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Diurnal oxygen rhythm in the southern Bight of the North Sea: net and gross primary production in April 1980 in a phaeocystis bloom

Erratum: page 5, line 20 should be read as follows: In cases of steady-state production one can assume ammonia assimilation and mineralisation to be applicable.

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DIURNAL OXYGEN RHYTHM IN THE SOUTHERN BIGHT OF THE NORTH SEA: NET AND GROSS PRIMARY PRODUCTION IN APRIL 1980 IN A PHAEOCYSTIS BLOOM

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Summary

In March and April 1980 community metabolism was measured through four-hourly oxygen determinations at three depths in a watermass marked with a subsurface drogue. The experiments were carried out in the area of maximum salinity 80 km W of Den Helder with R.V. Aurelia. In March oxygen percentages of 101 % were found ; an incomplete 48 h curve could be constructed and a net oxygen production of .9 g $O_2.m^{-2}.d^{-1}$ (.3g $C.m^{-2}.d^{-1}$) could be roughly estimated. In April, five weeks later the situation was drastically different. A mean oxygen percentage of 118 % in a widespread Phaeocystis bloom was found. A 72 hours oxygen curve showing regular diurnal rhythm was measured. During calm weather and high solar irradiance a daily oxygen percentage increase of 3.3 % was computed. Maximum hourly production values increased day by day linearly. Net and gross production values were 10.5 and 14.3 g $O_2.m^{-2}.d^{-1}$, corresponding with 2.0 and 3.1 g $C.m^{-2}.d^{-1}$, depending on several assumptions. Heterotrophs play a significant role in community metabolism. Apart from the inherent advantages compared with the ^{14}C-method, horizontal variability is a possible disturbing factor in obtaining consistent diurnal oxygen curves.

1. Introduction

The development and improvement of a high precision Winkler oxygen determination with photometric endpoint detection (Bryan et al, 1976; Tschumi et al, 1977; Hartwig et al, 1978; Tijssen, 1980) allowed the use of these measurements for primary production estimates even at moderate levels. This was proven for open Atlantic Ocean waters at 20°N (Tijssen, 1979) where net primary production values of around 8 $mgC.m^{-3}.d^{-1}$ were determined. In that investigation emphasis was laid on a method as independent as possible from the ^{14}C-method. Therefore no incubation technique was applied but instead diurnal oxygen variations (Odum, 1958) in the euphotic mixed layer ware determined, taking care that every time the same watermass was sampled.

It seemed worthwhile to try out this method in spring in the Southern Bight. A particularly good opportunity arose when our colleague R. Mulder from the physical oceanography department of our institute started Lagrangian current measurements with six large subsurface drifters, developed at NIOZ. The oxygen measurements described herein were performed during two cruises in March and April 1980. We used one of these drifters to define our sampling positions. We want to emphasize that this paper is preliminary; it does not cover all our relevant observations, nor all relevant literature.

2. Experimental conditions and methods

The drifters were launched at about 52°45'N,3°30'E in the region of maximum salinity (depth 25 m). A W-E salinity gradient of less than $.01^{o}/oo.km^{-1}$ was probably present. Sampling was done with a rosette sampler with thermometerframes attached to some of the 1.2 l waterbottles. Samples were taken every four hours at 5m,10m and 20m. Four oxygen bottles were filled at each depth, pickled with reagents within a few minutes, shaken twice and stored under water. Salinity samples from each depth and a nutrient sample were taken too. Thermometer readings were taken in duplicate from each depth only in April. Sampling was performed within a 100 m radius around the chosen drifter. In April six drifters were in use at the same time; the cluster radius was 500 m. Oxygen samples were titrated according to the high precision method described in Tijssen (1980). After removing outliers the mean and standard error of the three- or fourfold oxygen samples were computed. The March samples had a standard error of .1 % (N=35), the April samples .2 % (N=50). Salinities were measured on an Autosal 8400 Guildline salinometer.

3. Results

3.1. Hydrographic and atmospheric conditions

Local salinity, water temperature and wind speed are given in fig 1, together with daily irradiance values from de Kooy airport near Den Helder. Vertical salinity and temperature differences were almost absent and a mean watercolumn value is therefore given.

The two parts of the March curve were not taken in exactly the same watermass as the vessel was in Den Helder in between those periods and the drifter could not stay at sea without supervision.

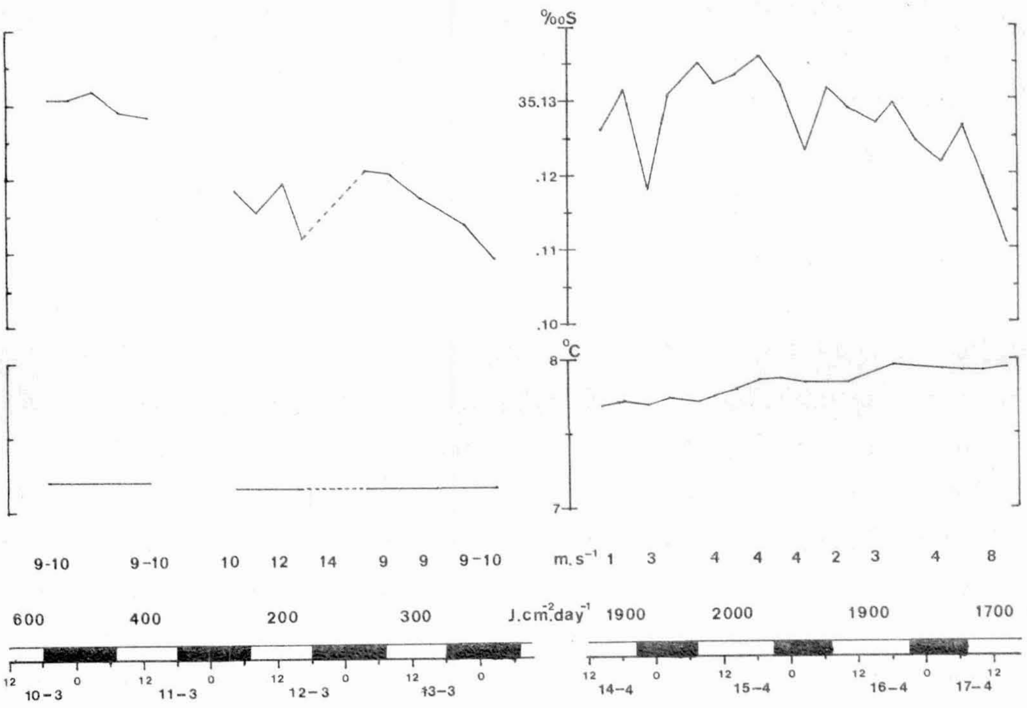

Fig. 1. Hydrographic and atmospheric conditions in March and April. Salinity, watertemperature, windvelocity, daily irradiance and light/dark periods.

3.2. Oxygen concentrations and concentration changes

Mean watercolumn oxygen concentrations were calculated with the formula:

$$\left[O_2\right] = 0.3\left[O_2\right]_{5m} + 0.3\left[O_2\right]_{10m} + 0.4\left[O_2\right]_{20m}$$

and are given in fig. 2. A and C. In March weather conditions did not permit to take a long series in one watermass due to heavy pitching of the Aurelia, but a 48 hours curve interrupted by several missing points could be obtained. In April calm, sunny weather permitted a 72 hours sampling period with no interruptions, but several "non-consistent" points in the curve occurred. Points (1), (2) and (3) were not used and the last part of the curve was shifted downwards 7.5 μgat.dm^{-3}. Sampling near a wrong drifter was a possible cause. For points (2) and (3) salinity values seem to warrant their removal. Oxygen production rates were deduced from the smoothed concentration curves.

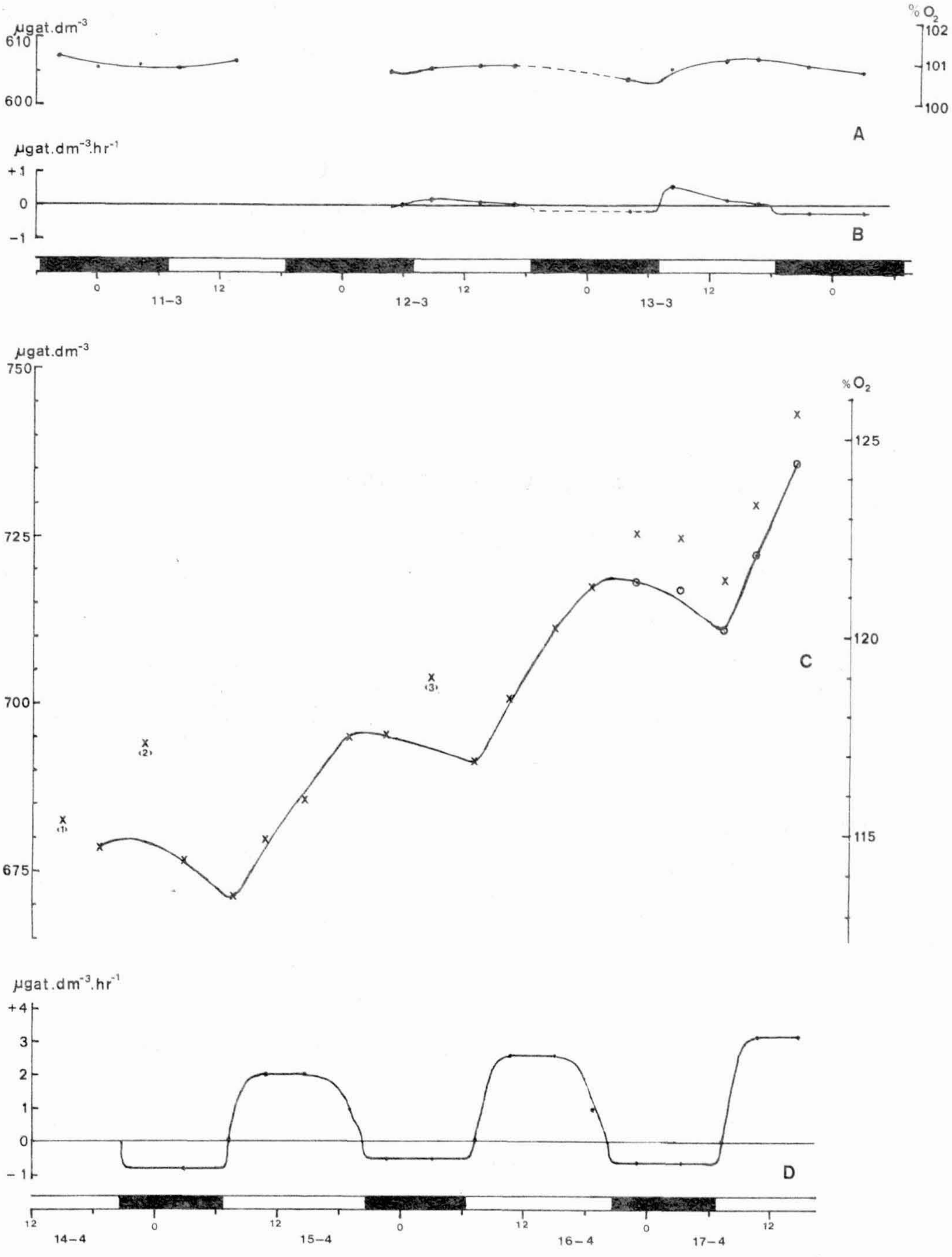

Fig. 2. Oxygen concentration curves from March (A) and April (C).
Rates of change of oxygen concentrations in March (B) and April (D).
x = original values o = shifted values.

The first derivative was graphically computed at sampling times (fig. 2B and D). The night part of the curves usually contained only 2 or 3 concentration values and mean night rates were therefore computed and are used in the rate curves.

4. Discussion

4.1. Definitions and oxygen to carbon conversion

In the discussion we shall use the following practical definitions:

I. Net daily community production of oxygen (NCPO) is the maximum difference of oxygen concentration detected within one day in a given watermass and corrected for exchange with the atmosphere (dimension $g\ O_2\ m^{-3}.d^{-1}$ or $g\ O_2\ m^{-2}.d^{-1}$)

II. Gross daily community production of oxygen (GCPO) is NCPO corrected for respiratory- and consumption losses, derived from the night decrease in oxygen concentration (RCLO) and assuming that night and day hourly losses are equal.

We realize that this gross production definition can be severely critisized, since photorespiration may be much higher than night respiration. In that case however the defined GCPO is at least a minimum estimate.

The conversion of oxygen production to carbon production is a matter of discussion too. In cases of steady-state production one can assume assimilation and mineralisation to be applicable. A photosynthetic quotient of 1.25 is therefore used for the March production values ($1\ g\ O_2 \triangleq 0.3\ g\ C$).

In April we happened to measure in an algal bloom with high long term net oxygen production far away from steady state conditions. In this case we better assume nitrate assimilation for NCPO (PQ= 2.0, $1g\ O_2 \triangleq 0.19\ g\ C$) and ammonia assimilation for GCPO minus NCPO (Williams et al, 1979)

4.2. NCPO, RCLO and GCPO

In many cases net oxygen production values derived from the concentration curves have to be corrected for exchange with the atmosphere. Provisional calculations for these cruises show that the corrections are of minor importance considering the low supersaturation in March and the low wind velocities in April ; for the time being they are neglected. GCPO is theoretically hardly affected by oxygen exchange under these condititions. In a homogeneous watercolumn of 25 m depth, 1 µgat $O_2 .\ dm^{-3} .h^{-1}$ corresponds to 0.4 g $O_2 .\ m^{-2} .h^{-1}$.

Daily and hourly oxygen values are given in table 1.

One has to bear in mind the different lengths of daylight periods in March (11 hours) and in April (14 hours).

Table 1

Net and gross oxygen production and oxygen consumption values in the Southern Bight of the North Sea at 52°45' N, 3°30' E.

	NCPO		RCLO			GCPO	Dimensions
March 12-13	0.4	1.4	1.0	1.0		1.7	g $O_2 .\ m^{-2} .d^{-1}$
	0.04	0.13	0.08	0.08			g $O_2 .\ m^{-2} .h^{-1}$
1980							
April 14-17	10	11	3.4	1.7	3.0	14.3	g $O_2 .\ m^{-2} .d^{-1}$
	0.71	0.79	0.34	0.17	0.30		g $O_2 .\ m^{-2} .h^{-1}$

Only one gross production value is given calculated as the mean from all available NCPO and RCLO values.

Considering the mean NCPO of 0.9 g $O_2 .m^{-2} .d^{-1}$ and the RCLO of 1.0 g $O_2 .\ m^{-2} .\ d^{-1}$ in March, these values almost balance each other; the mean oxygen concentration is furthermore near saturation. The impression obtained from these facts is a roughly steady state community metabolism with a moderate to low NCPO.

The derived carbon productions are given in the next table.

Table 2

Net and gross carbon production
in g C $m^{-2} .d^{-1}$

	Net	Gross
March 12-13	0.3	0.5
1980		
April 14-17	2.0	3.1

Comparison of these figures with those of Gieskes and Kraay (1975 and 1977), obtained with ^{14}C-method, for their subareas VI and VII shows that the values presented here are at least in the same range.
Even in April we find gross production to be at least 50 % higher then net production. If respiration in fast growing (pure) algal populations is indeed 0.5 %.h^{-1}, then again (Gieskes and Kraay, 1977) the major part of the oxygen losses must be contributed by heterotrophs.
The detailed shape of the April concentration curve allows two more interesting conclusions. First, the light period rates are remarkably constant. This observation suggests light-saturated production during the greater part of productive hours. In the second place the maximum production rate increased linearly from 2.0 to 2.6 to 3.2 µgat. $dm^{-3}h^{-1}$. The algal bloom, therefore appears to be in the straight part of the theoretical growth rate curve. If light- and nutriënt conditions permit, this growth rate increase could easily rise the oxygen concentrations in a week time to as high as 150 %. Linear back extrapolation places rate zero at 10 April 1980. The incorporation of an exponential first part of the growth curve reduces the start of the bloom to a date at least several days earlier.

The method described allows to gather quantitative production (positive and negative) estimates in open sea water with the exclusion of problems connected with the incubation of samples. The disadvantages are at the same time apparent,: the researchvessel can only make small trips in the vicinity of the drifter buoy during one measuring period and disturbances by horizontal variability are not unlikely. The latter point has not been studied sofar but needs close attention in the future.

5. Literature

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