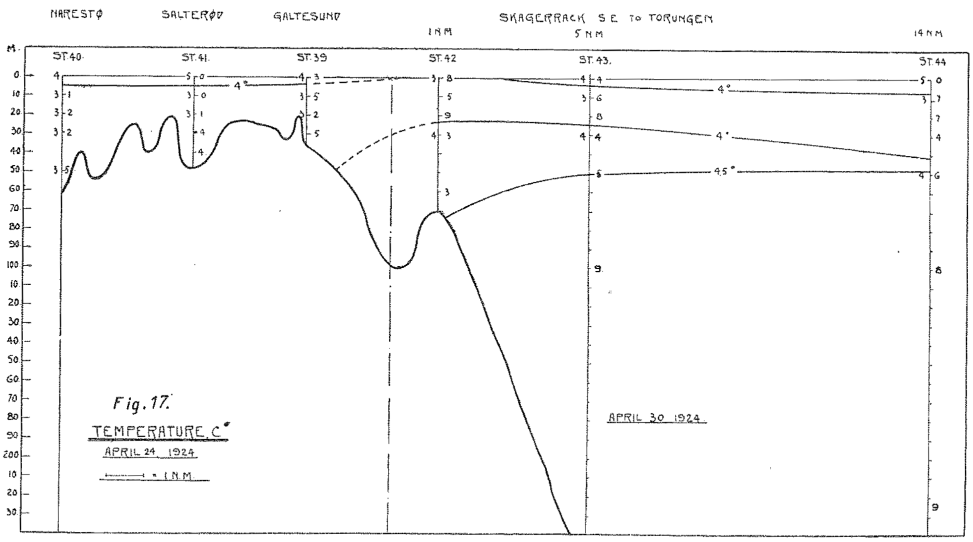


Fig. 17.
TEMPERATURE C°
APRIL 24. 1924
= 1 N.M.

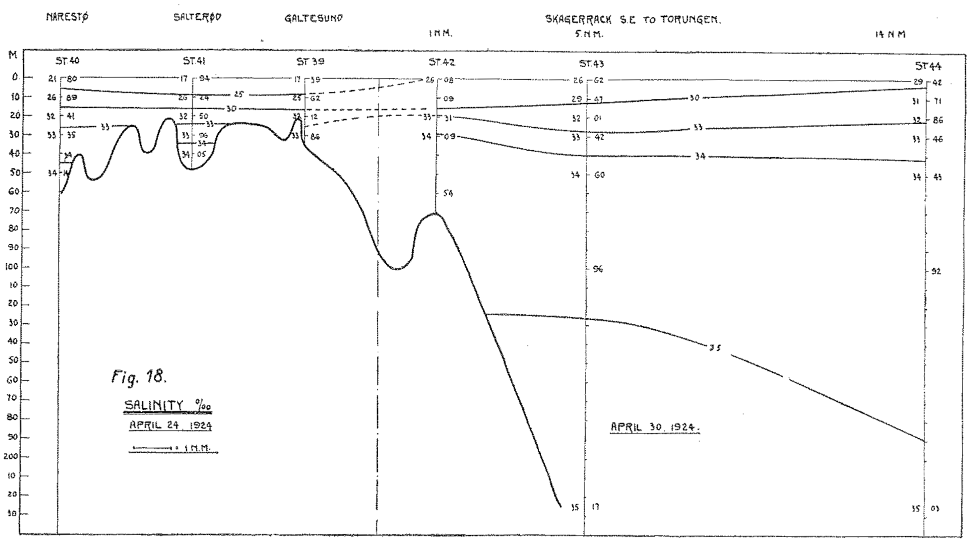


Fig. 18.
SALINITY ‰
APRIL 24. 1924
= 1 N.M.

At both ends of the sound the herring larvae are present in quantities — in the middle of the sound but two individuals. On the whole the middle of the sound is poor as to larvae.

The waters outside Torungen were not exploited until 30th of April. — Compared to the measurements of April 10th the temperature had risen about one degree Celsius except in the deeper layers where it is practically the same $< 5°$.

The upper layers are now fresher, at 5 n. m. the isohaline to 30 ‰ is situated below 10 m., on April 10th we had more than 31 ‰ at the surface.

Number of eggs. Eggs with oil-globule in ( ).
April 30th.

Depth	1 n. m. Stations 42	5 n. m. Station 43	14 n. m. Station 44
0 m.	209 (87)	20 (88)	20 (121)
10 —	44 (24)	15 (13)	34 (8)
20 —	14 (6)	30 (19)	6 (7)
30 —	13 (3)	38 (15)	25 (13)
50 —	0 (0)	10 (4)	3 (5)
70 —		8 (7)	
	280(120)	121 (146)	88 (154)

At station 42, 1 n. m. off Torungen, we have maximum of eggs without oil-drop — and near the surface. At 5 and 14 n. m. the number decreases, but is compensated by eggs with oil-drop. It is of interest to note that at the outer stations we caught a great deal of eggs in the intermediate layers.

The egg measurements from station 43 and 44 (Table 8) show that at those stations we have many eggs of a diameter 1.1 mm. — and the character of the embryoes makes it reasonable to assume that they belong to *Gadidae*. In the cod group of the eggs, we find *G. callarias,* and *G. aeglefinus* — but in small numbers.

Table 8. The size & number of eggs. Eggs with oil-globule in ( ).
April 24th. April 30th.

Diam. mm.	Narestø Station 40 4 hauls	Salterød Station 41 4 hauls	Galtesund Station 39 4 hauls	1 n. m. Station 42 5 hauls	5 n. m. Station 43 6 hauls	14 n. m. Station 44 5 hauls
0.7				(2)	(1)	(4)
0.8	9 (2)	111	5 (3)	20 (66)	1 (73)	4 (98)
0.9	28 (2)	148 (1)	32 (1)	37 (50)	2 (35)	5 (28)
1.0	24	231	13	66 (2)	11	13
1.1	26	156	18	23	24	32
1.2	11	59	53	20	19	6
1.3	48	62	42	74	30	8 (1)
1.4	47	29	46	31	26 (24)	8 (14)
1.5	6	6	7	6	6 (12)	8 (9)
1.6	4	16	6			
1.7	8	9	12	1		1
1.8	4	8	11	1	1	
1.9	3		2			
2.0	1		4	1	1	1
2.1	2		1			
2.2	1					2
3.0					(1)	
	222 (4)	835 (1)	252 (4)	280 (120)	121 (146)	88 (154)

The following species are identified:

Station 39. 1.2 mm. *Gadidae.*
1.3—1.4 „ *G. callarias.*
1.6—2.0 „ *Drepanopsetta.*
„ 40. 1.0 „ *Pl. flesus?*
1.2—1.5 „ *G. callarias.*
1.6—2.1 „ *Drepanopsetta.*
„ 41. 0.8 „ *Pl. limanda?*
0.8—1.1 „ *Pl. limanda & flesus.*
1.3—1.4 „ *G. callarias.*

Station 42. (0.7—0.9) mm. *Onos sp.*
1.0 „ *G. minutus?*
1.2—1.4 „ *G. callarias.*
1.7—2.0 „ *Drepanopsetta*
„ 43. 1.0—1.1 „ *G. minutus?*
1.3 „ *G. callarias.*
1.3—1.4 „ *G. aeglefinus.*
(1.4—1.5) „ *Brosmius brosme.*
1.8—2.0 „ *Drepanopsetta*
(3.0) „ *Argentina silus*
„ 44. 1.4 „ *G. callarias.*
(1.4—1.5) „ *Brosmius brosme.*
1.7—2.2. „ *Drepanopsetta*

Table 9. Larvae.

Station & Date	Depth	*Ammodytes*	*Clupea harengus*	*Gadus callarias*	*Cyclogaster montagui*	Not identified	*Pleuronectes flesus*	*Lumpenus*	*Drepanop-setta*	*Gadidae larvae*	*Gadus aeglefinus*	*Gadus minutus*	Total
40 24/4	0												
	10	1	4	1									6
	20		32	1	2	1							36
	30		18		2								20
		1	54	2	4	1							62
41 24/4	0												
	10		1	1			1						3
	20		1										1
	30							1					1
			2	1			1	1					5
39 24/4	0	2											2
	10	3	5	1									9
	20		12										12
	30		7	1	2				1				11
		5	24	2	2				1				34
42 30/4	0			1						1			2
	10		2	1									3
	20	1	40	2	1								44
	30		94										94
	50	3	65								1		69
		4	201	4	1					1	1		212
43 30/4	0												
	10												
	20		9	3								1	13
	30	1	4	3									8
	50		5	2									7
	70		1										1
		1	19	8								1	29
44 30/4	0												
	10		3										3
	20		4										4
	30		4										4
	50												
			11										11

The eggs with oil-drop of a diameter 1.3—1.5 belong to *Brosmius brosme*. They occur but at the deeper stations.

At station 43, at a depth of 70 meters was caught an egg of a diameter 3.0 mm. belonging to *Argentina silus.*

At station 42, 1 n. m. off Torungen, we have a lot of herring-larvae at 20—50 meters, but few at the outer stations.

The herring has demersal eggs and spawns at a moderate depth. The appearance of the larvae near the coast is to be explained by this fact. We have here an illustration as to the influence of the depth on the occurrence of the species. Near land larvae of species with demersal eggs. — Over the great depths the eggs are found of the deep-sea form *Brosmius brosme.*

Cod larvae (Table 9) are present at 1 and 5 n. m. — and at 1 n. m. we find the first larvae of *G. aeglefinus.* One larvae, evidently *G. minutus*, seems to indicate the nature of the *Gadidae* eggs of a diameter of 1.1 mm.

On 15th, 16th and 19th of May the same waters except 14 n. m. were examined once more. The surface water is warmed. In Galtesund, in the neighbourhood of the river, the temperature is 6.4°. In the middle of Tromøsund we find 9° and 5 n. m. off Torungen 7.7°.

The bottom temperature varies approximately from 3.5° to 4.9° and has risen very little since the last days of April. The quantity of water with a salinity less than 30 ‰ has augmented.

Fish eggs are caught in the following numbers:

Number of eggs. Eggs with oil-globule in ( ).

May 15th to 19th.

Depth	Naresto Station 63	Salterød Station 65	Galtesund Station 64	1 n. m. Station 66	5 n. m. Station 67
0 m.	17 (2)	0 (0)	2 (1)	29 (2)	10 (12)
10 —	51 (18)	77 (15)	129 (15)	1714 (88)	332 (101)
20 —	109 (4)	182 (10)	153 (9)	663 (64)	243 (51)
30 —	199 (23)	276 (7)	67 (4)	245 (16)	35 (2)
50 —				47 (2)	18 (5)
70 —					5 (1)
	376 (47)	535 (32)	351 (29)	2698 (172)	643 (172)

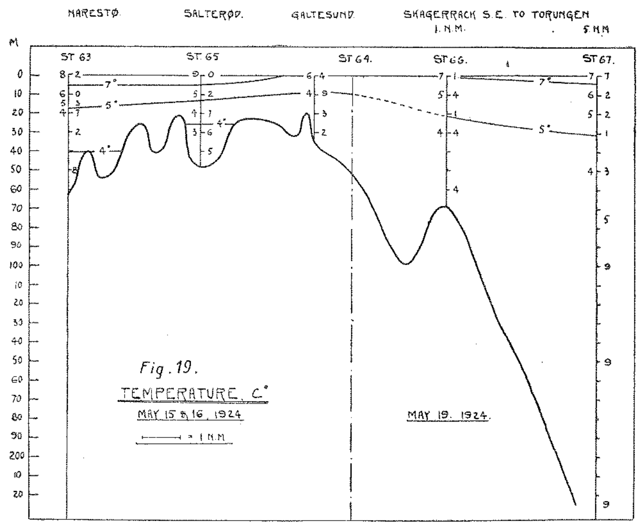


Fig. 19.
TEMPERATURE C°
MAY 15 & 16. 1924
= 1 N.M.

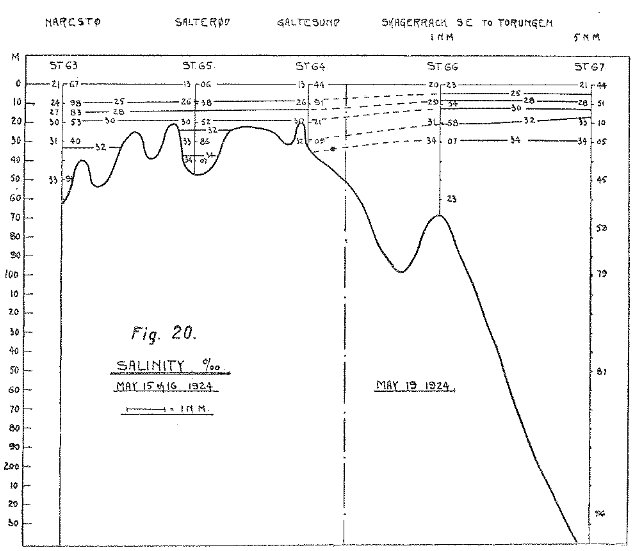


Fig. 20.
SALINITY ‰
MAY 15 & 16 1924
= 1 N.M.

Table 10. The size & number of eggs. Eggs with oil-globule in ( )
May 15th to 19th.

Diam. mm.	Narestø Station 63 4 hauls	Salterød Station 65 4 hauls	Galtesund Station 64 4 hauls	1 n. m. Station 66 5 hauls	5 n. m. Station 67 6 hauls
0.7	(4)	4 (2)	2 (4)	(22)	(35)
0.8	19 (33)	55 (23)	25 (21)	43 (102)	27 (123)
0.9	20 (6)	33 (3)	36 (3)	194 (39)	90 (8)
1.0	69	128 (3)	59	1786 (3)	314 (2)
1.1	194	157 (1)	108	591	142
1.2	28	124	66	42	44
1.3	27 (1)	9	39	25 (4)	18 (4)
1.4	16 (2)		14	17 (2)	8
1.5	1 (1)	3	1 (1)		
1.6		3			
1.7		2			
1.8		4			
1.9	1	9	1		
2.0		4			
5.0	1				
	376 (47)	535 (32)	351 (29)	2698 (172)	643 (172)

The following eggs are identified:

Station 63.	1.1	mm.	*G. merlangus?*
	1.3	„	*G. callarias.*
	1.3—1.4	„	*G. aeglefinus.*
	1.9	„	*Drepanopsetta.*
	5.0	„	*Hippoglossus vulgaris.*
„ 64.	1.9	„	*Drepanopsetta.*
„ 65.	1.2—1.3	„	*G. callarias.*
	1.5—2.0	„	*Drepanopsetta.*
„ 66.	1.0	„	*Cl. sprattus.*
	1.0—1.2	„	*Gadidae.*
	1.1	„	*G. merlangus?*
	1.3	„	*G. callarias.*
	1.3—1.4	„	*G. aeglefinus.*
„ 67.	(0.8	„)	*Onos mustela.*
	1.0	„	*Cl. sprattus.*
	1.1	„	*Gadidae.*
	(1.3	„)	*Brosmius brosme.*

*) *Table 11.* Larvae.

Station & Date	Depth	*Gadus minutus?*	*Gadus callarias*	*Drepanopsetta*	*Gadus aeglefinus*	*Cyclogaster montagui*	*Pholis gunellus*	*Clupea harengus*	*Ammodytes*	*Pleuronectes flesus*	*Gadus pollachius*	*Clupea sprattus*	*Onos cimbrius*	*Gadus esmarki?*	*Gadus sp.*	*Pleuronectes limanda*	*Gadus merlangus?*	Total
63	0																	
15/5	10	2	2	1	2													7
	20		5		3	1	2	2										13
	30		1	1	5	1	1	5	1									15
		2	8	2	10	2	3	7	1									35
65	0	1		1				15										17
16/5	10		3	1	5	1		7		1								18
	20		1					2										3
	30			2	1			5										8
		1	4	4	6	1		29		1								46
64	0							2										2
16/5	10		2		3					1	2	2	1					11
	20	2	2		1			6		1				1	1			14
	30				2		1	4										7
		2	4		6		1	12		2	2	2	1	1	1			34
66	0																	
19/5	10	1	1	1	7		1	3		3		1				3		21
	20	1	6		3	1		1	1	2		3		1		3		22
	30	1	5		4					2	1					4		17
	50		1		3		1											5
		3	13	1	17	1	2	4	1	7	1	4		1		10		65
67	0																	
19/5	10			1										1		1		3
	20	1			1					1							1	4
	30	1	3					1								1		6
	50		3															3
	70		2	1														3
		2	8	2	1			1		1				1		2	1	19

*) The identification of the larvae as to Gadus merlangus, G. minutus and G. esmarki may be incorrect.

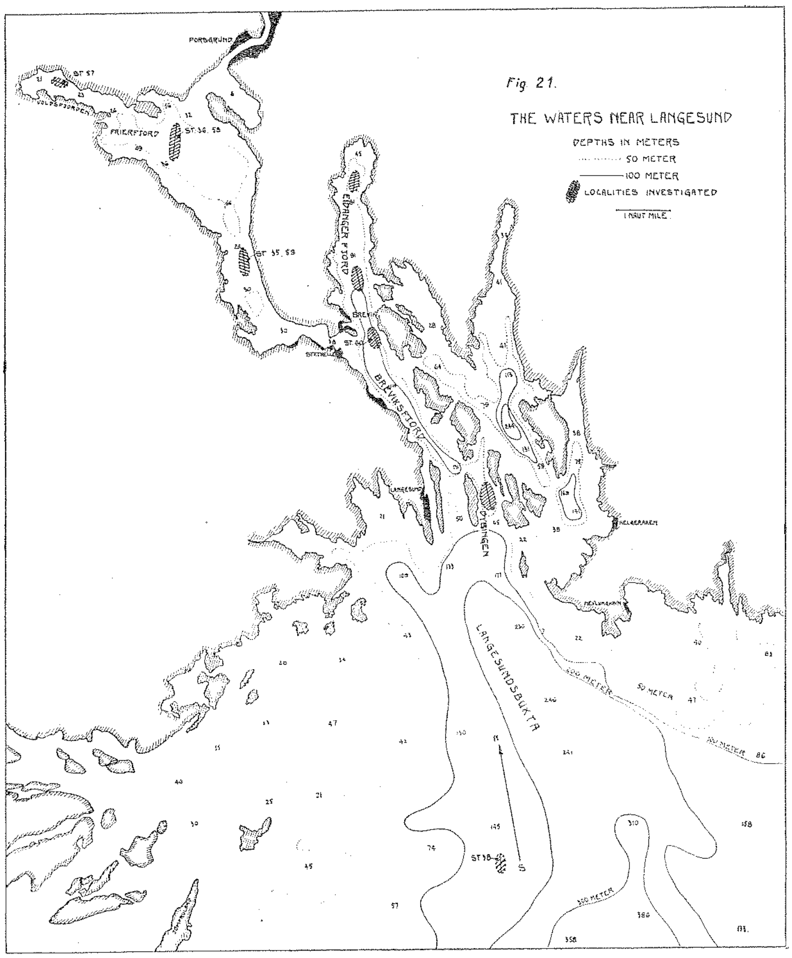
At the stations taken earlier it was usual to find the maximum of eggs in the higher layers. When we happened to find the majority of eggs near the bottom it was the eggs of *Pleuronectes limanda, Pl. flesus* and *Drepanopsetta platessoides* — and always in shallow water. At station 66, 1 n. m. off Torungen, we now have a pronounced maximum at 10 meters, and as is shown by the detailed tables IX B it is constituted of eggs of a diameter = 1.0 mm., and by closer examination we find that the majority of the eggs belongs to *Clupea sprattus*. Among the small eggs about 1.1 mm. I have also observed eggs with advanced embryoes surely belonging to the *Gadidae;* at station 66 I have noted eggs 1.1 mm. = *G. merlangus?*. The embryoes and early larval stages of some of our *Gadidae* are not so well described that I can identify the preserved individuals.

The eggs of *Brosmius brosme* — vide table 10 — are found in quite small numbers. In Galtesund and at Narestø the eggs of that size 1.3—1.5 mm. probably belong to *Trigla gurnardus*.

As shown by table 11 the quantity of larvae is great — and many species occur. The number of larvae of *Clupea harengus* has been reduced, but *G. aeglefinus* is now most abundant. We find *G. pollachius*, and *Clupea sprattus* — a good sign that the temperature is rising.

B. The waters near Langesund.

The Bay of Langesund, Langesundsbugta, is quite open to the Skagerrack. The bottom rises here but slowly from the great depth outside the coast which penetrates close to the town of Langesund. Here we find a couple of islands. The fjord is divided into several parts, and the soundings show that we have a barrier which separates the depth of the Langesundsbugta from that of the Breviksfjord. In the deepest sound, Dybingen, the depth is more than 160 meters, but with a threshold outside of about 75 m. And one inside at about 60 meters which must be regarded as the depth at which the Brevikfjord



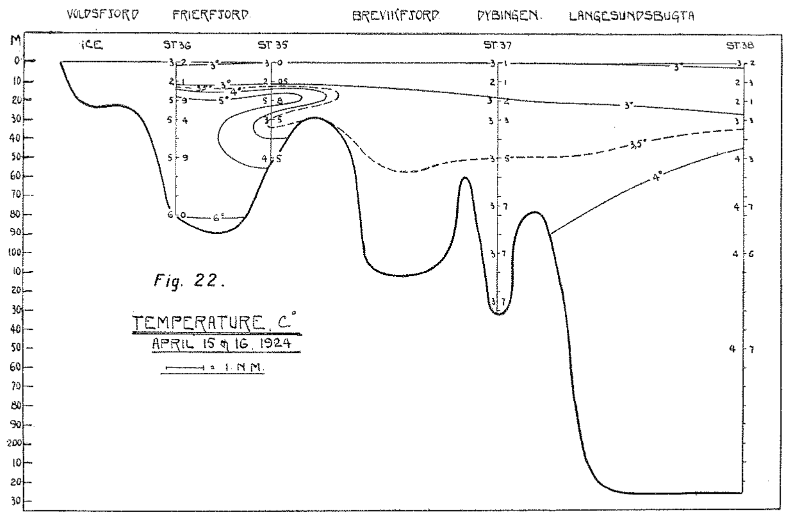


Fig. 22.

TEMPERATURE, C°
APRIL 15 & 16. 1924
= 1 N.M.

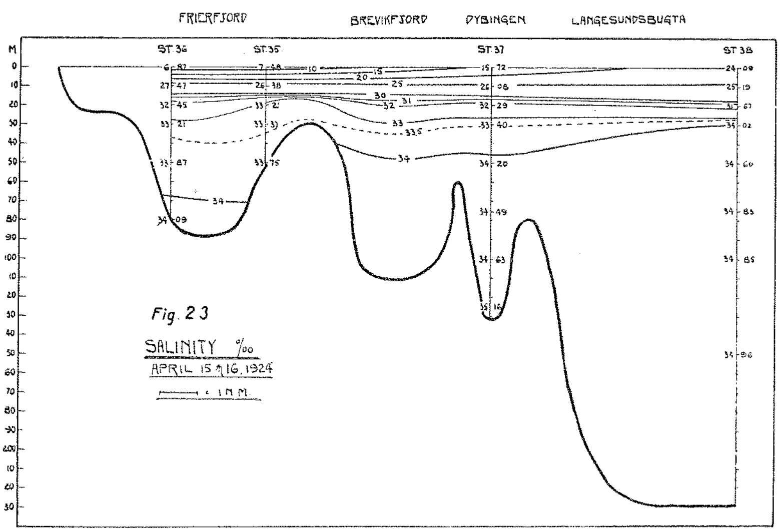


Fig. 23

SALINITY ‰
APRIL 15 & 16. 1924
= 1 N.M.

is separated from the bay of Langesund. Thus Dybingen is to be regarded as a basin, as to the deeper layers. The Brevikfjord is a little more than 100 m. deep, and passes in the neighbourhood of the town Brevik into the Eidangerfjord. To the west of Brevik, the fjord is narrow with shallow waters, less than 30 meters, and continues into the Frierfjord, a great basin with soundings as deep as 93 meters. From the Frierfjord, we pass into the Voldsfjord. It is quite narrow and with a depth not exceeding 25 meters. Into the Frierfjord the Skienselv pours quantities of fresh water and makes the surface of the fjord quite brackish.

From the description given it will be evident that we here have a series of localities representing the different types of waters from the open sea to the very isolated fjord. It will be obvious that the water at the different localities and depths cannot be in an immediate exchange with one another except near the surface. There are more thresholds as we pass from the sea into the inner fjord. These conditions must influence the character of the water. In the isolated fjord the water must be more or less stagnant.

Whether the water is stagnant or not in a fjord may be shown by simple temperature measurements. If the temperature in the deeper layers in the fjord differs several degrees from the temperature of the water outside, this must be taken as a sign that the circulation of the water is very restricted. This method, however, will not always hold good. If a single series of observations from the sea into the fjords give practically the same temperatures, we can say nothing as to the bottom layers of the fjord. It may be stagnant—and it may not.

By taking a series of measurements of the quantity of oxygen, however, the question will soon be settled. In the Skagerrack the quantity of oxygen will vary but little[1]) from the surface to a moderate depth. In the deep fjords, however, the differences will be very great—and in conformity to the degree of circulation of the water.

According to Gaarder (12), the oxygen of the watermasses in our fjords below 40 meters depends upon circulation, the comsumption of oxygen being greater than the production. If in layers from that depth downwards we find oxygen in concordance with the water out-

[1]) These variations are, however, of very great importance when studying the plankton growth of the waters, a question not discussed in this paper.

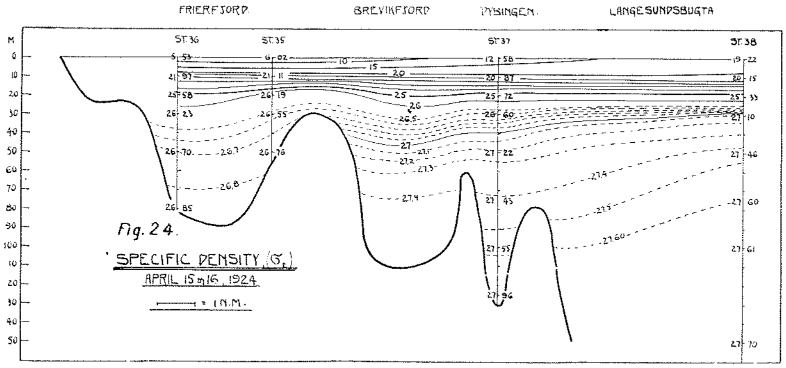


Fig. 24.
SPECIFIC DENSITY (σt)
APRIL 15 & 16, 1924

Table 12. The size & number of Eggs. Eggs with oil-globule in ( ).
April 15th & 16th.

Diam. mm.	Frierfjord Station 36 5 hauls	Frierfjord Station 35 3 hauls	Dybingen Station 37 2 hauls	Langesundsbugta Station 38 2 hauls
0.8	14	2		(8)
0.9	106	25 (4)	5	3 (5)
1.0	382	30	13	25
1.1	266	59	2	6
1.2	60	122	6	14
1.3	368	48	31	28
1.4	277	31	15	12
1.5	59	9	1	2
1.6	3			
1.7	3			
1.8		2		
	1538	328 (4)	73	90 (13)

The following species are identified:

Station 35. 1.1 *Cl. sprattus.*
1.5 *G. callarias.*
1.8 *Drepanopsetta.*
„ 36. 1.0 *Pleuronectidae* with very thick skin.
1.0—1.05 *Cl. sprattus.*
1.3—1.4 *G. callarias.*
„ 37. 0.9—1.0 *Pleuronectidae?*
„ 38. 1.0 *Pleuronectidae?*
1.4 *G. callarias.*

side the fjord, the water in a short space of time must have been pressed into the fjord from the sea, or there must have been a lively communication between the surface & bottom layers. According to the great differences in salinity between the top & bottom layers normally found in our fjords, the sp, gr. will differ too much to permit any such vertical communication. As time passes, however, and no renewal takes place, the quantity of oxygen will diminish—and in the course of time disappear altogether—and be replaced by sulphurated hydrogen.

In isolated fjords of a depth of say 50 meters or more—we in the quantity of oxygen have a means to state the "age" of the water in the fjord.

When studying the analysis of temperature & oxygen we get a strong impression that the circulation of the deep layers in the fjords at Langesund must be very slow. The more so as we advance from the outer part into the inner basins. On account of my knowlegde in hydrography being very limited, and as the hydrographical conditions were very complicated, Professor B. Helland-Hansen in Bergen, has been kind enough to construct the figures of these waters on the basis of the material compiled.

The fig. 22 shows the temperature of the sea water at the first cruise on the 15th & 16th of April. At that time the ice is still lying thick in the inner ²/₃ of the Eidangerfjord, the whole of the Voldsfjord and the N. W. part of the Frierfjord. At the mouth of the Langesundsbugta, St. 38, the bottom and middle water-layers have a temperature of a little more than 4° C. From 45 m. to the surface we have temperatures less than 4°, at 20 m. as low as 2° C.

At St. 37, Dybingen, the water of 4° has not penetrated over the threshold. The water of 3°—4° degrees reaches here from the bottom to about 20 meters—and also fills up the Brevikfjord and the Eidangerfjord. It penetrates into the Frierfjord and a portion of the warm water of that basin is lifted up and pressed outwards. The rest of the basin is filled with water of very high temperature, viz more than 5 degrees.

The fig. 25 pag. 52 shows that the water in the deep part of the Frierfjord is stagnant. The quantity of oxygen pr. liter sea-water is very low. Near the bottom it is next to nothing. It is interesting to

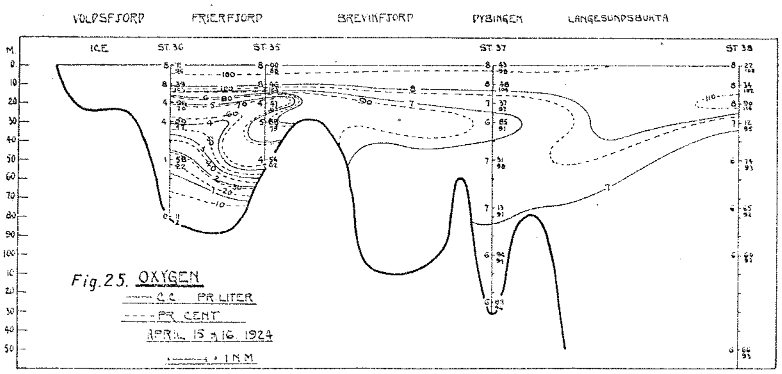


Fig. 25. OXYGEN
—— C.C. PR LITER
- - - - PR. CENT
APRIL 15 & 16 1924
1 N.M.

Table 13. Larvae.

Station & Date	Depth	*Clupea sprattus*	*Clupea harengus*	*Pleuronectes flesus*	*Gadus callarias*	*Drepanop-setta*	*Pleuronectes cynoglossus*	*Perca fluviatilis*	*Ammodytes*	*Pleuronectes limanda*	Total
36 15/4	0							1			1
	10	17	6	7	4		4				38
	20	6	7	16	2	3					34
	30	11	3	21	2	4					41
	50	5	3		1	1					10
		39	19	44	9	8	4	1			124
35 15/4	0		550						1		551
	10	2	240	5	1	1					249
	20	5	47	16	2		1			1	72
		7	837	21	3	1	1		1	1	872
37 16/4	0		1						1		1
	10		30								30
			31						1		31
38 16/4	0										
	10		3								3
			3								3

note the low quantity of oxygen at St. 35, 20 meters, just at the depth where we had the warm water penetrating outwards over the cold water.

Hauls with the egg-net gave the following number of eggs.

Number of eggs. Eggs with oil-globule in ( )

April 15th and 16th.

Depth	Frierfjord St. 36	Frierfjord St. 35*	Dybingen Station 37	Langesundsbugta Station 38
0 m.	1	0	25	41 (3)
10 —	499	52 (2)	48	49 (10)
20 —	330	276 (2)		
30 —	500			
50 —	208			
	1538	323 (4)	73	90 (13)

*) The haul at 20 meters lasted 15 minutes but the catches are reduced to 10 minutes.

Time being scarce the egg fishing was not carried out at all the ordinary depths. Only the two uppermost hauls were made at the two stations No. 37 and 38.

The station in the deep part of the Frierfjord, st. 36, is very rich in fish eggs. — We find here more than $1^1/_2$ thousand.

The table 12 informs us that the eggs here are of two different groups — one with a diameter about 1.0 mm. the other 1.3—1.4 mm. Among the eggs of 1.0 mm. we find a great number belonging to *Clupea sprattus.* Some of the eggs with a thicker skin — but of the same size — belong to the *Pleuronectidae.* Eggs of the cod group 1.3—1.4 mm. with advanced embryoes belong to *G. callarias.*

The table 13 shows the number of larvae caught, and the species determined. The majority belongs to *Pleuronectes flesus.* Then we have *Clupea sprattus, Cl. harengus, Pl. cynoglossus, G. callarias* and *Drepanopsetta* and one *Perca fluviatilis.* The last mentioned is caught near the surface in the fresh water covering the sea-water. The number of larvae is very high.

At st. 35, at the entrance of the Frierfjord, we also have many eggs of the same size but also some near 1.2 mm. At that station, I

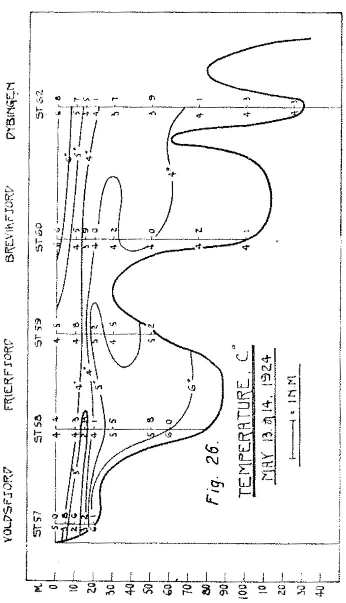


Fig. 26. TEMPERATURE C° MAY 13 & 14. 1924

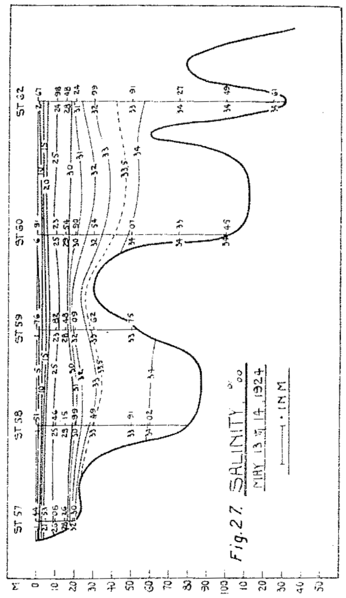


Fig. 27. SALINITY ‰ MAY 13 & 14. 1924

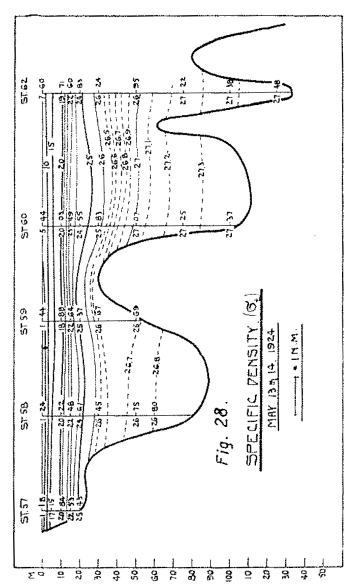


Fig. 28. SPECIFIC DENSITY (σ_t) MAY 13 & 14. 1924

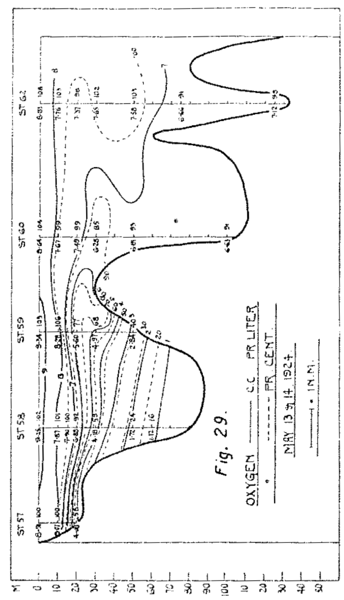


Fig. 29. OXYGEN —— C.C. PR LITER. - - - - PR CENT. MAY 13 & 14. 1924

have noted the eggs of *G. callarias* and *Cl. sprattus*. The larvae caught belong chiefly to the same species as at the inner station. But here we have large numbers of *Clupea harengus* close to the surface. Some weeks previously great quantities of spawning herring were caught at the same locality.

The number of eggs at Dybingen, st. 37, and in Langesundsbugta st. 38, is small, we find *Pleuronectidae-eggs* and eggs belonging to the cod group. The larvae caught are very few, some herring larvae at Dybingen but only three in Langesundsbugta.

It is rather unfortunate not to have the deeper hauls at st. 37 and 38. Keeping to the upper layers only it is evident that the fauna of fish eggs and larvae is very different in the Frierfjord and outside, the number of species and individuals are decreasing outwards.

In the deep Frierfjord with the warm water we find the eggs and larvae of the sprat — the eggs of which are not found in the coast waters until one month later. At the entrance of the Frierfjord — where the depth is moderate and the bottom rocky and covered with water of 3.5°—4° C., we find enormous quantities of herring larvae. A good illustration as to how the spawning of the different species depends upon the nature of the water and bottom. The sprat is a pelagic fish — with pelagic eggs, it may spawn where the condition of water is convenient — from these investigations it proves at a temperature near 6 degrees C. The herring is known to spawn in water of about 4 degrees, and as the eggs are demersal, on clean bottom and at a moderate depth. These conditions are present at st. 35.

It is interesting to note the great number of herring larvae at the very surface at st. 35 in water with a salinity less than 10 ‰. The larvae could even be noticed from the cutter close to the surface. Under those conditions it may be reasonable to assume that the herring larvae at st. 37 was brought out there by the strong surface current.

One month later, on the 13th and 14th of May, these waters were exploited once more. Fig. 26—29 Tab. 14 and 15.

The surface water has attained more than 6 degrees in the Brevikfjord and Dybingen, Langesundsbugta could not be exploited as thick

Table 14. The size & number of eggs. Eggs with oil-globule in ( ).
May 13th & 14th.

Diam. mm.	Voldenfjord Station 57 2 hauls	Frierfjord Station 58 5 hauls	Frierfjord Station 59 3 hauls	Brevikfjord Station 60 6 hauls	Langesundsbugta Station 62 4 hauls
0.7		3	1 (5)	(1)	(2)
0.8	15 (21)	24 (81)	48 (53)	18 (30)	4 (24)
0.9	12 (20)	82 (51)	65 (17)	62 (6)	9 (6)
1.0		1159	450 (1)	86	32
1.1		602	259 (1)	184	57
1.2	1	37 (1)	38	57	14
1.3	6	14	13	37 (1)	27
1.4	2	3	3	19	4
1.5				2	
1.6					
1.7		3		2	
1.8				5	1
1.9				4	
2.0				4	
2.1					1
	36 (41)	1927 (133)	877 (77)	480 (38)	149 (32)

The following species are identified:

Station 58.	(0.8) mm.	*Onos cimbrius.*
	1.0—1.1	„	*Cl. sprattus.*
	1.2—1.3	„	*G callarias.*
	1.7	„	*Drepanopsetta.*
„ 59.	0.9	„	Partly eggs of *Gadidae.*
	1.0	„	*Cl. sprattus.*
	1.2—1.3	„	*G. callarias.*
„ 60.	1.2—1.4	„	*G. callarias.*
	1.4—1.5	„	*G. aeglefinus.*
	1.7—2.0	„	*Drepanopsetta.*
„ 62.	1.3	„	*G. callarias.*
	1.8	„	*Drepanopsetta.*

Table 15. Larvae.

Station & Date	Depth	*Clupea harengus*	*Pleuronectes?*[1]	*Pleuronectes flesus*	*Gadus callarias*	*Clupea sprattus*	*Gadus aeglefinus*	*Drepanopsetta*	*Pleuronectes limanda*	*Pleuronectes cynoglossus*	*Gadus merlangus?*	*Ammodytes*	*Cyclogaster montagui*	*Pholis gunellus*	*Gadus minutus?*	*Defect larvae*	Total
57	0	3	1														4
13/5	10	14		6	7	6											33
		17	1	6	7	6											37
58	0																
13/5	10	109	1	21	8	22	3	2	1								167
	20	34		9		7	1	3		1							55
	30	39		6	1	20	1	2									69
	50	15		2	2	5											24
		197	1	38	11	54	5	7	1	1							315
59	0	26		2		1		1								1	31
13/5	10	68		9	13	6	3	1			1						101
	20	12		4	1	3	1	1				1	1	1			25
		106		15	14	10	4	3			1	1	1	1		1	157
60	0	17		1		10			1								29
13/5	10	159		10	18	4	5	5	3								204
	20	26		2	2			1	1				1			1	34
	30	4			2												6
	50	12			2												14
	70	7			1		1										9
		225		13	25	14	6	6	5				1			1	296
62	0	730			1	3	2										736
14/5	10	44		7	8	2	10	2					1	1	1		76
	[2]) 20	37			3		7						1				48
	30	21			2		1										24
		832		7	14	5	20	2					2	1	1		884

1) The specimens badly fixed & difficult to identify.

2) St. 62,20 m. The haul only 8 minutes, the catches reckoned for à 10 min. haul.

fog prevailed that day. In the Frierfjord the brackish water at the top has not reached 5 degrees, on account of the cold water coming from the inner part of the country. (The melting of the snow). The bottom layers are half a degree warmer in the Brevikfjord and in Dybingen, but the same in the Frierfjord, near 6°, as in April.

Intermediate layers have temperatures of 2.8°—4°.

The top layers are very brackish. The isohaline for 30‰ lies between 15 and 20 meters below the surface Fig. 27. For that reason egg fishing in the upper layers gives poor results — the water here is evidently too fresh.

The fig. 29 shows that the bottom layers in the Frierfjord are still very poor as to oxygen, in Dybingen, however, a renewal of the water must have taken place.

Number of eggs. Eggs with oil-globule in ( )

May 13th and 14th.

Depth	Voldsfjord Station 57	Frierfjord Station 58	Frierfjord Station 59	Brevikfjord Station 60	Dybingen Station 62*
0 m.	0	0	1 (1)	1	3 (1)
10 —	36 (41)	35 (93)	78 (51)	17 (14)	21 (27)
20 —		664 (20)	798 (25)	120 (4)	75 (3)
30 —		621 (9)		203 (10)	50 (1)
50 —		607 (11)		82 (5)	
70 —				57 (5)	
	36 (41)	1927 (133)	877 (77)	480 (38)	149 (32)

*) The haul at 20 meters lasted but 8 minutes but the catches are raised to give the results of 10 minutes.

In the Frierfjord we have plenty of eggs at 20—50 meters and quite a number in the Brevikfjord. At Dybingen the number is small. Looking at tab. 14 it is evident that eggs of a diameter 1.0 to 1.1 m. m. are dominating. It is the sprat eggs accompanied by eggs of small *Gadidae* and *Pleuronectidae*. The cod group is also present. A number of eggs with advanced embryoes are recognized as *G. callarias,* a few at st. 60 as *G. aeglefinus*.

All the stations, except in Voldsfjorden, are very rich in larvae, Tab. 15, abundant are *Clupea harengus* and *Cl. sprattus*. *Gadus callarias* and *Pleuronectes flesus* are also very common, and even *G. aeglefinus* occurs in numbers.

On the same dates, April 15th and May 14th, the *Eidangerfjord* was exploited (Table 16 and 17). The Eidangerfjord stands in open communication with the Brevikfjord, and st. 60 previously referred to may just as well be regarded as belonging to the Eidangerfjord.

The station 34, April 15th, at Kasistangen in the middle of the fjord was taken close to the ice covering the inner part.

The temperatures, salinity and oxygen will be found in Tab. IX D.

Hauls are made at 0 and 10 meters, the catches being some scores of eggs of sizes 1.0 and 1.3 m m. Of larvae are caught *22 herrings, 2 Ammodytes* and *2 Pl. flesus.*

Number of eggs. Eggs with oil-globule in ( )

Eidangerfjord.

Depth	Station 34 April 15th.	Station 61 May 14th.
0 m.	11	0
10 —	58	37 (29)
20 —		627 (4)
30 —		609 (12)
50 —		735 (10)
	69	2008 (55)

On the $^{14}/_{5}$ the station 61 in the inner part of the fjord gives fine catches — but especially rich are the deeper hauls, 20—50 meters. The majority of the eggs are of sizes, 0.9—1.2 m m. and embrace several species — *Gadidae*, *Pleuronectidae* and *Clupea sprattus*. Some of the cod group are also present and both *G. callarias* and *G. aeglefinus* are identified. The larvae of *Cl. harengus* are numerous, *G. callarias* and *Pl. flesus* are well represented — and also *G. merlangus* (?). Two individuals of *Pl. platessa* are of special interest. That species occurs very sparingly along our coast.

Table 16. The size & number of eggs. Eggs with oil-globule in ( ).

Diam. mm.	Eidangerfjord Station 34 2 hauls April 15th.	Station 61 5 hauls May 14th.
0.8		81 (48)
0.9	4	223 (7)
1.0	25	303
1.1	7	1003
1.2	9	273
1.3	13	42
1.4	8	51
1.5	2	23
1.6		
1.7		
1.8		4
1.9		
2.0	1	5
	69	2008 (55)

The following species are identified:

Station 34. Among the eggs of 1.0 mm. were some probably belonging to *Gadus sp.*

„ 61. 1.1 mm. *G. merlangus?*
1.2—1.3 „ *G. callarias.*
1.4 „ *G. aeglefinus.*
1.5 „ *Pleuronectes platessa?*
1.8—2.0 „ *Drepanopsetta.*

Table 17. Larvae.

Station & Date	Depth	*Clupea harengus*	*Pleuronectes flesus*	*Ammodytes*	*Pleuronectes platessa*	*Gadus callarias*	*Clupea sprattus*	*Drepanopsetta*	*Gadus aeglefinus*	*Gadus merlangus?*	Not identified	Total
34	0	6		2								8
15/4	10	16	2									18
		22	2	2								26
	0	303				1				1		305
61	10	38	17		2	18	2	2		1		80
14/5	20	30	4			4	1	2	1	2	1	45
	30	25	3			1				2		31
	50	21								2		23
		417	24		2	24	3	4	1	8	1	484

C. The waters near Kristiansand.

The Kristiansandsfjord has a deep but narrow entrance between the Islands of Oxø and Grønningen and the great depth keeps constant as we proceed towards the town of Kristiansand. The fjord also communicates with the sea through Flekkerøgapet to the west, and the narrow Randøsund to the east. Inside the Oksø—Grønningen the fjord forms a basin more than 250 meters deep. From this basin the Topdalsfjord goes into the country towards N. E.

The Topdalsfjord has a shallow and narrow entrance with a threshold 35—40 m. deep. Inside, however, we find a depth of 70 m. off Haanes. At the mouth of the Topdalsriver the fjord is filled up with shoals and islands, and the threshold here is about 28 meters. Inside this barrier we again find a deep part proceeding into the firth of Aalefjer.

The water in the basins in the Topdalsfjord is stagnant. Because of the threshold it does not communicate with the waters outside — a series of observations of temperature, salinity and oxygen will show that. (Tables 18—19—20 pag. 63—65).

In the inner basin the seasonal variations of temperature are small even at 30 meters below the surface. At 50 meters but some tenth of a degree — also in the outer basin off Haanes. Outside the fjord, however, off Odderø, the temperature-difference at 50 meters from April 3rd to September 4th 1924 is nearly 8 degrees. If the communication was free, we should not be able to find such difference at a distance of but a few nautical miles.

The salinity of the fjord-water is the same during 18 months. At 50 meters it only differs 0.1 pro mille in the inner basin. It is the same water which has been staying in the basins of the fjord during the said time. Measurements of the quantity of oxygen show the same, it is slowly diminishing in the bottom layers of the fjord, but high enough to suit the animal life, till in the autumn 1925.

These features indicate that when the investigations started here at the beginning of May 1924, the basins of the fjord had just been filled up by a submarine wave, carrying well ventilated water from the ocean into the fjord.

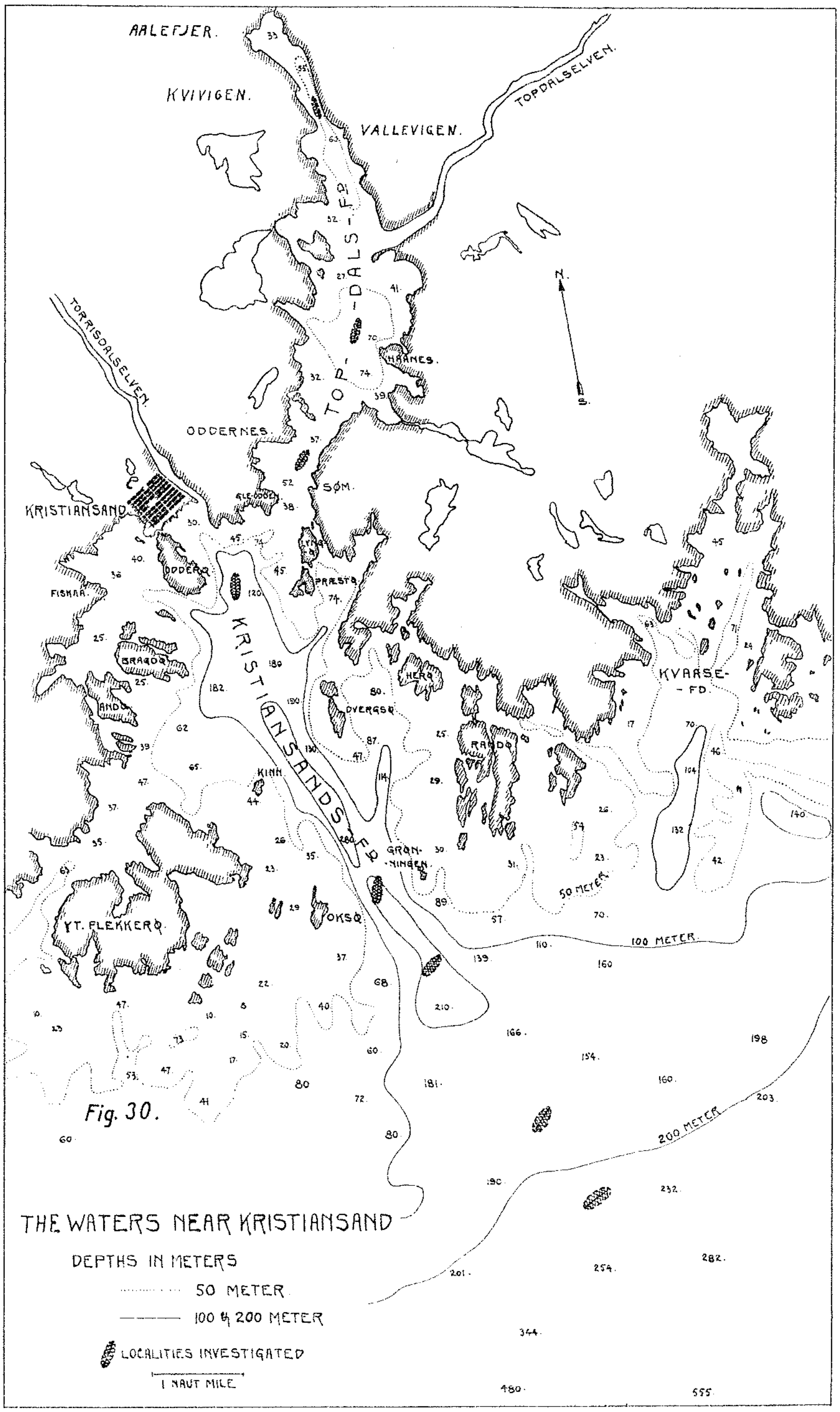


Fig. 30.

THE WATERS NEAR KRISTIANSAND

Tabel 18. Temperature.

	1924					1925	
	3/4	8/5	8/7	4/9	24/11	1/9	14/11
Topdalsfjord inner basin.							
0 m.		4.8	16.3	16.4			0.4
10 „		3.4	10.3	15.9			10.5
20 „		3.6	6 6	14.3			11.0
30 „		4.6	5.6	9.7			11.3
40 „							6.3
50 „		5.0	5.3	5.5			6.0
60 „							5.9
65 „			5.3	5.2			
67 „		5.1					
Topdalsfjord outer basin.							
0 m.		3.3	16.6	15 4	6.3	15.1	1.7
10 „		3.9	10.5	15.9	11.5	13.7	10.4
20 „		3.7	7.6	14.3	11.1	12.8	11.1
30 „		4.3	5.9	11.8	10.9		10.4
40 „						10.1	9.7
50 „		5.0	4.9	5.5	6.8	6.2	6.8
60 „						6.4	6.3
70 „		5.1	5.1	5.3	5.2		
Kristiansandsfjord.							
0 m.	2.7			15.0			4.6
10 „	1.7			16.0			10.1
20 „	2.7			15.4			9.4
30 „	4.2			14.6			9 7
50 „	4.9			12.7			9.7
75 „	5.2			7.2			
100 „				6.2			8.2
125 „	5.2						
150 „				6.1			7.0

For 18 months, at least, this water has been staying in the fjord, the salinity and temperature are practically the same — but the oxygen has been consumed by animal life and by the putrification of the sinking dead organisms. The phyto-plankton of those layers has not been rich enough to produce oxygen to compensate the consumption. And as the water in the fjord is very stable on account of the freshness of the water at the top, no vertical circulation of importance has taken place.

Table 19. Salinity.

	1924					1925	
	3/4	8/5	8/7	4/9	24/11	1/9	14/11
Topdalsfjord inner basin.							
0 m.		2.21	5.72	1.17			5.28
10 „		27.72	30.53	26.17			31.94
20 „		31.49	32.50	29.72			33.08
30 „		33.60	33.62	31.71			33.55
40 „							34.11
50 „		34.29	34.38	34.34			34.40
60 „							34.43
65 „			34.51	34.42			
67 „		34.33					
Topdalsfjord outer basin.							
0 m.		9.11	4.52	0.84	6.28	23.84	9.60
10 „		28.75	30.81	26.42	33.98	32.86	31.76
20 „		31.64	32.30	30.50	34.27	33.03	32.92
30 „		33.64	33.64	32.65	34.42		33.42
40 „						33.49	33.91
50 „		34.58	34.54	34.52	34.56	33.89	34.13
60 „						34.33	34.40
70 „		34.63	34.76	34.72	34.85		
Kristiansandsfjord.							
0 m.	24.65			3.98			14.18
10 „	30.41			28.53			32.25
20 „	32.21			29.07			32.94
30 „	33.87			32.59			33.42
50 „	34.63			34.00			34.05
75 „	34.79			34.90			
100 „				35.12			34.90
125 „	34.96						
150 „				35.33			35.21

These conditions may go on until the oxygen is quite consumed, and the bottom of the fjord will be unfit for animal life, until a new submarine wave will bring in new water from the sea and lift the old bottom layers up in the circulating area near the surface.

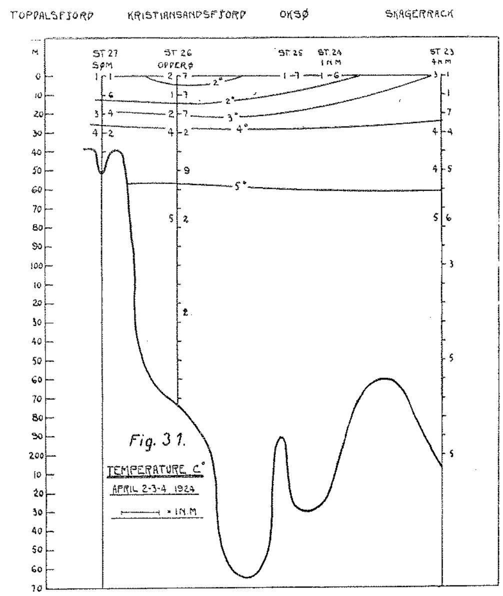
It goes without saying that those submarine waves are of very great importance to the animal life of the isolated fjords with shallow barriers — and must be taken into consideration when the question arises of the annual variations of the quantity of fish in the fjord.

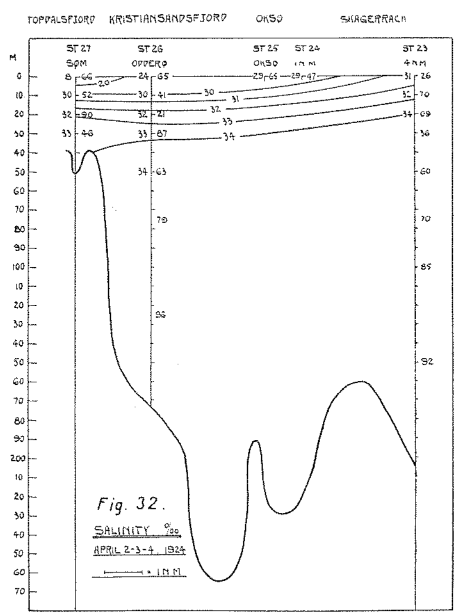
Tabel 20. Oxygen. C. c. pr. liter.

	1924					1925	
	3/4	8/5	8/7	4/9	24/11	1/9	14/11
Topdalsfjord inner basin.							
0 m.		8.50	6.58	6.79			9.40
10 „		7.86	7.84	5.52			5.89
20 „		7.44	7.18	5.14			5.34
30 „		6.09	6.65	5.18			4.87
40 „							2.68
50 „		5.64	4.04	3.73			2.86
60 „							0.18
65 „			3.99	3.07			
67 „		4.99					
Topdalsfjord outer basin.							
0 m.		8.75	8.10	7.12	8.25	6.60	8.79
10 „		7.89	6.85	5.43	7.20	5.61	5.72
20 „		7.22	7.30	5.23	6.81	5.33	5.42
30 „		6.38	6.38	4.72	NB.		5 51
40 „						6.23	5.00
50 „		6.07	5.78	4.84	4.82	4.05	3.72
60 „						1.85	1.17
70 „		5.64	4.77	3.30	3.29		
Kristiansandsfjord							
0 m.				6.56			8.20
10 „				5.14			5.87
20 „				5.02			5.87
30 „				4.94			5.95
50 „				5.18			5.90
75 „				5.14			
100 „				5.29			5.10
125 „							
150 „				5.35			5.60

On April 2nd—3rd—4th the waters from the mouth of the Topdalsfjord to 4 *n. m.* off Oksø—Grønningen were explored. The inner part of the Topdalsfjord was covered with ice. On the 4th of April the peasants of the district were seen driving across the fjord some hundred meters inside our station 27 at Søm.

The temperature at the surface was low 1,1—3,1 °, 4 degrees were found at nearly 30 meters, and the bottom outside the fjord was covered with water of a little more than 5 degrees.


TOPPALSFJORD
KRISTIANSANDSFJORD
OKSØ
SKAGERRACK
ST 27
SØM
ST 26
OPPERØ
ST 25
ST 24
1 N M
ST 23
4 N M
Fig. 31.
TEMPERATURE C°
APRIL 2-3-4 1924
= 1 N.M


TOPPALSFJORD
KRISTIANSANDSFJORD
OKSØ
SKAGERRACK
ST 27
SØM
ST 26
OPPERØ
ST 25
OKSØ
ST 24
1 N M
ST 23
4 N M
Fig. 32.
SALINITY ‰
APRIL 2-3-4 1924
= 1 N M

At the inner station the salinity was less than 30 ‰ from the surface to 10 meters, at the outer station we found 31.26 ‰ at the surface.

The following eggs were counted;

Number of eggs. Eggs with oil-globule in ( ).
April 3rd & 4th.

Dept	Søm Station 27	Odderø Station 26	Oksø Station 25	Off Oksø	
				1 n. m. Station 24	4 n. m. Station 23
0 m.	1327	178 (3)	90 (5)	12	4 (1)
10 -	57	22 (3)	16 (2)	14 (5)	1
20 -	126				1 (2)
30 -	75				0 (1)
50 -					0
	1585	200 (6)	106 (7)	26 (5)	6 (4)

The eggs are abundant at st. 27 at the entrance of the Topdalsfjord, and here with a pronounced maximum at 0 m. — and a second one at 20 m. The number is rapidly decreasing as we pass outwards, at st. 23 there is practically none.

The detailed table IX B from station 27 shows that the great number of eggs at 0 m. belongs to the cod group, the diameter measuring 1.2 — 1.5 mm. At the deeper hauls the eggs of 0.8—0.9 mm. are prevailing and also the eggs of *Drepanopsetta*. At station 26—25 & 24 we find the same sizes of eggs — the *Drepanopsetta*, however, is absent at the outer stations. It is astonishing to find such a quantity of eggs near the surface at station 27, as the observations show that the salinity here is very low. It may be, however, that the depth of the isohaline of 20 ‰ found by interpolation between the observations at 0 & 10 meter is not correct. The fresh water-layer at the top is probably very thin.

The number of larvae (Table 22) is very small, one *Gadus callarias*, one *Ammodytes* and one *Clupea harengus* at station 27, one *Ammodytes* at station 26.

Table 21. The size & number of eggs. Eggs with oil-globule in ( ).
April 3rd. & 4th.

Diam. mm.	Søm Station 27 4 hauls	Odderø Station 26 2 hauls	Oksø Station 25 2 hauls	Off Oksø 1 n. m. Station 24 2 hauls	Off Oksø 4 n. m. Station 23 5 hauls
0.8	33	7 (6)	5 (5)	1 (5)	(2)
0.9	177	71	12 (1)	3	1
1.0	55	33	11	3	1
1.1	11	6	2		
1.2	169	9	8	3	1
1.3	298	31	35	7	
1.4	426	31	28	8	2
1.5	400	5	5 (1)	1	1 (1)
1.6	1	2			
1.7	2	2			
1.8	7	2			
1.9	3				
2.0	2				
2.1					
2.2	1	1			
3.0					(1)
	1585	200 (6)	106 (7)	26 (5)	6 (4)

The following species are identified:

Station 23.	(3.0 mm.)	*Argentina silus.*
„ 24.	1.4 „	*G. callarias.*
„ 26·	1.6—2.2 „	*Drepanopsetta.*
„ 27.	1.3 „	*G. callarias.*
	1.6 - 2.2 „	*Drepanopsetta.*

On May 6th & 8th the same waters are explored once more Fig. 33—35, Table 23 & 24.

The temperature at the surface is 3.3°—4.8° C. The temperature near the bottom in the basins of the Topdalsfjord is just a little more than 5°. At the coast, however, that temperature is not reached. Layers of some 20 meters at station 53 and 47 have a temperature less than 4°, and the same temperature reaches the surface at station 52 & station 51.

The salinity is low at the surface, especially in the Topdalsfjord — this must be ascribed to the watermasses of the Topdal river.

Table 22. Larvae.

Station & Date	Depth	*Ammodytes*	*G. callarias*	*Cl. harengus*	Total
27 4/4	0				
	10				
	20	1	1	1	3
	30				
		1	1	1	3
26 3/4	0				
	10	1			1
		1			1
25 3/4	0				
	10				
					0
24 3/4	0				
	10				
					0
23 3/4	0				
	10				
	20				
	30				
	50				
					0

A great trouble regarding the fishing with the egg-net in the Topdalsfjord was caused by the occurrence of enormous masses of *Aurelia aurita* — the hauls at station 53 both at 10 & 20 meters and at station 52, 10 meters were quite spoiled.

Number of eggs, Eggs with oil-globule in ( ).
May 6th & 8th.

Depth	Kvivigen Station 53	Haanestangen Station 52	Søm Station 48	Oksø Station 47
0 m.	19 (1)	2	0 (1)	43 (51)
10 -	NB.	NB.	134 (4)	223 (62)
20 -	NB.	25 (5)	267 (5)	155 (39)
30 -	3	20	115 (11)	45 (9)
50 -		3		6 (3)
70 -				17 (3)
	22 (1)	50 (5)	516 (21)	489 (167)

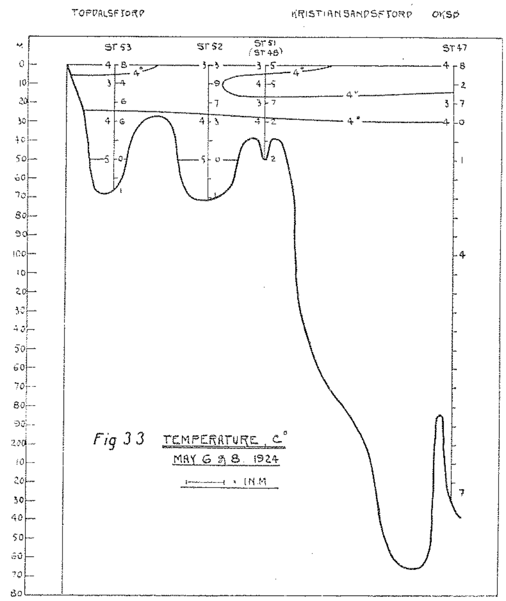


Fig 33 TEMPERATURE C°
MAY 6 & 8. 1924
= 1 N.M.

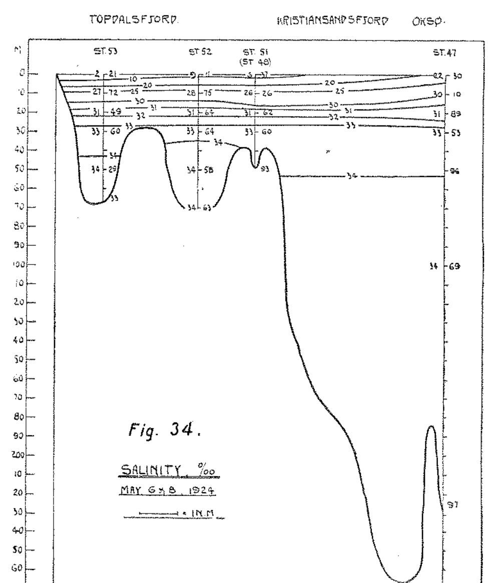


Fig. 34.
SALINITY ‰
MAY 6 & 8. 1924
= 1 N.M.

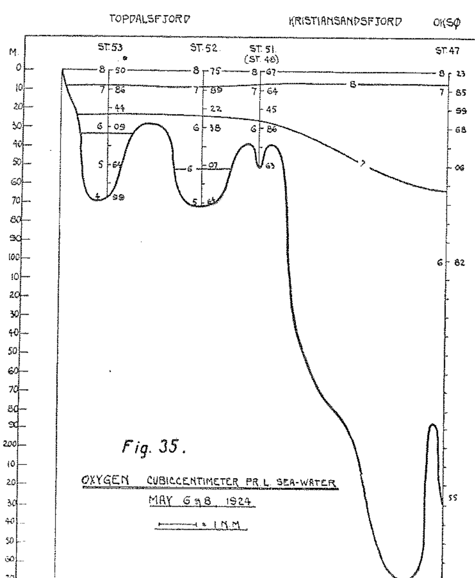


Fig. 35.
OXYGEN CUBICCENTIMETER PR L SEA-WATER
MAY 6 & 8. 1924
= 1 N.M.

Table 23. The size & number of eggs. Eggs with oil-globule ( ).
May 6th. & 8th.

Diam. mm.	Kvivigen Station 53 2 hauls	Haanestangen Station 52 4 hauls	Søm Station 48 4 hauls	Oksø-Grønningen Station 47 6 hauls
0.7			1 (1)	(22)
0.8			7 (10)	35 (105)
0.9		6	50 (3)	49 (18)
1.0	1	15	96	165
1.1	1	3	192	161
1.2	2	4	102	28
1.3	1	14	33	23 (4)
1.4	10 (1)	3 (1)	22 (4)	19 (14)
1.5	7	2 (4)	11 (3)	3 (4)
1.6				
1.7		1	1	1
1.8		1		
1.9		1		
2.0			1	2
2.1				2
2.2				1
	22 (1)	50 (5)	516 (21)	489 (167)

The following species are identified:

Station 47.	(0.8 mm.)	*Onos cimbrius.*
	1.1	„	*Gadus merlangus?*
	1.0—1.1	„	*Cl. sprattus.*
	1.3—1.4	„	*G. aeglefinus.*
	1.3—1.5	„	*G. callarias.*
	(1.4—1.5)	„	*Brosmius brosme?*
	1.7—2.2	„	*Drepanopsetta.*
„ 48.	1.1	„	*Gadus sp.*
	1.3—1.4	„	*Gadus callarias.*
	1.5	„	*Gadus aeglefinus.*
	(1.5	„)	*Brosmius brosme?*
	1.7—2.0	„	*Drepanopsetta.*
„ 52.	1.7—1.9	„	*Drepanopsetta.*

The number of eggs in the fjord is very small but at station 48 at the entrance to the fjord the number is high. Just so at station 47 near the light of Oxø. At the outer station we have a great number of eggs belonging to *Clupea sprattus*, at station 48 the *Gadidae* are very common. The eggs of a diameter 1.3—1.5 mm. with oil-drop I think must be ascribed to *Brosmius brosme*. This fish does

Table 24. Larvae.

Station & Date	Depth	*Clupea harengus*	*Gadus callarias*	*Gadus aeglefinus*	*Ammodytes*	Total
53	0	49	1			50
8/5	30	13				13
		62	1			63
	0	272				272
52	20	160				160
8/5	30	134				134
	50	170				170
		736				736
	0	265				265
48	10	111	1			112
6/5	20	200	4			204
	30	360	3			363
		936	8			944
	0	22		1		23
	10	131		1		132
47	20	840	1	1		842
6/5	30	115	1			116
	50	103				103
	70	160			1	161
		1371	2	3	1	1377

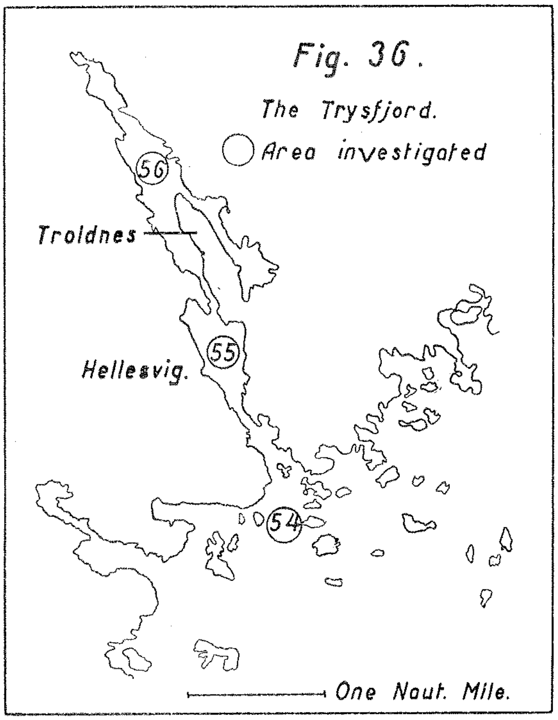
occur in the deep fjords — but I am not sure if also some *Trigla* eggs may be represented.

The larvae of *Clupea harengus* are found in great quantities—augmenting as we proceed from the fjord outwards. This is in concordance with the fact that enormous quantities of spawning herrings occurred here some weeks before. We have some *Gadus callarias* in the inner part and at the entrance of the fjord, at Oxø also some *Gadus aeglefinus* and one *Ammodytes*.

D. The Trysfjord.

The Trysfjord, to the west of Kristiansand, is another example of a threshold fjord.

As will be seen from the chart Fig. 36 the fjord is comparatively long but narrow — especiaiiy the entrance, and is divided by a sound into two parts, an outer and an inner basin. These two basins are deep compared to the shallow channel separating them and the water



layers are of course more or less stagnant. In the inner part the bottom layers are poisoned by sulphuretted hydrogen, and the quantity of oxygen in the middle layers is moderate.

In the outer basin the water is more ventilated. At the time of the investigations here, 9th of May, we find, however, an intermediate layer of water with low oxygen. The bottom layers are on the contrary well saturated with oxygen. These conditions I belive must be explained by an influx of heavy and well ventilated water from the Skagerrack which has filled up the basin from the bottom and lifted the „old"

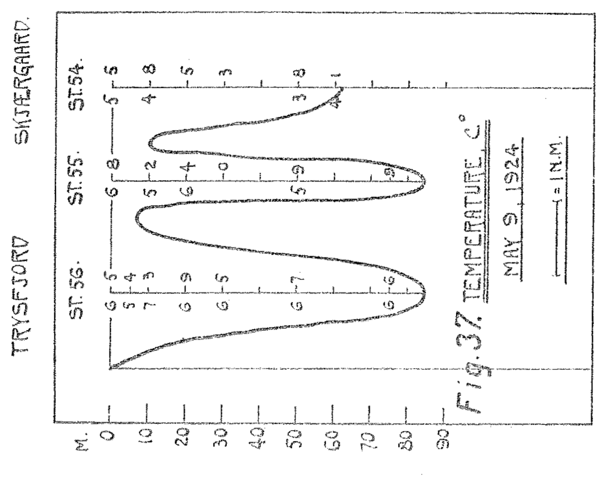


Fig. 37. TEMPERATURE C°
MAY 9, 1924

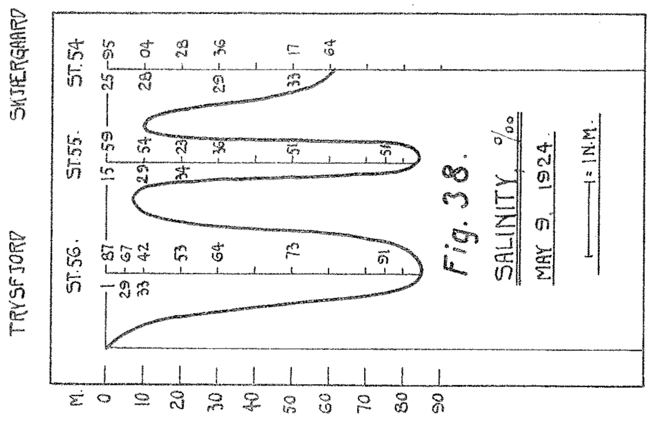


Fig. 38. SALINITY ‰
MAY 9, 1924

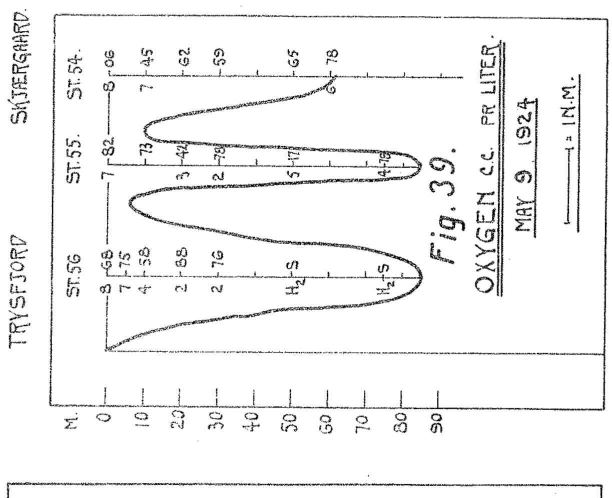


Fig. 39. OXYGEN c.c. PR LITER.
MAY 9, 1924

water up near the surface. It may be, however, that the low quantity of oxygen in the middle layers may be ascribed to an outflow of water from the inner basin. But the higher salinity of the water in the outer basin cannot be explained in this way, and I believe the first explanation given is the correct one.

The temperature of the deeper layers is in the main controlled by the temperature of the inflowing water. The brackish surface layers at the top will isolate them and the influence of the seasons is insignificant. We may then expect to find temperatures in the basins in concordance with the temperature of the inflowing water ɔ: with the heavy deep-sea water of the Skagerrack. In the outer basin we have water of a salinity of 34.51‰, and a temperature of 5.9° C., just the sâme water as we found in the Skagerrack on the 29th of March, then at a depth of 100 to 150 meters.

In the inner basin, however, the water is very stagnant. The layers coming into consideration here, when dealing with fish egg and larvae are the upper ones down to about 40 meters. The water from 40 meters to about 10 meters must also be regarded as stagnating, but here the water layers may keep sound. The amount of algae here will, by the aid of the sunlight, be sufficient to provide for the oxygen required.

On the accompanying table 25 I give the results of hydrographical measurements of this fjord four and sixteen months later.

In the inner basin we find that the difference in temperature from May to September is only $^2/_{10}$ of a degree at 20 meters. From 30 to 75 meters the difference is nil. One year later (September 1925) the temperature at 50 and 75 meters has altered but $^2/_{10}$ of a degree. The salinity also differs very little. — At 50 m. it has augmented from 33.73‰ in May to 33.86 in September and 34.00 one year later.

In the outer basin we find just the same. The temperatures in May and September 1924 differ but $^2/_{10}$ of a degree — from 20 m. to the bottom. One year later the temperature in the bottom layers is about two tenths of a degree higher. In the deepest layer the salinity is practically the same. In the middle layers the salinity is a little less.

It is of interest to state that the quantity of oxygen in the intermediate and deep layers is decreasing from May to September 1924,

Table 25. Trysfjord. Inner basin.

M.	Temperature			Salinity			Oxygen		
	1924		1925	1924		1925	1924		1925
	9/5	2/9	3/9	9/5	2/9	3/9	9/5	2/9	3/9
0	6.5	17.1	14.6	1.87	11.18	30.53	8.68	6.48	6.06
5	5.4	14.6		29.67	30.48		7.75		
10	7.3	8.9	11.8	33.42	33.17	33.13	4.58	6.07	7.32
20	6.9	7.1	8.6	33.53	33.48	33.80	2.88	3.35	4.69
30	6.5	6.5	7.5	33.64	33.68	33.87	2.76	0.84	1.45
40			6.9			33.95			H_2S.
50	6.7	6.7	6.9	33.73	33.86	34.00	H_2S.	H_2S.	H_2S.
75	6.6	6.6		33.91	34.00		H_2S.	H_2S.	
80			6.7			34.07			H_2S.
				Trysfjord. Outer basin.					
0	6.8	17.3	13.8	15.59	11.91	30.95	7.82	6.34	5.92
10	5.2	13.3	11.3	29.54	31.53	33.95	7.73	5.24	5.63
20	6.4	6.3	9.1	34.23	33.78	34.11	3.42	5.67	6.26
30	6.0	6.2	7.0	34.36	34.31	34.61	2.78	3.15	3.32
40			6.7			34.72			1.69
50	5.9	6.0	6.4	34.51	34.42	34.72	5.17	3.51	0.38
75	5.9	6.0	6.2	34.51	34.52	34.72	4.78	2.31	H_2S.
				Skjærgård					
0	5.5	16.2	13.4	25.95	24.69	32.61	8.06	5.97	5.70
10	4.8	16.1	11.0	28.04	25.95	34.38	7.48	6.00	5.60
20	4.5	16.0	10.5	28.28	27.65	34.43	7.62	5.87	6.38
30	4.3	15.9		29.36	28.53		7.59	5.58	
40		13.4	9.6		33.03	34.72		5.37	623
50	3.8			33.17			7.65		
60	4.1	11.3	9.0	33.64	33.08	34.72	6.78	5.37	7.03

and to September 1925 — in both basins, just in the same way as in the Topdalsfjord. We may be led to the conclusion that the cause is the same: new water has not passed into the basins of the fjord for 16 months.

For the sake of comparison I have added some observations from the Skjærgaard just outside the fjord. Here the seasonal variations are great to the bottom, and the quantity of oxygen does not vary much according to depth.

Table 26. The size & number of eggs. Eggs with oil-globule in ( ) May 9th.

Diam mm.	Inner basin Station 56 4 hauls	Outer basin Station 55 2 hauls
0.7	40	
0.8	110	2 (1)
0.9	1159 (4)	26 (3)
1.0	1597 (1)	92
1.1	10	4
1.2	1	23
1.3	16	7
1.4	4	1 (4)
1.5	1	
1.6		1
1.7	1	
	2939 (5)	156 (8)

The following species are identified:

Station 55.	1.0 mm.	*Cl. sprattus & Gadus sp.*
	1.4 „	*Gadus callarias.*
„ 56.	0.9—1.0 „	*Clupea sprattus.*
	1.4 „	*Gadus callarias.*
	1.7 „	*Gadus aeglefinus.*

At the station 54 no plancton hauls were taken, at station 55 only at 0 and 30 meters, at station 56 at 0—10—20—30 meters.

The upper layers of the inner part of the fjord are very rich in eggs and larvae — in spite of the fact that the layers some meters deeper are quite poisonous to them.

We have the following numbers:

Number of eggs. Eggs with oil-globule in ( )
May 9th.

Depth	Inner basin Station 56	Outer basin Station 55
0 m.	39 (5)	9 (8)
10 —	1719	
20 —	181	
30 —	1000	147
	2939 (5)	156 (8)

Table 27. Larvae.

Station & Date	Depth	*Clupea harengus*	*Gadus callarias*	*Pleurnectes flesus*	*Gadus merlangus?*	*Pleuronectes limanda*	*Onos cimbrius*	*Clupea sprattus*	*Gadus pollachius*	*Gadus minutus*	*Drepanop-setta*	Not identified	Total
56 $^{9}/_{5}$	0	1	1	1	2	1							6
	10		6	14		56	1	16	1				94
	20	1	1	5		22		14				6	49
	30			7				48	1			4	60
		2	8	27	2	79	1	78	2			10	209
55 $^{9}/_{5}$	0	13		1									14
	30	10		1						1	1		13
		23		2						1	1		27

The occurrence of eggs of the different diameters at each depth is revealed by the table IX B.

At station 56 in the inner basin we have two maxima, at 10 and 30 meters, and at both depths eggs of a diameter 0.9—1.0 mm. are dominating. At the surface we also have some eggs of the cod group. I have here noted eggs with advanced embryoes belonging to *G. callarias* 1.4 mm. and *G. aeglefinus* 1.7 mm. At 30 m. depth I have noted eggs of *Clupea sprattus*. It is evident, however, that looking at the larvae caught (Table 27) we may expect the eggs of about 1 mm, of diameter to belong to several species. It would have been of great interest to have identified the eggs caught in the different layers, but this is impossible with preserved material, in as much as the eggs and embryoes of some of these species are not properly described. The larvae of *Pl. limanda, Pl. flesus* and *Clupea sprattus* are very numerous — we have some *G. callarias* and we have the larvae of *G. pollachius.*

In the outer basin the station 55 gives a fair number of eggs — but nothing like station 56. The eggs are of the same diameter as at station 56, but the proportion of the cod group is somewhat greater. I have here noted the eggs of *Cl. sprattus* and eggs of a *Gadidae*, supposed to be *G. minutus.*

The number of herring larvae is greater than in the inner part, but the larvae of other species are not so abundant.

V. The Spawning of some of our Principal Fishes according to Temperature.

On the preceding pages I have given a survey of the material collected in the different areas. We will now summarize the results as to the most important species, especially the cod, and see if there may be any correlation between the quantity of eggs and larvae caught, and the hydrographical conditions of the waters in question.

The cod.

It being impossible to separate the young stages of the cod and haddock eggs, these two important species must partly be dealt with as a unity. When handled together the cod—haddock eggs are well defined and easily distinguished from other forms in these waters. Even the diameter of the eggs will suffice to separate them from other species—at least in the most prominent time of spawning. According to Ehrenbaum the diameter of the cod eggs varies from 1.16—1.60 mm., the eggs having the greatest diameter early in the spawning period. The eggs of the haddock measure 1.19—1.67 mm.

In order to have a survey of the cod—haddock group of eggs I have compiled the accompanying table based on the diameters of the eggs. And when in this special case only the eggs of a typical size 1.3 to 1.5 mm. are reckoned, we may be sure not to have eggs of other species included. At least not in numbers to confuse the results of the species in question. The eggs of *Pleuronectes cynoglossus and Pl. microcephalus* which attain a size great enough to interfere with the eggs of the cod are recognisable by their thicker skin—and were not found in any great numbers in the samples.

Table 28. Cod & haddock eggs 1.3—1.5 mm.

	March		April					May			
	13-14	28-29	3-4	9-10	15-16	24	30	6-8	9	13-14	15-19
Langesund:											
Voldenfjord ..										16	
Thorsberg					695					17	
Dybdal					101					21	
Sylterø					46					44	
Dybingen					94					32	
Langesundb...					84						
Arendal:											
Narestø				61		101					44
Salterød				33		97					12
Galtesund	317	78		56		95					54
1 n. m. off T.	208	56		44			111				41
5 —	569	68		13			54				25
14 —		16					23				
Kristiansand:											
Kvivigen.....								36			
Hånes								24			
Søm			1124					66			
Odderø			134								
Oksø			136					43			
1 n. m. off O.			32								
4 —			3								
Trysfjord:											
Troldnes									21		
Hellesvig									16		

In the tables 28—39, illustrating the quantities of the different species according to time and locality, the results of the fishing at 0—10—20 and 30 meters are summarized.

When in some places fewer hauls are made, the numbers are multiplied in a proper way to make the results comparable.

At the following localities a diverging number of hauls are taken:

Station 24 3/4 1 n. m. off Oksø hauls .... 0 & 10 meters
— 25 Oksø „ .... 0 - 10 —
— 26 Odderø „ .... 0 - 10 —
— 34 15/4 Sylterø (Kasistangen) „ .... 0 - 10 —

Table 29. Cod eggs identified.

	March		April					May			
	13-14	28-29	3-4	9-10	15-16	24	30	6-8	9	13-14	15-19
Langesund:											
Voldenfjord ..										0	
Thorsberg....					8					6	
Dybdal					3					7	
Sylterø					0					7	
Dybingen					0					1	
Langesundsb..					2						
Arendal:											
Narestø				0		14					1
Salterød......				0		8					2
Galtesund	6	1		2		3					0
1 n. m. off. T.	16	1		1			7				1
5 —	0	2		0			3				0
14 —		0					1				
Kristiansand:											
Kvivigen.....								0			
Hånes								0			
Søm.........			1					3			
Odderø			0								
Oksø			0					2			
1 n. m. off. O.			2								
4 —			0								
Trysfjord:											
Troldnes									1		
Hellesvig.....									2		

Station	35		Dybdal	haults	0 & 10 & 20 meters
—	37	$^{16}/_{4}$	Dybingen	"	0 - 10 —
—	38		Langesundsbugta	"	0 - 10 —
—	52	$^{8}/_{5}$	Haanes	"	0 - 10 & 30 —
—	53		Kvivigen	"	0 - 30 —
—	55	$^{9}/_{5}$	Hellesvig	"	0 30 —
—	57	$^{13}/_{5}$	Voldenfjord	"	0 - 10 —
—	59		Dybdal	"	0 - 10 & 20 —

This method is of course not quite correct, but is practical to get a necessary survey.

Table 30. **Cod.** *Gadus callarias* — Fry.

	March		April					May			
	13-14	28-29	3-4	9-10	15-16	24	30	6-8	9	13-14	15-19
Langesund:											
Voldenfjord . .										14	
Thorsberg . . .					8					9	
Dybdal					4					19	
Sylterød					0					22	
Dybingen					0					14	
Langesundsb. .					0						
Arendal:											
Narestø				0		2					8
Salterød				0		1					4
Galtesund	0	1		0		2					4
1 n. m. off T.	2	0		0			4				12
5 —	1	0		0			6				3
14 —		0					0				
Kristiansand:											
Kvivigen.								2			
Hånes								0			
Søm			1					8			
Odderø			0								
Oksø			0					2			
1 n. m. off O.			0								
4 —			0								
Trysfjord:											
Troldnes									8		
Hellesvig . . .									0		

The cod group of eggs is represented at all localities and at all dates when hauls are made, but the quantity varies much. (Table 28.) Maximum we find at Søm at the entrance to the Topdalsfjord on the 4th of April. Another one at Thorsberg in the Frierfjord on the 15th of April. At the coast and skjærgaard stations at Arendal we have maximum on 13th of March. Thus we find the maximum of cod and haddock eggs at the b e g i n n i n g of our investigations at each locality, and it may be that the eggs have been still more numerous before the investigations were started. And interesting enough, this seems to be the fact especially in the waters near Arendal. At the same date we here find a number of cod eggs with advanced embryoes. Among the quantities of cod—haddock eggs the numbers specified in Table 29 have reached a stage of development where they are easily distinguishable, from one another and from other species.

We find the cod eggs with advanced embryoes scattered all over the area investigated — from the first to the last station. In the middle of March we have a fair number of eggs in late stages at the coast station near Arendal. In the later days of the month there are few. In the later part of April they are again numerous in these waters.

In the waters of Langesund they are numerous in the Frierfjord at both dates — at Kristiansand and Trysfjord they are scarce.

Looking at the table showing the numbers of cod fry (Table 30) the results are very like those obtained from the late stages. We have a pronounced minimum in the late days of March and the first half of April in the waters near Arendal.

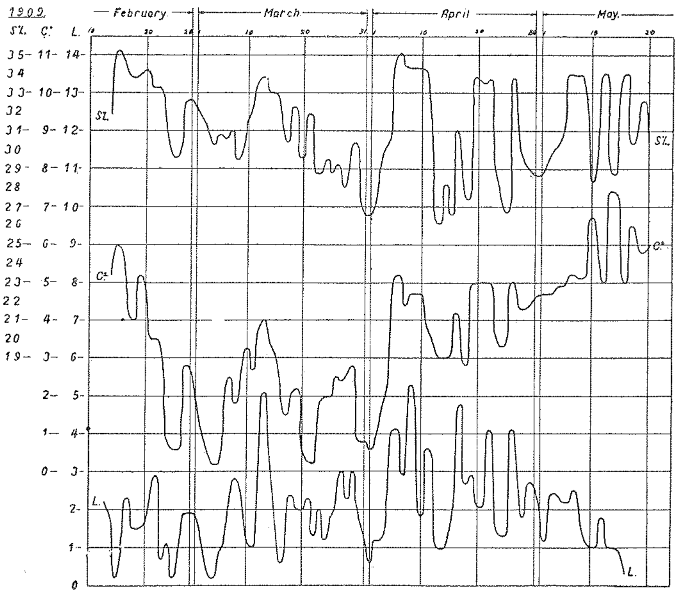
In the middle of April the Frierfjord gives a number, and from the last days of the month the number is augmenting, especially the fjords at Langesund are rich in cod larvae.

Looking at the table IX C. illustrating the length of the fry it will be evident that the newly hatched larvae, and quite small ones, less than 7 mm., are dominating. Only at the stations from the middle of May we find some older stages.

The results obtained by egg fishing may show that the spawning of the cod in the coast-waters at Arendal had taken place a good space of time before the commencement of the investigations medio March. The occurrence of eggs in late stages and cod larvae is characteristic enough. The spawning seems, however, to have been interrupted, or brought down to a minimum from the second half of March until medio April. From that time the eggs become more frequent — and especially the larvae are numerous medio May.

At the time when we find a minimum of cod eggs and larvae at the coast (first half of April), the fjords investigated give very fine results — and it is characteristic that the number of eggs are diminishing as we pass from the fjord outwards. One month afterwards we have a great number of cod larvae in the Frierfjord and adjacent waters, less in the Topdalsfjord. But here the eggfishing at that time was made difficult by great quantities of *Aurelia aurita.*

Fig. 40.

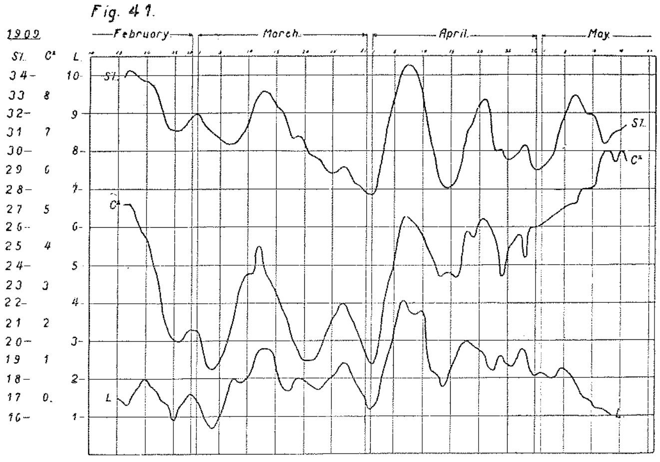


Salinity and temperature in the waterpipe leading to the spawning pond.

The quantity of cod-eggs in liters pr. 100 cod, this curve being placed 1 day to the left.

(1 liter cod-eggs = 476,000 eggs.)

Fig. 41.

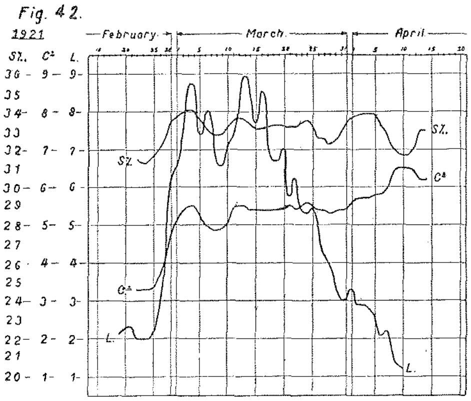


Salinity and temperature in the waterpipe leading to the spawning pond.

The quantity of cod-eggs in liters pr. 100 cod, this curve being placed 1 day to the left.

All values counted as a moveable mean stretching over 5 days.

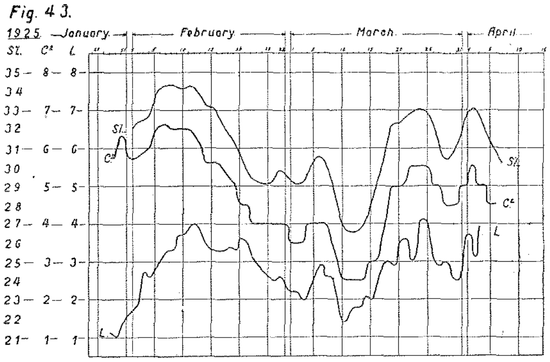
Fig. 42.



Salinity and temperature in the waterpipe leading to the spawning pond. The quantity of cod-eggs in liters pr. 100 cod, this curve being placed 1 day to the left.

All values counted as a moveable mean stretching over 5 days.

Fig. 43.



Salinity and temperature in the waterpipe leading to the spawning pond. The quantity of cod eggs in liters pr. 100 cod, this curve being placed 1 day to the left.

All values counted as a moveable mean stretching over 5 days.

It is generally assumed that the hydrographical conditions have a great influence on the spawning time of the fishes. According to Damas (4) the temperature and salinity of the sea-water in the principal spawning places of the cod in European waters are very homogeneous during the chief time of spawning.

By a series of observations it is shown that the salinity only varies between 34.73 ‰ and 34.94 ‰ — the temperature between 4.60 and 6.41° C. We may take this as the optimum values for the cod in our most prominent fishing places.

The observations from the Hatchery at Flødevigen show, however, that the cod kept in captivity will spawn at other temperatures and salinities too, but the influence of abnormal conditions is evident. As the temperature and salinity run parallel at that season we shall not be able to tell which of the two is the acting factor.

It will be justifiable to assume, however, that the temperature is the chief factor when the salinity is within reasonable limits. In nature this will surely be the case, as the salinity wanted always will be found at the open coast and in the deep fjords at a reasonable depth.

In the fig. 40 I have given the salinities and temperatures in the waterpipe leading to the spawning pond at the Hatchery for the season 1909. The observations are taken at 9 o'clock in the morning. The curve giving the amount of eggs pr. 100 cod ♂ + ♀ in liters (one liter equal to ca. 476 000 eggs), I have placed one day to the left. Thus the egg-quantity collected from 9 o'clock a. m. on the 19th of February to 9 o'clock a. m. on the 20th is put down on the 19th. In that way we are able to compare the egg-quantity with the temperature in the water inlet the preceding day.

The uniformity of the curves is apparent. As I am of opinion that a great quantity of food devoured by the cod may press upon the ovaries, the small divergences between the curves of egg-quantity and the temperature may partly be ascribed to irregular feeding.

In the fig. 41 from the same season the curves are smoothened by counting a moveable mean running over 5 days. Thus the values from 18th—19th—20th—21st—22nd of February are put down as a mean on the 20th a. s. o. The mean quantity of eggs for the same space of time on the 19th.

The spawning season in 1909 was comparatively long in the Hatchery, and the highest mean quantity for 100 fishes was 4.1 L. pr. 24 hours about the 8th of April — at a time when the temperature reached beyond 4°.

In 1921 (Fig. 42) the temperature of the sea-water was high from the beginning of March — from that time the intensity of spawning is very high — the highest mean quantity being near 9 L. The season, however, is very short.

In 1925 (Fig. 43) we have fair temperatures from the beginning of February, and the spawning augments quickly. But when the temperature about the 10th of March turns low, the spawning ceases — although in the middle of the spawning season. When the temperatures again turn favourable in the second half of March, the spawning augments once more.

These examples will be apt to show the influence of the surroundings upon the spawning of the cod. We must remember, however, that when in nature, the cod may be able, at least to some extent, to avoid the most unfavourable conditions.

When we turn to the hydrographical measurements in nature the question arises which measurements are to be reckoned? At the surface or at the bottom?

To illustrate this problem I will give some dates from Dr. J. Hjorts investigations in the waters of Canada, vide Dannevig: Canadian Fish—eggs and Larvae, pag. 36 and 37. In the Gulf of St. Lawrence the C. G. S. "Princess" made two cruises during the summer 1915. On the 4th of August we have the station 30 between Prince Edward Island and Cap Caspé.

Here, in the same hauls, we find eggs of the cod group (surely *G. callarias*) and eggs and larvae of the mackerel.

The results of the egg fishing were:

	Cod	Mackerel	
At surface (horizontal haul)	3 eggs	172 eggs	14 larvae
- 30—0 m. (vertical haul)	12 -	8 —	3 —
- 60—0 — —	25 -	1 —	0 —

The temperature, salinity and density of the sea-water at the same locality were:

	Temperature	Salinity	Density
0 m.	16.1 C.	27.85 ‰	20.27
10 -	15.7 -	27.83 -	20.33
25 -	10.5 -	28.67 -	21.97
40 -	7.9 -	29.49 -	22.99
50 -	5.65 -	30.37 -	23.97
60 -	0.45 -	31.64 -	25.40

We at once note that the majority of mackerel eggs and larvae occurs in the warm layers. Knowing that the mackerel is a pelagic fish which usually spawns near the surface, we may conclude that the mackerel has spawned at that temperature.

Not so with the cod eggs. The cod uses to spawn near the bottom, and the eggs rise to the surface if the density of the sea-water is high enough. Under normal conditions the cod eggs will not occur in the same layers as they are spawned, and the temperature at which the eggs are found tells nothing about the "spawning temperature".

In the case mentioned it will be reasonable to believe that the cod has spawned in the layers with a temperature of 5—7° C. and not at the bottom where the temperature of the water is less than half a degree C. And as the eggs found may have been carried away we can say nothing about the "bottom temperature" in the very spawning place. If in this place we had a depth of say 50 meters we may here have a temperature of more than 5° C.

The waters in the Skagerrack are more homogeneous, we have, however, the same problem here. The question arises: At what depth does the cod spawn?

In the general part of the „Rapport sur les Travaux de la Commission A. dans la periode 1902—1907" it is stated that the depths where the cod normally spawns are 40—80 meters.

On the northern slope of the North Sea Dr. Fulton of the Fishery Board of Scotland has found large cod in the spring ready to spawn at a "depth of 200 meters." On the Norwegian Skagerrack coast the spawning cod is often caught in water just deep enough to permit an open fishingboat to pass.

We may then assume that the cod spawns at very different depths — we may say from 200 meters to one meter below the surface.

I am of opinion that even in a limited area of the Norwegian Skagerrack coast the limits as to depth are very wide.

We must assume, however, that the same individuals which one year spawn near the surface, the next year will not spawn at 200 meters, although the horizontal distance between land and the 200 m. will be very short on the Norwegian Skagerrack coast. It will be a problem for the future to solve, whether the different types of cod distinguished by the fisherman: Deepsea-cod, Bank cod (Revtorsk), Litoral cod (taretorsk) may come into consideration when this question is discussed.

We must, however, confine ourselves to the fact that the cod, in the waters discussed, can spawn at very different depths. During the normal spawning time — that is from New Year until the end of April — the spawning will probably take place at different times at the different depths. The cod living in the littoral region will spawn when the hydrographical conditions are expedient, and just so with the cod living in deeper waters. And as the hydrographical conditions differ much in the different water layers, the spawning time for the cod in general may be very long.

Let us return to the egg-quantity outside the coast medio March. Looking at the fig. 6 page 19 it will be evident that some time previous, about the 20th of February, the temperature was relatively high and fit for the spawning of the cod except in the upper 20 meters. From the beginning of March the isotherms go down — the spawning conditions grow worse in the deeper waters. In the surface layers the temperatures keep low till in April when they begin to rise quickly. This fact may explain the augmenting number of cod eggs in the second half of April. It may be the result of the spawning of the cod of the littoral region.

As to cod larvae we may draw the attention to the fact that they are very scarce until the surface layers have got rid of the very low winter temperatures. The winter temperatures in themselves are not detrimental to the cod larvae — but the quantity of food suitable will augment when the winter conditions have passed away. According to Professor H. H. Gran, the food of the quite young ones consists of animal life. — They seem to disdain the algae plancton which is often rich in the cold water layers.

In the waters at Langesund, the station in the Langesundsbugta — lying in the coastal water — is just in concordance with the waters outside Arendal at that time medio April. In general, coming outside the coast, be it off Langesund, off Arendal or off Kristiansand, we must expect the same order of things: The Baltic Current is running along the coast.

But passing into the fjords things change — in the Frierfjord we find a lot of newly spawned cod eggs medio April, older stages and even larvae. The temperature is high 5–6° C. from 20 m. downwards. The occurrence of eggs in late stages, and larvae, indicates that the spawning has taken place some time previously. It would have been very interesting to have examined the quantities of eggs and larvae from some weeks earlier, but the ice was a hinderance to investigations at an earlier date.

One month later, medio May, the eggs are scarce — but the larvae abundant especially in the waters near the station which was rich in cod-eggs on the 15th of April. The temperature is now more than 4° C. in the upper layers.

In the waters at Kristiansand we have, on the 4th of April, a great number of cod eggs at Søm, at the mouth of the Topdalsfjord. The numbers are quickly decreasing outwards, just in the same way as at Langesund. The temperature at 30 meters, near the bottom at Søm, is more than 4 degrees — but just the same at the outer stations. We should remember, however, that just inside Søm we have the basin of the Topdalsfjord where the temperature — as mentioned before — is very constant — and at that time about 5 degrees. The eggs found at Søm may have been spawned on the slope towards this basin — but of course, this is a mere conjecture. But still it must be noted that the greatest number of eggs occur in the neighbourhood of the fjord.

The number of cod fry one month later is quite ordinary at Søm, but small in the fjord itself. As mentioned before, the egg fishing here was made difficult by enormous quantities of *Aurelia aurita*.

The Trysfjord was investigated on the 9th of May at a time when we could not expect to find cod eggs in quantities. In the inner part of the fjord 8 larvae were found.

To sum up the results of cod eggs and larvae caught: We find that in the coast waters we have a maximum of eggs at the beginning of the investigations medio March, also eggs with advanced embryoes and some larvae are present. The eggs and larvae decrease in number — with a slight augmenting in the second part of April. The larvae are especially numerous in May.

This order of things runs parallel to the changes in the temperature of the sea-water, the maximum of eggs being found some time after the convenient sea temperature at the depth where the spawning generally occurs. The increasing of the number of eggs late in April is parallel to the rise of temperature in the surface water.

The highest number of larvae is found when the surface has attained the summer character: the surface is warmer than the deeper layers.

The great number of cod eggs found in the Frierfjord and the Topdalsfjord is found in waters were we have relatively high temperatures convenient to the spawning of the cod — and the number is decreasing as we pass outwards.

As the high temperatures of the fjord have prevailed here during the winter the question arises why the spawning apparently is later here than at the coast. This question cannot be answered in a satisfactory way. The reason may be that the fjord has been covered with ice and snow, has been quite dark — or we may have to do with racial characters. A third point worth mentioning is the possibility that the spawning occurring here in the area of the temperate waters may be caused by migrating cod — seeking away from the unfavourable

Fig. 44. Temperature & Salinity. Skagerrack 1905. 2 N. M. off the Light of Risör.

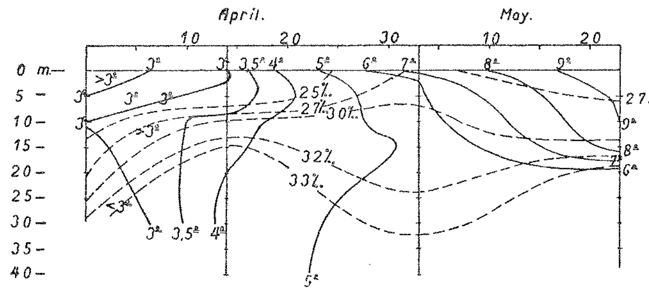


Fig. 45. Temperature C Observations 1 N. M. S. E. of Store Torungen. 1917.

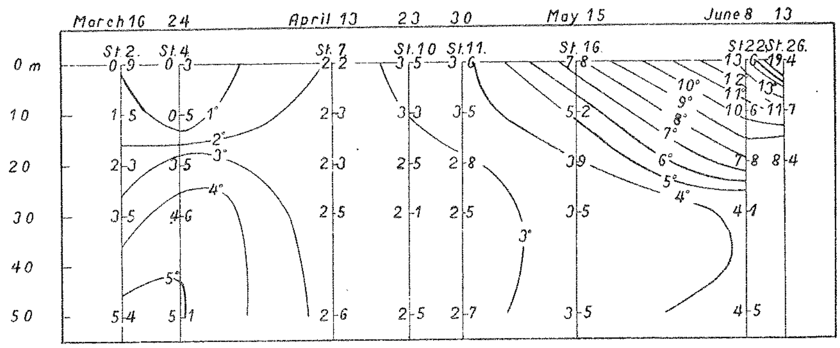
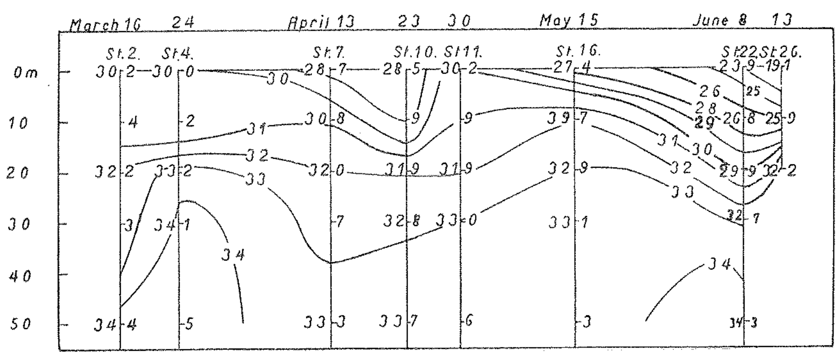


Fig. 46. Salinity ‰ Observations 1 N. M. S. E. of Store Torungen. 1917.



temperatures at the coast into the fjord where better conditions occur. This is made likely by the great invasion of spawning herrings in the same waters at that time. The cod may have followed the herring — or the immigration of the cod and herring may have the same cause: the hydrographical conditions of the waters.

When dealing with the cod fry from the very cold winter 1924 it would have been interesting to have material for comparison from more normal years. The only material which may come into consideration here is collected by K. Dahl in the Søndeledfjord and neighbouring waters during spring 1905, and the material collected by myself at Arendal during spring 1917.

K. Dahl (3) has in the days between 28/3 and 25/5 1905 four times exploited the Søndeledfjord, the Sandnesfjord and the Skagerrack 2 n. m. off Risør.

The Søndeledfjord is an isolated fjord with a basin in the inner part a little more than 70 m. deep with a threshold 20—30 m. deep. The outer part communicates with the Risørfjord — this is, however, by the islands outside cut off from the open sea, only some sounds of a depth maximum ca. 50 meters permit the circulation of the water.

The Sandnesfjord is open to the sea — but has also a threshold near the mouth, it may be 25 m. deep or a little more. The basin inside has a depth of 68 meters.

The catches pr. haul of 5 minutes with a planktonnet of 1. m. in diameter were the following:

Cod fry pr. horizontal haul of 5 min. 0—2—5—10—20 meters.

1905	28/3—1/4	12/4—14/4	29/4—4/5	15/5—23/5
Søndeledfjord..	7.7	4.2	1.9	2.2
Sandnesfjord...	4.9	0	0.8	0.1
Skagerrack	2.6	0	0.6	0

It will at once be seen that there is a great difference between the Søndeledfjord and the other localities investigated. — But as in this water there was put ˊut a quantity of cod fry from the Hatchery in the days between April 4th and 19th. the figures after the date first mentioned cannot be regarded as illustrating the normal occurrence of cod fry.

But the following may be noted: In the days 28th of March to the 1st of April the cod fry was abundant in all waters examined. In the Sandnesfjord and the Skagerrack at 2 n. m. off the light of Risør the cod fry was absent medio April — but occurred in slight numbers primo May.

The accompanying figure 44 shows that the temperature at the surface in the Skagerrack as early as the 1st of April is higher than in the underlying layers. On the 14th the surface is slightly colder again. Just the same in the Sandnesfjord. In the Søndeledfjord, however, the surface temperature is rising from the investigations on March 28th till the 13th of April. (Dahl 3.)

Thus we find maximum of cod fry in the waters when the temperature begins to rise above the underlying waters. In the waters outside the coast and in the relatively open Sandnesfjord the larvae disappear medio April — at the same time the surface layers have been cooled. In the Søndeledfjord the larvae occur in good numbers — and here the temperature is rising.

From the first to the second and third series of investigations the volume of water with a salinity ca. 22 ‰—30 ‰ has greatly diminished in all waters examined. If the absence of this water should be the reason of the lack of cod-fry medio April it ought to have been felt in the Søndeledfjord as well.

From my investigations 1917 we have the following number of cod fry pr. haul of 10 minutes. (Dannevig 7.)

Cod fry pr. horizontal haul of 10 min. 0—10—20—30 meters.

1917	16/3	23—24/3	3/4	11—13/4	21—23/4	30/4—2/5	15—16/5	8/6
Galtesund		0.3	0	0.3	9.8	7.8	0	0.3
Torungen	0	0		2.3	7.3	1.3	0.3	0

We have the maximum of cod fry about April 22nd.

The temperatures 1 n. m. off Torungen Fig. 45 reveal that at that time "summer conditions" are beginning in the sea, the surface layers are warmer than the underlying.

Looking at the temperature 3—4 weeks previously when the eggs ought to have been spawned the temperatures were relatively high in depths from 20 meter and downwards — and well suited for the spawning of the cod. In accordance herewith on the 23th—24th of March the cod group of eggs was at its highest.

I have summed up the results in 1924 for the localities in question. The number of larvae is small — and they occur late.

Cod fry pr. haul of 10 min. 0—10—20—30 meter.

1924	13—14/3	23—23/3	9—10/4	24/4	30/4	15—19/5
Galtesund.........	0	0.3	0	0.5		1
Torungen 1 n. m. off	0.5	0	0		1	3

In 1905 we have a maximum of cod fry during the last days of March.

In 1917 during the last days of April.

In 1924 medio May.

A table giving the sea temperatures at Torungen for the same years will be of interest.

	January	February	March	April	May
1905........	4.2	3.2	1.9	3.2	7.8
1917........	0.4	÷ 1.0	÷ 0.5	1.2	6.5
1924........	÷ 0.1	0.1	0.1	2.5	6.1

It will be evident that the quantity of cod larvae is closely correlated to the temperature of the sea-water — in a mild winter the maximum of larvae occur early (1905) in a cold winter late (1917 and 1924).

We may summarize the results of the investigations as to the cod in the following points.

A. The coastal water.

1. The spawning of the cod occurs in winter and spring when the hydrographical conditions (temperature) are favourable.
2. The larvae occur most numerous at a time when the surface temperature begins to rise over that of the underlying water.
3. When those conditions of temperature occur some weeks (= the time of the development of the eggs) after maximum of spawning, the number of cod fry is relatively high (1917).
4. When the maximum of spawning is followed by winter conditions during the time of the development and hatching, the quantity of larvae is low (1924).

B. The fjords with relatively high temperatures in the intermediate and deep layers.

1. The spawning here may take place at a late date — although the temperature has been favourable during the whole winter.
2. Maximum of larvae occurs when the temperature at the surface is rising.

The Haddock.

As mentioned in the preceding pages the early stages of cod and haddock eggs cannot be separated. The early stages of the haddock may then be included in the table of the cod group of eggs just referred to. The haddock eggs with advanced embryo do not occur until the last days of April — and in low numbers. Table 31. The catches of larvae are very small except medio May at some localities near the coast. Table 32.

According to D a m a s (4) the spawning temperature of the haddock is between 6° and 7° C., two degrees higher than that of the cod. The occurrence of haddock eggs medio May is in full conformity herewith — they appear several months later than the cod eggs.

Combined with the results of previous pelagic fishing we have the following catches of haddock larvae.

K. Dahl 1905 (3). Pr. haul of 5 min. in depths from 0—2—5—10—20 meter.

	28/3—1/4	12—14/4	29/4—4/5	15—23/5
Søndeledfjord..	0	0.05	0	0.7
Sandnesfjord ..	0	0	0.7	0.6
Skagerrack	0.4	0	1.2	0.6

Dannevig 1917 (7). Pr. haul of 10 min. in depths from 0—10—20—30 meter.

	16/3	23—24/3	3/4	11—13/4	21—23/4	30/4—2/5	15—16/5	8/6
Galtesund		0	0	0	3.3	3.5	1.7	0
Torungen 1 n. m. off	0	0		0.3	5.3	1	3.8	0

Dannevig 1924. Pr. haul of 10 min. in depths from 0—10—20—30 meter.

	13—14/3	26—29/3	9—0/4	24/4	30/4	15—19/5
Galtesund.........	0	0	0	0		1.5
Torungen 1 n. m. off	0	0	0		0	3.5

In the mild winter of 1905 haddock larvae occur from March, in 1917 from medio April, in 1924 from medio May.

Table 31. Haddock eggs identified.

	March		April					May			
	13-14	28-29	3-4	9-10	15-16	24	30	6-8	9	13-14	15-19
Langesund:											
Voldenfjord ..										0	
Thorsberg					0					0	
Dybdal					0					0	
Sylterød					0					3	
Dybingen					0					0	
Langesundb...					0						
Arendal:											
Narestø				0		0					3
Salterød				0		0					0
Galtesund	0	0		0		0					0
1 n. m. off T.	0	0		0			0				2
5 —	0	0		0			3				0
14 —		0					0				
Kristiansand:											
Kvivigen								0			
Hånes								0			
Søm			0					1			
Odderø			0								
Oksø			0					6			
1 n. m. off. O.			0								
4 —			0								
Trysfjord:											
Troldnes									1		
Hellesvig									0		

The occurrence in 1917 must be ascribed to the warm water observed from the 16th to the 24th of March, and the eggs and larvae in May 1924 must be regarded as pioneers of the spawning of that species. Late spawning of the haddock normally occurs in deep waters. In the Skagerrack K. Dahl has caught newly spent haddock in July (Damas (4) pag. 129).

Table 32. **Haddock.** *Gadus aeglefinus* — Fry.

	March		April					May			
	13-14	28-29	3-4	9 10	15-16	24	30	6-8	9	13-14	15-19
Langesund:											
Voldenfjord ..										0	
Thorsberg					0					5	
Dybdal					0					5	
Sylterø					0					5	
Dybingen					0					20	
Langesundsb. .					0						
Arendal:											
Narestø				0		0					10
Salterød				0		0					6
Galtesund ...	0	0		0		0					6
1 n. m. off. T.	0	0		0			0				14
5 —	0	0		0			0				1
14 —		0					0				
Kristiansand:											
Kvivigen								0			
Hånes								0			
Søm			0					0			
Odderø			0								
Oksø			0					3			
1 n. m. off. O			0								
4 —			0								
Trysfjord:											
Troldnes									0		
Hellesvig									0		

The Herring.

The young herring occur in great quantities in the fjords — the inner parts excluded. It is of interest to note that the occurrence of the young ones is in full conformity with the occurrence of the spawning herring that winter.

I have taken the following notes from newspapers etc. relating to the fishery of the spawning herring on the Skagerrack coast: *Fædrelandsvennen*, Kristiansand 20th February and later. Good fishing at Egersund (near Jæren) and good "aspects" at Ulvøsund (to the east of Kristiansand). Rich fishing Flekkerø—Kristiansand—Arendal till $^{25}/_{2}$.

Table 33. **Herring.** *Clupea harengus.*

	March		April					May			
	13-14	28-29	3-4	9-10	15-16	24	30	6-8	9	13-14	15-19
Langesund:											
Voldenfjord ..										34	
Thorsberg....					16					182	
Dybdal					1100					140	
Sylterø					44					206	
Dybingen					62					826	
Langesundb...					6						
Arendal:											
Narestø......				0		54					7
Salterød				0		2					29
Galtesund....	0	0		0		24					12
1 n. m. off T.	0	0		2			136				4
5 —	0	0		0			13				1
14 —		0					11				
Kristiansand:											
Kvivigen.....								124			
Hånes								756			
Søm.........			1					936			
Odderø			0								
Oksø........			0					1100			
1 n. m. off O.			0								
4 —			0								
Trysfjord:											
Troldnes									2		
Hellesvig									46		

Norges Handels- og Sjøfartstidende, Oslo $^{26}/_{2}$: Herring abundant at Hvaler (near the boundary of Sweden) great numbers of cod follow the herrings.

Fædrelandsvennen $^{28}/_{2}$. Herring abundant in the Langesundsfjord from ca. 20th of February. The bailif of E i d a n g e r informs me, 14th of May, that the herring was abundant in the fjord in March, was caught with "stegle" from the ice, and at Brevik in nets just as much as the fishermen wanted to have.

Fædrelandsvennen $^{12}/_{3}$. Herring very abundant Farsund—Ulvøsund.

Table 34. **Sprat.** *Clupea sprattus* — Fry.

	March		April					May			
	13-14	28-29	3-4	9-10	15-16	24	30	6-8	9	13-14	15-19
Langesund:											
Voldenfjord . .										12	
Thorsberg					34					49	
Dybdal					10					13	
Sylterø					0					14	
Dybingen					0					5	
Langesundsb. .					0						
Arendal:											
Narestø				0		0					0
Salterød				0		0					0
Galtesund	0	0		0		0					2
1 n. m. off T.	0	0		0			0				4
5 —	0	0		0			0				0
14 —		0					0				
Kristiansand:											
Kvivigen.								0			
Hånes								0			
Søm			0					0			
Odderø			0								
Oksø			0					0			
1 n. m. off O.			0								
4 —			0								
Trysfjord:											
Troldnes									78		
Hellesvig									0		

Fædrelandsvennen $^{22}/_{3}$. Herring fishery extraordinarily rich near Kristiansand.

Looking at the temperatures during the winter of 1924, 1—2 n. m. off Torungen Fig. 6 pag. 19 it is evident that the great herring fishery from 20—25 of February from Egersund in West to Sweden in East is simultaneous with the wave of warm and salt water occurring just at that time.

That the herring in the Skagerrack at the time of spawning follow the water of a temperature of 4° C. and a salinity of ca. 34 ‰ is well known (Cleve, P. T., Ekmann, G., Hjort, J., Petterson, O.: Skageraks Tilstand under indeværende sildefiskeperiode. Kristiania 1897).

From the dates given it will be evident that the herring was very abundant at Kristiansand and Langesund—Brevik, just in the waters where the greatest catches of the young were made. And I am acquainted with the fact that those waters during the summer 1924 were very well stocked with young herrings of that year's breeding.

The spawning herring was caught along the whole Skagerrack coast but especially near Kristiansand and Langesund—Brevik. As those localities in former years also have been prominent fishing places of the spawning herrings, there may be some reason to believe that the spawning conditions are favourable in those places.

Taking it for granted that the spawning of the herring is associated with the 4° and 34 ‰ sea-water we may presume that the herring at that time follow the said water — when the water is pressed against the coast, the herring will follow. When the water draws back again, the herring to a great extent will stay in the fjords and basins where the hydrographical conditions are convenient, especielly if the conditions at the coast in the meantime have turned unfavourable.

The occurrence of the young herring in 1917 will be seen from the accompanying table. In Dahl's analysis from 1905 the herring and sprat are not separated.

The Herring. Pr. horizontal haul of 10 min. 0—10—20—30 meters.

1917	16/3	23—24/3	3/4	11—13/4	21—23/4	30/4—2/5	15—16/5	8/6
Galtesund		0	0	0	12	0.8	0	0.3
Torungen 1 n.m.off	0	0		6.8	16	7.3	0.8	0

1924	13—14/3	28—29/3	9—10/4	24/4	30/4	15—19/5
Galtesund	0	0	0	6		3
Torungen 1 n. m. off	0	0	0.5		34	1

It is evident that the herring larvae both years occur from medio April.

The Sprat.

The eggs and larvae of the sprat, *Clupea sprattus*, occur in great numbers in the Frierfjord as early as medio April. At the coast, however, not until medio May. It is reasonable to seek the explanation of this in the relatively high temperatures of the fjord.

The early *spawning* of the sprat *in* the Norwegian Skagerrack fjords have been noted previously by Dahl (3) 1906 and Sund (46) 1910.

On the 9th of May the young sprats are abundant in the inner part of the Trysfjord, medio May in the Fjord at Langesund. In the waters at Arendal, however, sparingly at the same time.

In the fjords at Kristiansand they are absent, but near Oxø two specimens are caught.

At the localities investigated 1 n. m. off Torungen and in Galtesund the catches pr. haul of 10 *min.* of young sprats in 1917 and 1924 were:

1917	16/3	23—24/3	3/4	11—13/4	21—23/4	30/4—2/5	15—16/4	8/6
Galtesund.......		0	0	0	0	0	0	3.5
Torungen 1 n.m. off	0	0		0	0	0	0	0.3

1924	13—14/3	28—29/3	9—10/4	24/4	30/4	15—19/5
Galtesund.........	0	0	0	0		0.5
Torungen 1 n. m. off	0	0	0		0	1

In the coast waters the sprat larvae occurred in 1917 primo June and in 1924 from the late days of May when a temperature of about 6° was reached in the upper layers.

As will be remembered the winter 1917 was also a cold one.

The other species found will not be dealt with in this chapter, the material collected is too scant — also we know very little about the best spawning conditions of more of them. I will only give some tables where the catches are summed up.

Table 35. **Sand-eel.** *Ammodytes.*

	March		April					May			
	13/14	28/29	3-4	9-10	15-16	24	30	6-8	9	13-14	15-19
Langesund:											
Voldenfjord ..										0	
Thorsberg					0					0	
Dybdal					1					1	
Sylterø.......					4					0	
Dybingen					2					0	
Langesundsb. .					0						
Arendal:											
Narestø				9		1					1
Salterød				1		0					0
Galtesund	1	2		13		5					0
1 n. m. off. T.	12	2		0			1				1
5 —	3	1		0			1				0
14 —		0					0				
Kristiansand:											
Kvivigen								0			
Hånes								0			
Søm			1					0			
Odderø			2								
Oksø			0					0			
1 n. m. off. O.			0								
4 —			0								
Trysfjord:											
Troldnes									0		
Hellesvig									0		

Table 36. **Long rough Dab.** *Drepanopsetta platessoides.* Eggs.

	March		April					May			
	13-14	28-29	3-4	9-10	15-16	24	30	6-8	9	13-14	15-19
Langesund:											
Voldenfjord ..										0	
Thorsberg					0					3	
Dybdal					1					0	
Sylterø					2					3	
Dybingen					0					2	
Langesundb...					0						
Arendal:											
Narestø				40		19					1
Salterød				36		13					16
Galtesund	12	54		74		34					1
1 n. m. off T.	6	1		7			4				0
5 —	0	1		5			2				0
14 —		0					3				
Kristiansand:											
Kvivigen								0			
Hånes								2			
Søm			16					2			
Odderø			14								
Oksø			0					2			
1 n. m. off O.			0								
4 —			0								
Trysfjord:											
Troldnes									0		
Hellesvig									0		

Table 37. **Long rough Dab.** *Drepanopsetta platessoides* — Larvae.

	March		April					May			
	13-14	28 29	3-4	9-10	15-16	24	30	6-8	9	13-14	15-19
Langesund:											
Voldenfjord ..										0	
Thorsberg					7					7	
Dybdal					1					4	
Sylterø.......					0					6	
Dybingen					0					2	
Langesundsb. .					0						
Arendal:											
Narestø				0		0					2
Salterød				1		0					4
Galtesund	0	0		0		1					0
1 n. m. off T.	0	0		0			0				1
5 —	0	0		0			0				1
14 —		0					0				
Kristiansand:											
Kvivigen								0			
Hånes								0			
Søm			0					0			
Odderø			0								
Oksø			0					0			
1 n. m. off O.			0								
4 —			0								
Trysfjord:											
Troldnes									0		
Hellesvig									2		

Table 38. **Dab.** *Pleuronectes limanda.* Fry.

	March		April					May			
	13-14	28-29	3-4	9-10	15-16	24	30	6-8	9	13-14	15-19
Langesund:											
Voldenfjord . .										0	
Thorsberg					0					1	
Dybdal					1					0	
Sylterø					0					5	
Dybingen					0					0	
Langesundb. .					0						
Arendal:											
Narestø				0		0					0
Salterød				0		0					0
Galtesund	0	0		0		0					0
1 n. m. off T.	0	0		0			0				10
5 —	0	0		0			0				2
14 —		0					0				
Kristiansand:											
Kvivigen								0			
Hånes								0			
Søm			0					0			
Odderø			0								
Oksø			0					0			
1 n. m. off O.			0								
4 —			0								
Trysfjord:											
Troldnes									79		
Hellesvig									0		

Table 39. **Flounder.** *Pleuronectes flesus* Fry.

	March		April					May			
	13-14	28-29	3-4	9-10	15-16	24	30	6-8	9	13-14	15-19
Langesund:											
Voldenfjord . .										12	
Thorsberg					44					36	
Dybdal					21					20	
Sylterø					4					13	
Dybingen					0					7	
Langesundsb. .					0						
Arendal:											
Narestø				0		0					0
Salterød				0		1					1
Galtesund	0	0		1		0					2
1 *n. m.* off T	0	0		0			0				7
5 —	0	0		0			0				1
14 —		0					0				
Kristiansand:											
Kvivigen								0			
Hånes								0			
Søm			0					0			
Odderø			0								
Oksø			0					0			
1 n. m. off O.			0								
4 —			0								
Trysfjord:											
Troldnes									27		
Hellesvig									4		

VI. On the Influence of the Cold Sea-water on the Grown Fish.

In most winters the fjords of the Norwegian Skagerrack-coast will be covered by ice. In extraordinarily cold winters the waters of the skjærgaard will also freeze and even outside the coast the drifting ice may be a hinderance to the communications.

During the severe ice winters the ordinary fishing is stopped for the time the ice prevails. In the skjærgaard and in the fjords, however, some fishing is carried on from the ice by hook and line.

From ancient time two characteristic features are noticed to follow the severe ice-winters with respect to the grown fish:

1. Just before the drifting ice sets in along the coast, in many places great numbers of dead and dying fish are found at the surface in the skjærgaard. They can be taken by a catcher or by hand, and later on, when the ice is formed, many of them are found dead in the ice.
2. The shallow waters along the coast get quite devoid of fish, but in deeper parts of the skjærgaard — and in the fjords — great catches may be made.

It will be reasonable to look at the dead fish and the absence of the fish from the shallow waters as a result of the low sea-temperatures, the salinity not being extraordinarily low under those circumstances.

When discussing those questions it will be of importance to know the temperature at which the fish will succumb by cold or try to escape, and what the temperature of the sea water is in ice-winters.

On the 25 of April 1924 an experiment was performed at the Flødevig Sea-Fish Hatchery to illustrate the effect of very cold sea-water on the cod and the lobster.

A cylindrical tank 55 cm. in diameter and 70 cm. high of galvanized iron was placed in a somewhat bigger wooden tank and the space between them filled up with snow and a little salt. The water in the iron tank was renewed by a constant current of sea-water which was cooled down to a temperature near zero before entering the tank. The salinity of the water used was between 28.0—28.3 ‰.

Five codfishes 20—30 cm. of length, and two lobsters 24—25 cm. long were taken up from the sea (T. = 3.5° C.) and placed in the iron tank.

The observations made are the following:

April 25th.

11.35 a.m. The cod and lobster placed in the tank.
The temperature at the surface 0.7, at the bottom of the tank 0.6.

11.55. a.m. Temperature at surface and bottom ÷ 0.4. The fish agitated, the lobster "sits on its tail."

12.05 p.m. T. at surface ÷ 0.6, at bottom ÷ 0.8. One of the lobsters turned on the side.

12.10 p.m. T. ÷ 0.9 at surface & bottom. The second lobster with head down. The cods are shivering.

12.15 p.m. 1 cod floating upside down.

12.20 p.m. T. ÷ 1.1, at surface and bottom. All the cod floating upside down, but one shows sign of life when touched by hand.

12.35 p.m. Surface ÷ 1.1, bottom ÷ 1.3. Neither fish nor lobster show any sign of life.

12.55 p.m. Surface ÷ 0.7, bottom ÷ 0.6. The water inlet from the pipe augmented, and the temperature is allowed to rise.

1.00 p.m. The temperature in the tank is now 4.5. Neither the cod nor the lobster show any sign of life.

3.25 p.m. The cod and lobsters taken up — no sign of life. The lobsters are taken up to the laboratory and — by chance - placed near an electric stove. After some moments they show sign of life, they were then placed in a bucket of sea-water that was heated slowly to a temperature 12—13° C. in half an hour.

4.00 p.m. Now the lobsters show sign of life and are placed in the tank with running sea-water T = 4.5 C.

April 26th.
9.00 a.m. The lobsters all right, and transferred to an aquarium.
July 1st.

The lobsters liberated into the rearing pond.

The experiment show that the critical temperature for the cod is about 1° C. below zero, as to the lobster the critical temperature is not reached at ÷ 1.3° C.

These observations are in full concordance with the observations made in nature and with the investigations made on the depression of the congealing point of the blood of teleostian fishes. This varies between 0.5 and 1° C. It will be justifiable to assume that the death of fish will occur when that temperature is reached.

If the sea temperature sinks 1° below zero, dead fish normally occur — if that temperature is not reached, no dead fish are reported. As to the lobster I never heard of a lobster that had succumbed by cold when staying in sea water. The osmotic pressure, or the depression of the congealing point of the blood of that animal has not been investigated as far as I know.

The temperature at which the fish feel unwell is not easily stated, and in the following pages I rather consider the temperature of the prominent spawning places of the different species as their optimum temperatures. It is generally acknowledged that just at the spawning time the different species are very dependent on the outer conditions. (34).

As to the temperature of the sea-water during the ice-winters we have very few observations, except at the very surface. The observations taken are of a mere adventitious character. It will be understood that just at the time when the drifting ice sets in, hydrographical measurements at sea cannot be performed except from a well equipped ship. The motor cutter belonging to the Hatchery is not fitted for such work. When the question of the influence of the low temperatures on the fish arises it is of importance to have the minimum temperatures, these cannot be observed, however, without selfregistrating apparatus.

In the following pages, I will give the results of some temperature measurements — and describe the observations made on dead fish.

On the 29th of January 1917 I took some samples with a glass-bottle, not isolated, from the ice on the bay of Flødevigen.

Depth	T. C.	S ‰ [1]
0 m.	÷ 0.3	5.8
1 „	÷ 0.7	17.9
3 „	÷ 1.2	
5 „	÷ 1.2	23.0
10 „	÷ 1.2	26.4
17 „	÷ 0.3	28.6
18 „ bottom		

Next day the 30th of January we made the following observations from the ice on the fjord between Havsø & Merdø. (Eckmanns Waterbottle with reversible thermometer).

Depth	T. C.	S ‰ [1]
1 m.	÷ 1.1	24.27
5 „	÷ 1.2	25.64
10 „	÷ 1.1	26.38
15 „	0.8	30.64
20 „	3.4	32.74
30 „	5.9	34.03
40 „	6.2	34.31
50 „	6.2	35.12
54 „ bottom		

From the observations of 29th of January it will be seen that the temperature reaches its lowest point between 3 and 10 m. below the surface where the salinity is between 23 and 26 ‰.

On the 30th of January, we find the minimum at 5 m. and in the same water with regard to salinity. At 15 m. the temperature has passed zero, the salinity rises quickly and at 20 m. we have "Bankwater" with a salinity betwen 32—34 ‰ and a temperature of 3.4 ° C. At 40 m. we find a salinity of 34.31 ‰ and a temperature of more than 6 degrees.

From the 16th of March the same year — when the ice had disappeared — I have some hydrographical stations 1 n. m. S. E. of Torungen. The temperature and salinity (found by titrations) are put down on the graphs Fig. 45 & 46 page 92.

[1]) Calculated from hydrometer measurements.

At the surface we have a temperature near zero during the month of March — then it rises quickly especially in May and June.

At 50 m. depth the lowest temperature observed 2.5° occurs on the 23th of April, and not until the 8th of June has the temperature passed 4° degrees at that depth.

This year I had no records of dead fish.

In 1922 we had the first temperature below zero at 1 m. below the surface on the 30th of January, the last on the 25th of February.

On the 3rd of February the lowest temperature was observed, viz. ÷ 1.4°. On that date the same T. ÷ 1.4° was found from surface to bottom (15 m.) on the bay at Flødevigen. (Watersample taken by not isolated waterbottle). The next day the waters here were covered with ice.

During the preceding days a great quantity of dead fish was found drifting along the coast, and later on frozen fast to the ice. The species reported are: *Gadus pollachius*, *Gadus virens*, *Gadus callarias*, *Gobius niger* and *Labrus rupestris*. Especially small and medium fishes of the three first mentioned species. A fisherman reported that the cod in a trap placed on 5 fathoms were dead — and glaced with ice when brought to the surface. The water near the surface at the place in question was very brackish, and as the cod had been kept at the bottom at a temperature perhaps as low as ÷ 1.4° the ice was apparently formed when the trap was lifted to the surface.

The salinity of the water on the 3rd of February when the temperature was at its lowest, was 26.7 ‰, at the surface.

During the winter 1923, we had a short but severe period of cold weather, and on the 1st and 2nd of March we have the following temperatures and salinities:

	1 m.		15 m.*)	
March 1.......	÷ 1.4	28.7 ‰	÷ 1.1	28.8 ‰
„ 2.......	÷ 1.1	28.2 ‰	÷ 1.4	28.4 ‰

On the 2nd of March I observed dying fishes coming up to the surface, viz. *Labrus rupestris* and *Raniceps ranius*. That same day dead cod was reported from the Tromøsund to the east of Arendal.

*) Observed in the waterpipe bringing water from that depth.

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Two fishermen reported that a great quantity of Bull-head *(Cottus scorpius)* was observed dead on the bottom in shallow water (1—3 fathoms). The salinity of the cold water that year varied between 24 and 29 ‰.

An observation made that year seems to illustrate that the cod can survive in water with a temperature as low as 1.4° C. below zero. Two codfishes and two lobsters were put in a cauf in February, and kept there at the quay till the 28th of March. They were all in excellent condition. It may be, however, that the "heat" produced by the physiological processes of the fish and lobsters have been great enough to keep the temperature in the narrow cauf some tenth of a degree higher than outside. The fact that the cauf was lying on the bottom may strengthen this theory.

That the lobster survived is in concordance with observations referred to, pag. 110 But exposed to the lower temperatures of the air they are very soon killed. Some examples as to the hardihood of the lobster may be given. In an aquarium at the Hatchery on the 2nd of January 1924 a lobster was found frozen to the glass by the tentacles. The temperature in the water of the aquarium was then ÷ 1.1 C. but must have been still lower during the night. As the salinity of the water (reckoned from an aerometer measurement) was 26.8 ‰ it must have been more than ÷ 1.5° in order to make the formation of ice possible. When the lobster was thawed up it was all right. A lobster merchant in Arendal, Mr. E. Evensen, tells me that he has taken the live lobsters out of the well, were they are kept near the surface, when the sides and top inside were quite covered with ice.

As will be understood from the observations referred to in another chapter the winter 1924 was very long and severe. The observed temperatures, however, at 1 m. below the surface at Flødevigen did not sink to 1° C. below zero — but temperatures about zero were prevailing for three months. No dead fish were reported from the environs of Arendal, but farther to the West, between Kristiansand and Mandal, cod were found dead in the fishing gear, and lots of dead cod were reported.

Mr. Lauritz Fuglevik from Skogsøy, east of Mandal, reported to me that a great number of *Conger vulgaris*, great specimens, were found along the coast among the drifting ice, and secured for the household by the inhabitants. Some specimens of *Labrus mixtus* were also reported, and near the Naze two specimens of porpoises *Phocaena communis* were found dead on the beach.

Mr. Fuglevik, who is very well informed about old days of that district tells me that dead cod, green cod, conger and porpoises were found along the beaches in the severe winters of old days, — and he was of opinion that the phenomenon was caused by the extreme cold Baltic water setting in from the Skagerrack. And I believe he is right. As a matter of fact, frozen fish is never found in the fjords — but always at the coast, or especially in the sounds near the coast.

Great quantities of dead fish have now and then been reported also from the fjords, but this phenomenon is always accompanied by a strong smell of sulphurated hydrogen from the water — and is always restricted to the very isolated fjords where the bottom layers are constantly poisoned.

The first point mentioned that used to follow the ice winters: the occurrence of dead fish, must, on behalf of the observations referred to, be ascribed to the very cold sea-water. By experiments it is shown that the cod succumb in water of a temperature near 1^0 below zero — and in the sea water those temperatures, and even lower, are found. And the dead fish at the coast always appears in very severe winters.

On the preceding pages I have given some facts as to the occurrence of dead fish, and low sea-temperatures observed.

In order to simplify the problem of the effect of the cold sea-water, however, it will be necessary to recall to mind how the low temperatures of the air act upon the sea-water, and where the low sea-temperatures are to be found.

When a watermass homogenous according to salinity is cooled, the upper layers exposed to the cold air will attain a greater density — it will sink in order to be replaced by new light water. This process will go on till the whole water column has attained the temperature of the greatest density — provided that the freezing temperature of the water is not attained before.

Both the temperature at which the sea-water attains its greatest density and the freezing point vary according to the salinity of the water. And in the way that the temperature of the greatest density is higher than the freezing point in water of a salinity less than 24.695 ‰.

The corresponding values are (Krümmel 27):

Salinity	Freezing point	Maximum of density
0 ‰	0.000 C.	3.947 C.
10 -	÷ 0.534 -	1.860 -
20 -	÷ 1.074 -	÷ 0.310 -
30 -	÷ 1.627 -	÷ 2.473 -
40 -	÷ 2.196 -	÷ 4.541 -

From this follows that the influence of the cold atmosphere will be different upon brackish and salt sea-water. In the case of the fresh and brackish water the vertical circulation brought about by the cooling influence of the air will cease before the freezing point is attained. In the salt water, however, the vertical circulation may proceed even in the under-cooled water masses if such may occur.

In the fjords we normally have a great layer of brackish water near the surface. This will be cooled down to the temperature of the greatest density. The vertical circulation will then cease and the very surface layer will be cooled still more — and freeze. Thus the brackish water will isolate the salt water from the atmosphere.

And that is why the temperatures of the deep layers of the isolated fjords vary but little. In the open sea the water layers will be much more homogeneous, and as the currents also will bring about vertical circulations the sea-water to a great depth may come into contact with the cold air.

It will, therefore, be understood that the lowest temperatures of the normal sea-water will be found in the Skagerack, and whether this very cold water will come into the fjords or not will depend upon the topography of the fjords. Into an isolated fjord it will not make its way — but in an open fjord this will be the case. But at a slow rate.

In a paper: *"On the after-effect of ice-winters upon the deepsea temperatures of the Kattegat"* Dr. Johan Gehrke (13) gives very interesting data concerning this question.

At the Skaw the water is very salt, 8 m. below the surface the mean salinity is more than 31 ‰ every month of the year. Here the air temperatures affect the temperature near the bottom (38 m.) very quickly. The temperature deficiency at the bottom is greatest in the first month after the disappearance of the ice, and in the fourth month every effect of an ice-winter has disappeared altogether.

At Schultz Grund in the south of the Kattegat the surface is covered by the brackish Baltic water, and here the temperature at the bottom (26 m.) will not reach maxium of deficiency until the fourth month after the disappearance of the ice.

Reckoned from the centre of the winter Dr. Gehrke shows that at Schultz Grund, in a short ice-winter, the maximum of temperature deficiency in the bottom layers falls about 5 months after the centre of the winter (reckoned after the temperature of the air). In a long ice-winter it will take half a year.

By the aid of the observations from the light ships, Læsø Trindel and Anholt Knob it is shown that: "The ice-winters give rise to a wave of negative anomalies proceeding from the Skagerrack and traversing the salt deep-water of the Kattegat from North to South.

The time of culmination of the temperature deficiency falls later and later as the wave progresses".

Some examples of the temperature in more isolated waters will be given from my own material. From the Frierfjord, the inner part of the fjord entering from the open bay at Langesund, I have the following temperature series. For the sake of comparison I give the temperatures from Langesundsbugta which is in direct communication with the Skagerrack.

It will be evident from the observations that the temperature of the layers from 30 m. downwards in the Frierfjord is practically not affected by the temperatures of the seasons. The small divergences, some tenths of a degree, show that the water is colder in September than in April.

Depth	Frierfjorden 1924		Langesundsbugta 1924	
	15/4	23/9	16/4	24/9
0 m.	3.2	12.5	3.2	13.3
10 -	2.1	13.9	2.3	13.7
20 -	5.9	11.0	2.1	13.8
30 -	5.4	5.1	3.3	14 2
50 -	5.9	5.6	4.3	14.4
75 -			4.7	
80 -	6.0	6.0		
100 -			4.6	13.3
150 -			4.7	
222 -				6.3

In the open bay of Langesund, however, the seasonal variations are very important, at least at 100 m. below the surface.

On the basis of the preceding pages I will now try to sketch the effect of the cold sea water on the grown fishes — and also to explain the experiences referred to, made by the population of the coast.

When the cooling of the sea-water takes place in the autumn the species which have approached the northern limit of their distribution will retire from the surface which is first cooled, then also from the intermediate layers. Thus the mackerel, the *Labriidae,* some *Gobiidae* and so on will leave the surface and littoral region and seek the deeper, more temperate waters. The pelagic fishes, such as the mackerel will perhaps even leave the Skagerrack, the littoral fishes will keep to the bottom — but at a greater depth.

When the cooling of the sea-water in the Skagerrack proceeds, temperatures unfavourable even to the winter and spring spawners, the cod, haddock, coalfish etc. are attained, and these species will seek away from the cold water, down into the depressions in the skjærgaard, into the isolated fjords perhaps, or down along the slope of the Skagerrack.

According to Damas (4) the most prominent spawning temperature of some of our *Gadidae* is:

Gadus merlangus	5—10° C.
Gadus virens	ca. 7 -
Gadus aeglefinus	6—7 -
Gadus callarias	4—6 -

It will then be reasonable to suppose that the species will leave the waters in the order mentioned, and if the temperature continues falling in the deeper layers, the ripe individuals at least will tend to seek out of the Skagerrack.

The younger individuals, not mature, will be more hardy, but if the very cold water with a temperature of one degree below zero, or more, suddenly sets into the skjærgaard, great numbers of the young fish may be cut off from the retreat and succumb.

The effect of the low temperatures will of course depend upon the degree to which the sea-water is cooled, and how long the unfavourable circumstances will last.

A short, but severe, period will kill enormous masses of young fishes along the shore. A long, but moderate, cold period will not kill the fish — but will have time enough to act upon even the deep waters of the Skagerrack and make them unfavourable to the spawning of several of our fishes commonly spawning here.

From what is said about the temperatures in the spring 1924 and the accompanying table from May 6th and 7th, it will be evident that the convenient spawning temperature for the whiting, the coalfish and the haddock was not present in the Skagerrack during the chief spawning period of those species.

And I think the scarcity of the whiting and haddock off the Norwegian Skagerrack coast in the years 1924—1925 must be ascribed to that phenomenon. Our fishery statistics are not fit to give any information on that question, but the Danish Director of Fisheries informs me by letter of 17th of February 1925 that the Danish catch of haddock in the Skagerrack in 1924 was about $^1/_{10}$ of the catches in the two preceding years.

In the deep and isolated fjords the temperatures required for the species in question will always be present, and as shown by the egg fishing, the quantities of eggs here may be very great.

Hydrography 6th—7th of May 1924.

Depth	Oksø—Grønningen Station 47		14 n. m. off Oksø Station 50		28 n. m. off Oksø Station 49	
	Temp.	S ‰	Temp.	S ‰	Temp.	S ‰
0 m.	4.8	22.30	5.2	29.78	5.4	32.36
10 -	4.2	30.10	4.7	30.82	4.8	34.79
20 -	3.7	31.89	4.8	33.55	4.2	34.79
30 -	4.0	33.53	4.5	33.91	4.7	34.96
50 -	4.1	33.96	4.6	34.61	4.9	35.03
75 -			4.6	34.88	5.1	35.16
100 -	4.4	34.69	5.1	34.90	5.0	35.16
160 -					5.1	35.17
225 -	4.7	34.97				
Bottom	240 m.		ca. 500 m.		170 m.	

VII. Summary.

When in 1924 the winter turned very severe, and the hatching operations could not be carried on at Flødevigen, I got the permission of the Director of Fisheries and the Department for Commerce, Fisheries etc. to use some of the money granted for the hatching operations, to investigate the effect of the cold water on the spawning of some of our principal fishes, especially the cod.

The permission was given on the 14th of March, and from that date the investigations were started. Previously, however, some temperature measurements were taken, and also some hauls with egg nets on the 13th and 14th of March.

As to the spawning of cod, the investigations ought to have started at an earlier date, but, as will be understood, I had no grant available till medio March.

The investigations were planned to give the characteristic features of the hydrography of the waters, especially the temperature, and to ascertain the relative quantity of eggs and larvae in the waters exploited.

The investigations were carried on at the following localities:

Langesund	$^{15}/_{4}$	—	$^{14}/_{5}$
Arendal	$^{13}/_{3}$	—	$^{19}/_{5}$
Kristiansand	$^{2}/_{4}$	—	$^{8}/_{5}$
Trysfjord			$^{9}/_{5}$

The ice in the fjords did not allow the investigations at Langesund and Kristiansand to be started at an earlier date, and the investigations in the Trysfjord were of a merely adventitious character.

In the waters at Langesund, Fig. 21, pag. 47 we have stations representing the different types of fjords from the open Langesundsbugta to the isolated Frierfjord. At Kristiansand, Fig. 30, pag. 62.

from the open sea to the moderately isolated Topdalsfjord. At Arendal the Skjærgaard is represented by the Tromøsund and Galtesund, Fig. 8, pag. 22. We have coast stations outside Torungen,and some stations on the slope towards the great depth of Skagerrack.

The figure 6 pag. 19 gives the temperatures observed 1—2 n. m. off Torungen from the 24th of January. On that date we have temperatures below zero down to 10 meters, but the temperature of the bottom layer is still more than 6° C. As time passes the temperatures near the surface keep near zero till in April. At the beginning of May it rises to 5°. At 50 meters a temperature of 5.8° is reached on the 29th of January. Later on the temperature of 5° is not found at that depth, and at 70 meters only during the last days of March and the first days of April.

The occurrence of eggs and larvae of the cod and some other species is shown by the tables 28—39.

It is evident that the number of eggs of cod and haddock, Table 28 page 80, which cannot be separated in the early stages, is relatively high in the waters at Arendal medio March, decreases in the last days of the month, and keeps low till the last days of April. It is the same with the cod-eggs in advanced stages, Table 29 and the larvae, Table 30. The months of March and April are usually very important with regard to the spawning and the hatching of the cod, and the scarcity of cod eggs and larvae during the last part of March and April this year must undoubtedly be ascribed to the low temperatures. The relatively high number of eggs medio March is caused by the high temperatures in the bottom layers some days previously (Fig. 6, Page 19). The augmenting in the last days of April is caused by the rising temperatures at the surface. I think there is reason to believe that the early eggs are from the cod spawning at a moderate depth, the late eggs from the littoral cod.

Some few eggs with advanced embryoes of the haddock are found on the 30th of April, a quantity of larvae on the 19th of May.

Turning to the fjords, things change. The cold sea-water is only felt in the open fjords — the isolated fjords have relatively warm water during the winter, ɔ: the temperatures in the deep basins keep very constant. The fig. 22, pag. 48 illustrates the temperatures from the isolated Frierfjord to the Skagerrack. The investigations from the 15th and 16th of April show that the eggs of the cod group are abundant at that time in the Frierfjord when we had a minimum at Arendal. Just the same at Kristiansand. At the entrance of the Topdalsfjord, with the relatively high temperatures in the basins, fig 31, pag. 66 the largest number of cod-haddock eggs are found on the 4th of April — and here also with decreasing numbers seawards.

We have great quantities of eggs belonging to the cod group (mostly cod, haddock only present in small numbers) in the fjords with water suitable for the spawning of the cod. At the same time, we have small numbers outside the coast in unfavourable temperatures.

The cod larvae occur from the very beginning of the investigations on the 13th of March near Arendal — but decrease in numbers and are absent in these waters on 9th and 10th of April. In the last days of April they are found in small numbers but are numerous on the 15th to 19th of May — just at the time when the surface temperatures begin to rise.

In the Frierfjord we have some larvae medio April, medio May they are numerous throughout the fjords — here also when the temperature begins to rise at the surface. Near Kristiansand they are scarce.

In chapter V, I have compared the results in 1924 with *K. Dahl's* investigations of the waters near Risør in 1905 and my own in 1917 at Arendal.

The conclusion drawn is the following: In 1905 we have maximum of cod fry during the last days of March. In 1917 during the last days of April. In 1924 medio May.

The winter 1905 was a mild one — 1917 and 1924 cold ones. Vide the table page 95 giving the temperature of the sea at Torungen lighthouse.

In the years 1917 and 1924 the maximum of cod fry appears in the catches at the time when the surface temperatures begin to rise above those of the intermediate layers.

In 1917 this happened within a month after the maximum of spawning, and the number of cod fry was high. In 1924 nearly two months passed, and the number of larvae found was low.

We may get the impression that when the surface water in the spring begins to be warmed the conditions are favourable to the larvae.

When these conditions occur some time after maximum of spawning (equal to the time of development of the eggs) the quantity of larvae is great. On the contrary, has the temperature of the surface still the winter character at the time of hatching, the results will be poor.

Besides the propagation of the fishes I was also interested in the occurrence of the grown fish under those extraordinary circumstances.

The fishermen have from ancient time noticed that the cold sea-water greatly influences the occurrence of the marketable fish.

The following is noticed:

1. Just before the drifting ice sets in along the coast, in many places great numbers of dead and dying fish are found at the surface in the skjærgaard. They can be taken by a catcher or by hand, and later on, when the ice is formed, many of them are found in the ice.
2. The shallow waters along the coast are quite devoid of fish, but in deeper parts of the skjærgaard — and in the fjords — great catches may be made.

In chapter VI I have related some notes made with regard to the occurrence of dead fish, the accompanying temperatures of the sea-water, and the critical temperatures of the cod found by experiment.

We may sum up the results in few words: The critical temperature for the cod is near 1° C. below zero. In severe winters that temperature is found at the coast, and then dead fish may be found in the outer skjærgaard.

As to the occurrence of the fish this question is more difficult, but I think the question may be explained in the following way: When in autumn the sea-water is cooled the fishes living near the coast in the summer will withdraw from the cold water, the littoral fishes will seek down to deeper layers. The pelagic fishes will perhaps even leave the Skagerrack. As the cooling of the water proceeds and temperatures unfavourable to the whiting and haddock are attained, they will also seek down into the deep basins — or to the depths of the Skagerrack, and in severe winters even the cod will have to withdraw from the littoral region.

In this way the low temperatures will expel the species from the littoral region, from moderate depths — and even from the Skagerrack. I have no figures to elucidate that question, but I am of opinion that the scarcity of e. g. the haddock during 1924 in the Skagerrack is to be ascribed to the low temperatures unfavourable to that species. The temperature of the sea-water in the prominent spawning places of the haddock is 6°—7° C. The measurements from the Skagerrack in spring 1924 show that this temperature was not present.

When the question arises as to the general effect of a severe winter upon the fish and fisheries on the Norwegian Skagerrack coast, it will not be possible, from the observations made during a few years, to answer that question in a satisfactory way. I will only draw the attention to some points which are of the importance that they deserve to be more closely examined.

A very severe cold in the winter may cool the surface water of the Skagerrack down to more than 1 degree below zero. If that very cold water is pressed against the coast it will be detrimental to a great deal of fishes, especially to the young specimens, the mature ones seem to withdraw at a higher temperature.

The species often found dead under those circumstances are: *Labrus rupestris, Gobius niger, Gadus pollachius, Gadus callarias and Conger vulgaris.*

If the severe period prevails for a long time, the deeper layers will be cooled so that the temperatures in the Skagerrack will be unfavourable to the spawning of the whiting and the haddock, and even the cod will withdraw from the littoral region to the moderate depths of the Skagerrack, the skjærgaard, and the fjords.

As to the spawning of the cod and the hatching of the eggs, and survival of the young ones, a cold period early in the year will postpone the spawning until the temperatures begin to rise again, and the circumstances will be favourable to the young.

If the maximum of spawning has been attained when the cold period sets in, the circumstances seem to be unfavourable to the hatching and the survival of the young fish. In mild winters this will often be the case, a mild January and February may be followed by a cold period in March and April.

This refers to the coast-waters; in the isolated fjords the temperature of the sea-water in the deeper layers is not influenced by the atmosphere. As previously mentioned, however, the spawning in the fjords in 1924 was performed relatively late — whether this is to be ascribed to racial characters, to immigration from outside, or to the ice-cover of the fjords I cannot tell. Here also we find maximum of cod larvae when the temperature at the surface begins to rise above that of the underlying layers.

From what is said it may be concluded that the influence of a very cold winter on the propagation of our fishes will be a different one at the open coast and in the fjords. The fjords are likely to profit at the expense of the coast waters.

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Table IX A.

The table shows the approximate spawning time and the diameters of eggs of the common spring-spawning fishes on the Norwegian Skagerrack-coast.

Compiled from E. Ehrenbaum: Eier und Larven von Fischen.

Table IX E.

The monthly temperatures of the surface water at Torungen 1874—1923. Compiled from the Reports of the Norwegian Meteorological Institute and Aksel S. Steen: Havoverflatens temperatur ved Norges kyst.

Table IX A.

The table shows the approximate spawning time and the diameters of eggs of the common spring-spawning fishes on the Norwegian Skagerrack-coast.

Compiled from E. Ehrenbaum: Eier und Larven von Fischen.

	January	February	March	April	May	June	
1. *Pleuronectes limanda L.*		0.84	0.84	0.82	0.78	0.76	0.66—0.98
2. *Callionymus lyra L.*[1] ..				x	x	x	0.69—0.94
3. *Labrus rupestris L.*......					x	x	0.72—0.94
4. *Pleuronectes flesus L.* ..		1.00		0.92	x		0.82—1.13
5. *Clupea sprattus L.*[2] ...					0.97	0.93	0.82—1.23
6. *Gadus minutus Risso*...			x	x	x	x	ca. 1.00
7. *Gadus esmarki Nills* ...		1.08	x				1.00—1.19
8. *Gadus virens L.*	x	x	x	x			1.03—1.22
9. *Gadus pollachius L.*....			x	x	x	?	1.10—1.22
10. *Gadus merlangus L.*....		1.21	1.18	x	1.10	1.06	0.97—1.32
11. *Pleuronectes cynoglossus L.*[3]					x	x	1.07—1.25
12. *Pleuronectes microcephalus Donow*[4]				x	1.37	1.33	1.13—1.45
13. *Gadus callarias L.*......		1.45	1.40	ca. 1.33[6]	x		1.16—1.60
14. *Gadus aeglefinus L.*....		1.52	x	x	1.34		1.19—1.67
15. *Pleuronectes platessa L.*		1.96	x	1.84			1.66—2.17
16. *Drepanopsetta plattessoides Fabr.*[5]		x	x	x			1.38 - 2.64
Eggs with distinct Oil-drop.							
1. *Onos cimbrius L.*.......			0.90	0.87	0.83	0.75	0.66—0.98
2. *Onos mustella L.*.......		0.85	0.81	0.79	0.76		0.66—0.98
3. *Scophthalmus norvegicus Gthr.*					x	x	0.72—0.92
4. *Raniceps raninus L.*....						0.85	0.75—0.91
5. *Caranx trachurus L.*[7] .						x	0.84—1.04
6. *Trachinus draco L.*.....						x	0.94—1.11
7. *Molva molva L.*				1.06	1.03	x	0.97—1.13
8. *Rhombus maximus L.* ..				1.09	1.09	x	0.91—1.19
9. *Zeugopterus punctatus Bl*					x	x	1.00—1.07
10. *Solea vulgaris Quensel*[8]					x	x	0.95—1.38
11. *Lepidorhombus whiff Walb.*				?	x	?	1.07—1.22
12. *Scomber Scomber L.*....					x	x	0.97—1.38
13. *Trigla gurnardas L.*....					x	x	1.16—1.55
14. *Rhombus laevis Rondel.*				x	x	x	1.24—1.50
15. *Brosmius brosme Asc.*..				x	1.35	x	1.29—1.51

[1]) *C. lyra:* The egg-coating with net-structure. [2]) *C. spratus:* The yolksack segmented. [3]) *Pl. cynoglossus:* The egg-coating thick and striped. [4]) *Pl. microcephalus:* The egg-coating thick with hurdle-work structure. [5]) *Dr. platessoides:* The peri-vittellin space great. [6]) From my own measurements at Flødevigen. [7]) *C. trachurus*: The yolksack segmented. [8]) *S. vulgaris:* Several small oil-drops.

Table IX E.

The monthly temperatures of the surface water at Torungen 1874—1923. Compiled from the reports of the Norwegian Meteorological Institute and Aksel S. Steen: Hav overflatens temperatur ved Norges kyst.

	Month												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
1874	5.0	3.3	2.6	5.1	8.3	12.2	16.1	15.3	13.9	11.7	8.1	3.2	8.7
1875	0.2	0.1	÷0.1	4.2	8.6	12.6	16.3	17.1	15.0	10.3	5.5	3.4	7.8
1876	2.1	1.1	0.7	3.3	8.2	12.6	15.2	15.5	13.6	10.4	6.8	1.3	7.6
1877	0.4	0.6	0.7	2·4	6.4	11.2	14.6	15.4	13.5	10.4	7.9	5.6	7 3
1878	2.5	2.6	2.8	5.6	9.7	13.1	16.1	17.2	15.2	12.0	7.3	2.9	8.9
1879	0.9	÷0.5	1.2	2.6	8.0	12.1	15.6	16.7	13.9	11.0	6.2	3.4	7.6
1880	1.7	2.2	2.4	4.4	8.2	13.4	15.9	18.7	16.2	10.2	6.5	4.5	8.7
1881	0.6	÷1.1	÷0.5	1.6	7.1	11.9	14.5	14.4	13.3	9.3	7.0	5.3	6.9
1882	4.9	3.9	4.2	5.9	9.1	13.6	16.3	17.0	14.9	11.1	6.4	2.5	9.2
1883	0.7	1.7	0.9	3.5	7.5	14.2	16.6	15.8	14.3	11.3	8.4	5.8	8.4
1884	3.6	3.0	1.7	4.7	8.0	11.8	16.7	17.5	16.0	12.3	8.1	5.0	9.0
1885	1.9	1.1	2.1	4.1	7.9	11.6	15.4	15.5	12.5	9.4	5.6	4.6	7.6
1886	2.8	0.2	÷0.6	3.3	7.3	11.6	13.9	15.1	14.1	11.0	8.2	6.0	7.7
1887	3.1	3.1	2.6	4.0	8.5	12.6	14.3	14.7	12.7	9.8	6.2	3.8	7.9
1888	2.0	0.0	÷0.9	1.0	6.6	12.2	14.6	14.0	13.1	9.7	6.4	4.7	7.0
1889	3.4	1.1	0.0	3.1	11.9	12.1	15.2	15.0	13.3	9.8	7.5	4.5	8.0
1890	4.0	2.6	2.8	4.4	10.0	11.6	14.5	14.9	14.2	11.2	7.7	3.0	8.4
1891	1.2	2.9	2.0	3.5	7.5	13.0	16.2	16.0	13.6	11.6	7.7	5.9	8.4
1892	2.7	1.7	0.8	4.2	7.6	12.8	15.1	14.9	13.4	9.7	7.5	4.1	7.8
1893	1.0	÷0.7	1.1	4.1	9.2	13.9	16.5	16.7	13.7	11.3	7.6	5.7	8.3
1894	3.1	2.7	2.5	5.7	8.4	12.5	16.3	15.2	13.2	9.0	6.4	5.2	8.3
1895	1.6	÷1.5	0.2	3.5	10.8	13.0	14.1	14 8	13.9	10.3	6.7	4.0	7.6
1896	1.6	2.5	1.6	3.5	9.5	15.5	16.0	16.1	13.7	10.1	6.7	2.8	8.3
1897	0.4	1.5	1.0	3.1	8.0	12.8	14.9	16.8	14.1	10.7	7.6	4.4	7.9
1898	4.5	3 3	1.5	3.9	7.4	12.0	13.7	13.8	12.9	10.4	7.1	6.0	8.0
1899	2.9	1.7	2.1	3.9	7.6	12.8	16.4	15.9	13.1	10.7	8.6	4.9	8.3
1900	0.9	÷0.8	÷0.3	1.9	6.4	13.2	14.4	16.3	13.9	10.8	7.1	5.5	7.4
1901	2.8	÷0.2	0.2	3.3	9.8	12.7	18.0	16.2	14.0	11.7	7.5	5.0	8.4
1902	3.6	1.1	0.5	3.3	6.7	12.3	13.5	13.6	11.9	8.9	6.1	2.2	6.9
1903	1.4	2.6	2.9	4.2	8.1	14.2	14.6	14.5	12.8	9.6	7.5	3.7	8.0
1904	2.2	0·4	÷0.3	2.7	7.0	12.9	13.8	15.1	13.9	10.7	7.5	4.7	7.6
1905	4.2	3.2	1.9	3.2	7.8	13.8	15.8	14.5	12.9	8.8	5.4	4.4	8.0
1906	2.3	2.5	2.0	3.8	8.6	13.3	14.7	15.0	13.5	10.4	7.9	5.7	8.3
1907	3.0	0.6	2.0	4.2	7.8	11.8	14.6	13.4	13.1	11.6	7.3	3.8	7.8
1908	4.0	4.1	1.5	3.9	7.8	13.7	16.7	15.9	13.7	11.4	7.1	5.5	8.8
1909	3.9	1.3	÷0.4	2.8	7.2	12.4	14.4	14.8	13.4	12.2	7.0	4.7	7.8
1910	3.4	2.1	2.6	5.1	9.4	14.5	16.4	16.8	14.6	11.1	6.2	4.4	8.9
1911	3.8	2.7	2.5	5.0	10.3	14.6	15.4	17.6	14.3	9 2	7.2	4.6	8.9
1912	2.5	0.1	2.2	4.8	8.4	12.7	17.2	16.2	13.1	10.1	6.6	5.7	8.3
1913	3.3	1.9	3.4	4.3	8.5	11.3	15.0	14.9	14.0	10 5	9.0	6.7	8.7
1914	3.2	4.0	2.5	4.5	8.5	13.9	17.6	17.6	15.1	11.0	6.2	5.7	9.2
1915	2.0	1.5	0.7	3.8	8.0	12.2	15.0	16.1	13.6	9.2	4.4	2.3	7.4
1916	2.5	2.3	0.4	3.3	8.0	11.5	16.0	15.7	13.2	9.9	6.8	4.2	7.8
1917	0.4	÷1.0	÷0.5	1.2	6.5	13.1	16.0	16.8	13.8	10.2	7.3	4.2	7.3
1918	1.4	0.0	÷0.3	3.1	8.9	10.2	14.0	15.4	12.3	10.4	7.5	4.4	7.3
1919	2.4	0.3	1.1	3.1	9.4	11.9	16.4	14.0	12.8	9.7	4.3	2.5	7.3
1920	1.6	2.0	3.0	4.5	8.3	13.7	15.0	15.1	13.2	9.7	7.8	4.4	8.2
1921	3.8	2.5	3.9	6.1	10.0	13.2	14.0	14.6	12.8	10.9	7.1	5.0	8 7
1922	3.7	÷0.9	1.3	3.0	6.5	11.8	14.3	14.9	13.3	8.9	6.7	5.0	7.4
1923	3.8	1.6	0.4	3.5	7.2	10.2	13.9	14.3	12.5	10.3	7.1	2.7	7.3