

Zooplankton-phytoplankton relationships at the Prince Edward Islands during April/May 1985 and 1986

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Time-course measurements of water-column fluorescence, zooplankton gut pigment and phytoplankton concentration were made at the Prince Edward Islands during April/May 1985 and 1986. Fluorescence records showed a decrease in pigment levels during the night. This is particularly marked in the pico- and nanosize fractions. This, coupled with the zooplankton total gut pigments suggests that grazing is responsible. The netsize plankton, however, did not show any general trend of diurnal variations and only very few species in this size class showed a significant night decrease in the water-column. As the persistent phytoplankton blooms in the area are mostly composed of netplankton, it is suggested that this rich food source is scarcely exploited by the pelagic grazers. The possible direct transfer of primary biomass from the pelagic to the benthic subsystems is also discussed.

Tydreksmetings van waterkolom-fluoresensie, soöplankton-dermpigment en fitoplanktonkonsentrasie is geneem by die Prins Edward-eilande gedurende April/Mei 1985 en 1986. Fluoresensierekords het 'n afname in pigmentvlakke gedurende die nag getoon. Dit is veral opvallend in die pico- en nanogrootte fraksies. Dit, tesame met die totale soöplankton dermpigmente, stel voor dat beweiding verantwoordelik is. Die netgrootte plankton het egter nie enige algemene neiging tot daaglikse variasies getoon nie en baie min spesies in hierdie grootteklas het 'n beduidende nagtelike afname in die waterkolom getoon. Omdat die volgehoue fitoplanktonbloeie in die gebied meestal saamgestel is uit netplankton, word voorgestel dat hierdie ryk voedselbron feitlik nie ontgin word deur pelagiese beweidings nie. Die moontlike direkte oordrag van primêre biomassa vanaf die pelagiese na die bentiese substelsels, word ook bespreek.

Introduction

Since the beginning of the investigation on the marine resources of the Prince Edward Islands (47°S, 38°E), the persistence of phytoplankton blooms in the shallow inter-island region has been widely shown (El Sayed *et al.* 1979, Allanson *et al.* 1985, Boden 1988). The relevance of these blooms is such that the local primary production rates appear to be an order of magnitude higher than at the notably rich Antarctic Polar Front (Boden 1988).

As yet, there is however no available information on how and to what extent this potentially rich food source is utilized by higher trophic levels.

Some aspects of the interaction between the local community of pelagic filter feeders and phytoplankton blooms were investigated during the April/May 1985 and 1986 cruises of SA *Agulhas* to the Prince Edward archipelago and are presented in this paper.

Methods

Time-course recording of the fluorescence levels in the water-column was made at intervals of four hours during the 1985 cruise by using a Turner Model 111 fluorometer (Yentsch & Menzel, 1963). Two stations of 30 and 36 hours were occupied: station A, located over the Natal Bank, and station B, located midway between Prince Edward and Marion Islands (Fig. 1). Water samples for fluorescence analysis were collected with 1.7 l Niskin bottles at six standard depths, i.e. 0, 10, 20, 30, 40 and 50 m at station A and 0, 20, 40, 60, 80 and 100 m at station B.

At the same stations and with the same frequency, zooplankton was collected with a 200 µm WP-2 UNESCO net by vertical hauls from the bottom to the surface.

Gut pigment level for the major groups (copepods, ostracods and euphausiids) was determined following the method of Mackas & Bohrer (1976). Six and eight pigment measurements were made at stations A & B respectively in conjunction with the determination of fluorescence levels.

Phytoplankton and zooplankton samples were obtained during the 1986 cruise at two 24 hour stations, D and C, situated north of Marion Island and between the eastern coast of Marion Island and the Natal Bank respectively (Fig. 1). At each station, zooplankton sampling was carried out with the same procedure adopted during 1985. Phytoplankton was obtained by pumping water through a

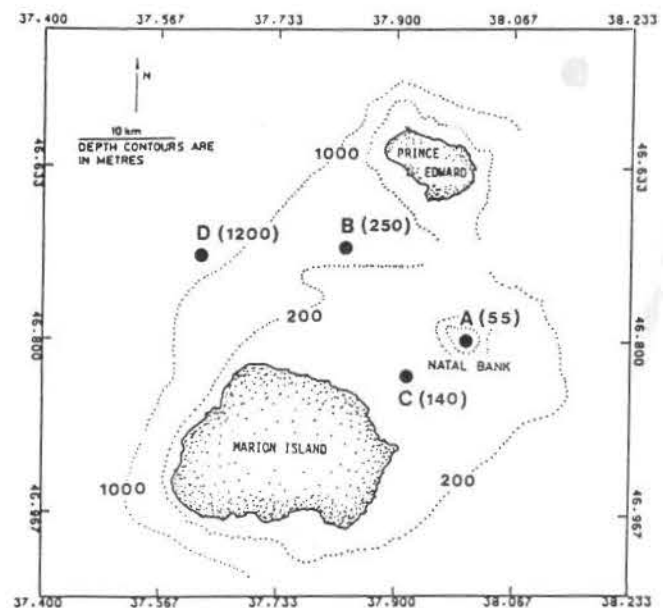


Fig. 1. Position of the sampling stations at the Prince Edward Islands. Stations A and B were occupied during April/May 1985, stations C and D were occupied during April/May 1986.

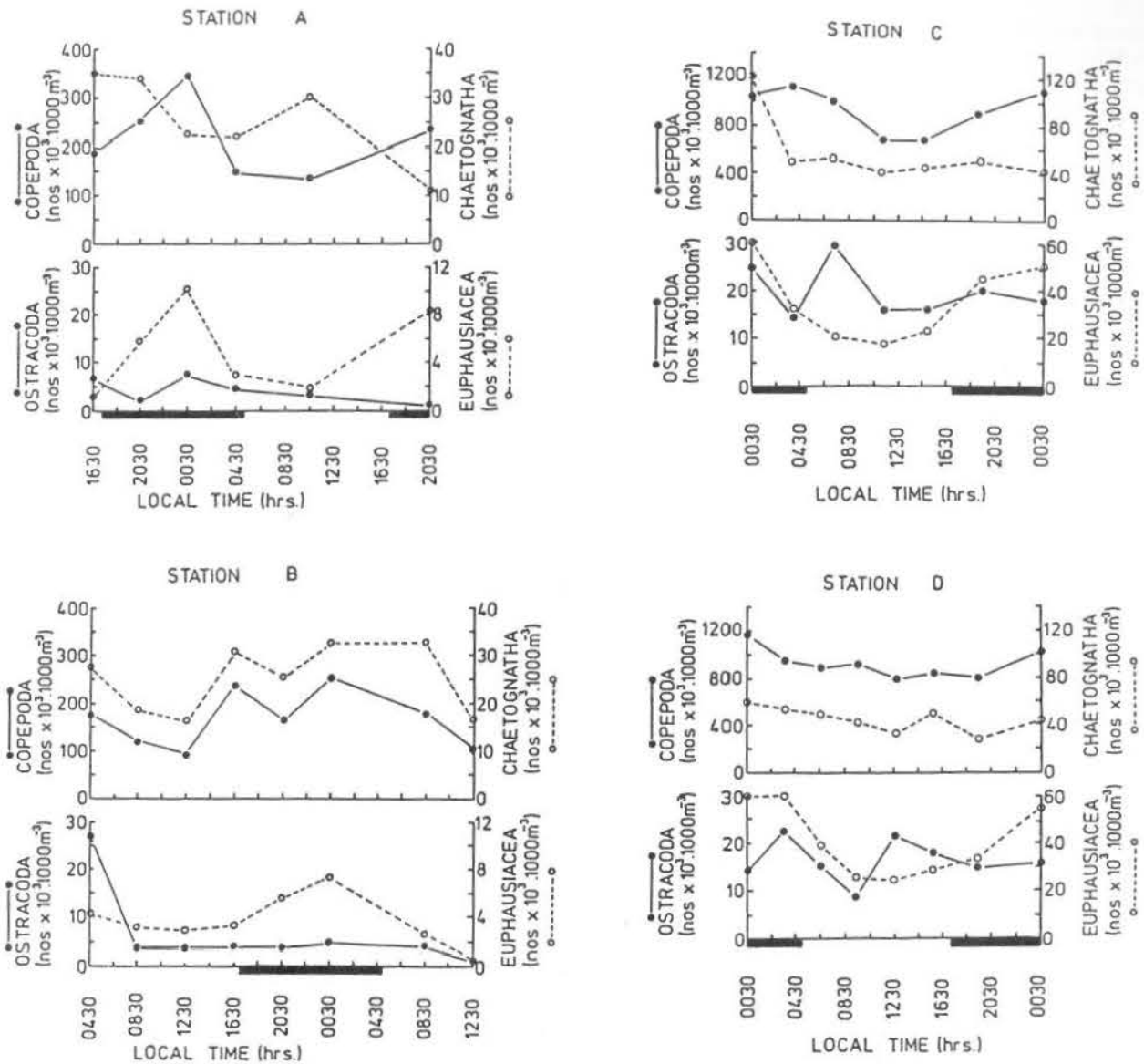


Fig. 2. Abundance estimates of the four dominant components of the zooplankton community (stations A and B, April/ May 1985; stations C and D, April/ May 1986). Period of darkness is indicated by thickening of the horizontal axis.

large-scale filtration apparatus (Berman & Kimor 1983) at a flow rate of about 15 l/m by means of a submersible pump. Phytoplankton was retained by three different filtration units of 130, 80 and 22 μm nominal mesh size. The filtration system was operated at regular intervals of about three hours and water was pumped from two standard layers, i.e. from 50 m to 25 m and from 25 m to the surface.

Aliquots of the phytoplankton samples were counted for the major taxa by means of an inverted microscope after sedimentation in 10 ml chambers (Hasle 1978).

Fluorescence and phytoplankton data were normalized by the transformation $\text{Log}(x + 1)$ which also provides for zero values (Cassie 1968). Numerical differences between day and night samples were tested by the analysis of variance subprogram ONEWAY of the SPSS statistical package (Nie *et al.* 1975). The pooled variance model was used to test all possible *a priori* contrasts between the different groups by the t-statistics.

Results and discussion

Zooplankton gut pigment.

In both years the zooplankton community was largely dominated by copepods (Fig. 2) which constituted about 85 per cent

and 95 per cent in number of the total catch of 1985 and 1986 respectively (Perissinotto in press). Ostracods and euphausiids were very poorly represented, each constituting less than three per cent in both years. The chaetognaths contributed about 12 per cent of the total in 1985 and two per cent in 1986. However, this is not a constant structure as the zooplankton community of the Prince Edward archipelago presents a great diversity with frequent changes in dominance (Allanson *et al.* 1985, Boden & Parker 1986). Fluorescence levels, measured in each group of herbivores during 1985, showed that the ostracods had the highest pigment content per individual (Fig. 3). However, when considering the pigment level per unit volume the copepods made the greatest contribution (Fig. 3).

Strong diurnal feeding rhythms were evident in the copepods and ostracods at both stations. Diurnal variations were, however, hardly detectable in the gut pigments of euphausiids (Fig. 3). Night-time peaks, with maxima recorded between 1800 and 2200 hours, constituted an almost constant pattern, indicating a possible synchronism in the timing of onset of night feeding in all of the groups. At the Prince Edward Islands, intermittent feeding is expected in the case of strong vertical migrants, like euphausiids and the copepod *Metridia gerlachei* (Perissinotto in press), as they are in contact with their food source only during part of the

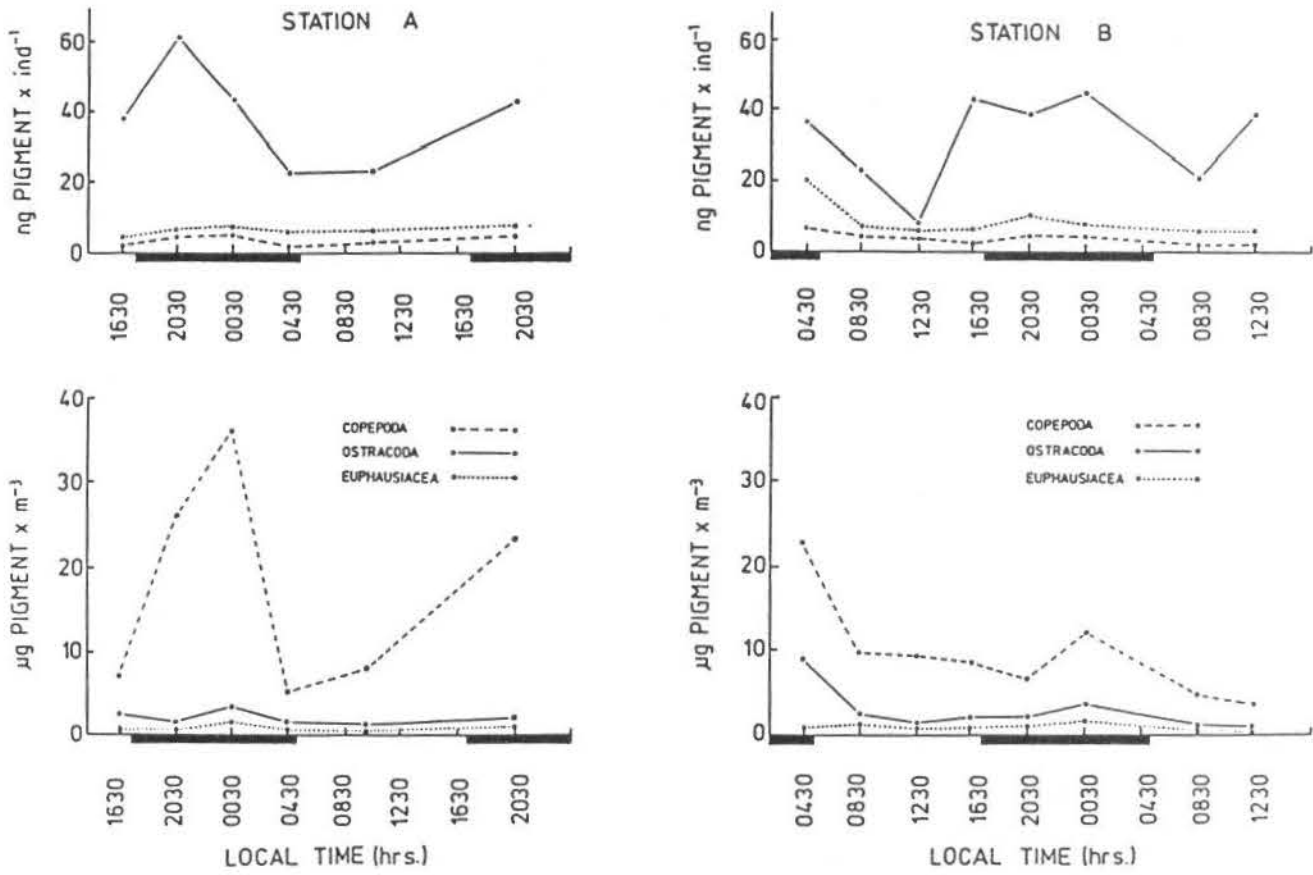


Fig. 3. Variations in total gut pigment levels per individual zooplankter and per unit volume (April/May 1985). Period of darkness is indicated by thickening of the horizontal axis.

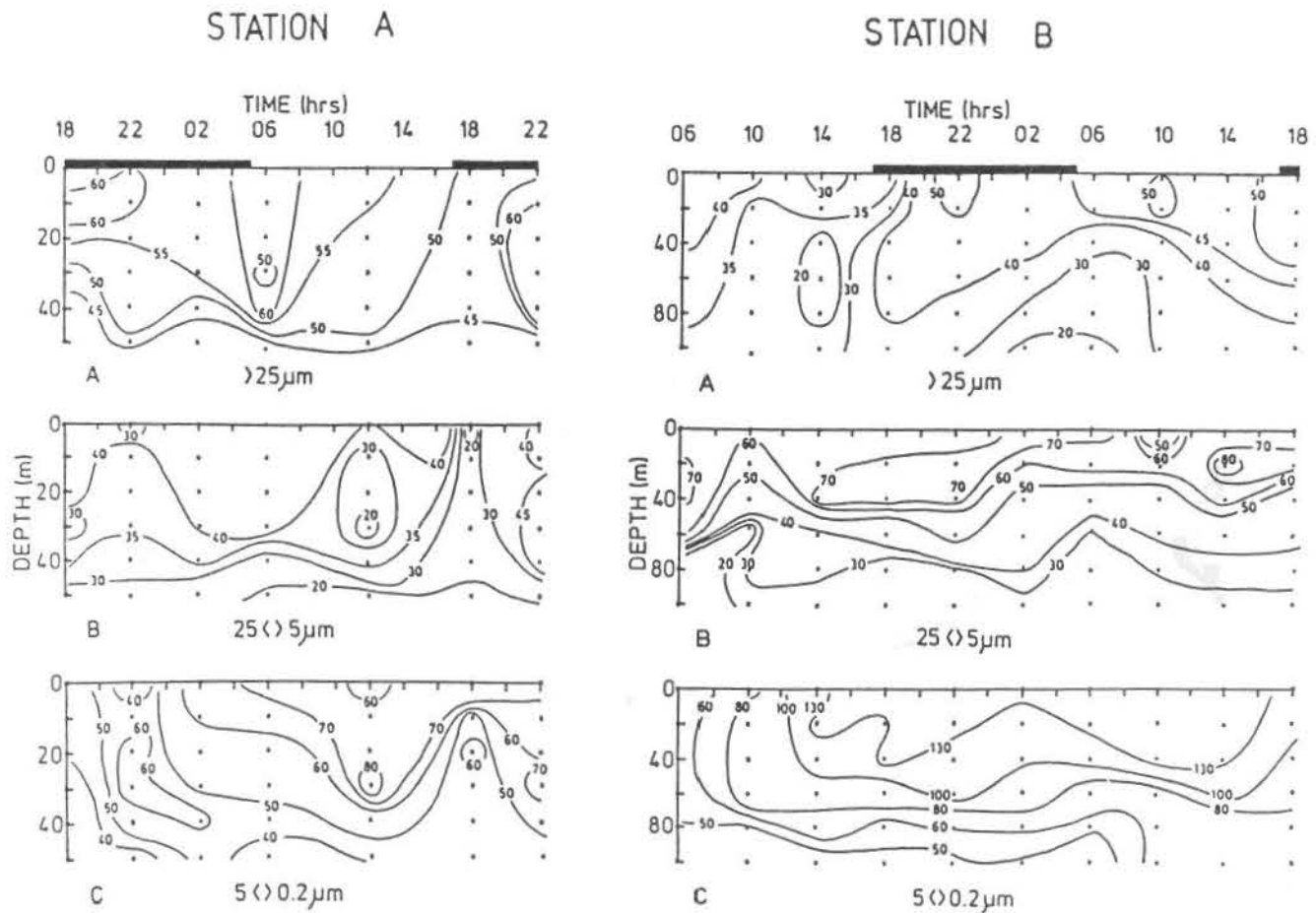


Fig. 4. Time-course depth profiles of the relative fluorescence of three size fractions of phytoplankton (April/May 1985). Period of darkness is indicated by thickening of the horizontal axis.

day. Intermediate or upper-layer migrants, like the bulk of the copepods, and non-migratory forms, like the ostracods, are however permanently in contact with their food and a continuous feeding pattern would be expected. Thus, these results indicate that the diurnal feeding rhythms of the local zooplankton may not be related to vertical migratory behaviour. This would support the hypothesis that vertical migrations and diurnal feeding activity of zooplankton are distinct processes controlled independently, although both are probably initiated by critical light levels (Head *et al.* 1985).

Table 1
Product-moment correlation matrices of zooplankton gut pigment versus size fractions of water-column fluorescence. As the comparison involves only one value per time-point, fluorescence levels were integrated over the entire water-column sampled. Station A, n = 6; station B, n = 8. Level of significance: 90 % (*), 95 % (**).

STATION A	copepods	ostracods	euphausiids
net ($\mu\text{m} > 25$)	-0.443	0.560	0.317
nano ($5 < \mu\text{m} < 25$)	0.298	0.645 *	0.244
pico ($0.2 < \mu\text{m} < 5$)	0.014	0.521	0.345
STATION B	copepods	ostracods	euphausiids
net ($\mu\text{m} > 25$)	0.550	0.450	0.532
nano ($5 < \mu\text{m} < 25$)	0.425	0.394	0.080
pico ($0.2 < \mu\text{m} < 5$)	0.296	-0.222	0.887 **

Table 2
Phytoplankton ANOVA matrix (t-statistics of pooled variance); contrasts between day and night data from April/May 1986. Level of significance: 90 % (*), 95 % (**), 99 % (***).

STATION LAYER	C 50m-surf.	D 50m-surf.
<i>Chaetoceros atlanticus</i>	0.45	0.50
<i>Chaetoceros affinis</i>	0.57	0.71
<i>Coscinodiscus</i> complex (87 μm)	1.19	0.24
<i>Coscinodiscus</i> complex (10 μm)	1.92 *	1.93 *
<i>Rhizosolenia alata</i>	0.48	2.52 **
<i>R. alata f. curvirostris</i>	0.16	0.65
<i>Nitzschia</i> spp.	1.75	1.03
<i>Fragilaria granulata</i>	1.24	0.26
<i>Fragilaria striatula</i>	5.30 ***	1.09
<i>Gymnodinium</i> complex (17 μm)	0.84	2.03 **
<i>Gymnodinium</i> complex (45 μm)	0.23	1.64
<i>Corethron crophilum</i>	1.41	0.89
<i>Pleurosigma</i> complex (40 μm)	0.85	0.98
<i>Pleurosigma</i> complex (90 μm)	1.62	0.51
<i>Pseudoenotia doliolus</i>	0.23	1.67
<i>Thalassiothrix longissima</i>	0.31	0.72
<i>Dactyliosolen antarctica</i>	1.67	1.30
<i>Ceratium</i> spp.	0.90	1.94 *
<i>Dictyocha speculum</i>	0.23	1.57
<i>Gonyaulax</i> complex (36 μm)	0.15	0.39

Phytoplankton and fluorescence

Fluorescence measurements showed that fairly high values are found from the surface to 50 m. Nano- ($5 < \mu\text{m} < 25$) and picoplankton ($0.2 < \mu\text{m} < 5$) appeared to show some degree of a diurnal cycle, with higher values observed during the day (Fig. 4). The reduction in fluorescence during the night was especially marked in the 0.2-5 μm fraction at both stations A and B. Conversely, the netsize plankton ($> 25 \mu\text{m}$) did not show any clear trend of diurnal variations. When these results are viewed in conjunction with the levels of zooplankton gut pigment, it appears

as though grazing played an important role in determining such a pattern. As the product-moment correlation coefficients show (Table 1), the only significant relationships between fluorescence levels and amount of pigment per individual zooplankter was found for the pico- and nanosize classes. These fractions were positively correlated with the gut content of euphausiids and ostracods respectively (Table 1). None of the zooplankton groups had significant correlations with the fluorescence levels in the netsize class. This is consistent with the results of the time-course analysis of the major netplankton taxa encountered during April/May 1986. At that time a significant night decrease in number in the upper watercolumn was observed only for five out of the twenty phytoplankton groups examined (Table 2). Specifically, *Coscinodiscus* complex (10 μm diameter) decreased both at station C and D, *Rhizosolenia alata*, *Gymnodinium* complex (17 μm diameter) and *Ceratium* spp. decreased only at station D while *Fragilaria striatula* decreased only at station C (Table 2).

The contribution of the pico- and nanoplankton ($< 20 \mu\text{m}$) to the phytoplankton biomass of the Prince Edward Islands is quite low compared to other areas of the Southern Ocean and amounts to only 21.5 ± 6.33 per cent of the total (El Sayed *et al.* 1979). Similarly, measurements of size-fractionated primary production indicate that picoplankton contributes about seven per cent and nanoplankton about 11 per cent to the total phytoplankton production in the area (Boden unpubl.). This is probably related to the fact that the recurrent phytoplankton blooms observed in the shallow inter-island region of the Prince Edward archipelago are often composed mostly of the large diatom *Rhizosolenia curvata* and the spiny, chain-forming *Chaetoceros radicans* (Allanson *et al.* 1985, Boden 1988). Although some degree of copepod grazing on *Chaetoceros* has been shown (Schnack 1979), these diatoms are usually reported not to be relished by pelagic filter feeders (Parsons *et al.* 1967, Hargrave & Geen 1970). The silicoflagellate, *Dictyocha speculum*, is frequently found in bloom stage in these waters. It contains chloroplasts but is heavily silicified. It is not known to be a staple in zooplankton diet. It is, however, an important contributor to the local primary productivity.

The number of observations available for the Prince Edward Islands is still too limited to draw comprehensive conclusions. Nevertheless, the fact that during 1985 and 1986 a significant grazing impact of zooplankton on phytoplankton was detectable only on the pico- and nanosize fractions, seems to indicate that the local large autotrophic resource may go almost unexploited by the pelagic herbivores. If this were the case, the rich phytoplankton blooms could represent a very important transfer of biomass from the pelagic to the benthic subsystems, thus explaining the large benthic biomass observed in the saddle between the two islands (Boden & Parker 1986). The benthic-pelagic coupling seems to follow a direct pathway as high chlorophyll fluorescence values were measured at 50 m depth for all phytoplankton fractions (Fig. 4) and the bottom depth is partly above this level, especially on the Natal Bank (station A). Benthic filter feeders would then be in a position to utilize the phytoplankton directly.

There is also a possibility that bloom diatoms in the area undergo a mass sinking into deeper water in a similar fashion to that described by Bodungen *et al.* (1986) for the Bransfield Strait where the sinking was triggered by formation of resting spores. Resting spores, particularly of *Chaetoceros radicans* in bloom stage, have often been found in the phytoplankton of the Prince Edward Islands (BPB, pers. obs.) and appear to indicate a direct link between pelagic primary producers and benthic filter-feeders. However, we have no evidence that these spores sink below the mixed layer and, since *C. radicans* is an oceanic chaetoceric, suspect that they may be 'Schwebesporen' (Karsten 1905). The resting spores of forms such as the coscinodiscoid and navicoid

genera almost certainly sink, to remain dormant for a period or to enter the food chain.

Sinking vegetative cells and detrital organic matter are possibly the more important, direct contributors to the food chain. Evaluation of the impact of selective zooplankton grazing on fractionated size classes of phytoplankton by on-board, grazing experiments on selected, identified zooplankton taxa collected by bongo-nets were undertaken on a recent Marion Off-shore Ecological Study of the SA Scientific Committee for Antarctic Research (MOES II) - 03/29/89 - 05/08/89. In addition sediment traps were deployed in strategic positions on the shoal between Marion and Prince Edward Islands. The results of these investigations are not yet available but will be released as a separate contribution when they have been evaluated.

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References

- ALLANSON, B.R., BODEN, B.P., PARKER, L.D. & DUNCOMBE RAE, C.M. 1985. A contribution to the oceanology of the Prince Edward Islands. In: Antarctic nutrient cycles and food webs. Eds W.R. Siegfried, P.R. Condy & R.H. Laws. Springer-Verlag, Berlin, pp. 38-45.
- BERMAN, T. & KIMOR, B. 1983. A large-scale filtration apparatus for net plankton sampling. *J. Plankton Res.* 5: 111-116.
- BODEN, B.P. 1988. Observations of the island mass effect in the Prince Edward archipelago. *Polar Biol.* 9: 1-8.
- BODEN, B.P. & PARKER, L.D. 1986. The plankton of the Prince Edward Islands. *Polar Biol.* 5: 81-93.
- BODUNGEN, B. Von, SMETACEK, V.S., TILZER, M.M. & ZEITSCHHEL, B. 1986. Primary production and sedimentation during spring in the Antarctic Peninsula region. *Deep-Sea Res.* 33: 177-194.
- CASSIE, R.M. 1968. Sample design. In: Zooplankton sampling. Eds D.J. Tranter and J.H. Fraser. The UNESCO Press, Paris, pp. 105-121.
- EL SAYED, S.Z., BENON P., DAVID P., GRINDLEY, J.R. & MURAIL, J-F. 1979. Some aspects of the biology of the water-column studied during the Marion Dufresne cruise 08. *CNFRA* 44: 127-134.
- EL SAYED, S.Z., STOCKWELL, D.A., REHEIM, H.A., TAGUCHI, S. & MEYER M.A. 1979. On the productivity of the southwestern Indian Ocean. *CNFRA* 44: 83-110.
- HARGRAVE, B.T. & GEEN, G.H. 1970. Effects of copepod grazing on two natural phytoplankton populations. *J. Fish. Res. Bd. Can.* 27: 1395-1403.
- HASLE, G.R. 1978. The inverted-microscope method. In: Phytoplankton manual. Ed. A. Sournia. The UNESCO Press, Paris, pp. 88-96.
- HEAD, E.J.H., HARRIS, L.R. & ABOU DEBS, C. 1985. Effect of day length and food concentration on *in situ* diurnal feeding rhythms in Arctic copepods. *Mar. Ecol. Prog. Ser.* 24: 281-288.
- KARSTEN, G. 1905. Das phytoplankton des Antarktischen Meeres nach dem Material der deutschen Tiefsee-Exped., 1898-1899. *Dtsch. Tiefsee Exped.* 2: 139-219.
- MACKAS, D.L. & BOHRER, R. 1976. Fluorescence analysis of zooplankton gut contents and investigation of diet feeding patterns. *J. Exp. Mar. Biol. Ecol.* 25: 77-85.
- NIE, N.H., HULL, C.H., JENKINS, J.G., STEINBRENNER, K. & BENT, D.H. 1975. Statistical package for the social sciences, 2nd edition. McGraw-Hill, New York, pp. 675.
- PARSONS, T.R., LE BRASSEUR, R.J. & FULTON, J.D. 1967. Some observations on the dependence of zooplankton grazing on the cell size and concentration of phytoplankton blooms. *J. Oceanogr. Soc. Japan* 23: 10-17.
- PERISSINOTTO, R. In press. The structure and diurnal variations of the zooplankton of the Prince Edward Islands: implications for the biomass build-up of higher trophic levels. *Polar Biol.*
- SCHNACK, S.B. 1979. Feeding of *Calanus helgolandicus* on phytoplankton mixtures. *Mar. Ecol. Prog. Ser.* 1: 41-47.
- YENTSCH, C. & MENZEL, D. 1963. A method for the determination of phytoplankton chlorophyll and phaeophytin by fluorescence. *Deep-Sea Res.* 10: 221-231.