FiskDir. Skr. Ser. HavUnders., *16*: 489—505.

PHYTOPLANKTON OBSERVATIONS IN OFFSHORE NORWEGIAN COASTAL WATERS BETWEEN 62°N AND 69°N

I. Variation in time of the spring diatom maximum 1968—71

By

Trygve Braarud and Ingrid Nygaard
Department of Marine Biology and Limnology, University of Oslo

ABSTRACT

Braarud, T. and Nygaard, I. 1978. Phytoplankton observations in offshore Norwegian coastal waters between 62° N and 69° N. I. Variation in time of the spring diatom maximum 1968—71. *FiskDir. Skr. Ser. HavUnders.*, *16:* 489—505.

An attempt was made to trace yearly fluctuations in the timing of the spring diatom maximum along the Norwegian west coast, 62° N—69° N. Quantitative data on the diatom population at 281 stations with 0 m samples and 120 stations with additional samples from the 10, 20 and 30 m levels, collected in March—April during the four years 1968—71, were used. A delay of about three weeks from the southern to the northern part of the area, as previously observed, was again established. The years 1970 and 1971 were years with an early maximum while 1969 was a definitely late year within the whole area. The time variation in 1968—71 recorded in the Trøndelag and Helgeland subareas, showed trends different from those of the neighbour areas. The phytoplankton data were not adequate for a detailed analysis of the factors responsible for the timing of the maximum each year in the respective parts of the investigated area.

PREFACE

A study of the plankton in offshore coastal waters along the Norwegian coast from Møre to Vesterålen was adopted as part of the Norwegian contribution to the International Biological Programme (IBP), section Marine Productivity (PM). The plankton work formed an integrated part of a marine biological survey, "The recruitment mechanism for herring and cod", undertaken by the Institute of Marine Research, Fisheries Directorate, Bergen, in March—April 1968—71.

The present report on the phytoplankton material deals with the variation in time of the spring diatom maximum of the near-coastal and intermediate coastal waters off Møre, Trøndelag, Helgeland and Vestfjorden—Vesterålen in 1968—71.

Cand. real. Ingrid Nygaard carried out the microscopical examination by means of the Utermöhl technique (UTERMÖHL 1931) of the water samples from 400 stations. The financial support through IBP sources was, however, inadequate for her continued engagement at the project until the results could be presented for publication. The senior author is, therefore, mainly responsible for the editing of the report.

In subsequent reports, accounts will be given of the seasonal and regional occurrence of the more important diatom species and of groups playing a subordinate role in the phytoplankton during March—April.

INTRODUCTION

In Norwegian coastal waters the spring diatom maximum is the most spectacular event in the annual phytoplankton cycle as indicated by popular designations as "bloom" or "outburst". Within a period of few weeks a huge production of organic matter takes place, doubtless being of major importance for the secondary producers and the subsequent links in the production chain. Success of the reproduction of these later stages may depend upon a satisfactory coordination in time of spawning and availability of food for the fish larvae. In this connection variation in time of the season of high productivity by phytoplankton in spring may play a role.

With this reasoning in mind, a program for the study of phytoplankton in water samples collected during a survey organized by the Institute of Marine Research, Fisheries Directorate, Bergen, was set up. The purpose was to bring out information on variation from year to year and from one part of the area of investigation to the other in the time of the diatom maximum.

SUBAREAS AND WATERMASSES

For the present purpose, the area of investigation was divided in four subareas (fig 1):

Møre — from 62° N to 63° 30° N
Trøndelag — from 63° 30° N to 65° N
Helgeland — from 65° N to 67° N
Vestfjorden—Vesterålen — from 67° N to 69° N

The topography and hydrography of the offshore coastal areas which the survey covers, are so diverse that the environmental situation for phytoplankton and zooplankton, even within one of the subareas, exhibits a rather broad range. In order to obtain a meaningful basis for

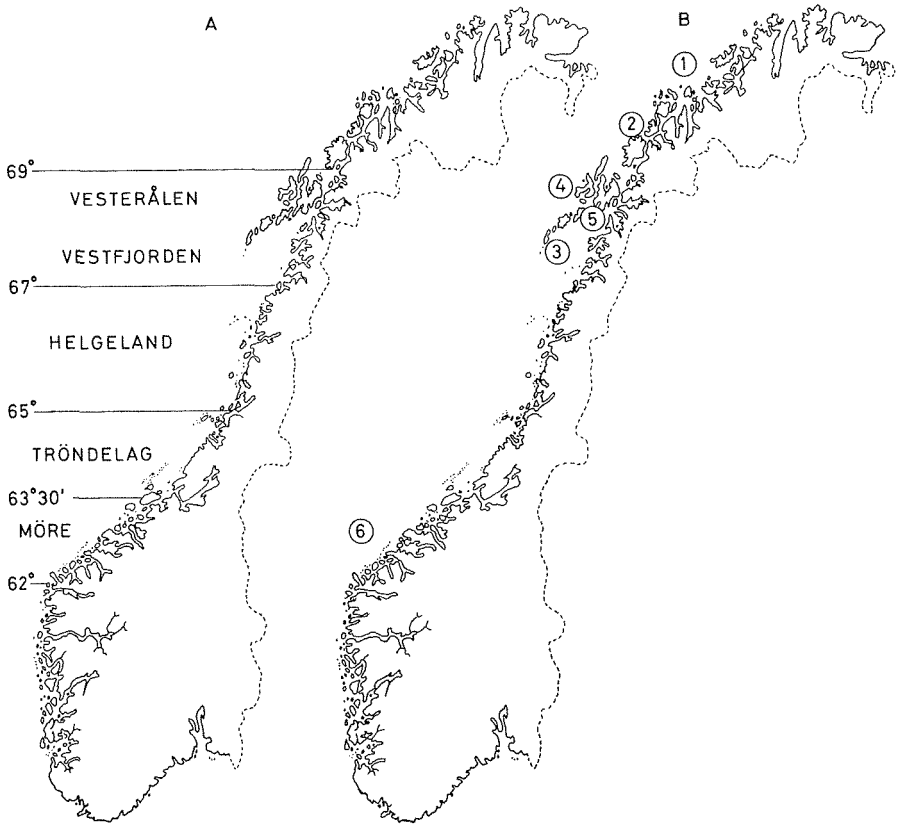

Fig. 1. A. The investigated area for the phytoplankton survey 1968—71 of the Norwegian IBP—PM project.

B. Number in circles: Reference to previous quantitative phytoplankton studies in spring in Norwegian offshore coastal waters north of 62° N. 1) Lopphavet, HEIMDAL 1974. 2) Malangen, GAARDER 1938. 3) Lofoten, FØYN 1929; GRAN 1930. 4) Vesterålen, GRAN 1930; BRAARUD *et al.* 1958. 5) Vestfjorden, NORDLI 1949; BRAARUD *et al.* 1958. 6) Møre, GRAN 1929, 1930; BRAARUD and KLEM 1931.

comparison of the time sequence of the spring diatom development along the coast, a division of the watermasses encountered in a section from a fjord area out to the atlantic drift has been adopted for the upper 50 m. In addition to the old distinction between coastal and atlantic water based on salinities (HELLAND-HANSEN and NANSEN 1909), the term "semi-atlantic waters" for stratified waters with coastal water overlying Atlantic water within the upper 0—50 m layer is introduced. This situation may be expected to involve a certain admixture of atlantic water to the overlying water within the euphotic zone. Trophic conditions for phytoplankton growth may in the semi-atlantic waters differ essentially

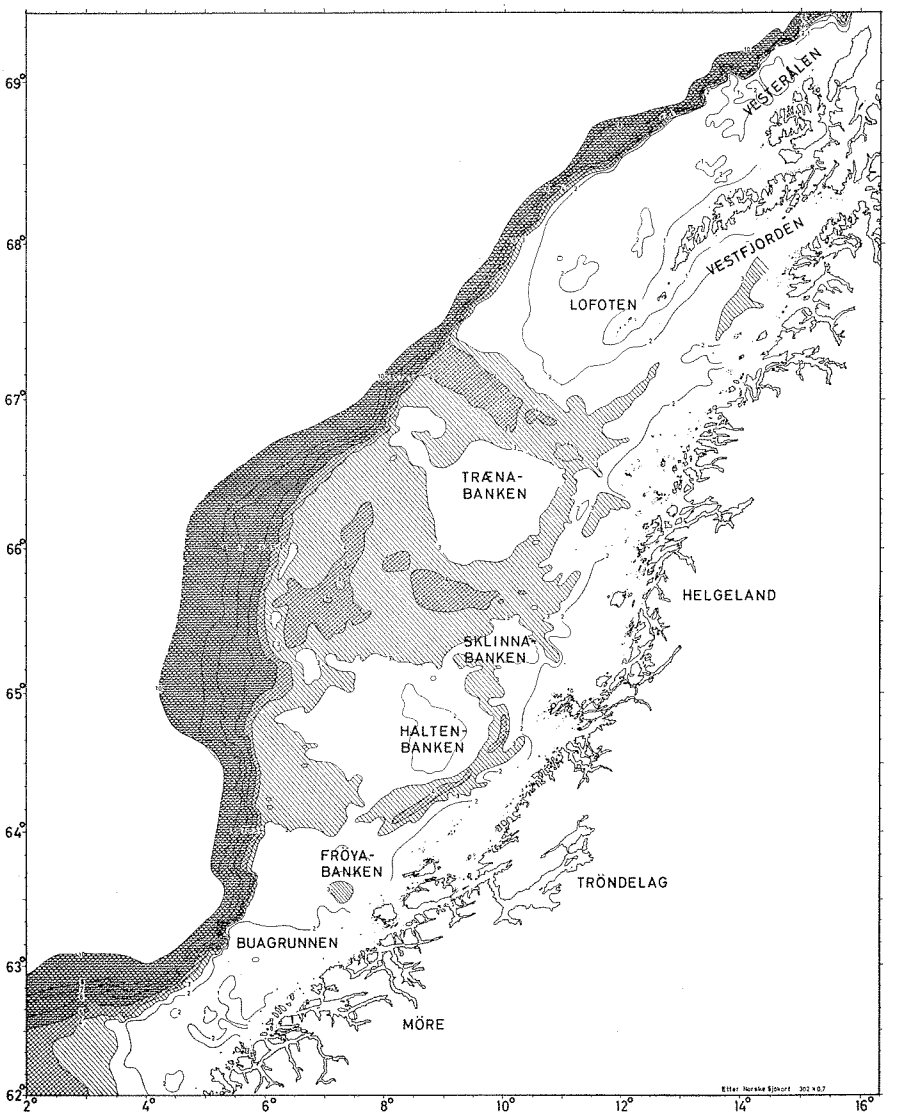

Fig. 2. Bathymetric map of the investigated area. Depths in hectometer. The figure represents an extension of Fig. 1 in NAKKEN and LJØEN (1969) and was supplied by LJØEN.

from those in the coastal waters, and the same may pertain to other environmental conditions as well. In Fig. 3 a diagram is shown, indicating the five categories of watermasses encountered in the section. While the border lines between the atlantic and semi-atlantic waters and between the latter category and the intermediate coastal waters are based upon

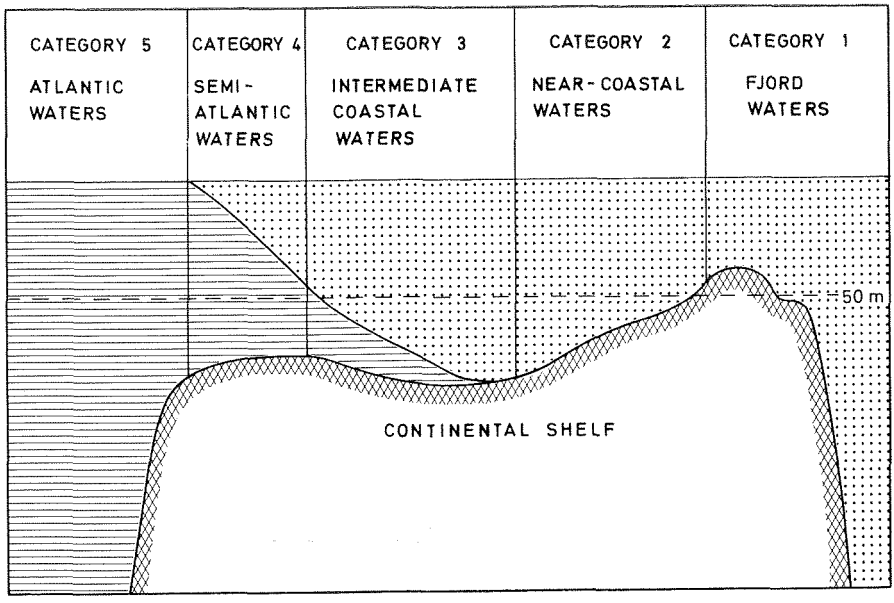

Fig. 3. A hydro-topographical division of the watermasses 0—50 m on the Norwegian west coast. Salinities within the 0—50 m layer: Category 1, 2 and 3) lower than 35‰, category 4) lower than 35 ‰ in the uppermost strata, higher than 35‰ beneath, category 5) higher than 35‰, even at the surface. ≡ >35‰, ⁝⁝ <35‰

hydrographical criteria, the topographical delineation of the intermediate coastal and the near-coastal waters is more arbitrary. The extention of the various categories differs with locality and season, and may show yearly variation within any of the subareas investigated.

QUANTITATIVE PHYTOPLANKTON DATA 1968—71

At most of the stations surface samples only were examined while in some cases samples from the 10, 20 and 30 m levels were also studied. In Table 1 the number of stations of the two categories are given for the four subareas and for each year. Only 2 ml samples were examined, using the Utermöhl technique. Original tables for each station as well as excerpt tables for the various cruises are deposited at the University of Oslo, Department of Marine Biology and Limnology. Hydrographical data are available from the Norwegian Oceanographic Data Centre, Bergen.

The situation in semi-atlantic and atlantic waters will be considered in a subsequent report.

Table 1. Stations for which quantitative phytoplankton data were obtained. Italized figures indicate numbers of stations with data for more than the 0 m sample. Otherwise only the 0 m sample has been examined. The number of stations of each category as well as their total number are given for each subarea and each year.

Year	Area				Sum for each year
	Møre	Trøndelag	Helgeland	Vestfjorden —Vesterålen	
1968.....	56 + *5*	20 + *7*	11 + *3*	26 + *11*	113 + *26*
1969.....	16 + *5*	7 + *5*	17 + *3*	29 + *8*	69 + *21*
1970.....	14 + *9*	21 + *17*	7 + *15*	15 + *13*	57 + *54*
1971.....	6 + *2*	21 + *2*	3	12 + *15*	42 + *19*
	92 + *21*	69 + *31*	38 + *21*	82 + *47*	281 + *120*
Sum for each subarea.	113	100	59	129	Total 401

METHOD FOR ESTIMATING THE TIME OF THE SPRING DIATOM MAXIMUM

In handling the observational data, which are scattered in time as well as geographically, it was found neccessary to refer the situation at each station to a common scale, indicating various stages of the spring diatom increase. It is obvious that the adoption of such a procedure for the whole area of investigation requires that it is not based upon too strict a gradation. Conditions in the Møre area in the south and in the Vestfjorden—Vesterålen area in the north are so different hydrographically (BRAARUD, GAARDER and NORDLI 1958) that it might have been preferable to treat them separately. However, the inclusion of the two subareas in the middle of the coastal region investigated, makes it infeasible to draw any rational division line between a southern and a northern situation. We shall, therefore, deal with each of the four subareas shown in Fig. 1.

The following stages of the spring diatom increase were distinguished:

Stage 0 — No sign of any increase of the diatom population after the winter minimum.
— I — A definite increase is noticeable.
— II — The diatom population has reached about 50/ml.
— III — The diatom population has increased further, apparently approaching maximum.
— IV — The population has reached 1 000/ml or more.
— V — Post-maximum situations are given this designation, regardless of the size of the diatom population.

This coarse scale is subjective, and other criteria than the numerical size of the diatom population have been employed as well. A sample with a diatom population of 100/ml might either be referred to stage III or to V. The additional criteria which then have been considered are: 1) The composition of the diatom community, 2) the occurrence of resting stages and, in some cases, the general composition of the other components of the phytoplankton.

When the composition of the diatom population is used, our knowledge from previous investigations of the spring diatom increase has been employed, such as the early appearance of *Chaetoceros socialis* and *C. furcellatus*. The percentage of resting spores in these species is also taken as an indicative detail.

During the collation of the phytoplankton data from this survey, observations were made on the relative abundance of the artificial group "monads and unidentified flagellates" (MF) at various stages of the diatom spring growth. In the south a definite increase took place after the diatom maximum had passed. A detailed discussion of the quantitative distribution pattern of this group relative to the diatom population is planned to be published separately. For the Møre area in 1968, when the observational material was relatively adequate, a condensed table is presented (Table 2). It indicates that post-maximum stages are apt to have acquired much larger populations of MF than those occurring in pre-maximum stages with similar diatom abundance or when the diatom maximum is reached. In the northernmost area, the picture is not as consistent in this respect, possibly because density stratification at this time of the year is far less pronounced in the northern than in the southern area (BRAARUD *et al.* 1958).

Table 2. Changes in the component "Monads and unidentified flagellates" (MF) during the phytoplankton development in the offshore coastal waters after the winter minimum. Examples from the Møre area in 1968. Populations as cells/ml. For definition of development stages 0—V, see p. 494.

Stages	0	I	II	III	IV	V
Cruise 2a						
7—12 March						
Number of stations	9	—	—	—	—	—
Diatoms, cells/ml	<8					
MF, cells/ml						
Range.....	3—23					
Mean.....	10					

Tabie 2 cont.

Stages	0	I	II	III	IV	V
Cruise 2b						
25—27 March						
Number of stations	—	—	3	2	7	—
Diatoms, cells/ml	—	—	<250	<800	2300–5800	—
MF, cells/ml						
Range			7—14	1—22	1—21	—
Mean.....			10	11	9	
Cruise 3a						
7—8 April						
Number of stations	2	3	1	5	4	5
Diatoms, cells/ml	<7	130	530	1400–1700	2600–3200	150–1100
MF, cells/ml						
Range	6—16	0—8	5	8—36	4—11	9—40
Mean.....	11	3		18	7	21
Cruise 3b						
18—23 April						
Number of stations	—	—	—	—	1	29
Diatoms, cells/ml					3800	<1—557
MF, cells/ml						
Range					11	78—3300
Mean.....						734
Cruise 4						
17—29 April						
Number of stations	—	—	—	—	2	23
Diatoms, cells/ml					1000—2500	2—481
MF, cells/ml						
Range					9—39	21—1735
Mean.....					24	574

Stage V is even less well-defined than the earlier stages. In some cases the decline of the population after the diatom maximum may be very rapid, as shown by the observations by GRAN (1927) in Fig. 4. However, dependent upon the hydrographic situation and the grazing intensity, a slower decrease may occur. This may particularly be expected in the northern coastal area where wind-generated turbulence is apt to be especially effective in supplying nutrients from deeper layers to the euphotic zone due to the small density gradients encountered there at the season in question (HEIMDAL 1974).

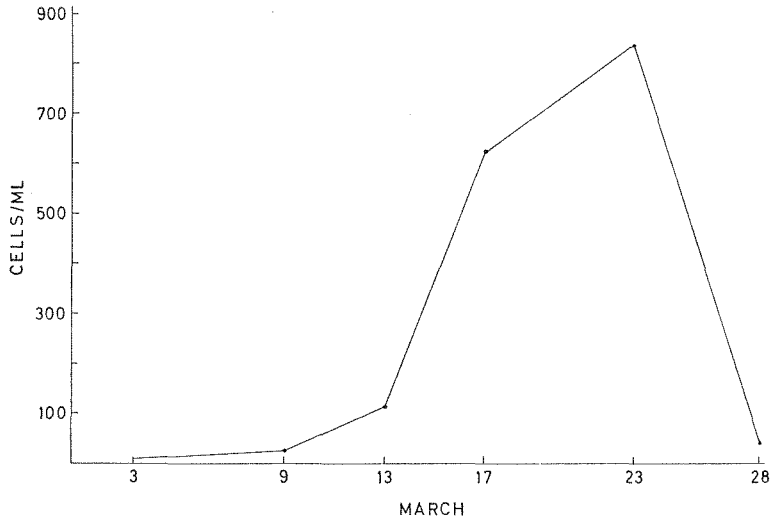

Fig. 4. Changes in the diatom population (1—2 m) at Kårtveit, south of Bergen, 3—28 March 1922. Records from GRAN (1927).

The size of the MF populations recorded may to some extent be influenced by the amount of larger forms in the sample. When diatoms are very abundant, the accuracy of the counting of the very small forms of MF is apt to be considerably reduced. For this reason the records of MF populations for stages III and IV may be too small. This inaccuracy would, however, hardly invalidate the use of the present criterion for distinguishing between stage V and stages I and II in cases when the diatom population of the former is of a similar, fairly modest size as in I and II.

VARIATION IN TIME OF THE SPRING DIATOM MAXIMUM 1968—71

The present survey can only give fragmentary information on variation in the time schedule of the spring diatom increase within the coastal area 62°—69° N. Irregularities in the cruise program of the co-operative project, curtailment of the microscopical work for financial reasons and the preselection of samples for the phytoplankton studies have made the observations less suited for a description of the time schedule in the four subareas in each of the four years of investigation.

In Table 1 the number of stations for which phytoplankton data were obtained, is given for the various years and subareas. A further documentation of the observational material on which the estimation of the time of the diatom maximum has been based, is given in Table 3 for the Møre, Trøndelag and Helgeland subareas and in Table 4 for Vest-

fjorden—Vesterålen. For each of the subareas the tables give information on which stages have been observed in each week and, for each stage, the number of stations at which it was represented is noted in parenthesis.

Fig. 5 gives a diagrammatic summary of the results. It should be accepted with due reserve since in many cases the observations are too scanty for a more accurate estimate. This is especially the case for Helgeland.

A comparison between the results for the Møre and Vestfjorden—Vesterålen subareas shows that in all years a delay in the north of 3—4

Table 3. Subareas Møre, Trøndelag and Helgeland. Summary for each year of recordings of she stages 0-V (see p. 494) observed in March-April and the first week of May. For each stage, the number of stations at which it was observed in the week and year in question is given in parenthesis.

Month	March				April				May
Week	1	2	3	4	1	2	3	4	1
1968 Cruise 2a, 2b, 3a, 3b, 4.....	MØRE								
		0 (7)		III (1) IV (7)	II (1) III (2) IV (3) V (6)		V (13)		
1969 Cruise 6a, 6b, 6d					II (4) III (2) IV (2)		V (6)		
1970 Cruise 8a, 8b, 8c, 9a, 9b ...					V (3)	V (11)	V (5)	V (4)	
1971 Cruise 10		0 (4)			V (4)				
1968 Cruise 2a, 3a, 3b, 4	TRØNDELAG								
		0 (1)			III (2)		V (3)	V (13)	V (1)

Table 3 cont.

Month	March				April				May
Week	1	2	3	4	1	2	3	4	1
1969 Cruise 6a, 6c, 6e					II (5)		V (2)		V (1)
1970 Cruise (8a, 8b) 9a, 9b					V (5)	V (8)		V (10)	
1971 Cruise 10	0 (15)				V (9)				
1968 Cruise 3a, 3b, 4	HELGELAND				0 (1) I (2)		V (5)	V (3)	
1969 Cruise 6b, 6c, 6d, 6e						0 (1) I (1)	II (6)	V (3)	V (5)
1970 Cruise 8a, 8b, 9a, 9b					0 (2) I (2) II (1)	0 (2) I (1) II (2)		V (4)	
1971 Cruise 10				0 (2)	0 (2)				

weeks was registered. This is in accordance with previous investigations in these areas (see p. 491). An earlier spring maximum in Vestfjorden than in near-coastal waters off Vesterålen, which was indicated in 1968—71, has also been observed before. The early stages of the diatom increase in these areas were, however, rather synchronous.

The two subareas between Møre and Vestfjorden do not seem to show any consistent agreement with the trend of the yearly variation of any of their neighbour areas during the four year period. For Møre and Trøndelag, there was in 1968 and 1969 a considerable time difference

Table 4. Vestfjorden—Vesterålen. The various stages of the spring diatom development late March to early May, 1968—1971. Scale 0—V, see p. 494. For each reference to stage the number of stations is given in parenthesis. See also legend to Table 3.

	Vestfjorden, outer and central							Offshore						
Month		March	April				May		March	April				May
Week		4	1	2	3	4	1		4	1	2	3	4	1
	Central	I—II				V		Near	II				V	
1968		(4)				(5)		the coast	(1)				(8)	
Cruise														
1a, 1b	Outer	I—II				IV		Farther	I				IV	
		(4)				(5)		offshore	(8)				(3)	
				0										
				(1)										
1969	Central			I		V		Near the			I		V	
Cruise				(2)		(8)		coast			(2)		(5)	
5a, 5b				II										
				(2)										
	Outer			I—II			V	Farther			0		V	
				(7)			(3)	offshore			(5)		(2)	
	Near			IV				Near the			II—			
1970	land			(1)				coast			III		V	
Cruise											(6)		(3)	
7a, 7b	Outer			II			V	Farther			0—I		V	
				(3)			(5)	offshore			(3)		(3)	
	Central		II				V	Near the		0—				IV—
1971			(5)				(3)	coast		II				V
Cruise										(2)				(2)
11a,	Outer		II				IV—	Farther		0				IV—
11b			(3)				V	offshore		(4)				V
							(1)							(5)

while in the «early years» 1970 and 1971 the maxima appeared to be synchronous. With regard to the time variation from year to year, the situation in the four subareas cannot be expected to have the same trend considering the large geographical distance which they cover. However, an earlier maximum in Vestfjorden in 1970 and 1971 than in the other years is in accordance with what was observed in Møre and Trøndelag.

COMPARISON WITH RESULTS FROM PREVIOUS SURVEYS

For the Vestfjorden—Vesterålen area observations are available for a number of years. On the basis of these, we have tried to give a characterization of the various years by reference to the scale which has been

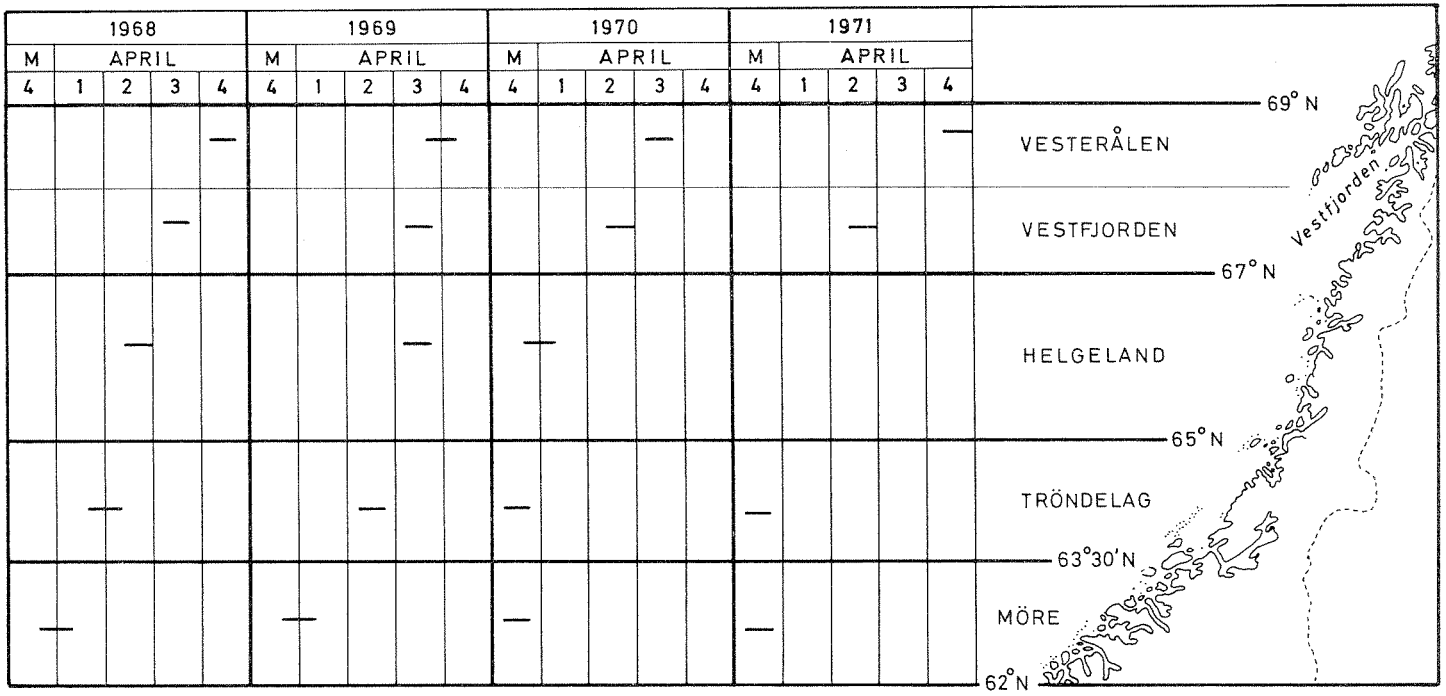

Fig. 5. Estimated cccurrence of the spring diatom maximum in four subareas of the Norwegian coast between 62° N and 69° N in 1968, 1969, 1970 and 1971. The diagram is based upon observations in the near-coastal waters, and the time is indicated by weeks, from the fourth week of March to the fourth week of April. For data and methods, see the text.

Table 5. For the period 3rd week of March to 2nd week of May, available quantitative phytoplankton data have been used for a characterization of the spring diatom development with the use of a 0—V scale (see p. 494) and reference to the nearest week. The origin of the data is given in the text. The Malangen locality is not strictly offshore, but at the mouth of a fjord system, while the station on the shelf off Ullsfjord is comparable to the near-coastal stations in Vesterålen.

A	Vestfjorden								Offshore on the shelf							
Month	March		April				May		March		April				May	
Week	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
1922		0	I—II	II		II										
1923	0	0	0—II	II	II—							I—				
					III	V						IV				
1924	0	0	I	I—II						0		I				
1925								V								
1926		0—I	I	I	II	V		V		0	I	III		V		V
1927						V								V		
1929	0	0	0	I	0—II	V				0				IV		
1945		II		III		V					I			V		
1946	I									I		II		V		
1949[1])												IV				

B	Malangen 1930—31					The shelf off Ullsfjord (U 3) 1963—64			
	I		IV	V	V	0	I		I

[1]) Observation from a single station by NORDLI (1949).

used for 1968—71, defined on p.494. The results are presented in Table 5 A, based on observations in 1922—27 by FØYN (1929), in 1929 by GRAN (1930) and in 1945—46 by BRAARUD *et al.* (1958). As a supplement, corresponding information is given in Table 5 B for Malangen and the shelf outside Ullsfjord, based on the observations by GAARDER (1938) and HEIMDAL (1974).

The following conclusions may be suggested with regard to the timing of the spring diatom development in the different years as indicated by these surveys.

In Vestfjorden — A very late maximum in 1922.
A remarkably late start of the increase in 1929.

Offshore — Somewhat early development in 1923, 1926, 1949. Late maximum in 1929.

Malangen — The situation in 1930—31 was comparable to what had been recorded in some years in Vestfjorden, perhaps with a slightly earlier maximum.

Off Ullsfjord — 1962—63, 1964. Maximum even later than in Vesterålen.

The general impression gained from these observations is that in the Vestfjorden—Vesterålen area and still further north, considerable variation may be expected from one year to another as to the time when diatom growth starts after the winter minimum and the further increase towards maximum. Ordinarily the increase appears to start in the first week of April, and the maximum may, with few exceptions, be observed in the third to fourth week of April. However, deviations from this time schedule seem well documented in the publications mentioned above.

From the other subareas the only observations which may be used for comparison with the results from the present survey, are those by GRAN (1929, 1930) from Møre.

On the basis of his quantitative investigations in 1926 and 1927 and older qualitative phytoplankton data, GRAN (1929, p. 49) stated: "We found the maximum number in the Skagerrak from February—March, off Bergen during the later half of March, at Romsdalen at the end of March and during the early half of April, and at the Lofoten Islands during the first half of April." Observations from 1929 in the same section from Romsdalsfjorden to Storegga (GRAN 1930) indicated that maximum had been reached in the last week of March at the stations nearest land, in agreement with his general statement quoted above.

A combination of the results from the older surveys with those from the 1968—71 survey seems to justify the following broad conclusions.

1. There is a delay of about three weeks in the occurrence of the spring diatom maximum when going from Møre (62° N) to Vestfjorden—Vesterålen (69° N). This is in accordance with the general statement by GRAN (1929) quoted above as well as with observations in 1945—46 by BRAARUD *et al.* (1958) at Eggum and Skrova in the north and Sognesjøen and Utsira in the south.
2. In the Møre subarea, the years 1970 and 1971 had earlier maxima than 1968 and 1969 which showed a delay also compared with GRAN's observations in 1929.
3. Also for the other subareas there was in 1970 a relatively early maximum, as in the Møre area, while in 1969 the maximum was relatively late in all subareas. North of Møre the variation in the time schedule in 1968 and 1971 did not show any common trend for the three subareas.
4. In the Vestfjorden—Vesterålen subarea there is generally an earlier maximum in Vestfjorden than in Vesterålen, in accordance with observations in previous surveys.

CONCLUDING REMARKS

From quantitative phytoplankton data for Eggum and Skrova in the Vestfjorden—Vesterålen area and Sognesjøen and Utsira in the southern part of the Norwegian west coast, BRAARUD *et al.* (1958) documented a delay in 1946 of about three weeks in the spring diatom development in the north compared with the south. In their summary (p. 41) they commented on the background for this delay: "Factors of general nature: the different light supply due to geographical position and the delayed vernal stabilization at the northern stations, conditioned by a smaller fresh-water supply, were pointed out as main factors causing the delay in spring phytoplankton growth in the north. Extensive winter mixing, inducing a more pronounced dilution of the winter population in the north, may also result in smaller phytoplankton stocks in early spring".

The observations from the present survey demonstrate that within the coastal area from 62° N to 69° N yearly fluctuations in the timing of the spring diatom maximum occur. They are well within the time range indicated by the general statements of GRAN (1929) and BRAARUD *et al.* (1958). In actual situations, however, the variation from year to year may be large enough to be taken into consideration in the search of causes for unsuccessful reproduction in commercial fishes. The present phytoplankton material is, unfortunately, inadequate for an analysis of the background for the yearly variations observed in the four year period 1968—71. For this purpose a concentrated study of the situation within a much smaller area would have been preferable. The hydrography of the offshore coastal waters is so complex that a very dense station net is needed for an adequate analysis of the environmental situation for diatom growth.

In a subsequent report, the variations in the composition of the diatom vegetation within the area of investigation will be discussed, also in view of the hydrographical heterogeneity of the Norwegian coastal waters (BRAARUD and NYGAARD, in prep.).

ACKNOWLEDGEMENTS

The Norwegian committee on the International Biological Program (IBP) organized the program on Marine Productivity. The present contribution deals with one aspect of its project 1, which was a part of a project, "The recruitment mechanism for herring and cod", which was planned and operated by the scientific and technical staff of the Insti-

tute of Marine Research, Fisheries Directorate, Bergen. This institute provided the water samples for the phytoplankton studies as well as hydrographical and biological data from the cruises and the bathymetric chart in Fig. 2. We are greatly indepted to all who in this way have facilitated the present study.

REFERENCES

BRAARUD, T. and KLEM, A. 1931. Hydrographical and chemical investigations in the coastal waters off Møre and in the Romsdalsfjord. *Hvalråd.Skr. 1*: 1—88.

BRAARUD, T., GAARDER, K. R. and NORDLI, O. 1958. Seasonal changes in the phytoplankton at various points off the Norwegian west coast. *FiskDir. Skr. Ser.Hav-Unders., 12* (3): 1—77.

FØYN, B. R. 1929. Investigation of the phytoplankton at Lofoten, March—April, 1922—1927. *Skr. norske Vidensk-Akad. Mat.-naturv. Kl., 1929* (10): 1—71.

GRAN, H. H. 1927. The production of plankton in the coastal waters off Bergen March—April 1922. *FiskDir. Skr. Ser.Hav.Unders., 3* (8): 1—74.

— 1929. Investigation of the production of plankton outside the Romsdalsfjord 1926—1927. *Rapp. P.-v. Réun. Cons.perm. int. Explor. Mer, 56*: 1—112.

— 1930. The spring growth of the plankton at Møre 1928—29 and at Lofoten in 1929 in relation to its limiting factors. *Skr.norske Vidensk-Akad. Mat.-naturv. Kl., 1930* (5): 1—49.

GAARDER, K. R. 1938. Phytoplankton studies from the Tromsø district 1930—31. *Tromsø Mus.Årsh., 11, 55 (1932)* (1): 1—159.

HEIMDAL, B. R. 1974. Composition and abundance of phytoplankton in the Ullsfjord area, North Norway. *Astarte, 7*: 17—42.

HELLAND-HANSEN, B. and NANSEN, F. 1909. The Norwegian Sea: Its physical oceanography based upon the Norwegian researches 1900—1904. *FiskDir. Skr. Ser. HavUnders., 2 (Part 1)* (2): 1—390.

LJØEN, R. and NAKKEN, O. 1969. On the hydrography of the shelf waters off Møre and Helgeland. *FiskDir. Skr. Ser. HavUnders., 15*: 285—294.

NORDLI, O. 1949. Fytoplanktonundersøkelser i Lofoten 1945—1946 og 1948. (Phytoplankton investigations in Lofoten 1945—1946 and 1948.) Thesis in botany, Univ. Oslo, 1949/II. [Manuscript].

UTERMÖHL, H. 1931. Neue Wege in der quantitativen Erfassung des Planktons. (Mit besonderer Berücksichtigung des Ultraplanktons.) *Verh. int. Verein.theor. angew. Limnol., 5*: 567—596.

Received 5 March 1977.
Printed 7 June 1978