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Kieler Meeresforschungen	Sonderheft 4	Kiel 1978

Phytoplankton spring bloom and maximum oxygen content in the Baltic proper

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Abstract

Using the mean annual variations in temperature and oxygen content at ten stations in all parts of the open Baltic proper, relations between phytoplankton spring bloom and maximum oxygen content in the near-surface layer are pointed out. By means of the calculated times of the oxygen maxima and the observed times of the spring blooms, regional peculiarities of the three fundamental areas of the Baltic proper – Arkona Sea, Bornholm Sea and Gotland Sea – are explained. – The results show that there is a clear connection between phytoplankton spring bloom and maximum oxygen content. Furthermore, the longer the phase lag between oxygen maximum and temperature minimum, the longer the period of higher oxygen content in spring.

Zusammenfassung

Die Frühjahrsblüte des Phytoplanktons und der maximale Sauerstoffgehalt in der zentralen Ostsee

Anhand von mittleren jährlichen Variationen der Temperatur und des Sauerstoffgehaltes auf zehn Stationen, die in allen offenen Seegebieten der zentralen Ostsee liegen, wird ein Zusammenhang zwischen der Frühjahrsblüte des Phytoplanktons und dem Sauerstoffgehalt in der oberflächennahen Wasserschicht aufgezeigt. Mit Hilfe der Eintrittszeiten des Sauerstoffmaximums und der Frühjahrsblüte werden jeweils regionale Unterschiede zwischen den drei Hauptgebieten der zentralen Ostsee – der Arkona See, Bornholm See und Gotland See – erklärt. Die Ergebnisse zeigen, daß eine klare Beziehung zwischen der Frühjahrsblüte des Phytoplanktons und dem maximalen Sauerstoffgehalt besteht. Je länger die Zeitverzögerung zwischen dem Sauerstoffmaximum und dem Temperaturminimum ist, desto länger ist die Zeitdauer eines erhöhten Sauerstoffgehaltes im Frühjahr.

The oxygen content of the surface water of the shelf seas at temperate latitudes is subject to characteristic annual fluctuations. These are caused primarily by seasonal variations in temperature which affect the solubility of oxygen. The annual fluctuations in the oxygen content are modified by exchange processes across the air-sea interface and the metabolic activities of marine organisms.

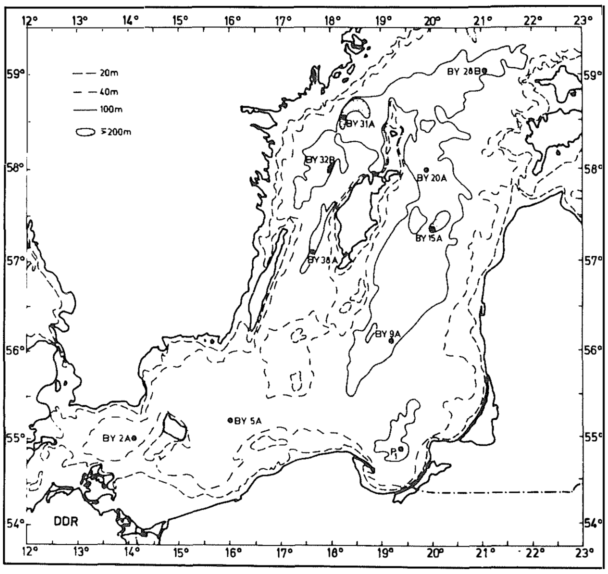

Figure 1
Positions of the observation stations

Investigations into the mean annual fluctuations in temperature (MATTHÄUS, 1977) and oxygen content (MATTHÄUS, 1978) at 10 stations in the open Baltic proper (Fig. 1) drew attention to regional peculiarities associated with the times of the oxygen maximum. During the cooling period, the solubility of oxygen increases rapidly as the temperature drops and reaches its highest value at the temperature minimum. By far the greatest part of the dissolved oxygen is of atmospheric origin (MATTHÄUS, 1974, 1975), the only oxygen source in the sea itself being the assimilation activities of the plants. In contrast to the shallow coastal regions where the phytobenthos participates in the production of oxygen, in the offshore regions of the sea oxygen is produced only by photosynthesis of the phytoplankton. Any modification of the oxygen maximum can thus be ascribed mainly to phytoplankton activities.

If this aspect is taken into account when considering the times of the oxygen maximum in the three fundamental sea areas of the Central Baltic – Arkona Sea, Bornholm Sea and Gotland Sea – the following connections are found between the maximum oxygen content and the phytoplankton spring bloom:

The calculated times of the oxygen maximum in the Arkona Sea at the end of March/beginning of April (Figs. 2 and 3a) coincide well with the times of the blooming period of phytoplankton observed, for example, during April in 1969, already from the beginning to the middle of March in 1970 (KAISER and SCHULZ, 1973a) and at the end of March/beginning of April in 1971 (KAISER and SCHULZ, 1973b).

Furthermore, the mean maximum oxygen content can be observed at a depth of 5 m. This fact corresponds well to the depth at which the assimilation maximum can be expected and indicates the effect of the plankton bloom on the mean maximum in the annual oxygen variations.

The conditions required for the phytoplankton bloom are apparently already present in the Arkona Sea in the middle of March (KAISER and SCHULZ, 1976). Nutrient

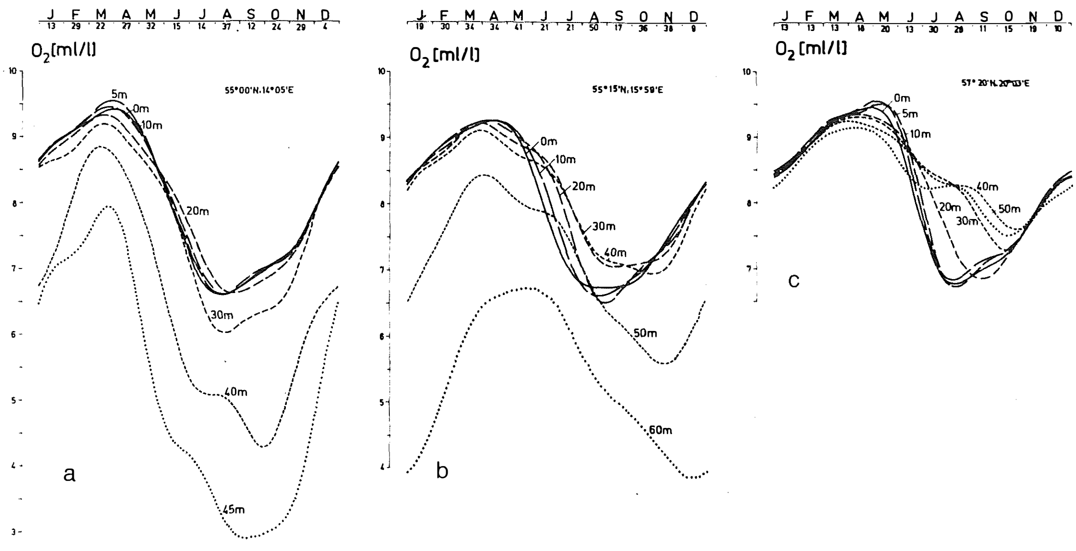

Figure 2
Mean seasonal variations of oxygen content in the Arkona (a.), Bornholm (b.) and Gotland Deeps (c.)

supply and light intensity are already sufficient at this time. The haline stratification which is almost always present in the euphotic zone of this area obviously permits – in contrast with other parts of the Central Baltic – the blooming before thermic stratification takes place.
In comparison to other parts of the Baltic, in the Arkona Sea the consideration of the mean annual variation alone provides no particular indication of the fact that the oxygen content is increased by photosynthetic activity (Fig. 2). This is due to the fact that the plankton bloom in the Arkona Sea generally nearly coincides with the temperature minimum and the maximum solubility of oxygen. The quantum of dissolved oxygen resulting from phytoplankton assimilation can only contribute to an increase in the maximum due to solubility conditions.

The mean maximum oxygen concentration in the upper 10 m in the Bornholm Sea occurs in the middle of April (Figs. 2 and 3b). The phytoplankton bloom in this region has been ascertained by various authors as taking place between the end of March and the middle of April (WELLERSHAUS, 1964; KAISER and SCHULZ, 1973a; RENK, 1974). Due to the absence of haline stratification in the euphotic zone, the spring bloom here is connected to the occurrence of thermal stratification and, for this reason, generally occurs later than in the Arkona Sea. This is expressed by a wider and flatter oxygen maximum (Fig. 2), resulting from the time interval between the maximum oxygen solubility (= temperature minimum) in March and the time of maximum oxygen production during the blooming period in April.
In the Gotland Deep, the occurrence of the maximum oxygen content at a depth of 0–10 m from the beginning to the middle of May (Figs. 2 and 3c) also coincides well with the observation of the phytoplankton bloom during the first half of May (SCHULZ and KAISER, 1973, 1974, 1975). The spring bloom in the Gotland Sea is connected to the occurrence of thermic stratification in the euphotic zone.

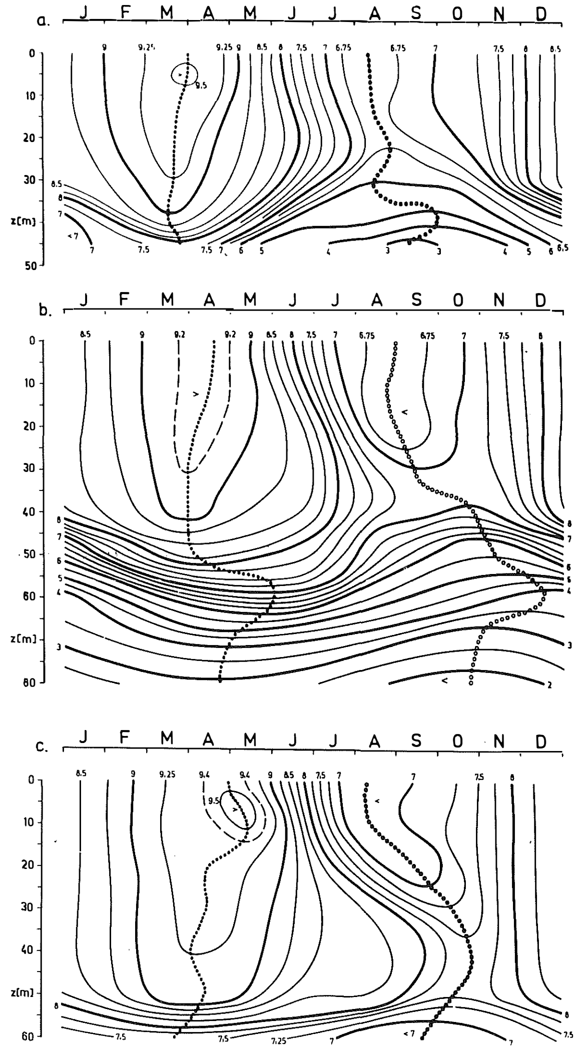

Figure 3
Isoplethes fo the mean oxygen content [ml/l] in the Arkona (a.), Bornholm (b.) and Gotland Deeps (c.)

Fig. 4 summarises the times at which the oxygen maximum occurs in the upper 10 m of the Baltic proper. The mean maxima are shifted increasingly towards the spring as the Central Baltic is approached. The maximum oxygen concentration can be observed at the end of March/beginning of April in the Arkona Deep (BY 2 A), in the middle of April in the Bornholm Deep (BY 5 A) and at the end of April in the Gdańsk Deep (P_1). The maximum is reached from the beginning to the middle of May in the eastern part and at the end of April/beginning of May in the western part of the Gotland Sea. Since the temperature minimum in the upper 40 m occurs during March in the open Baltic proper (MATTHÄUS, 1977), the phase lag between oxygen maximum and temperature minimum increases towards the Central Baltic (Fig. 5).

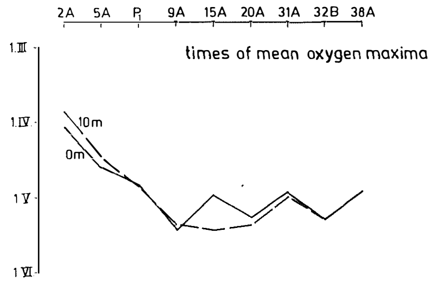

Figure 4

Times of the mean oxygen maxima in the upper 10 m of the open Baltic proper

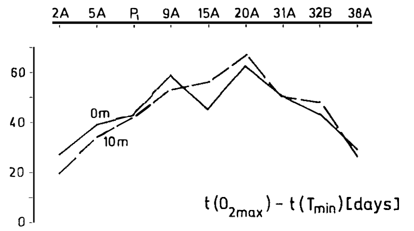

Figure 5

Phase lag between the times of oxygen maximum t (O_{2max}) and temperature minimum t (T_{min}) in the upper 10 m of the open Baltic proper

Summarising, these investigations show that the maximum oxygen content in the near-surface layers of the open Baltic proper is determined by the times of the phytoplankton spring bloom. Although the oxygen solubility in the water has already dropped considerably in the Gotland Sea during May (MATTHÄUS, 1975),so that no oxygen is taken up from the atmosphere (MATTHÄUS & KREMSER, 1975, 1976), the oxygen concentration in the upper 10 m still reaches maximum values. The greater the interval between the occurences of temperature minimum and oxygen maximum, the longer will be the period of high oxygen concentrations in spring.

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