REPORT ON NORWEGIAN FISHERY AND MARINE INVESTIGATIONS VOL. III NO 7

PUBLISHED BY THE DIRECTOR OF FISHERIES

Qvantitative Investigations of Plankton at Lofoten, March—April, 1922—1924

Preliminary Report

by

BIRGITHE RUUD

With 3 charts and 5 diagrams

BERGEN 1926

A.S. JOHN GRIEGS BOKTRYKKERI

During the years 1922—1925 the Norwegian Fishery Investigations, under the leadership of Mr. Oscar Sund, collected material in order to explain the connection between the occurrence of the newly hatched cod fish on the one hand, and the hydrographical-biological conditions on the other.

The object was in particular to ascertain, whether there were such variations from year to year in the occurrence of the quantities of plankton that they could have influence upon the quantities of nourishment that each year constitute the basis of the food of the young cod.

The samples of plankton collected for the quantitative investigations were examined at the Botanical Laboratory of the University in Oslo, under the direction of Professor H. H. Gran. A preliminary report of these investigations for March—April will be given below. The plankton algae represent the primary nourishment in the sea; the entire animal life of the sea, including the tiny organisms upon which the young cod live, develops upon the basis of the organic nourishment produced by the plankton algae by their assimilation of carbonic acid.

On the Lofoten bank the cod spawn in the first months of spring. When the young cod are hatched in the spring, they have by degrees to begin to seek nourishment for themselves. The first condition for its existence and further development is that precisely during this first period, when it drifts passively with the current, the young fish must find sufficient nourishment in the layer of water in which it finds itself.

It is therefore of special interest to have an investigation made of the plankton on the Lofoten bank in spring; to ascertain the quantity and composition of the plankton at that time and in what degree it is dependent upon hydrographical and meteorological conditions.

By comparing the results of the various years it will also be possible to see whether the quantity of plankton varies from year to year.

If the existence of such a variation can be proved, we should be inclined to assume that this might perhaps be one of the causes of the great variations in the annual supply of young cod.

The samples of plankton were collected in the course of the expeditions of the fishery investigation on the M/S. »Corona«, March—April 1922, and on the M/S. »Johan Hjort«, July—October 1922, March—May 1923, June—August 1923, February—April 1924, May 1924, May—July 1925, and in addition on the M/S. »Tovik«, July—September 1924.

Along all the coasts of the North Europe there is a rich flowering of plankton in spring. At that time the plankton chiefly consists of diatoms. These are the plankton organisms that can multiply most rapidly in favourable circumstances, and during the first period of the spring flowering they divide at least once a day so that their number increases enormously in a short time. (H. H. Gran, 1916). This spring flowering occurs at sligthly different times at various places, and may also vary slightly from one year to another. At Lofoten it begins in the latter half of March and lasts to the end of April. Uufortunately there is no material to enable us to trace the development in its entirety during any one year. Both in 1922 and in 1924 the spring expedition to Lofoten of the fishery investigation was broken off too early, in 1922 on April 22nd and in 1924 even sooner, viz. as early as April 11th. In 1923, on the other hand, the expedition did not begin until the spring flowering was already in progress in the Vest Fjord.

In order to obtain an estimate of the quantity of organic matter produced by the plankton algae during the spring flowering, we may investigate the content of oxygen in the water before the production has commenced, and when it has reached its maximum, for in the assimilation of carbonic acid there is produced a quantity of oxygen that is directly dependent upon the quantity of organic matter they have constructed. A part of the oxygen is consumed by the plants and by the animals in breathing, so that the values we obtain correspond to the net surplus of production. In order to utilize this method of calculation, however, the analyses of oxygen must be entirely accurate. Winckler's method, which is used in the determinations of oxygen, gives excellent results, but the exactitude of the method depends upon the samples not being exposed to great changes of temperature

betore titration, because in that case the values obtained may be too large. The values of oxygen for 1922 and 1923 show irregularities, and in some cases give so high values above saturation that it cannot be assumed that they correspond to the actual conditions. For that reason the greatest importance has been attached in the following pages to the oxygen values for 1924.

It is to be hoped that the deficiencies thus exhibited by the material at hand, will be supplied by a concluding investigation in the spring of 1926, which, it is to be hoped, will solve the questions that still remain open. Yet even at the present time the investigations have given such results that it was considered important to publish them in this short report.

The final results of the investigations in their entirety will be published when they are completed, and then also all the various plankton organisms, both from the spring and the summer material, will be dealt with in detail, and the complete tables will be published. In this preliminary report only the most characteristic species have been included in the tables, and in addition the sum of all the diatoms. A comparison with the production of plankton in other regions will also be reserved for a later and detailed report.

The plankton at Lofoten in spring was known before through the investigations of H. H. G r a n (1897 and 1900) and of E. J ø r g e n s e n (1905).

Through these investigations the species that might be expected to be found, were made known; but a general survey of the quantities of plankton is not obtained until a quantitative investigation is made. This quantitative investigation was undertaken in the following manner. By means of water bottles samples of water were taken from various depths at each station. Some of the samples of water were fixed by means of Flemming's fluid according to H. H. G r a n ' s method for plankton investigations (H. H. G r a n 1912), and other were examined hydrographically at the Geophysical institute at Bergen. Of the plankton samples certain quantities were centrifuged — most often 50 ccs — and the content of organisms determined by counting the various species. In the tables the quantities of plankton are estimated per litre of water.

Quantitative investigations of plankton have shown that coast water

is far richer than that of the open sea as regards content of plankton. The advantage thus possessed by the coast water must be attributed to the circumstances that river water constantly brings supplies of nutritive matter from the land. Nathansohn (1909) showed that at every increased supply of fresh water there resulted a flowering of plankton.

The circumstance that off the coast of North Europe it is precisely in spring that we have the greatest flowering of diatoms which require for their rapid development a special abundance of nutritive salts, must be attributed to the particularly copious supplies from land at that time. H. H. Gran has pointed out that the snow water in spring carries out the maximum quantity of nutritive salts for the year, and he therefore regards the melting of snow to be the chief cause of the rich production in our coastal waters during spring (Samtiden«, 1922). The conditions at Lofoten are particularly favourable as proof of this theory, for at our southern coast this problem is more difficult to study because we have there not only to take inti account supplies from land, but also the wealth of nutriment in the snow water that comes from the Baltic countries with the Baltic Current and influences the development of plankton along the coast. On the other hand, Lofoten lies so far away that we cannot expect to have there in spring the snow waters from the Baltic countries of the same year, and in addition the Baltic Current by degrees has its nutritive substances drawn off during its long journey, so that it may here be left out of consideration. As will be shown later on, the spring flowering at Lofoten is an entirely local phenomenon in which the melting snow from the land alone plays a part.

If H. H. Gran's theory is correct, the spring flowering of plankton must immediately follow the first melting of snow, and the quantity of plankton must to a large extent be dependent on the snow water.

It is only in the upper layers of water where the intensity of light is sufficiently great to maintain the assimilation of carbonic acid, that the plankton algae can produce organic matter. For this they constantly consume nutritive salts, but when after a time the plankton algae sink, and animals, which have developed at their expense die and likewise sink, the upper layer of water in this way will steadily become poorer in nutritive salts if they receive no supplies from land. The deeper layers of

water, on the contrary, will constantly become richer in nourishment by this incessant sinking of organic matter, which by degrees is decomposed and again passes into the inorganic form. Nathansohn (1906) therefore pointed out the great significance of vertical currents in marine life; layers rich in nourishment are carried up from the depths to the light so that the nutritive salts can again by the aid of the plankton algae be brought into the circle of life. This interesting problem also could be studied by an investigation of plankton at the Lofoten Bank. It is precisely out at the Edge that we must have vertical vortices in the sea where the Atlantic current is pressed against the slope by the rotation of the earth.

The contents of this report are arranged in the following manner:

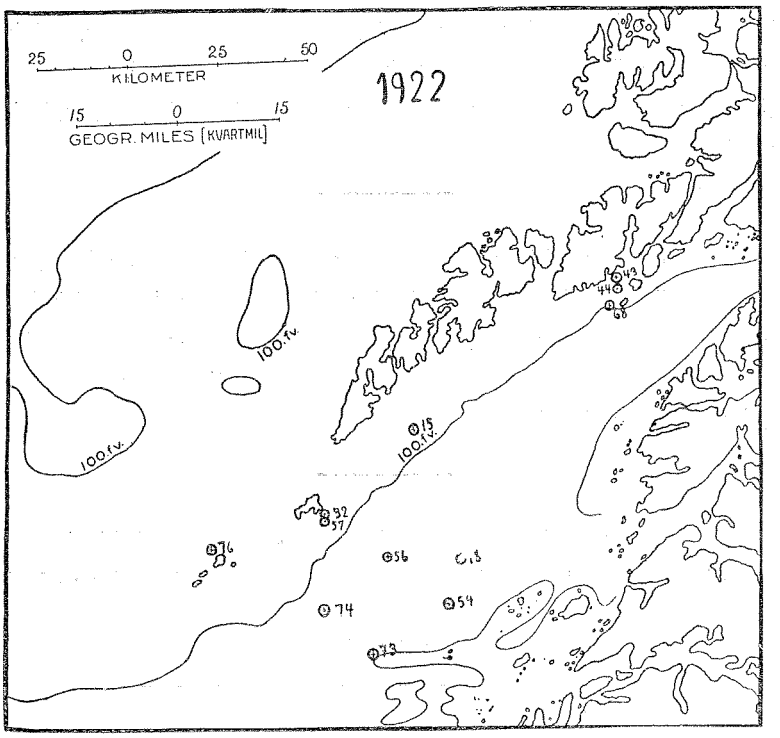
Firstly the development of plankton in spring is dealt with for each of the three years separately. Then follows a survey of the spring flowering of plankton at Lofoten in general, and the preliminary results given by the investigations.

1922. In the spring of 1922 there was no appreciable increase in the quantity of plankton in the Vest Fjord before the last days of March.

Table I.

24—3 22	St. 15	St. 18
Depth in m	0	0
Temperature °C	3.0	3.0
Salinity ‰	33.80	33.92
P_H	8.20	8.20
Diatoms	1 440	740
Thalassiosira sp.	480	380
Fragilaria oceanica		
Skeletonema costatum	380	240

As late as the 24th there were not more than 1440 diatoms per litre at St. 15, which is situated on the bank. Yet this is nevertheless double of what there was at the same time out in the fjord at St. 18. This indicates that the spring production of diatoms had just commenced on the bank, whilst in the centre of the fjord winter conditions still existed as regards plankton.



It will appear from Table I that the salinity is lowest on the bank. In the tables, *Thalassiosira gravida, Thalassiosira Nordenskiöldii* and *Coscinosira polychorda,* are placed together under *Thalassiosira sp.*

The next table shows the conditions on the bank east of Værøy, 5 days later. The quantity of plankton has considerably increased. The temperature has become lower than it was at St. 15, but the salinity and the concentration of the hydrogen ions are approximately the same.

On April 4th a great development of diatoms had taken place in the fjord. It will appear from Table III that at that time the temperature and salinity were extremely low. St. 43 and 44 are both situated at Høla.

Table II.

29—3 22	St. 32	
Depth in m.	0	20
Temperature °C.	2.8	2.94
Salinity ‰	33.81	33.81
P_H	8.20	8.20
Diatoms	3,600	4,880
Thalassiosira sp.	1400	2200
Fragilis oceanica		
Skeletonema costatum	920	1480

Table III.

4—4 22	St. 43		St. 44	
Depth in m.	0	20	0	20
Temperature °C.	2.35	2.48	2.37	2.42
Salinity ‰	33.73	33.73	33.73	33.75
P_H	8.25	8.22	8.30	8.27
Diatoms	23,400	19,600	57,340	43,040
Thalassiosira sp.	4720	7280	10900	11980
Fragilaria oceanica	1520	320	1580	1180
Skeletonema costatum	13060	9580	35220	21600

At both stations the quantities of plankton were greatest at the surface, larger at St. 44 where the depth is 80 m., than at St. 43, where the depth is 143 m.

Also the number of species has increased considerably, but *Thalassiosira, Fragilaria* and *Skeletonema* are still the predominating species.

A week later about the same physical conditions prevailed at the same place, but the maximum of plankton had sunk from the surface

Table IV.

11—4 22	St. 68			
Depth in m.	0	20	50	90
Temperature °C.	2.28	2.36	2.80	5.58
Salinity °/oo	33.78	33.80	33.87	34.51
P_H	8.25	8.20	8.20	8.17
Diatoms	41,280	66,040	73,100	9,200
Thalassiosira sp.	14480	23080	23820	4000
Fragilaria oceanica	2280	8240	5360	880
Skeletonema costatum	12960	16800	24600	1280

Table V.

9—4 22	St. 54		St. 56		St. 57	
Depth in m.	0	20	0	20	0	20
Temperature °C.	4.58	4.83	3.23	3.35	3.06	3.35
Salinity °/oo	34.61	34.61	34.00	34.03	34.00	34.05
P_H	8.30	8.25	8.27	8.27	8.32	8.30
Diatoms	6,040	19,840	19,840	40,360	32,440	36,640
Thalassiosira sp.	3920	11000	6640	21760	10120	15920
Fragilaria oceanica		1840	3040	4880	3120	7120
Skeletonema costatum	1440	4240	4720	5720	12960	4560

down to a depth of 50 m. Even at a depth of 90 m., where the temperature and salinity show quite oceanic conditions, we have a quantity of diatoms amounting to 9,200 cells pr. litre.

It would appear that *Thalassiosira gravida* sinks most quickly. The maximum is still made by the same species, but the number of the latter has further increased. In particular there are more species of *Chaetoceras* some of which have their maximum on the surface.

Out at the mouth of the fjord the quantity of plankton increased on April 9th from east to west. Table V shows that the quantity of the plankton was greatest at St. 57, which lies on the banks east of Værøy. At this station too, the temperature and salinity were lower than in the centre of the fjord at St. 54, where also the quantity of plankton was smallest.

On April 22nd the quantity of plankton at the mouth of the fjord had somewhat decreased, but the maximum was still at a depth of 20 m.

Table VI.

22—4 22	St. 73			St. 74			St. 76		
Depth in m.	0	20	75	0	20	75	0	20	75
Temperature °C...	5.36	5.20	5.19	5.20	4.80	5.21	5.20	4.91	5.29
Salinity °/oo	34.40	34.52	34.79	34.20	34.42	34.71	34.42	34.36	34.70
P_H	—	—	—	8.27	8.22	8.17	8.30	8.27	8.20
Diatoms	8400	25100	3080	5760	18720	7660	2820	3960	2180
Thalassiosira sp. .	5120	21880	1450	2520	14960	5780	2360	3540	1640
Fragilaria oceanica	920	920	800	—	800	—	—	—	—
Skeletonema costatum	400	—	280	80	160	1120	—	—	60

There was then about the same temperature and salinity both on the bank and in the centre of the fjord; but the quantity of plankton was then least at St. 76 on the bank.

The number of species is quite considerable; but *Thalassiosira, Fragilaria* and *Skeletonema* are still the predominating ones. The investigations in 1922 were broken off at this time. As the last samples do not exhibit any distinct decrease in the quantity of plankton, we must assume that the spring flowering of diatoms lasted for some time onwards. If compared with the production in 1923, we may even assume that at that juncture it had not yet reached its maximum.

1923. In 1923 the first samples of plankton were taken in Vest Fjord on March 20th. Table VII shows the conditions at that time at St. 3, which lies outside Øksnesodden.

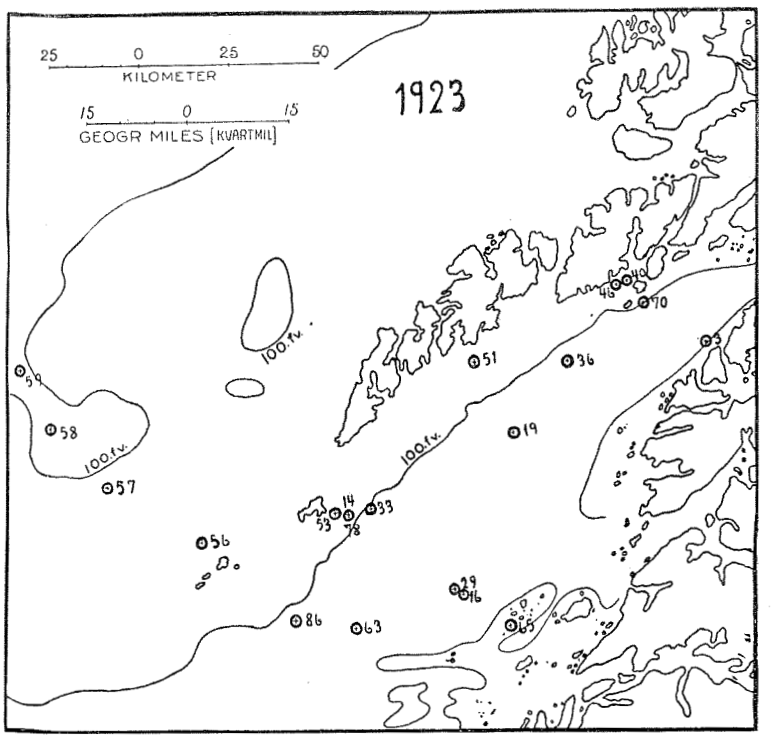


Table VII.

20—3 23	St. 3	
Depth in m	0	30
Temperature °C.	2.31	2.31
Salinity ‰	33.40	33.44
Density σ_t	26.69	26.72
Diatoms	1200	60
Thalassiosira sp.	120	40
Fragilaria oceanica	480	
Skeletonema costatum	240	

The temperature and salinity are rather low, and it appears as if the plankton has only just commenced its spring flowering.

Some days later the quantity of plankton has increased to the double at the same place, whilst farther out complete winter conditions still prevail. On March 26th there are still winter conditions at St. 16 in the middle of the mouth of the fjord. At St. 14 which lies on the bank east of Værøy the quantity of plankton is also small, but at St. 19, which is situated farther in, the quantity of plankton has further increased.

Table VIII.

26—3 23	St. 16		St. 14		St. 19	
Depth in m.	1	30	1	20	1	30
Temperature °C.	3.93	4.00	3.73	3.90	2.82	3.17
Salinity ‰	34.06	34.13	33.91	33.96	33.49	33.72
Density σ_t	27.07	27.12	26.99	27.00	26.715	26.905
Diatoms	220	160	20	860	5280	1300
Thalassiosira Sp.	20	40	20		1560	300
Fragilaria oceanica				600	2080	360
Skeletonema costatum	180	120		160	120	120

It appears from this table that the amount of plankton is greatest at the station where the water is coldest and most mixed with fresh water.

Table IX.

4—7/4 23	St. 29		St. 33		St. 36		St. 40	
Depth in m.	1	30	1	30	1	30	1	30
Temperature °C.	4.33	4.43	3.09	3.06	3.11	3.00	3.11	2.94
Salinity ‰	34.15	34.25	33.63	33.97	33.49	33.55	33.27	33.49
Density σ_t	27.09	27.175	26.79	26.99	26 75	26.89		
Diatoms		20	2040	2520	4380	380	10400	245500
Fragilaria oceanica			640	800	1240		1360	3480
Thalassiosira sp.			320	1680	980	220	2320	1960
Skeletonema costatum			600		440		940	158800

A week later there are still full winter conditions in the middle of the mouth of the fjord, at St. 29, whilst the quantity of plankton increases inwards along the bank.

Tb. IX also shows how an increase in the quantity of plankton is in direct connection with a decrease in temperature and salinity.

The number of species has now considerably increased but the *Thalassiosira species, Fragilaria oceanica* and *Skeletonema costatum* still constitute the bulk of the plankton. The great maximum at depth of 30 m. at St. 40 is due to *Skeletonema costatum.* This station lies near the land in Høla. On April 11te *Chaetoceras* was predominant at St. 46, which also lies in Høla. The maximum there was then at a depth of 50 m., mainly resting spores of *Chaetoceras sociale.* Outwards on the bank the quantity of plankton rises in the surface layers, and at St. 53 east of Værøy the maximum is found at a depth of 1 m.

Table X.

11—12/4 23	St. 46		St. 51		St. 53	
Dept in m.....	1	50	1	50	1	50
Temperature °C.....	3.32	3.42	3.40	3.26		
Salinity °/₀₀	33.10	33.63	33.32	33.58		
Density σ_t.....	26.38	26.78	26.53	26.75		
Diatoms	5300	147460	9980	19960	17120	2820
Thalassiosira sp.....	180		2320		2080	80
Fragilaria oceanica.....	480		620		5200	260
Skeletonema costatum.....	180			80	60	

On April 13th plankton samples were taken at Stations 56—59, which are situated in a north westerly direction from Røst. At the innermost station, St. 56, the quantity of plankton decreases downwards, and we there found the same conditions as in the fjord. At Station 57, which also lies on the bank, the quantity of plankton likewise decreases from 1 to 20 m., but at a depth of 30 m. the quantity of plankton is again much greater than at the surface. We may thus readily assume that we

have here to take into consideration a sinking down of plankton from the surface layers. But the plankton found at 30 m. differs from that higher up in that it entirely lacks species of *Fragilaria* and *Chaetoceras*. In addition to Skeletonema costatum the plankton consists of *Nitzschia* and *Thalassiosira*.

The temperature and salinity increase downwards.

Table XI.

12—4 23	St. 56		St. 57		St. 58		St. 59	
Depth in m.	1	30	1	30	1	30	1	50
Temperature °C.	4.41	4.39	4.39	4.91	4.93	5.33	6.66	6.70
Salinity °/₀₀	34.09	34.14	33.95	34.36	34.37	34.62	35.15	35 16
Density σ_t	27.05	27.09	26.94	27.20	27.21	27.36	27.60	27.60
Diatoms	12840	900	12420	87080	1360	40	1954330	449460
Thalassiosira sp.....	1240	60	1880	660	20	40	19450	
Fragilaria oceanica	9140	600	7540					
Skeletonema costatum	100		100	86200	1220		1932240	446240

At St. 58, which is also situated on the bank, there is little plankton. It consists of the same species as those in the surface layers at St. 57. On the other hand St. 59 is very rich in plankton. This station lies outside the bank. The depth is 800—900 m. The hydrographic values show that we have there pure Gulf Stream water. The quantity of plankton cannot be ascribed to production in the Vest Fjord. At a depth of 30 m. at St. 57, we have here species of *Thalassiosira* and *Nitzschia*, and mostly *Skeletonema costatum*. At this station the quantity of plankton steadily decreases downwards.

Out at the mouth of the fjord at St. 63, the spring production of plankton had reached its maximum on April 17th. The quantity of plankton was greatest in the surface layers, and decreased downwards. At St. 65, which lies farther to the east at Helligvær, the greatest amount of plankton was deeper down. The same was the case at Røst, where in addition the quantity of plankton was smaller.

Table XII.

17—19/4 23	St. 63			St. 65		
Depth in m.	1	50	75	1	50	100
Temperature °C.	4.93	5.22	5.24	4.51	4.62	5.10
Salinity ‰	34.31	34.46	34.48	34.12	34.30	34.47
Density σ_t	27.16	27.23	27.26	27.06	27.19	27.27
Diatoms	270920	14040	13560	71500	95240	19060
Thalassiosira sp.	4200	320		25680	10320	720
Fragilaria oceanica				1720	8460	
Skeletonema costatum	251400	13560	13520	5760	2080	8840

In the case of both stations the total number of diatoms is too small, as the samples there contained so many resting spores of *Chaetoceras sociale* that they could not be counted. There was a particulary large number at St. 65, where also clumps of *Phaeocystis Pouchetii* rendered counting difficult.

In the fjord there were still many diatoms on April 24th, more at a depth of 30 m. than in the surface layers. Species of *Chaetoceras* were now predominant, and then especially large numbers of *Chaetoceras furcellatum* and *Chaetoceras contortum.* Table XIII shows this. St. 70 lies just outside Skråven.

Table XIII.

24—4, 28—4, 2—5 23	St. 70		St. 78		St. 86	
Depth	1	30	1	30	1	50
Temperature °C.	3.12	3.02	4.29	4.06	5.15	5.21
Salinity ‰	33.42	33.44	33.95	33.98	34.38	34.40
Density σ_t	26.67	26.66	26.94	26.99	27.19	27.20
Diatoms	24840	233500	440	4700		80
Thalassiosira sp.	4240	36340		440		
Fragilaria oceanica						
Skeletonema costatum						

At this station there were also large quantities of resting spores of *Chaetoceras sociale* which were not counted, and in addition large clumps of *Phaeocystis Pouchetü.* Out on the bank, east of Værøy, the spring plankton had already considerably decreased on April 28th, and on May 2nd it had entirely disappeared at St. 86, which lies to the south east of Røst. We then find at this station a very scanty amount of plankton, consisting of chains of *Chaetoceras decipiens* and *Chaetoceras criophilum.*

1924. In the spring of 1924 samples of plankton were taken in the Vest Fjord from the middle of February to the middle of April. The February samples contained extremely little plankton. The same applies to the samples taken during the first half of March. Even as late as March 21st at St. 106, there were not more than 400 diatoms per litre at a depth of 10 meters.

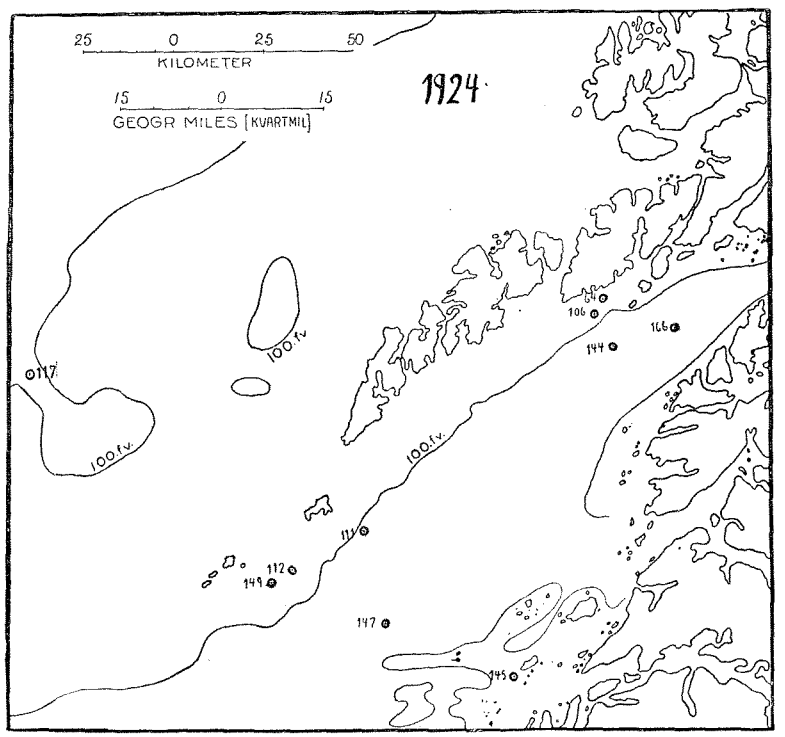


Table XIV.

1924	18—2, st. 31	5—3, st. 64	21—3, st. 106
Depth in m.	0	0	10
Temperature °C.	1.05	1.81	2.18
Salinity ‰	33.05	33.305	33.31
Oxygen cc. per l.			7.71
Oxygen %			100
Diatoms	100	140	400
Thalassiosira sp.			20
Fragilaria oceanica			180
Skeletonema costatum			80

St. 31. is situated in Ofoten Fjord, Stations 64 and 106 in Høla.

On March 24th the quantity of plankton had increased at Sts. 111 and 112, which lie on the bank east of Værøy, whilst at St. 117, which lies outside the edge, there was extremely little. The salinity here is comparatively low at a depth of 10 meters.

Table XV.

24—25—3 24	St. 111			St. 112			St. 117		
Depth in m.	1	10	25	1	10	25	1	10	25
Temperature °C.	2.62	2.59	4.02	2 45	2.46	2.68	5.96	5.94	5.95
Salinity ‰	33.69	33.68	33.98	33.68	33.68	33.64		33.33	35.15
Oxygen cc. per l.	7.445	7.27	7.185	7.43	7.40	7.355	6.85	6.975	6.865
Oxygen %	97	95	98	97	97	96.5		98	98.5
Diatoms	3200	2340	520	3660	3220	1340	20	240	80
Thalassiosira sp.	380	440	80	480	500	480		20	20
Fragilaria oceanica	140	80				160			
Skeletonema costatum	1400	1280	280	2360	1560	440		200	

This table shows that the quantity of plankton decreases with increasing temperature and salinity, both horizontally and vertically. At this time the plankton mainly consists of *Skeletonema costatum, Fragilaria oceanica* and species of *Thalassiosira.*

The same species are also found in the fjord at St. 144 on April 5th (Tb. XVI), but there are in addition several species of *Chaetoceras.* The quantity of plankton is greatest at a depth of 1 meter.

One week later, at approximately the same place, St. 166, we have the same quantity of plankton, but we find the maximum deeper. Still more species have now arrived, but *Fragilaria oceanica, Skeletonema costatum* and *Thalassiosira* are still in predominance.

Table XVI.

5—4, 11—4 24	St. 144			St. 166		
Depth in m.	1	10	75	1	10	25
Temperature °C.	1.89	1.84	4.37	1.64	1.63	181
Salinity °/₀₀	33.28	33.25	34.04			
Oxygen cc. per l.	8.08	8	7.58	8.14	8.51	7.975
Oxygen °/₀.....	104	103	104			
Diatoms	25080	23600	620	10125	13670	22600
Thalassiosira sp.....	3320	4640	40	2920	3980	4680
Fragilaria oceanica....	7200	4160		1000	160	2920
Skeletonema costatum	6680	6160	140	600	2800	2880

On April 9th there are considerable numbers of diatoms at St. 145 (Tb. XVII), which lies just off Fleinvær. The quantity of plankton is much less at St. 147 which lies right in the mouth of the fjord, and at St. 149, which lies on the bank to the east of Røst.

At all of these stations the quantity of plankton is greatest in the surface layers. There are many species here too, but *Skeletonema costatum, Fragilaria oceanica* and *Thalassiosira* species constitute the chief quantity also here.

It will appear from the following table that the hydrographic conditions are approximately equal at all stations.

Table XVII.

9—4 24	St. 145			St. 147			St. 149		
Depth in m.	1	25	50	1	25	50	1	25	75
Temperature °C.	3.55	3.49	3.59	3.62	3.91	4.29	3.40	3.82	4.19
Salinity ‰	34.045	34.01	34.04	34.04	34.135	34.51	34.04	34.13	34.20
Oxygen cc. per l.	7.70	7.585	7.55	7.825	7.40	7.24	7.725	7.44	7.185
Oxygen %.....	104	102	101	105	101	98	103.5	102	98
Diatoms	52980	30560	10340	8880	6000	660	6500	5360	400
Thalassiosira sp.	5720	6681	760	3960	1520	180	1240	2560	120
Fragilaria oceanica.....	1440	5000				100			
Skeletonema costatum..... ...	13360	3520	2560	1560	920	120	2100	1000	160

As in 1922, the spring expedition of the fishery investigation to Vest Fjord was terminated in 1924 before the spring flowering of the plankton had finished.

The former qualitative investigations (H. H. Gran 1897 and 1900, E. Jørgensen 1905) show that the plankton at Lofoten in the spring from its composition is an arctic-neritic plankton. It consists mainly of spore forming organisms which in accordance to their development are bound to the coast. After a comparatively short period of vegetation in the upper layers of the water, where they actively divide so that their numbers rapidly increase, they sink downwards, either from internal causes or because the conditions of life in the surface layers are no longer favourable to them. The descent may take place more or less slowly. It depends upon the specific weight and the size of the cells, the movements of the water, and its viscosity. The latter depends upon temperature and salinity.

The most predominant species in the spring plankton in Vestfjord are:

Achnanthes taeniata, Grun,
Chaetoceras contortum, Schütt,

Chaetoceras furcellatum, Bail,
Chaetoceras sociale, Lauder,
Coscinosira polychorda, Gran,
Fragilaria oceanica, Cleve,
Navicula Vanhøffenü, Gran,
Skeletonema costatum, Grev,
Thalassiosira gravida, Cleve,
Thalassiosira Nordenskiøldii, Cleve,
Thalassiothrix nitzschioides, Grun.

This Arctic-Neritic plankton is also found on the coast of Greenland and in the Barents Sea, but it there has a few more arctic forms. It has in addition many species in commen with »sira« plankton which occurs in the Skagerak and off the west coast of Norway in February—April. But species such as *Chactoceras furcellatum, Fragilaria oceanica,* and *Navicula Vanhøffenü,* which are also amongst the predominating species in the Vestfjord plankton, are lacking in the sira plankton. Amongst other species that occur less frequently in the Vestfjord plankton may be mentioned: *Bacterosira fragilis, Detonula confervacea, Eucampia groenlandica, Fragilaria islandica, Pleurosigma fasciola.* These are also not found in the sira plankton, at least not at all prominently. The Vestfjord plankton also differ quantitatively from the sira plankton. The largest number of diatons counted in the Vestfjord is shown in table XII, viz. 270,920 per 1. This maximum for the most part consists of *Skeletonema costatum,* which is a very tiny form. The maximum of sira plankton in the Skagerak amounts to about 1 000 000 diatoms per 1. (H. H. Gran, 1915) and the same amount is found off the west coast of Norway. (H. H. Gran, 1922). The predominating forms in the sira plankton are the very large *Thalassiosira* species. Of *Skeletonema costatum* there have been counted as many as 24 180 000 per 1. in the Oslo Fjord (H. H. Gran, 1915). We obtain better comparative results, if we compare the quantity of organic matter produced by the plankton algae. We can estimate this directly by measuring the content of oxygen of the water before the production has begun and when it has attained its maximum, for at that time of the year the quantity of oxygen that is consumed in the respiration of plants and animal is insignificant in comparison with the oxygen liberated in the photosynthesis of the plants.

The percentage of saturation for oxygen at a depth of 1 metre on March 24th 1924 was 97.34 per cent and as early as April 5th 103.8 per cent. This is only one half of the increase in oxygen found by H. H. Gran off the west coast of Norway. The field of production there also extends farther out from land. The far larger production off the west coast must be attributed to the circumstance that the spring flowering there is influenced by the snow water which is brought by the Baltic Current from the Skagerak and the Baltic, whilst in the Vestfjord it is an entirely local phenomenon dependent upon the melting of snow from the land. The tables from the meteorological stations in Lofoten show that the melting of snow there does not begin until the first half of March, and we then have a constant melting of snow interrupted by periods of cold and snow alternating from one year to another.

In 1922 the first mild weather occurred on March 22nd and rain and melting of snow then continued for some time. It was not until April that there was a new period of cold with successive mild weather and melting of snow.

In 1923 the average temperature in March was higher than that in 1922. During the whole of the latter half of the month there was a comparatively high temperature with an unusually large amount of rain, from the 20th to the 30th, varying slightly at the various meteorological stations. A fresh period of cold did not occur until April 12th.

In 1924 the spring was colder than that of the previous year. There was mild weather from March 12th to 15th, but the following 14 days were colder. In April rain and snow alternated, but the temperature remained low, until the middle of the month. This is clearly shown by the graphical representation of the noon temperature for March at the Svolvær meteorological station.

The material is not sufficient to enable us to trace the dependence in every detail of the development of plankton upon the melting of snow. But if we look at tables I, VII and XIV, which show the commencement of the production of plankton during the 3 years, it will be seen that no year shows any rise in the quantity of plankton before the melting of snow has commenced.

In addition it must also be the melting of snow that causes the

development of plankton in the Vestfjord to follow the same scheme each year. The first rise in the production of plankton is first found near the land in the fjord and the quantity of plankton then increases out on the bank, and then finally increases in the middle of the mouth of the fjord.

This must be attributed to the circumstance that the snow-water fuert takes effekt near the land and does not extend outwards until later.

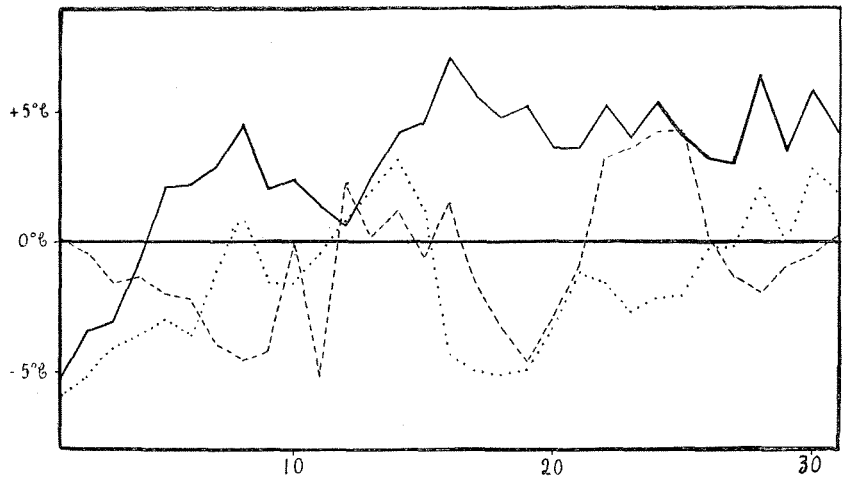


Fig. 1. The noon temperature for March — — — 1922, —— 1923, · · · · 1924 at the meteorological station of Svolvær.

It will be observed from the tables that when the spring production is at its commencement, the quantity of plankton is dependent upon decreasing salinity.

This can be represented graphically by plotting the decreasing salinity as abscissa and the quantity of plankton os ordinate. Fig. 2. shows (cp. Table IX) four stations with decreasing salinity from 1923. St. 29 is situated in the middle of the mouth of the fjord, St. 33 and 36 in along the bank, and St. 40 at Høla. The values for salinity and quantity of plankton are shown from a depth of 1 meter.

Both in 1922 and in 1924 the spring expedition of the Fishery Investigation was broken off before the spring flowering of the plankton was ended. For that reason it is not possible to estimate quantitatively

the influence of the melting of snow upon the amount of the production of plankton and the possible variations from year to year.

In 1924 the investigations concluded on April 11th. On that day samples of plankton were taken at St. 66. at Høla. Table XVI shows

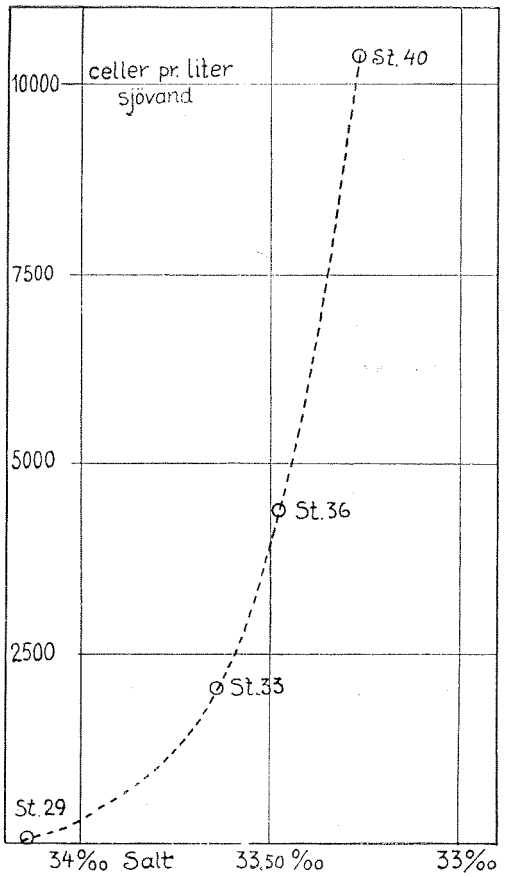


Fig. 2. The quantity of plankton dependent on decreasing salinity.

what the conditions were there at that time. The maximum of plankton at a depth of 25 metres was 22 600 diatoms per litre. In 1922 and 1923 samples of plankton were also taken at Høla on April 11th. In 1922 the greatest number of diatoms, 73 100 per litre, were found at St. 68 (Table IV) at a depth of 50 metres. The same was the case in 1923 at St. 46 (Table X), where the number of diatoms per litre was 147 460.

At that time the quantity of plankton was also considerably less in 1924 than in 1922 and 1923. This agrees with the circumstance that the amount of snow melted in 1924 was very scanty in March and at the beginning of April as compared with that of the previous years.

1923 was the year in which the atmospheric temperature was highest, and the melting of snow greatest in March and the first part of April. We also have in 1923 the largest quantity of plankton at Høla on April 11th. We can represent this graphically by plotting the mean

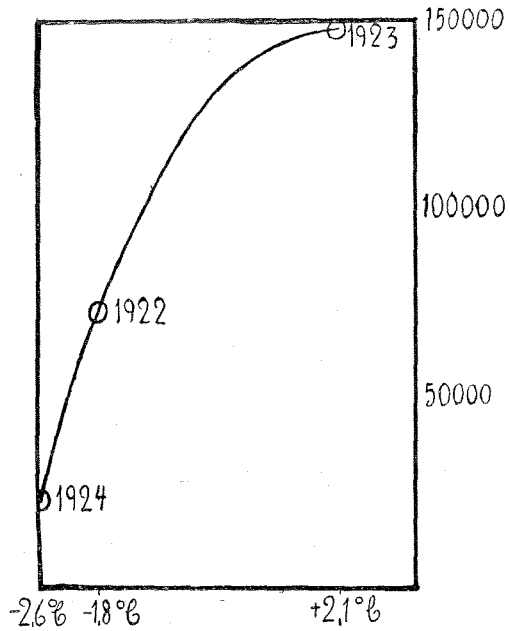


Fig. 3. The quantity of plankton dependent on the mean temperature for March.

temperature at Svolvær meteorological station in March as absciss, and the quantity of plankton on April 11th at Høla as ordinate. The curve clearly shows how the development of plankton is directly dependent upon previous melting of snow. We cannot conclude from this that the production of plankton as a whole was greatest in 1923, because the development might merely have been delayed in 1922 and 1924, and have attained the same dimensions as those of 1923 at a later period after the conclusion of the spring expeditions.

In the same manner that the spring plankton begins its development near the land in the fjords its development also first ends there.

In 1922 the maximum of plankton as early as April 11th had sunk to 50 metres at Høla, whilst one weeek before it was at the surface. (Fig. 4).

The curve from April 11th shows that the quantity of plankton decreases greatly from 50 metres to 90 metres.

The plankton between 50 and 90 metres has come into a layer of water with a much higher salinity than the water above. On account of the greater specific weight of this layer of water the sinking of the plankton there takes place much more slowly.

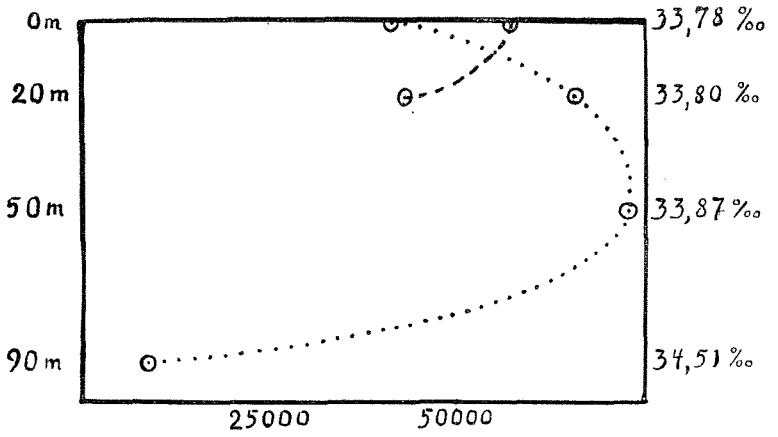


Fig. 4. The quantity of plankton at Høla — — — 4/4 22, · · · · 11/4 22.

Also at Høla on April 11th 1923 the greatest quantity of plankton was at a depth of 5 metres, but farther out on the bank to the east of Værøy the greatest amount of plankton was in the surface leyers. (Fig. 5).

Here too the curve shows that the sinking has stopped at a depth between 50 and 75 metres, where there is also a transition to salter layers of water. H. H. Gran showed similar conditions in his work from 1915.

The descent does not take place parallelly for all species. This must be due on the one hand to the circumstance that the species differ from each other in specific weight, size, and form, and on the other hand to the fact that the development of the various species does not take place simultaneously. This becomes very clearly apparent if we trace the successive appearance of the various species in 1923, for which year we have samples right up to the conclusion of the spring flowering, and

we are therefore able to obtain a survey of the development in its entirety.

The tables show that at the beginning of spring 1923 the plankton consisted almost exclusively of *Fragilaria oceanica, Skeletonema costatum* and *Thalassiosira;* in addition there were small quantities of *Navicula Vanhøffenü* and *Achnanthes taeniata.*

As by degrees the plankton increased in quantity, the number of species also increased, but *Fragilaria oceanica, Skeletonema costatum* and *Thalassiosira* still constituted the bulk, even after the first descent had begun. We can also follow this development in 1922 and 1924, as far as the material for those years extends.

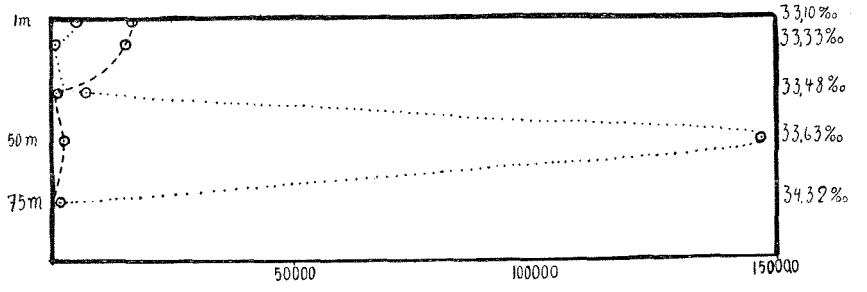


Fig. 5 . The quantity of plankton $^{11}/_{4}$ 23 · · · · at Høla, — — — east of Værøy.

In 1923 we find the same species at a later stage, with the exception of *Navicula Vanhøffenii* and *Achnanthes teaniata,* which is then lacking; but the *Chaetoceras species* are now the predominating elements in the plankton, especially *Chaetoceras contortum, Chaetoceras furcellatum* and *Chaetoceras sociale.* At the same time there has taken place a mass development of a tiny brown flagellate *Phaeocystis Pouchetii.*

At the end of April the quantity of plankton decreases, and on May 2nd at the outermost part of the fjord, there was a very scanty plankton, consisting of *Chaetoceras criophilum* and *Chaetoceras decipiens.* These are the two species which H. H. Gran in his work of 1900 considers to be characteristic of an oceanic Chaeto plankton, which occurred in Ofoten Fjord at the end of July 1899. We should therefore be able to assume that the rich production of coast plankton found in the Vestfjord in spring is replaced by this scanty, oceanic plankton.

On April 12te 1923 a cruise was taken on the M/S »Johan Hjort« from Røst in a north-westerly direction right out to the Edge.

The samples from that cruise exhibit different conditions as regards the quantity of plankton and the salinity from those in the Vest Fjord (Table XI). The salinity steadily increases outwards and at the outermost station, St. 59, there is pure Gulf Stream water. We should expect to find from this that the quantity of plankton decreased outwards. This is also the case as regards the inner stations, where we find the same plankton as that of the Vestfjord, and which is evidently derived from those waters. But out on the edge the case is altered. At St. 59, where we have the greatest salinity, we have also the largest quantity of plankton. The number of diatoms is there 1 954 330 per litre at a depth of 1 metre. No such large quantity of plankton is found at any station in the Vestfjord.

It also differs from the Vestfjord plankton qualitatively in that it lacks *Fragilaria oceanica* and *Chaetoceras* species. It consists of *Skeletonema costatum* which constitutes the bulk, and in addition species of *Thalassiosira* and *Nitzschia.*

The rich production of plankton there may be due to vertical currents out on the Edge, that bring layers rich in nutriment up to the surface.

But *Skeletonema costatum* is markedly a coast form and especially develops in large quantities near the land. This should indicate that the plankton out on the Edge is carried by the current from coast farther south. We should then also expect, however, that the water would not be so markedly oceanic as it actually is.

In 1924 a cruise was also taken from Røst out to the edge to the north-west, but at an earlier date than in 1923, viz. March 25th (Table XV).

At St. 117, which is situated outside the edge, there was a remarkably low salinity at a depth of 10 metres, a salinity that was much lower than at the stations inside. This layer of water with a low salinity contains a plankton that differs from that at the stations inside by lacking *Fragilaria oceanica* and *Chaetoceras* species. It consists of *Skeletonema costatum* and species of *Thalassiosira* in small quantities. According to its composition it is the same plankton as that which we

found at the Edge on April 12th 1923. The low salinity of the layer of water indicates that it came from the coast.

It is thus conceivable that the plankton at the Edge in 1923 also originally came from the coast farther south, but that then it rapidly developed at the Edge on account of the abundant supply of nutriment from the depths.

Before definitely deciding this question, however, it would be necessary to make continued investigations.

The preliminary results of the investigations of plankton at Lofoten in March—April may be summarised in the following manner:

1. The plankton at Lofoten in spring is a coast plankton, the flowering of which commences at slightly different times in each year.
2. The spring flowering of the plankton is an entirely local phenomenon. It first commences near land, later on out on the bank, and finally in the middle of the mouth of the fjord.
3. The date of the spring flowering of the plankton depends upon the melting of snow, for each year it follows immediately after the snow has begun to melt.
4. After the development of the plankton has commenced, the quantity at every place is dependent upon the supply of snow water transported to that place.
5. At the Edge there occurs a plankton that is not connected with the development of plankton farther in on the bank. According to its composition it is a coast plankton of a more southern character, and its rich development may possibly be attributed to the supply of nutriment from the depths, occasioned by vertical currents.

Literature.

1897. Gran, H. H.: Protophyta: Diatomacea, Silicoflagellata Cilioflagellata. Christiania. (Den Norske Nordhavs-Expedition 1876—78, Hefte 24).

1900. — Hydrographic-Biological Studies of the North Atlantic Ocean and the Coast of Nordland. Christiania. (Report on Norwegian Fishery- and Marine Investigation, Vol. I, No. 5).

1912. — Preservation of Samples and Quantitative Determination of the Plankton. Copenhagen. (Publication de Circonstans, No. 62).

1915. — The Plankton Production of the North European Waters in the Spring of 1912, Copenhague. (Bulletin Planktonique pour l'année 1912).

1916. — Kulturforsøk med planktonalger. Kristiania. (Forhandlinger ved de skandinaviske naturforskeres 16. møte).

1922. — Snesmeltningen som hovedaarsak til den rike produktion i vort kysthav om vaaren. Kristiania. (Samtiden).

1905. Jørgensen, E.: Protistplankton, Bergen. (Bergens Museums skrifter: Hydrographical and Biological Investigations in Norwegian Fjords, by O. Nordgaard, The protist Plankton and the Diatoms in Bottom Samples, by E. Jørgensen).

1906. Nathansohn, A.: Ueber die Bedeutung verticaler Wasserbewegung für die Produktion des Planktons im Meere. Leipzig. (Abh. der Mathematisch-Physischen Klasse d. Kgl. Sächs. Ges. d. Wiss. Bd. XXIX, No. V).

1910. — Etudes hydrobiologiques d'après les recherches faites à bord de l' »Eider« au large de Monaco de janvier à juillet 1909. (Annales de l'Institut Oceanographique, T. I., Fasc. 5).