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Primary production in the Southern Baltic in 1985 and 1986 compared with long-term mean seasonal variation

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Abstract

On the basis of long-term investigations, the course of seasonal variations of mean daily primary production and mean chlorophyll-a concentration in the Southern Baltic waters are presented. The mean annual primary production of the Gdańsk Deep, Bornholm Deep and the Gotland Deep amounted to 124.4 gC m⁻², 88.8 gC m⁻² and 107.2 gC m⁻², respectively. The primary production of the Southern Baltic in 1986 was higher than in 1985, and higher than the long-term mean value. The mean annual production for the Southern Baltic in 1986 amounted to 130 gC m⁻². On the basis of long-term observations of primary production and chlorophyll-a of the Southern Baltic, certain upward trends in phytoplankton production were observed.

Introduction

Light and dissolved inorganic compounds play a fundamental role in the processes of organic matter production in the sea. Irradiation in the water may undergo considerable fluctuations from day to day, depending on the changes in cloud cover and weather conditions. Estimation of primary production *in situ* within a certain period, e.g. one year, therefore requires taking measurements with sufficiently high frequency. This requirement is difficult to fulfill particularly in offshore waters. Therefore, estimation of annual production may be subject to certain reservations.

Polish investigations of primary production of the Southern Baltic have been carried out since 1965. During these 21 years, several hundred measurements of primary production have been made at several stations in this area and during various seasons. They served to monitor average seasonal changes in primary production at those stations, and they reveal changes in primary production between the various stations. The differences are no doubt to great extent connected with varying nutrient supply in these areas. In general, higher primary production is observed in river estuary areas, i.e. in areas subjected to increased eutrophication.

Material and methods

Measurements of primary production were carried out at three stations: P₁ (54°50'N, 19°20'E) in the Gdańsk Deep, P₅ (55°15'N, 15°59'E) in the Bornholm Deep, and P₄₀ (55°38'N, 18°36'E) in the southern part of the Gotland Deep, during cruises of the research vessel „Hydromet” in 1985 and 1986.

Primary production was measured by a radio-isotope method (STEEMANN-NIELSEN 1952, 1965, ICES 1981). The measurements were carried out at the following depths: 0, 3, 5, 10, 15 and 20 m. These data later served to calculate production under 1 m². Bottles with phytoplankton were incubated *in situ* for 4 hours at noon. A solution of radioactive

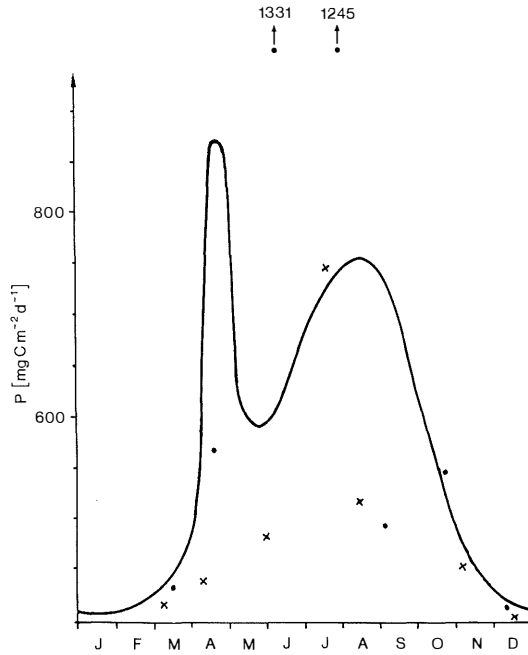


Figure 1

Seasonal changes in primary production ($\text{mg C}^{-1} \text{m}^{-2} \text{d}^{-1}$) in Gdańsk Deep; unbroken line – averaged results for a long-term period. Results of own measurements in 1985 (crosses) and 1986 (dots) Polish investigations since 1965

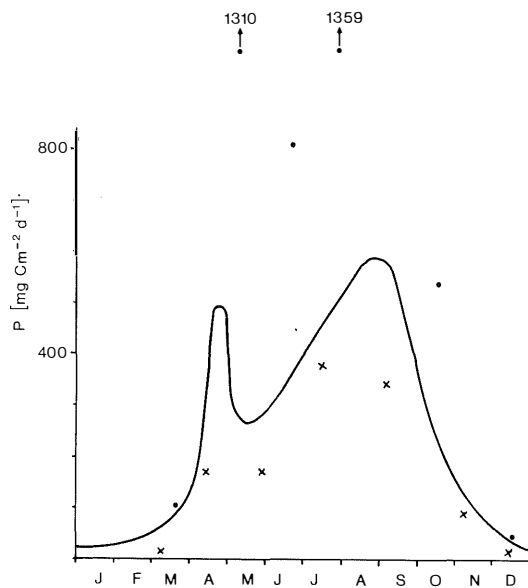


Figure 2

Seasonal changes in primary production in Bornholm Deep; unbroken line – averaged results for a long-term period. Results of own measurements in 1985 (crosses) and 1986 (dots) Polish investigations since 1965

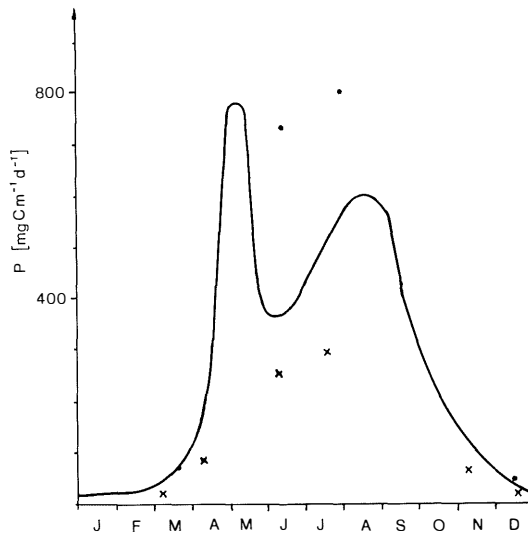


Figure 3

Seasonal changes in primary production ($\text{mg C m}^{-2} \text{d}^{-1}$) in Gotland Deep; unbroken line – averaged results for a long-term period. Results of own measurements in 1985 (crosses) and 1986 (dots) Polish investigations since 1965

sodium carbonate (^{14}C) with an activity of $6 \mu\text{Ci ml}^{-1}$ was used for the measurements. Chlorophyll-*a* was determined by means of a spectrophotometer method, using the formulas of JEFFREY and HUMPHREY (1975). Total insolation during incubation, and the daily dose of solar energy incident on the sea surface was measured by a solarimeter placed on a special mast.

Results and discussion

Seasonal changes of averaged primary production from 1971 to 1985 for each station are presented in Figs 1 – 3. They also show the results of primary production measurements made in 1985 and 1986. The values of primary production averaged for a long-term period were determined in the following way: a calendar year was divided into ten-day periods, production averaged for each decade of days, and the arithmetic mean of all results of corresponding decades over the long-term period was determined. The averaged results obtained for each decade of days in a year make it possible to draw a graph of seasonal changes in primary production, shown in Figs 1 – 3. The same method was used to draw the curve illustrating seasonal changes of chlorophyll-*a* concentrations in the upper 10 m in the Gdańsk Deep, Fig. 4.

The curves presented in Figs 1 – 3 served as a basis for calculating mean annual primary production at each station. It equaled 124.4 gC m^{-2} for the Gdańsk Deep, 88.8 gC m^{-2} for the Bornholm Deep and 107.2 gC m^{-2} for the Gotland Deep.

A spring phytoplankton bloom was not encountered in 1985. Water temperatures in the euphotic layer in spring were lower compared to long-term mean values. Routine measurements of primary production as well as of chlorophyll-*a* concentrations made in 1985 point to generally lower values than the long-term means (Figs 1 – 3). Distribution of chlorophyll-*a* in the euphotic layer of the Southern Baltic between May 23 and June 6, 1985, is presented in Fig. 5. The map of chlorophyll-*a* distribution is based on measurements

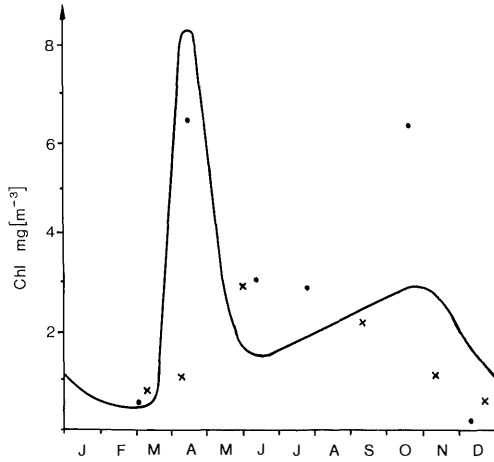


Figure 4

Seasonal changes in chlorophyll-a concentrations ($\text{mg} \cdot \text{m}^{-3}$) in the 0-10 m layer in the Gdańsk Deep; unbroken line – averaged results for a long-term period. Crosses – measurement results in 1985, dots – in 1986 Polish investigations since 1965

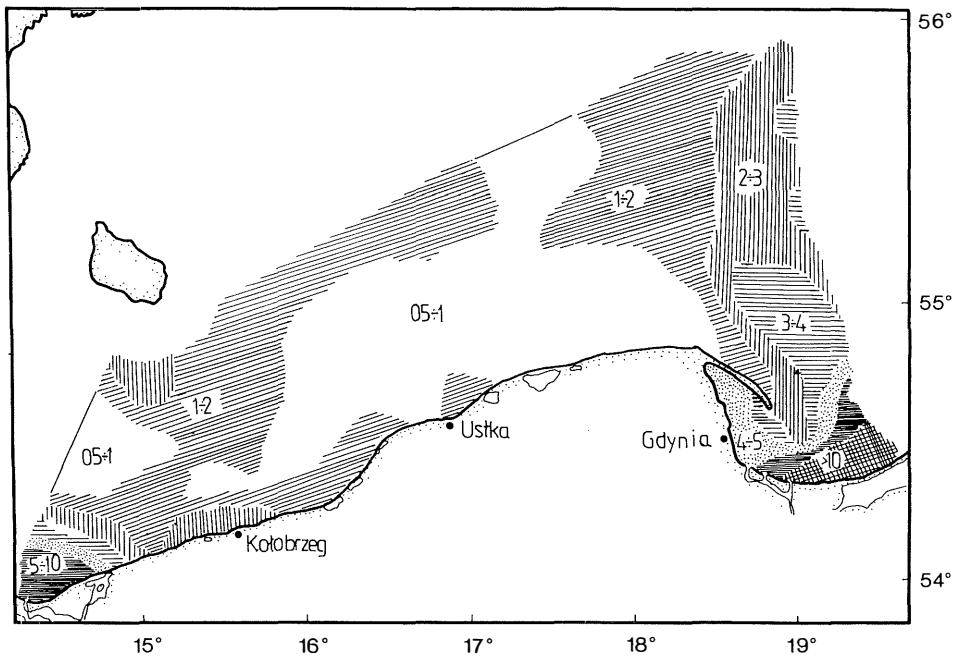


Figure 5

Distribution of chlorophyll a ($\text{mg} \cdot \text{m}^{-3}$) in the 0-10 m layer between May 23 and June 6, 1985

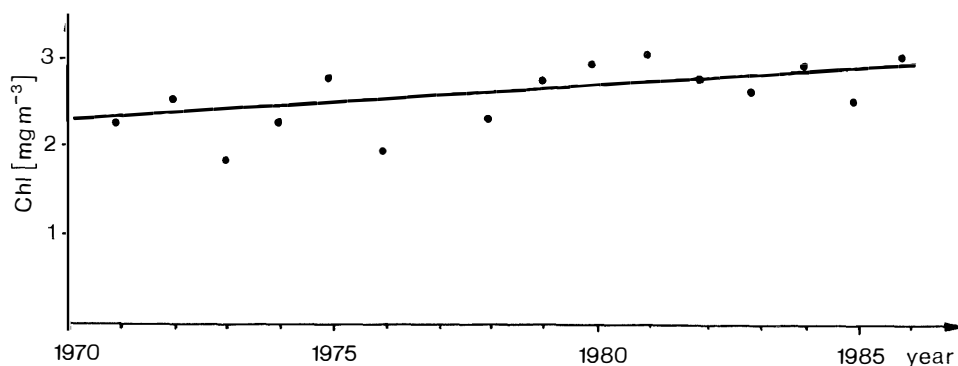
made at over 100 sampling stations. It appears from the map that chlorophyll-a concentrations in the gulfs and estuaries of large rivers were much higher than in the offshore waters. A similar picture of chlorophyll-a distribution was also obtained during earlier investigations (RENK 1974, 1983).

In the winter period and in the first weeks of spring 1986, surface water temperature in the Southern Baltic was lower than long-term mean values, thus vertical thermal stratification of the water began later. That is why the spring phytoplankton bloom, and also the beginning of the vegetation season in the Southern Baltic, were slightly delayed. On the other hand, relatively high primary production was observed in May, June, and July at all stations, much higher than long-term means for this season. In October, primary production observed in the Bornholm and Gotland Deeps was exceptionally high for that season. High concentrations of chlorophyll were also observed at that time.

Table 1

Annual primary production of the Southern Baltic ($\text{gC m}^{-2} \text{ year}^{-1}$)

	Years		Lon-term mean-value	Mean value for the years	
	1985	1986		1971–1974	1981–1985
Gdańsk Deep	102.2	132.6	124.4	106.3	129.2
Bornholm Deep	86.5	134.2	88.8	81.7	91.0
Gotland Deep	92.6	129.1	107.2	91.8	115.7

**Figure 6**

Long-term changes of mean annual chlorophyll-a concentrations (mg m^{-3}) of the Gdańsk Deep

Annual production is most strongly affected by the production of the summer season. The accuracy of annual primary production estimation might give rise to certain reservations because of the relatively low frequency of measurements. Nevertheless, an attempt was made to estimate annual primary production for three main stations of the Southern Baltic. Annual production was obtained as a sum of monthly production values. Monthly production was in turn, obtained by multiplying the mean value for a given month by the number of days of the month. In the case of months when no measurements were taken, the mean value for a long-term period was assumed as the monthly value. The results for annual primary production, calculated in the above-mentioned manner, are presented in Table 1. Primary production was lower than the long-term mean in 1985 and higher by 25 % in

1986. Table 1 also presents the values of annual production for 1971 – 1974 and 1981 – 1985, showing upward trends in primary production in the past decade. Mean increase in annual primary production within the past period is estimated at 1.7% per year. An increase in chlorophyll-*a* concentrations has likewise been observed within the same period (NAKONIECZNY et al. 1986). The mean chlorophyll concentrations in the summer seasons are presented in Fig. 6.

Upward trends in primary production have also been observed by other authors (SCHULZ et al. 1982, STEEMANN-NIELSEN 1965, GARGAS et al. 1978, AERTEBJERG-NIELSEN et al. 1981, WULFF et al. 1986). The increase in primary production and phytoplankton biomass was accompanied by an increase in zooplankton biomass, visible since 1950 (MANKOWSKI 1978, KURZYK et al. 1983, RENK et al. 1985, CISZEWSKI 1985).

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