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Long - term observations of oxygen and chlorophyll a in Kiel Bight

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Biological Oceanographers try to measure relevant parameters to be able to explain and predict biological phenomena in the sea. In the last decade it was shown mainly by physical oceanographers, that the environmental factors e.g. temperature, salinity and nutrients are by no means distributed uniformly in space and time. It was recognized that biological parameters also show an immense heterogenity and variability, e.g. the rate of primary production and parameters to characterize the standing stock of phyto- and zooplankton.

The estimation of the heterogenity and variability in the sea is extremely difficult. There seem to be only a few possibilities to monitor biological variables at all. Chlorophyll might be the only parameter which can be measured continuously in vertical profiles from ships or at the sea surface from aircrafts and satelits.

One way to get an idea of the fluctuations of variables has been to obtain long-term observations over wide areas like the Hardy-Plankton-recorder survey of the Oceanographic Laboratory, Edinburgh, to estimate the abundance of phyto- and zooplankton or to measure the most important parameters governing primary production or the standing stock of plankton regularly at a fixed station. These data can be used to try to explain biological processes. They are also very valuable to show the increasing negative effects of domestic and industrial pollution on marine plankton communities.

In Kiel Bight long-term observations of hydrographical, chemical and biological parameters have been carried out since 1957 by the Institut für Meereskunde, Kiel (KREY, 1961). In this paper the data on oxygen and chlorophyll a will be discussed. The samples have been obtained at the station Boknis Eck ($\varphi = 54^{\circ}\ 31'$ N, $\lambda = 10^{\circ}\ 03'$ E) in Kiel Bight in monthly intervals. Standard depths of 0.5, 5, 10, 15, 20 and 26 m were sampled.

Oxygen was determined by the Winkler-Method. Chlorophyll a was estimated by the method discussed by LENZ and ZEITZSCHEL (1968).

Kiel Bight is an area of intense hydrographical and marine biological interest as it forms a transition zone between the Baltic proper and the Kattegat. The hydrography of this area is characterized by the inflow of salinity-poor baltic water from the East at the surface and more saline Kattegat water through the Small- and Great Belt from the North along the bottom. The degree of mixing is determined generally by meteorological conditions, particularly wind. (JACOBSEN 1908, WATTENBERG 1950, KÄNDLER 1951).

The seasonal fluctuation of temperature follows a warming up of the surface water in summer and its cooling in winter. This causes a reversal in the temperature relationship between the surface and the bottom during these seasons, with the spring and autumn acting as the transition months. In summer a marked thermocline develops at about 10 - 15 m depth. In winter the vertical distribution of temperature is rather uniform due to mixing which is very pronounced in this area because of the great turbulence in this relatively shallow bight.

The distribution of surface salinity is usually lowest during the months of May - September. This coincides with the season of maximum outflow of Baltic water. Short-term variations in the bottom salinity occur due to fluctuations in the inflow of Kattegat water. In winter the salinity is uniformly distributed due to mixing which is in strong contrast to the summer, when a very well-developed halocline can be observed as a result of the stable water conditions.

The vertical stability in Kiel Bight is caused by the simultaneous development of both a strong thermocline and halocline and is quite marked during the summer months. In this respect salinity plays a more pronounced role than temperature (KREY and SARMA 197o).

The chlorophyll a data from 1960 to 1970 and oxygen data from 1957 to 1970 are shown in Figs 1 - 5. The integrated chlorophyll a values for 11 years are given in Table 1.

As for chlorophyll a, there is a marked difference from year to year. There are years like 1960, 1965, 1966 and 1970 with rather low over all means between 65.5 and 92.7 mg Chl/m^2. Years with maximum chlorophyll a concentrations are 1961 and 1962. The over all mean for 11 years from about 750 samples is 120 mg/m^2. Chlorophyll a data are a measure to obtain an approximation of the phytoplankton standing stock. Although the relationship between phytoplankton-carbon and chlorophyll a is not constant(ZEITZSCHEL 1970) an average factor of about 35 can be used to calculate the phytoplankton carbon from chlorophyll a data. This implies that at the station Boknis Eck a long-term average of 4,2 g/m^2 phytoplankton carbon is to be found in the water column.

The seasonal cycle of phytoplankton standing stock is characterized by a spring maximum of 343.2 Chl. mg/m^2 in March, a minimum in May - June (51.7 - 54.4 Chl. mg/m^2) and a small increase from July - November.

According to KREY and SARMA (1970) there is a good correlation at this station between the rate primary production and chlorophyll a. The primary production in Kiel Bight is also characterized by a major and a minor bloom during the spring and the autumn, respectively with comparatively low values during other seasons. This finding is somewhat different from the seasonal profiles reported from the Great Belt and Kattegat by STEEMANN NIELSEN (1964), who found that the production rates are usually higher in autumn. The location of the present station at a more sheltered area away from the main currents may be a possible explanation. This facilitates the greater accumulation of the plankton populations in the area during the bloom periods. But because of the more stable conditions this population could not remain at the surface layers over long periods to maintain the high production rates, due to the greater sedimentation rates (KREY and SARMA 1970).

The oxygen content of the water has been measured in monthly intervals since 1957. Figs 3 - 5 show that there are significant changes from year to year. The over-all yearly pattern is, however, similar. There are values > 10 mg oxygen/l in winter due to mixing of the water column and in spring due to the phytoplankton activities mainly near the surface. During the period of summer stability, a gradual decrease in the oxygen content is observed from 10 m downward, which may later lead to very oxygen-poor conditions near the bottom.

Oxygen concentrations of < 5 mg/l are generally found from July to September in depths > 20m. Near the bottom there are short periods with less than 2 mg/l. Exceptionally low oxygen concentrations were recorded in 1970. A tongue of less than 5 mg reaches from the bottom up to 10 m in September.

The low oxygen concentrations near the bottom are determined by the stagnation of the water column due to the marked thermocline and halocline. The oxygen near the bottom is used up for remineralisation processes of the settling phytoplankton organisms. At Boknis Eck there seems to be (up to now) no significant influence of the intensive sewage disposal at Bülk at the entrance of the Kiel Fjord. These long-term observations will be continued over the next years to have a reference station which makes it possible to distinguish between natural long-term changes of the environment and the effect of the increasing pollution of the Baltic.

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Table 1: Kiel Bight $\varphi = 54^{\circ}31'$ N, $\lambda = 10^{\circ}03'$ E
Chlorophyll a (mg/m^2) integrated over 26 m.

	Jan.	Febr.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	$\bar{x}$
1960	-	-	195.5	43.1	24.1	22.5	33.6	34.2	27.1	98.2	78.9	94.0	65.5
1961	121.0	140.6	414.8	870.0	104.0	99.2	118.0	123.9	83.3	126.0	246.7	178.2	218.8
1962	-	230.6	461.3	185.5	94.2	118.0	409.4	78.5	85.6	166.5	207.6	182.4	201.8
1963	-	-	308.7	212.2	42.7	55.8	54.5	72.1	72.1	57.1	120.0	228.3	122.4
1964	134.4	233.0	356.9	195.5	29.9	92.6	82.2	64.8	130.4	78.6	75.6	33.6	125.6
1965	35.3	116.1	342.3	23.2	21.0	17.5	43.1	63.0	39.6	100.8	64.1	89.2	79.6
1966	30.0	80.8	224.2	47.2	18.2	19.5	30.9	68.7	39.7	76.0	135.3	98.4	72.4
1967	221.7	46.3	61.1	790.0	115.5	39.8	68.3	240.8	90.9	57.8	88.4	91.7	102.0
1968	33.3	30.4	973.7	71.7	26.8	68.3	90.0	45.4	290.8	89.0	82.0	47.7	154.1
1969	16.7	35.8	198.1	340.3	21.1	31.0	56.9	55.8	57.3	143.5	85.3	70.5	92.7
1970	27.0	17.9	238.2	114.4	71.7	34.2	44.9	64.0	70.5	120.0	152.8	68.1	85.3
$\bar{x}$	77.4	103.5	343.2	263.0	51.7	54.4	93.8	82.8	89.8	101.2	121.5	107.5	-

Fig. 1 Kiel Bight φ: 54°31' N λ: 10°03' E Chlorophyll a (μg/l)

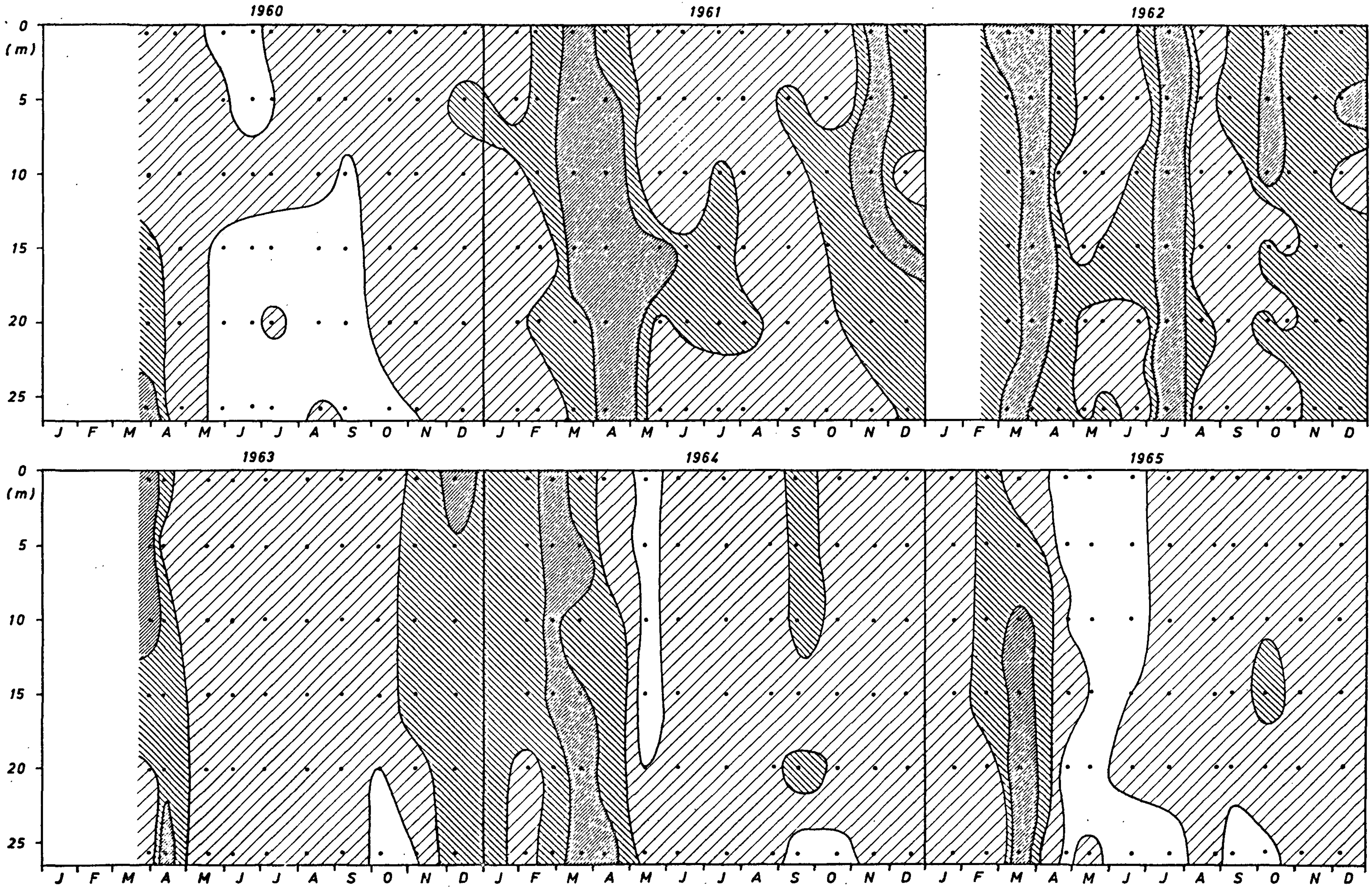

Fig. 2 *Kiel Bight* φ: 54°31′ N λ: 10°03′ E Chlorophyll a (µg/l)

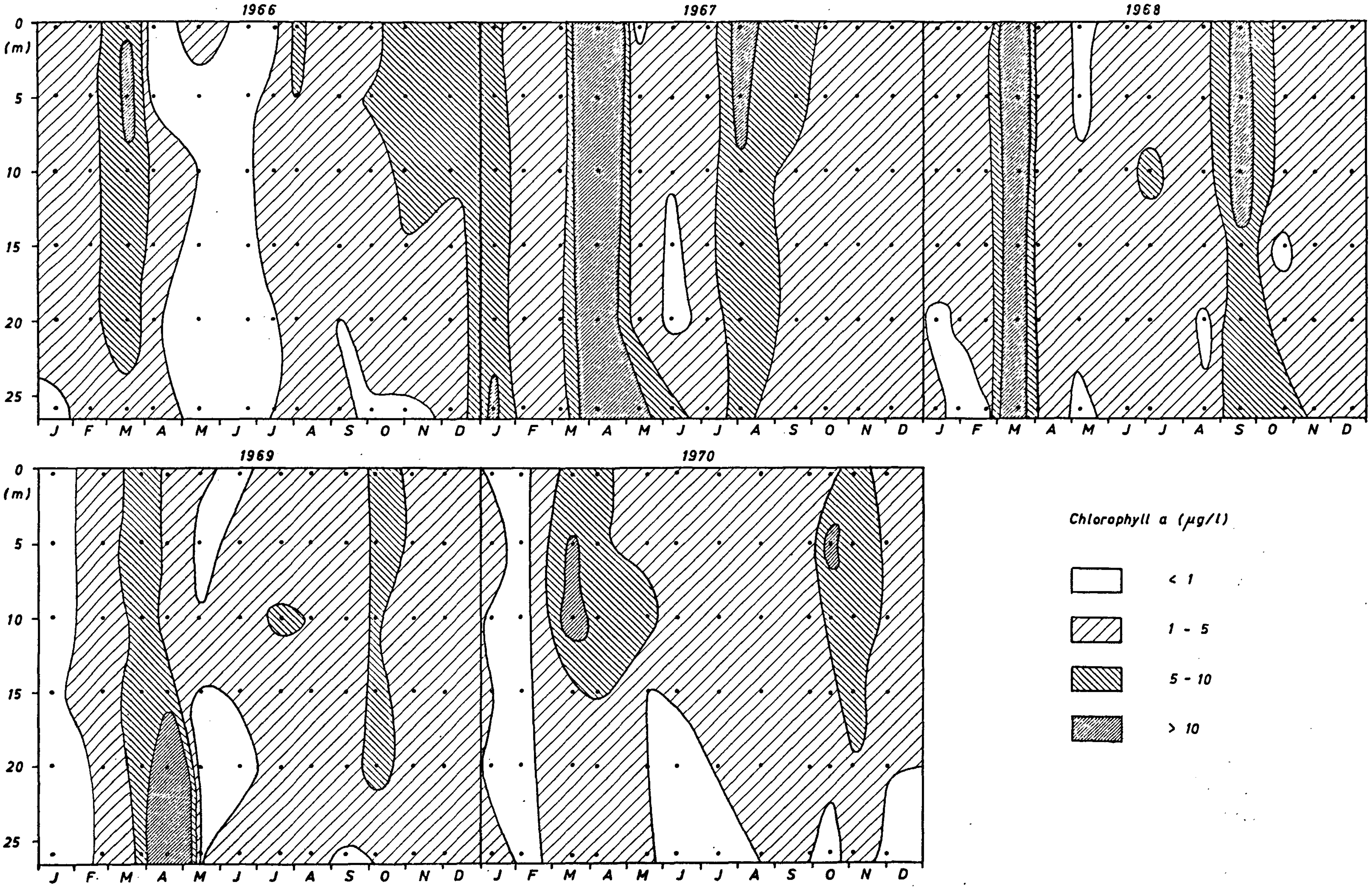

Fig. 3 Kiel Bight φ: 54° 31′ N λ: 10° 03′ E Oxygen (mg/l)

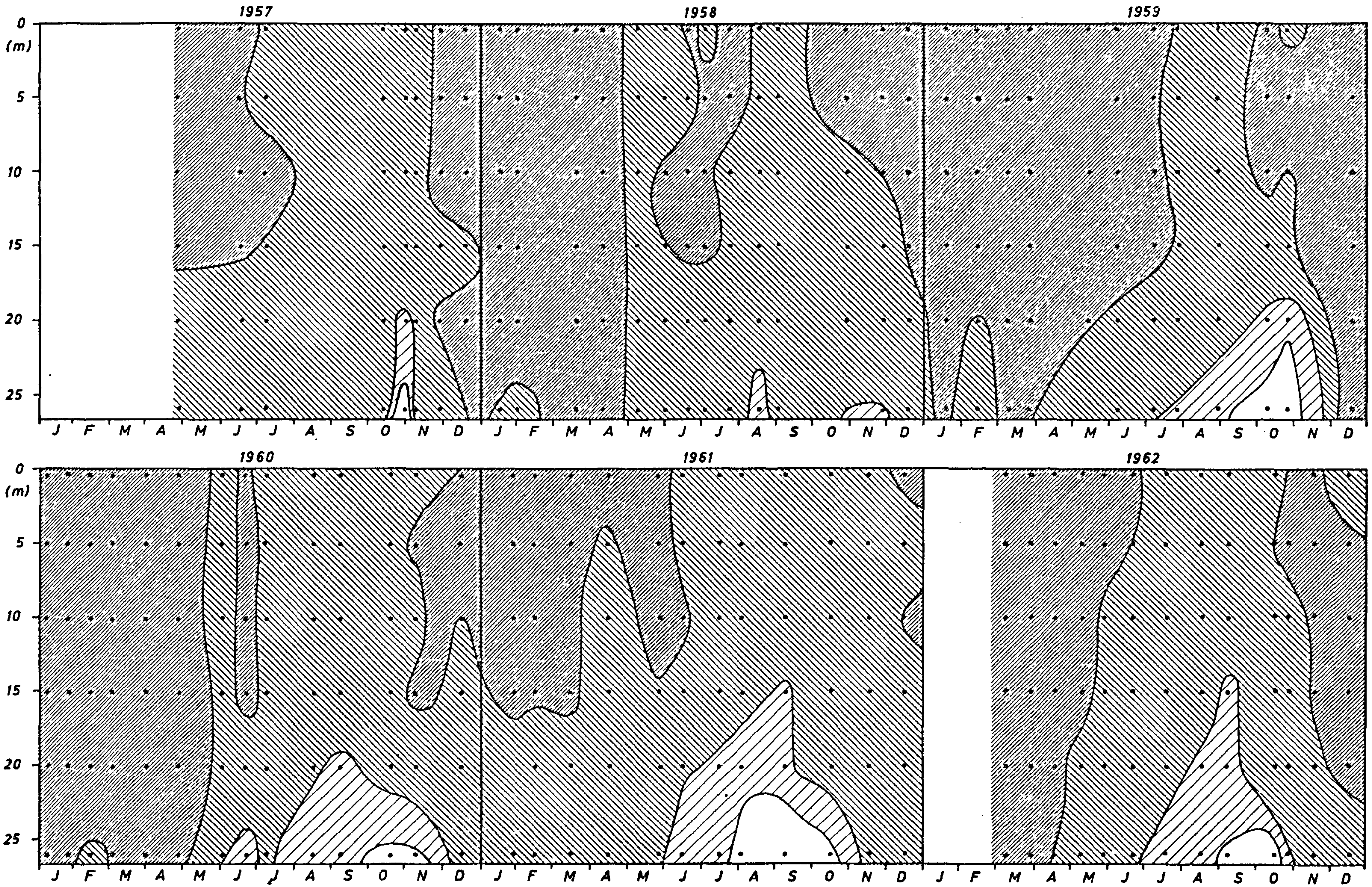

Fig. 4 Kiel Bight φ : 54° 31′ N λ : 10° 03′ E Oxygen (mg/l)

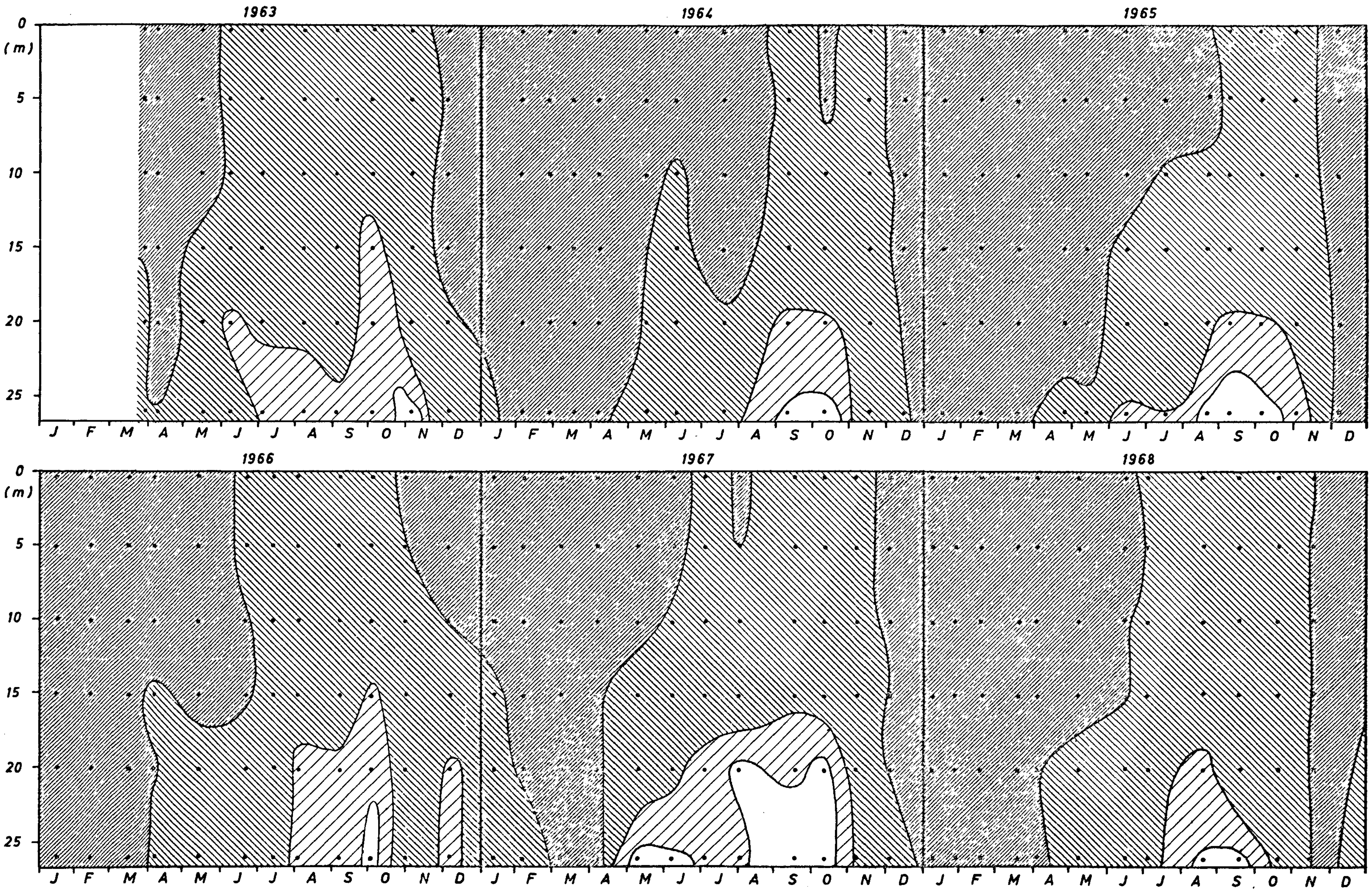

Fig. 5 Kiel Bight φ: 54° 31′ N λ: 10° 03′ E Oxygen (mg/l)