The South African SIBEX I Cruise to the Prydz Bay region, 1984: VII. Light, chlorophyll *a* and primary production in the survey area

B.R. Allanson
Dept. of Zoology and Entomology
Rhodes University, Grahamstown 6140

This paper reports on some of the light properties, and the vertical and horizontal distribution of algal biomass in the study area. The usefulness of these in indicating the presence of continental-shelf transitional areas, as well as major hydrographic features, is evaluated. Three important features of this area were identified.

In dié artikel word verslag gedoen oor 'n aantal ligeienskappe van die algbiomassa in die ondersoekgebied, asook oor die vertikale en horisontale verspreiding van die alge. Die bruikbaarheid van hierdie gegewens as aanduidings van die aanwesigheid van vastelandsplatoorgange, asook van belangrike hidrografiese kenmerke, word geëvalueer. Drie belangrike kenmerke van dié gebied is geïdentifiseer.

Introduction

This contribution reports on some of the light properties of the ocean over the SIBEX I grid as well as the vertical and horizontal distribution of algal biomass as defined by chlorophyll *a* concentrations. These properties are examined in the light of onboard determinations of photosynthetic activity. A valuation is made of their usefulness in indicating the presence of continental-shelf transitional areas as well as major hydrographic features such as gyres.

Results and Discussion

Light

At each daytime station where weather permitted Secchi disc transparency was measured using a 300 m diameter disc. At the same station the attenuation (km^{-1}) was determined using a Carbon −14 Agency, Denmark photometer, the photosensitive element being a selenium barrier cell. A bandpass filter (Schott VG 14) was placed in the light path. The filter has a λmax = 525 nm, T max = 85 % and $\Delta\lambda^{1}/_{1000}$ = 120 nm (473-593 nm). Thus the instrument read the average attenuation coefficient in the interval 473-593 nm which represents the lower wavelengths of those generally considered effective in photosynthesis.

Fourteen Secchi disc transparency measurements were successful and 10 attenuation measurements were made. From these data a mean Secchi disc depth of 19,4 ±2,7 m was found and a mean attenuation coefficient, $\bar{k}$ = 0,052 ±0,01 m^{-1} obtained equivalent to a euphotic depth, 1 % = 99 ±11 m. The relation between the Secchi disc depth (D) and $\bar{k}$ m^{-1} for λmax of 525 nm is given by $\bar{k}\ m^{-1} = \frac{1{,}01}{D}$. Thus when the attenuation coefficient cannot be measured, a good approximation of k is given by the reciprocal of D, namely 0,052. The euphotic depth (1 %) is then found from ln 100/0,052 = which falls within the standard deviation of the distribution found for the euphotic depth during this cruise. We therefore suggest that this reciprocal of Secchi disc depth replace that normally used for the estimation of k, namely 1,70/D (Parson *et al.* 1979). This would seriously underestimate the euphotic depth.

The high transparency of this region of the Antarctic Ocean at this time of the year reflects reduced algal growth, and the loss of cells from the upper mixed layer. The elevation of plant pigment just above the insertion of the Winter Water between 90 – 100 m coupled with the low integral primary productivity values supports this view.

Chlorophyll *a*

The concentration of chlorophyll *a* was determined from 5 ℓ samples using the SCOR-UNESCO method (Strickland & Parsons 1968). The samples were taken from the same depth as were used for C-14 production measurements within the euphotic zone. A comparison between the efficiency of Whatman GF/C and GF/F glass fibre filters was made at each station and depth. No significant difference was established between the filter types.

Chlorophyll increased southwards through the euphotic depth as shown in Figure 1. Marked elevations between 80 and 100 m were often linked to the presence of pycnoclines

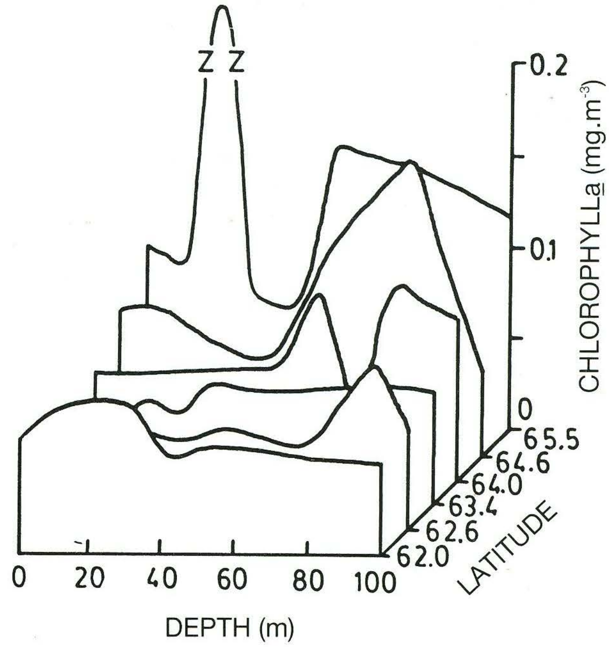

Fig. 1. The distribution of chlorophyll *a* with depth and latitude within the SIBEX grid.

at which the cells of predominantly *Thalassiothrix longissima* accumulated. The highest concentration of chlorophyll was found in the vicinity of the pack-ice (65°22'S, 56°00'E), 0,255 mg m^{-3} at 28 m. Overall the chlorophyll was low, 0,04 – 0,88 mg m^{-3} (n = 86) which matched very closely the data of Henry (1983) from the South African FIBEX exercise. This differs widely from the results from two stations occupied by the Japanese icebreaker *Fuji* (Ino & Fukuchi 1984) within our grid area. On February 23 and 24, 1982 they recorded a mean chlorophyll *a* over the same depth of 0,25 – 0,06 mg m^{-3} at 63°00'S, 53°00'E and 0,27 – 0,04 mg at 63°00'S 60°00'E. A comparison is shown for four stations in Figure 2.

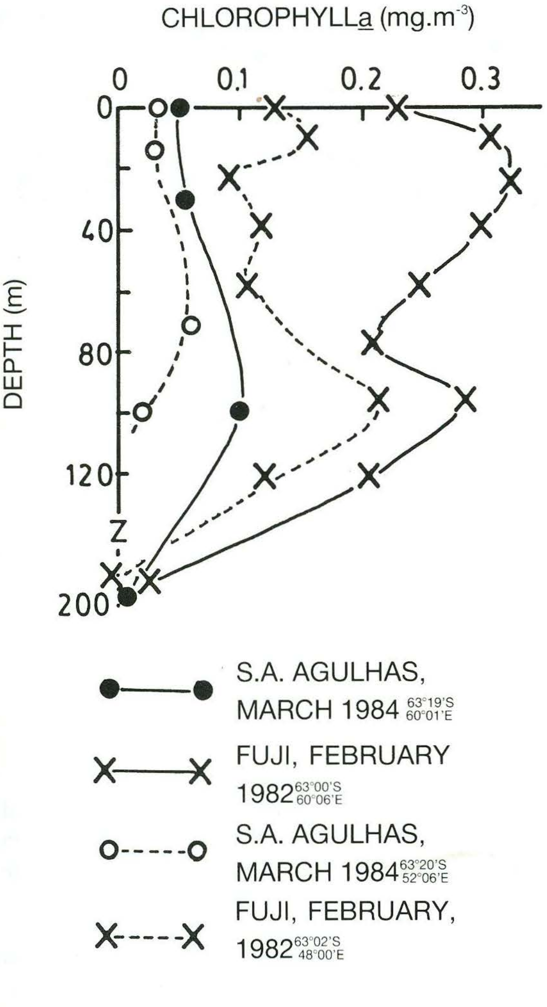

Fig. 2. Variations in chlorophyll *a* concentrations within the water column showing a deep chlorophyll maximum at 100 m.

The existence of a deep chlorophyll maximum at about 100 m is evident in the Japanese data as in our own, although as Figure 1 shows this maximum was more obvious at stations south of 63°S, nearer to the pack-ice.

Primary production

At each of 23 day stations C-14 primary productivity measurements were made using an onboard incubator. Samples were drawn from light depths equivalent to the neutral density filter array used in the incubator. Surface samples were exposed to 100 % and 150 % irradiance. The light flux measured at the sea surface and in the incubator was similar, 356 μEinstein $m^{-2}s^{-1}$. The samples were incubated for 4 hours at a specific activity equivalent to 4 μCi 100 $m\ell^{-1}$. The standardised $Na^{14}CHO_3$ used was supplied by the Carbon-14 Agency, Denmark.

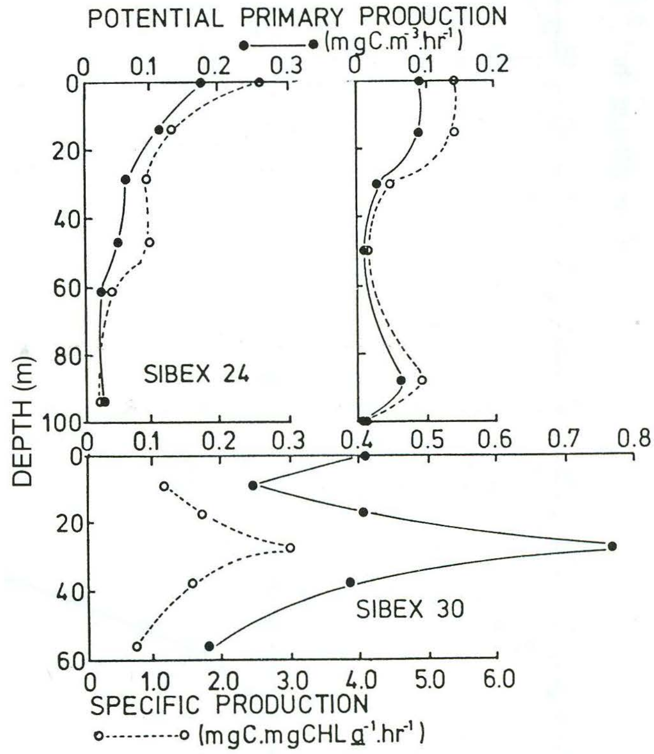

Fig. 3. Variations in primary production with depth and specific production.

The marked variation in vertical distribution of chlorophyll is reflected in the primary productivity/depth curves shown in Figure 3. Because of the vertical variation in carbon fixation, the simple arithmetic models for estimation of integral production could not be used. In order, therefore, to generate values of integral photosynthetic fixation, the areas under the curves were obtained planimetrically. These integrals are given in Figure 4.

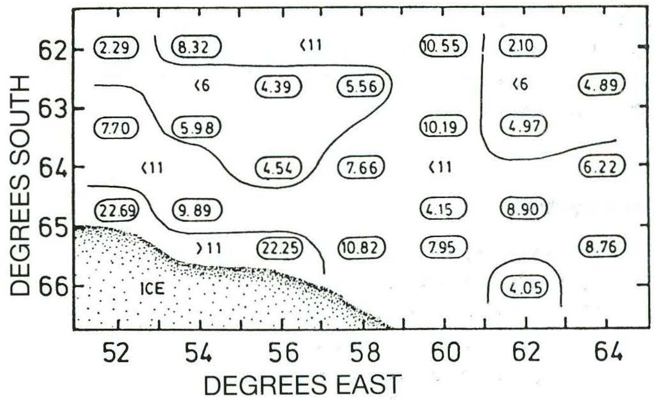

Fig. 4. Integrals of potential primary production (mg $C.m^{-2}h^{-1}$) over the SIBEX grid.

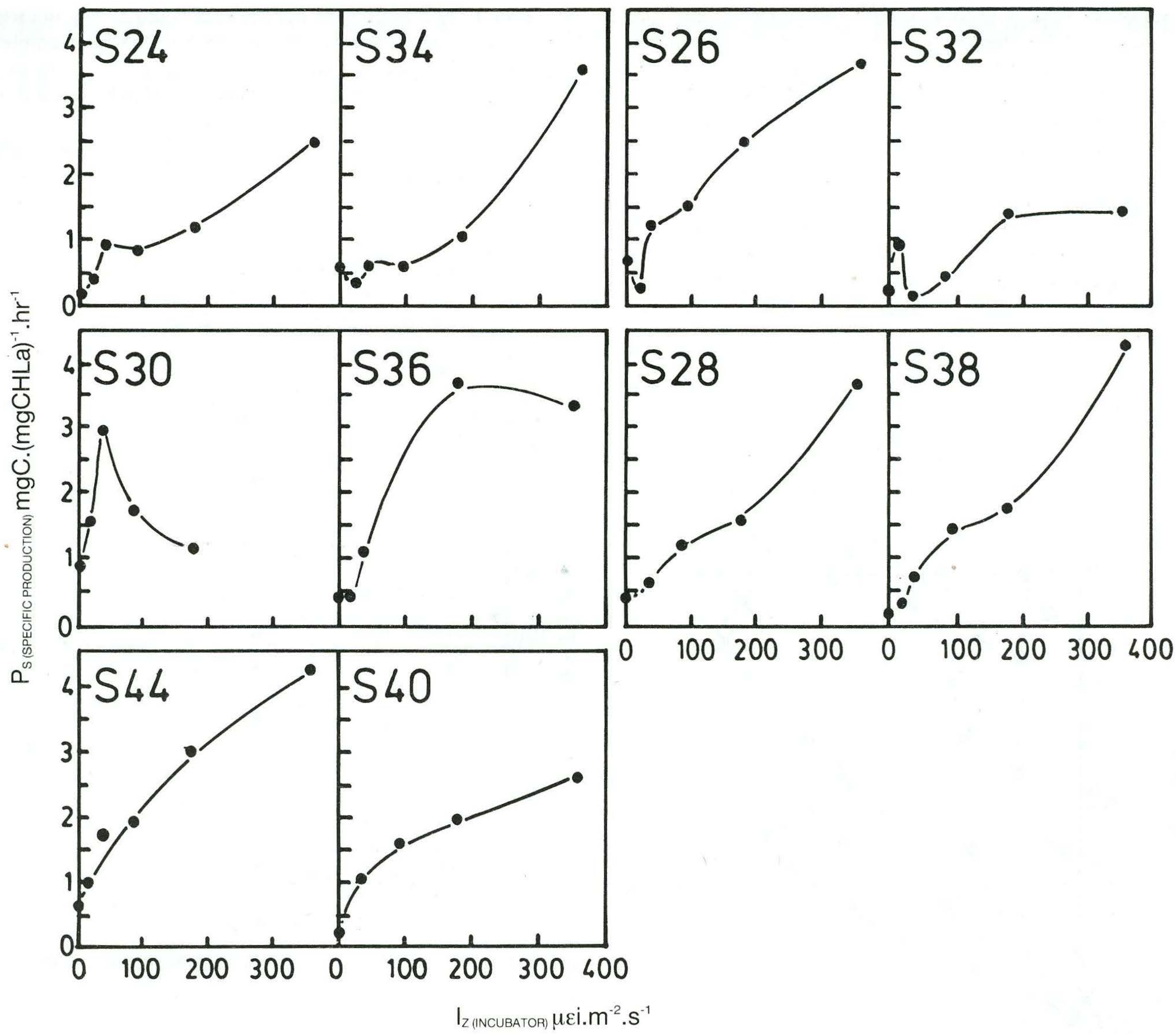

Fig. 5. Production – light intensity curves for a number of SIBEX stations showing the variation in slope and minimal inhibition.

The southward increase of areal productivity is clear as would be expected from the general increase in phytoplankton biomass. The levels of this productivity are within the range found in comparable south latitudes during FIBEX. Cognizance must be taken however when making this comparison of the depth of the euphotic zone – the shallower the zone, the higher is the chlorophyll *a* concentration to effect the same integral of production.

Discussion

While these descriptive data are of comparative value, those which can relate specific productivity (mg C.mg Chl$a^{-1}h^{-1}$) to light flux in P/I curves are of greater interpretative value. These data are illustrated in Figure 5.

The variation shown is not as unsystematic as would first appear. The changes in slope of the curves at low light intensity confirms; (1) the accumulation of algal biomass at the bottom of the euphotic zone, and (2) a change in community structure. P/I curves are species specific, and in a well-mixed euphotic zone, the curve is generally accepted as a mean construct. A further important observation is that only the communities at S 30 (64°30'S, 56°00'E) and 36 (62°00'S, 54°00'E) showed inhibition. The communities at the remaining stations exhibited either a linear response or maximum productivity at the surface over the flux range used in the incubator. The linear response suggests that the phytoplankton community is not operating at maximum efficiency. This could be related to the accumulation of chorophyll degradation products. Evidence for this comes from two studies by Bacon, Monteiro & Orren (unpublished) and Orren, Monteiro & Haraldsen (this volume). Using HPLC techniques on filtered samples from standard depths they have shown the presence of chlorophyllide which, because it absorbs at the same wavelengths as chlorophyll *a*, could give an over-estimate of photosynthetic pigment. Similarly the acidification of acetone extracts produced acid ratios near unity. This indicated increased concentration of phaeo-pigments relative to chlorophyll *a* in the phytoplankton.

Conclusions

While our evidence in support of a gyre is equivocal, the studies reported on this paper emphasise, in addition to a marked increase in photosynthetic activity at the continental shelf transition (Figs. 1 and 4), at least three important features of this sector of the Antarctic ocean: (1) poor mixing of the upper 100 m, the depth of the euphotic zone and as a consequence, (2) marked vertical distribution in chlorophyll and, therefore, phytoplankton abundance, and finally (3) algal communities may have developed photosynthetic systems capable of short-wavelength absorption (Raymont 1980).

Implicit in these results is the need to provide: (1) a satisfactory analysis of the hydrodynamic structure and processes within the upper 100 m of these seas, (2) an analysis of the change in algal species structure throughout the water column, and (3) their photosynthetic efficiency included within which is a critical examination of *in situ* and incubator techniques. It is hoped that SIBEX II will direct attention to these and other components of upper oceanic processes which must influence the productivity and, therefore, abundance of zooplankton including krill.

References

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