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Yearly variations in the phytoplankton vegetation of the Norwegian Sea.

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Norwegian investigations of the quantitative distribution of phytoplankton in the Norwegian Sea include surveys in May or June in 1952 and 1953 (Ramsfjell 1960), 1954 (Paasche 1960), 1958 (Paasche & Rom 1961), and 1959 (Nygaard, unpublished). Samples from various depths down to 30 metres were sedimented and counted by means of the inverted microscope. The following table may be useful in summarizing to what extent the different water masses have been investigated.

	June 1952	June 1953	June 1954	May 1958	June 1959
Norwegian coastal water			+	+	+
Atlantic water south of 71°N	+	+	+	+	+
" " north of 71°N	+	+	+		
Arctic-Polar water between Jan Mayen and Spitsbergen	+	+	+		
Local waters off Spitsbergen	+	+	+		
East-Icelandic Arctic Current	+	+			+
Icelandic coastal water (or Irminger Current)	+	+			+

The investigations from 1952-59, in conjunction with more limited information from certain other sources, may serve as a basis for a tentative description of the spring phytoplankton development in the Norwegian Sea. It should be stressed, however, that our knowledge of this process is still very incomplete. Thus the concept of a well-defined spring vegetation period in off-shore waters, although very useful at the present stage, may have to be revised eventually when more information has become available. It should be pointed out as well that in order to describe the situation in a water mass as a whole with reference to a hypothetical

yearly cycle, one is forced to disregard local variations to an extent which may not otherwise be justified.

The spring development does not begin at the same time and is not of equal duration in the different hydrographical areas. Within each area, the time of the onset of blooming is probably determined by the incoming amount of radiation energy in conjunction with the thickness of the mixed layer, and is thus ultimately dependent upon hydrographical and meteorological features, as well as latitude. Our results confirm earlier observations that the spring period is brought to an early end in areas where there is a marked stratification within the uppermost 50-100 metres, probably as a consequence of a rapid exhaustion of nutrient salts. However, even in areas where there is no pronounced stratification (e.g. Atlantic waters) may the vernal blooming be of short duration in some years. The reasons for this are not obvious at present, but it appears likely that yearly variations in, say, grazing, climatic conditions, or vertical turbulence are involved. The gross features of the spring development appear to be the same in all parts of the Norwegian Sea. The spring communities have a different specific composition in the different water masses, but certain features in common, first and foremost a predominance of diatoms of medium or large cell size. Certain other forms, such as Phaeocystis, may be of importance as well. Towards the end of the spring period this type of vegetation is succeeded by a plankton where small-celled organisms (small diatoms, dinoflagellates, and, in Atlantic water, coccolithophorids) frequently form the sole constituent. In terms of total cell concentration, this summer vegetation is not necessarily inferior to the spring plankton. But if the size of the phytoplankton communities is expressed in terms of cell surface area, the transition from spring to summer conditions usually becomes manifest as a decrease in standing stock size. Production measurements by Berge in 1954 and 1958 suggest a concomitant decrease in production.

Our results indicate that the duration of the spring period, as well as the amount of phytoplankton produced during that time, is highly variable from one year to the next, and more so in certain areas than in others. The data collected so far provide no information on the amplitude of such variations, and can only be used for an approximate estimate of how far the spring development had

proceeded each year at the time of sampling.

It will presumably be possible eventually to tie up yearly variations in the quantitative aspects and the duration of the spring period with corresponding variations in specific composition. At the present stage, however, it is difficult to explain observed differences in the specific composition of spring plankton collected at the same time of the year in two different years. Such differences might be ascribed to one or more of the following circumstances. 1) Differences in environmental factors may have led to a selection of two different sets of species. 2) The stocks initially present may have been different, due to variations in seeding from other water masses. 3) The development may have been somewhat delayed in one year in relation to the other, the apparent difference in specific composition reflecting two stages in a common spring succession.

1. Norwegian coastal waters.

The spring development in the Norwegian Coastal Current usually begins in March-April, due to a pronounced stratification.

June 1954: Summer vegetation, poor in species but with large amounts of Fragilariopsis nana.

May 1958: Mainly summer plankton, but relatively large concentrations of a number of spring forms at some stations.

June 1959: Poor summer vegetation.

2. Atlantic water.

The spring increase probably starts in the last half of April or the first half of May .

June 1952: Typical summer plankton predominant in the entire Atlantic area.

June 1953: Mostly summer plankton, but certain spring forms (Chaetoceros debilis, Ch. densus, Thalassiosira gravida) abundant at some localities. The vegetation represented various stages of transition between spring and summer plankton.

June 1954: Abundant spring plankton in the central and northwestern areas (S = 35.00-35.20‰): Rhizosolenia styliformis, Chaetoceros spp. (primarily Ch. debilis), Coscinodiscus centralis. Nitzschia spp., Thalassiosira gravida, Phaeocystis. Summer

plankton at southeastern stations (S above 35.20‰).

May 1958: Spring plankton, possibly representing a fairly early stage in the development. The specific composition was partly the same as in 1954, but temperate-oceanic forms (Rhizosolenia styliformis, Coscinodiscus centralis) were less prominent. Strong components of neritic Chaetoceros species and of the Arctic-boreal Rhizosolenia hebetata and Thalassiothrix longissima suggest that initial stocks were largely of non-Atlantic origin.

June 1959: Spring plankton having certain features in common with the 1954 vegetation (Rhizosolenia styliformis, Coscinodiscus centralis), although resembling the 1958 plankton in other respect (Thalassiosira longissima, certain neritic forms). But Chaetoceros debilis was much less predominant than in either 1954 or 1958.

In 1952 and 1953, typical ~~Atlantic~~ spring plankton (Rhizosolenia styliformis, Thalassiothrix longissima, and associated forms) was encountered only in the immediate vicinity of the border towards colder water masses farther west. It appears that the spring period may last longer in areas where a continuous admixture of Arctic water takes place.

In the Atlantic region as a whole, the transition from spring to summer plankton appears to be promoted to some extent by the slight thermal stabilization which frequently takes place in the uppermost strata as the year advances.

3. Arctic-Polar water between Jan Mayen and Spitsbergen.

The spring development is strongly dependent upon ice conditions and hydrographical features, and the time of the onset of blooming appears to be more susceptible to yearly variation here than in any other area.

June 1952: Probably a fairly late stage in the spring development, with few if any genuinely Arctic forms. Most species belonged to a category of algae that may also be of importance in Atlantic water (Chaetoceros spp., Thalassiosira gravida, Rhizosolenia hebetata).

June 1953: Very abundant spring plankton, representing a much earlier stage than the 1952 vegetation. Thalassiosira gravida occurred in huge concentrations, but a number of more pronounced

Arctic diatoms were of importance as well.

June 1954: Poor vegetation of the summer type, with a composition not very different from that of Atlantic summer plankton.

The temperature was about the same in all three years. In 1952 and 1953, there was very little stability in the uppermost layers. This probably caused a delay in the spring development, which, according to our observations, lasted during the greater part of June. In 1954, on the other hand, a strong ice melting earlier in the year apparently resulted in low surface salinities with ensuing high stability values. Conditions thus favoured an early vernal blooming, which may have been of an abnormally short duration that year.

The observations from 1952 and 1954 suggests that during the later stages of the spring development, an admixture of plankton stocks of Atlantic origin may exert a considerable influence on the composition of the phytoplankton in this area.

4. Local waters at Spitsbergen.

June 1952: The phytoplankton was less abundant than in 1953 and did not possess the characteristics of typical Arctic spring plankton.

June 1953: Very abundant Arctic plankton of the early spring type.

June 1954: Temperate-neritic plankton, possibly a late stage in the spring succession.

The differences between the three years were probably connected somehow with observed differences in temperature. Temperatures in 1952, and especially in 1954, were considerably higher than in 1953.

5. The East-Icelandic Arctic Current.

The hydgrography of this part of the Norwegian Sea is quite complex, and the observations from two of the years (1952 and 1953) are far too incomplete to provide a reliable picture of the situation in the area as a whole.

The spring increase probably starts in May.

June 1952 (in water of 5-6°C): Early spring plankton, with large stocks of Eucampia, Nitzschia, Thalassiosira, and some purely Arctic forms.

June 1953 (in water of 5-6°C): Spring plankton at a later

stage than in 1952: Chaetoceros spp., Thalassiosira gravida, Rhizosolenia hebetata. A certain degree of Atlantic influence was manifest; thus Rhizosolenia styliformis occurred at some stations.

June 1959: a) (in water of 3-5°C): More or less the same type of vegetation as in June 1953, probably a fairly late spring plankton, with some Atlantic features.

b) (in water of 0-2°C midway between Jan Mayen and Iceland): Spring plankton of local or Arctic origin: Phaeocystis, Thalassiosira gravida, Nitzschia spp.

6. Icelandic coastal water and Irminger Current:

June 1952: Moderately rich spring plankton: mostly neritic Chaetoceros spp.

June 1953: Abundant spring plankton: Chaetoceros spp., although other species than in 1952. In addition many dinoflagellates.

June 1959: Very abundant spring plankton, of the same composition as in the Icelandic Arctic Current at 3-5°C, but with some additional neritic Chaetoceros species.

The interpretation of these observations is difficult, especially since the temperatures were very different each year.

Concluding remarks

The observations from 1952-59 may be conveniently summarized if a hypothetical spring development curve is used as a reference. Of the two such curves presented in Fig. 1, the one relating to cell surface area is preferred because it brings out most clearly the disappearance of large and medium-sized plankton algae, which by our definition marks the end of the spring period. Using this curve, the stage reached by the phytoplankton in the different areas and years by the time of sampling is indicated in Fig. 2.

On comparing the data from Atlantic water with those from Arctic-Polar waters between Jan Mayen and Spitsbergen, it becomes evident that the development may very well be accelerated in one area while at the same time retarded in the other. This fact clearly demonstrates that yearly variations in the spring development are largely dependent upon variations in the local growth

conditions within each area.

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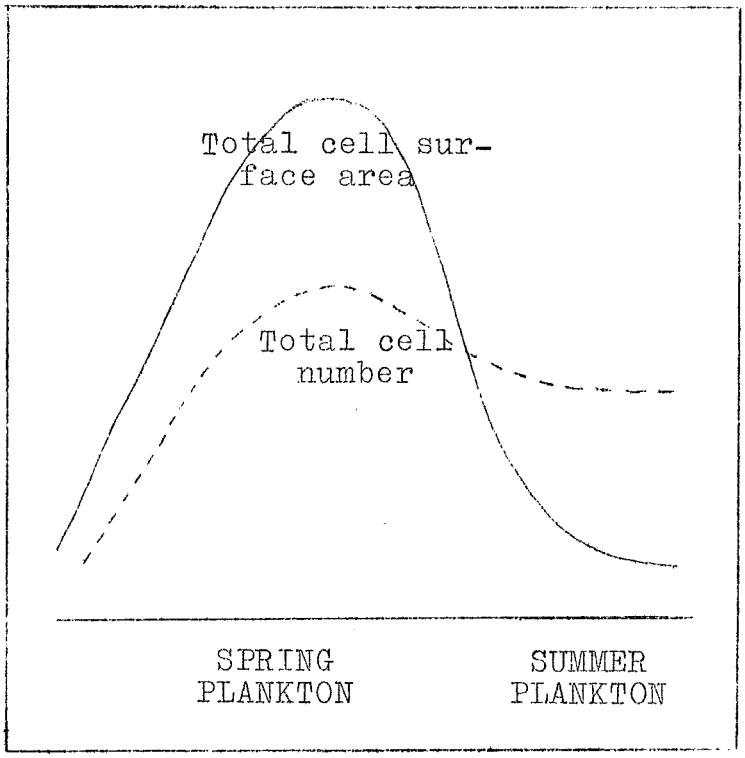

Fig. 1.

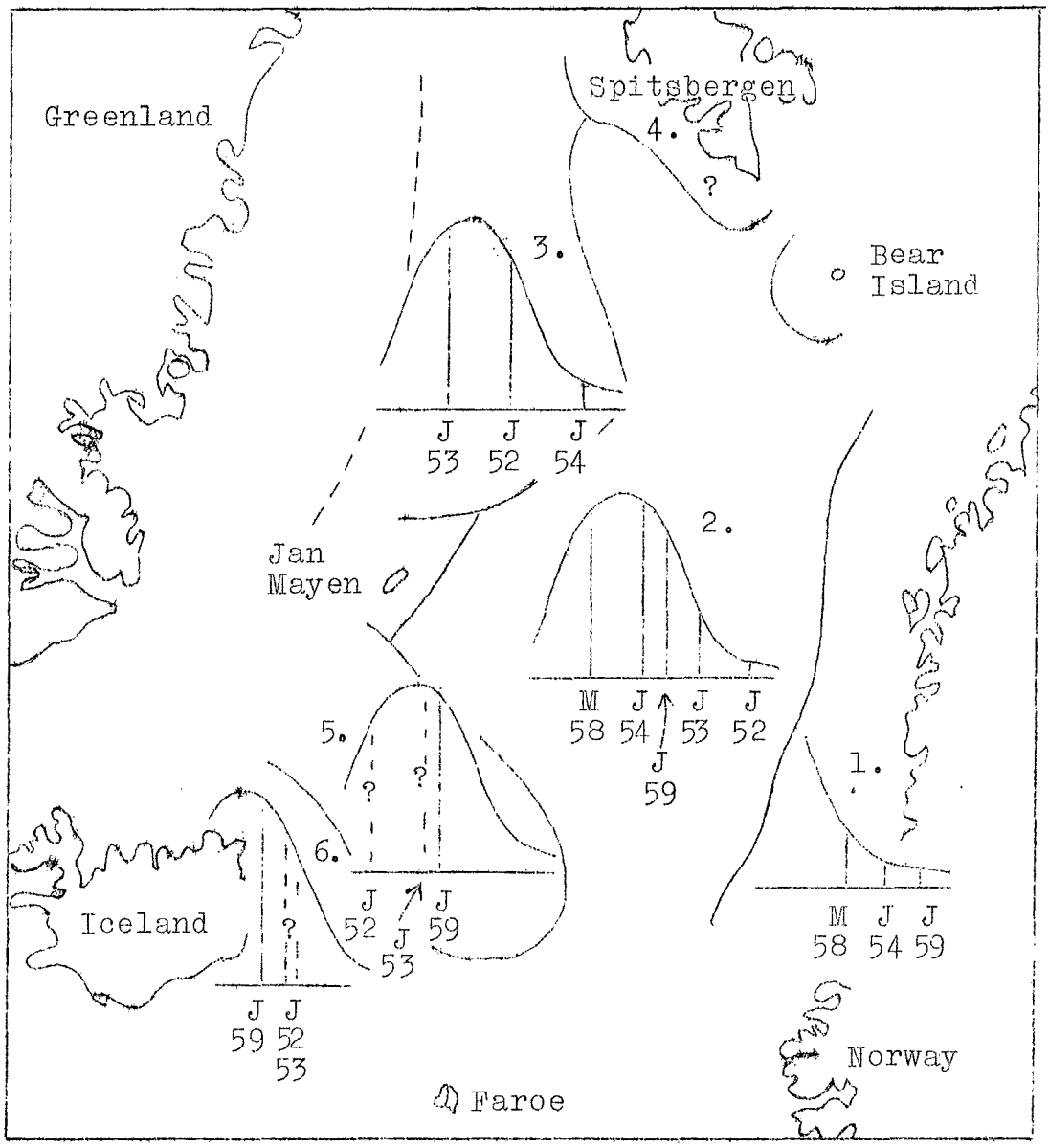

Fig. 2. 1: Norwegian coastal water
2: Atlantic water
3: Arctic and Polar water
4: Local water off Spitsbergen
5: East-Icelandic Arctic Current
6: Icelandic coastal water