The South African SIBEX II Cruise to the Prydz Bay region, 1985: Cruise description and preliminary review of results

D.G.M. Miller
Sea Fisheries Research Institute
Private Bag X2, Roggebaai, 8012

This paper summarizes South Africa's participation in SIBEX II in the south Indian Ocean (48 - 64°E) during February - March 1985. The two basic objectives of the cruise were to provide a temporal comparison of oceanology in the region with earlier results from an Australian survey and to undertake meso/fine-scale studies of various processes associated with krill (Euphausia superba) *swarm dynamics. Unfortunately, survey work had to be prematurely curtailed as a result of rudder damage to the ship concerned (the R/S* Africana). *A review of data collected is given and an attempt is made at their interpretation.*

Die verslag bied 'n opsomming van Suid-Afrika se deelname in Februarie en Maart 1985 aan SIBEX II in die suidelike Indiese Oseaan (48°-64°0). Die vaart was gerig op 'n vergelyking in tyd van die gebied se oseanologie teenoor dié tydens 'n vroeëre Australiese opname, asook op 'n meso- en kleinskaalopname van kril (Euphausia superba) *se swermdinamika. Weens skade aan die skip (N/S* Africana) *se roer is die opname verkort. 'n Oorsig oor die data wat versamel is, en 'n voorlopige interpretasie daarvan, word hier gegee.*

Introduction

The south Indian Ocean research plan for the Second International BIOMASS Experiment (SIBEX) was structured around the proposed existence of a semi-permanent gyre in the Prydz Bay region (50-85°E)(Anon 1982). It has been hypothesized that this gyre is not only a prominent feature of the water circulation in this area but that it also exerts a significant effect on krill *(Euphausia superba* Dana) distribution. Four nations (Australia, France, Japan and South Africa) therefore agreed that their contribution to SIBEX would comprise a co-operative study of the above region, and as such would be implemented over two consecutive austral summers.

The first phase of the experiment (1983/4) attempted to identify the dominant oceanological features between 50 -

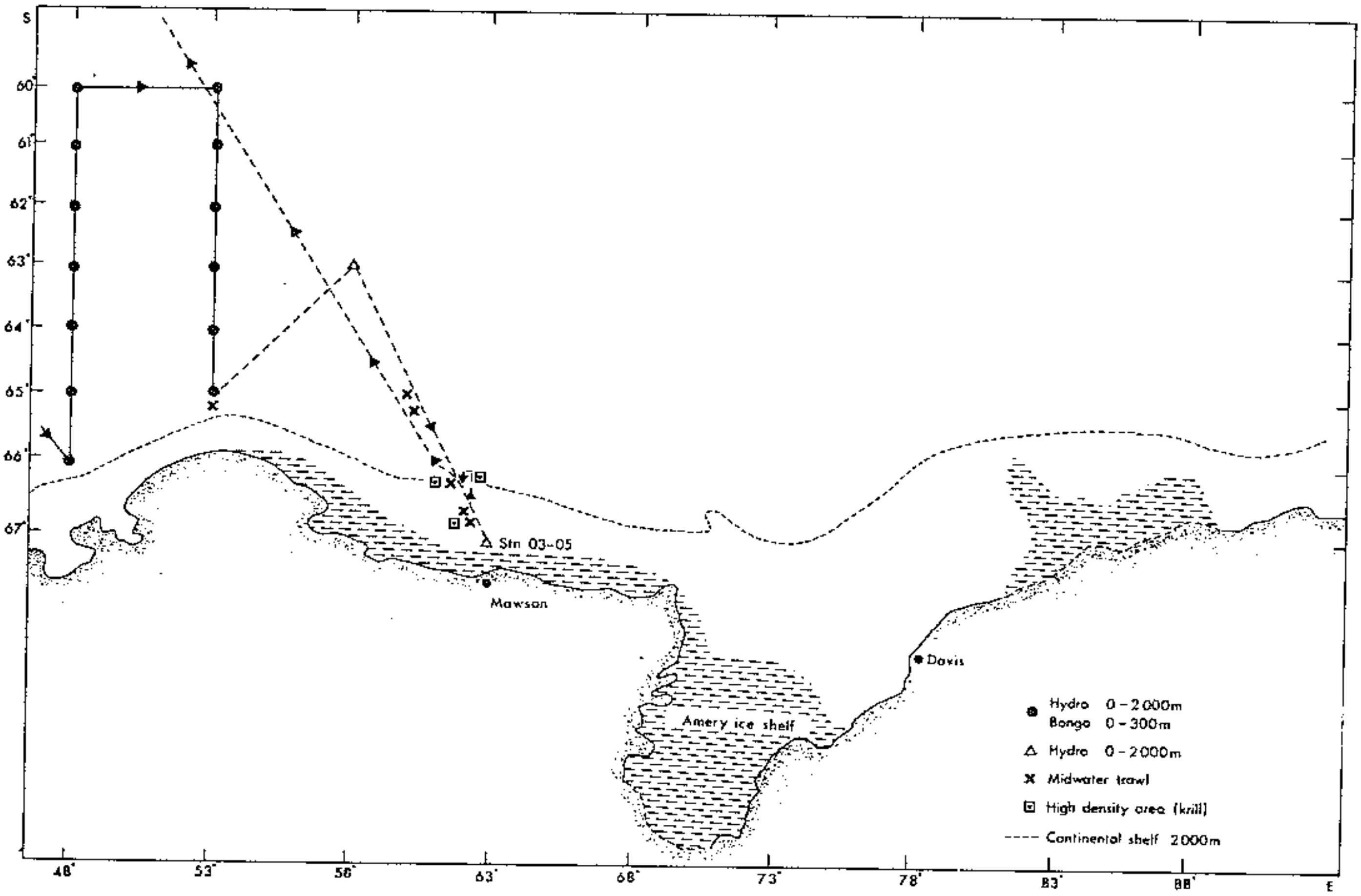

Fig. 1. South African SIBEX II survey cruise track showing position of hydrographic and net stations. Bottom topography is also shown.

85°E, from 60°S to the ice-edge. South African results from this phase (SIBEX I) found no evidence to suggest any persistence in the proposed western edge of the gyre between 52 and 64°E. Also, no large concentrations of krill were encountered (Allanson & Boden 1985).

On review of SIBEX I results, South Africa's contribution to SIBEX II was formulated in consultation with the other nations involved. In keeping with the overall objectives of SIBEX, and in accordance with national priorities, it was agreed that the South African contribution should be divided into two parts.

Initially, two survey transects (along 48°E and 52°E, from 60°S to the ice-edge) would be repeated in order to provide a temporal comparison with an Australian overview of hydrography between 48°E and 85°E carried out early in the summer of 1984/85. The second part of the survey would utilize R/S *Africana's* multi-research capabilities to study meso- and fine-scale processes associated with krill swarm dynamics, particularly the interrelationship between krill and phytoplankton in so far as it is affected by oceanological variability.

Unfortunately, the cruise and research programme were prematurely terminated as a result of a rudder malfunction which necessitated *Africana's* return to Cape Town under tow. This paper presents a summary of some of the results that were obtained. Participants in the cruise will in due course publish detailed results separately. In view of the incompleteness of the survey programme, it is essential that such interpretations that are offered be treated with extreme caution. A more complete data listing and account of the cruise has been given in Miller (1986a).

Cruise description

The cruise was originally planned for the period 20 Feb. to 5 Apr., 1985, with actual survey activities taking place between 27/2 and 25/3. The cruise track is given in Figure 1 and the survey was divided into three phases. These were:

Phase 1 – Australian Leg (27/2-5/3)

Thirteen stations were occupied (Fig. 1). Each station consisted of an oblique Bongo net (mouth diameter - 2 x 0,56 m^2, 500 and 300 µm mesh nets) haul from 300 m to the surface (Table 1). A CTD/rosette array was used to sample the following standard depths - 0, 10, 20, 50, 75, 100, 150, 200, 500, 1000 and 2000 m. The CTD provided conductivity, salinity and temperature profiles while rosette samples were used for nutrient (PO_4-P, NO_3-N, NO_2-N, NH_4-N and SiO_3), salinity and dissolved oxygen analyses. Stations occupied close to local apparent noon ("productivity stations") included a second CTD/rosette dip to 150 m with a vertical fluorometer (Sea MarTech) attached, a vertical incident spectroradiometer dip to 150 m, a vertical plankton net (3.5 µm mesh) haul to 100 m and a Secchi disc dip. Water samples from various light penetration depths were used for nutrient salt analysis, for determination of chlorophyll-*a* and phaeopigment concentrations, and for estimation of net, nano and pico plankton size fractions. Samples were also used for quantitative determination of phytoplankton species composition and estimation of primary production (using the ^{14}C method and simulated *in situ* incubation - O'Reilly & Thomas (1983)) for the net, nano and pico size fractions.

Table 1
SIBEX II : net and hydrographic station details.

Station	Net/ Hydro	Position	Date	Time SAST	Haul Depth (m)	Sounding (m)
A001	Bongo *Hydro	66°00'S 48°00'E	28.2	19h15	300	2128
A002	Bongo *Hydro	65°55'S 47°59'E	1.3	02h55	300	3000
A003	Bongo **Hydro	64°01'S 48°00'E	1.3	09h50	300	3190
A004	Bongo *Hydro	63°01'S 48°01'E	1.3	19h44	300	4900
A005	Bongo *Hydro	62°00'S 47°57'E	2.3	04h30	300	4130
A006	Bongo *Hydro	61°00'S 47°59'E	2.3	15h45	300	4660
A007	Bongo *Hydro	60°02'S 47°59'E	2.3	19h26	300	5320
A008	Bongo **Hydro	60°00'S 53°00'E	3.3	10h45	300	5240
A009	Bongo	60°59'S 52°59'E	3.3	21h45	300	---
A010	Bongo **Hydro	61°59'S 52°59'E	4.3	07h30	300	5170
A011	Bongo *Hydro	62°48'S 53°01'E	4.3	16h45	300	4860
A012	Bongo *Hydro	63°59'S 52°59'E	5.3	01h20	300	588
A013	Bongo *Hydro	64°43'S 52°54'E	5.3	12h40	300	2800
01-01	15.41	65°35'S 53°32'E	5.3	14h17	35-65	----
021	**Hydro	63°36'S 56°45'E	6.3	10h40	----	4780
02-01	*Hydro	63°00'S 58°00'E	6.3	16h30	----	1100
02-02	15.41	65°26'S 60°51'E	7.3	06h35	22-30	----
02-03	**Hydro	65°26'S 60°55'E	7.3	11h15	----	3950
03-01	15.41	65°37'S 61°14'E	7.3	13h14	58-74	----
03-02	15.41	66°11'S 61°38'E	7.3	15h15	17-25	----
03-03	15.41	66°23'S 61°59'E	7.3	17h47	55	----
03-04	15.41	66°26'S 62°04'E	7.3	18h47	>500	----
03.05	**Hydro	66°59'S 63°00'E	8.3	12h00	----	336
1-001	15.41	66°28'S 62°42'E	8.3	16h30	33	----
1-002	Hydro	66°00'S 62°41'E	8.3	23h35	----	3200

* Standard hydrographic station (see text for details);
** Productivity station (see text for details).

Continuous hydroacoustic records were collected between stations and at all other times when the ship was steaming at survey speed (± 10 knots). Krill were detected and assessed using a hull-mounted Simrad EKS 120 echo-sounder system, interfaced with a custom-built digital echo-integrator. Echoes from the upper 100 m of the water column were integrated in 10 m depth channels, or at a finer level of resolution (1 m) for depths where krill concentrations were present. The echo-sounder was calibrated immediately before and after the cruise as recommended by Foote (1983) using a steel sphere of known acoustic properties. Calibration was also carried out during the cruise, weather and sea conditions permitting, with the on-board hydrophone calibration monitoring system, following procedures outlined in Anon (1980). The acoustic processing algorithms used to determine krill density are outlined in Anon (1986) and have been fully described in Miller (1986a).

Throughout the survey, a commercial (Polish 16/41) krill trawl was used to identify acoustic targets (Table 1) and was fished for varying lengths of time (usually about 20 minutes). The displacement volumes/wet weights of all net catches were measured immediately and Bongo net catches were preserved in 10 per cent buffered formalin for later analysis ashore. Trawl catches were sorted and krill extracted for routine analysis (i.e. assessment of length frequency distributions, and determination of proportionate maturity stage distributions and gut fullness). Details of analysis procedures are given in Miller (1986a).

Phase 2 - Extensive Grid (5/3 – 8/3)

The fundamental objective of this phase of the survey was to locate areas of high krill abundance so setting the boundaries of fine-scale studies to be carried out during Phase 3. Two north-south transects (Fig. 1) were completed in order to obtain as representative a transgression as possible of the near-ice, East Wind Drift, Antarctic Divergence and West Wind Drift zones south of 60°S and between 53 - 64°E. Continuous acoustic records and *ad hoc* trawls (both blind and aimed) were used to locate and identify krill concentrations. Standard hydrographic stations (as in Phase 1) were occupied at the beginning and end of each transect. Productivity stations were occupied at local apparent noon and water samples collected from depths corresponding to 85, 40, 20, 10, 1,0 and 0,1 per cent incident light levels. In addition, two krill trawls were deployed to collect fish. One of these hauls was to a depth of 500 m.

Phase 3 – Intensive Leg (8/3)

During Phase 2 an area of relatively high krill abundance was located at 66°25'S; 62°00'E (Fig. 1). A fine-scale intensive sampling grid was set up around this position in order to investigate the spatial relations and environmental associations of selected swarm groups. The grid consisted of 7 north-south transects, transect legs being approximately 50 km in length and spaced 8 km apart. A hydrographic station was sited every 65 km. As a result of the rudder malfunction, this phase of the survey had to be prematurely curtailed when *Africana* returned to Cape Town, arriving 23/3/85.

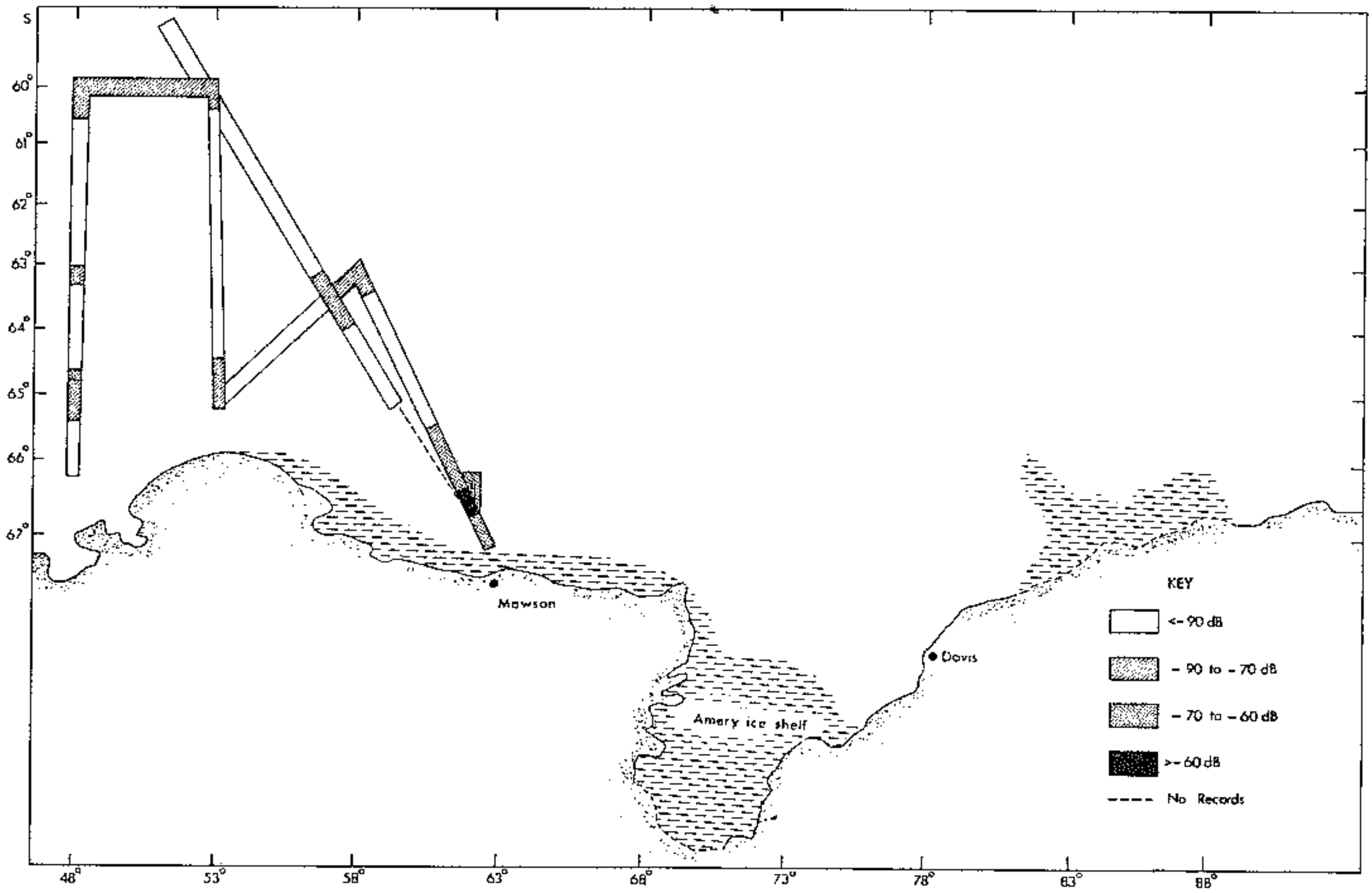

Fig. 2. Horizontal distribution of krill densities in the South African SIBEX II survey area.

Throughout all three phases of the survey and in transit from Cape Town, underway ornithological observations were made using the 10-minute card/one hour block system recommended by BIOMASS (Anon 1984). When the ship was on station, instantaneous scans were made every half an hour as described by Cooper (1985) for up to six replicates. The maximum number of each bird species observed at one time was recorded.

Summary of results

A number of the cruise's primary objectives remained unfulfilled due to its premature termination. In particular, the process-orientated component of the survey was not fully implemented. It was in these studies that *Africana*'s multipurpose capabilities were expected to make the most substantial contribution to the overall objectives of SIBEX - namely to improve understanding of various processes associated with krill swarm dynamics.

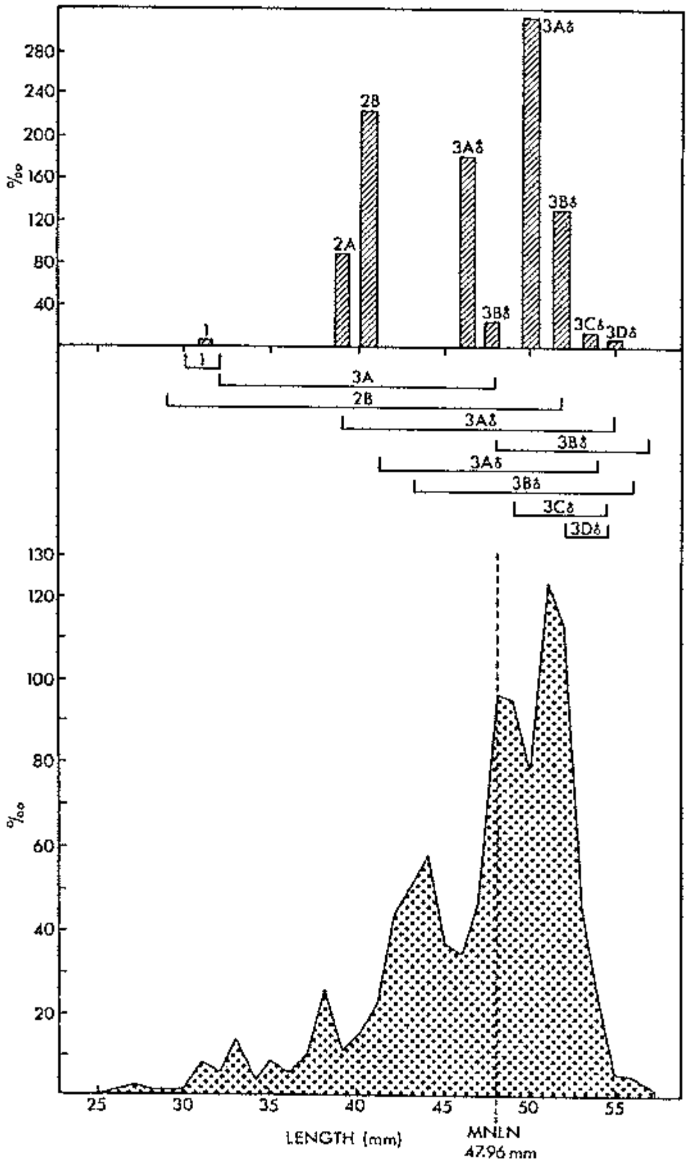

Fig. 3. Accumulated maturity stage and length frequency distributions of krill collected with the Polish 16.41 Commercial Krill Trawl during acoustic target identification.

Krill

Krill abundances were generally low (mean density = 0,48 g/m^2) compared with a previous acoustic survey of the area (1,67 g/m^2)(Anon 1986) and with net catch results from SIBEX 1 (5,21 g/m^2)(Miller 1985, 1986b). The areal biomass south of 60°S and between 48-64°E was calculated to be 1,24 x 10^5 tonnes, some five times lower than estimates from SIBEX I net catch results (Miller 1986b). An area of enhanced abundance (12,89 g/m^2) was observed close to the continental shelf break (Fig. 2) which, given results from elsewhere in the Antarctic, was not unexpected (*cf.* review by Amos 1984). The mean krill density detected during the day (1,18 g/m^2) was ten times greater than that detected at night (0,11 g/m^2). Again this was not unexpected (see Anon 1986). Most of the krill swarms observed were small with a mean intercept length of 37,63 m and a mean thickness of 15,81 m. These values were much in keeping with similar results reported for krill swarms observed farther to the west during FIBEX (Hampton 1985).

Preliminary analysis of the Bongo net catches during Phase 1 indicated a low abundance of krill larvae and, in conjunction with acoustic results, adults. A number of fish larvae and postlarvae were also collected (see Ichthyology results).

All five "aimed" midwater trawl catches yielded krill. Mature female krill (Maturity Stages 3A-C according to Makarov & Denys' (1981) classification) dominated these catches, and only small numbers of mature males (Stages 3A and B) or gravid/spent females (Stages 3D-E) were present (Fig. 3). It is interesting to note that commercial trawl catches taken during a previous Korean expedition to the area, at about the same time of the year, also contained a proportionately large number (85 % of the total catch) of mature female krill (Anon 1983). Four of the above catches contained satiated animals with undigested food matter in both fore-gut and hepatopancreas. The presence of satiated animals tends to substantiate a causative link between the presence of relatively large phytoplankton particles (> 20 μm)(see Phytoplankton results) and active feeding, since larger particles are most efficiently retained by grazing krill (Boyd *et al.* 1984).

Phytoplankton and primary production

Conspicuous chlorophyll maxima were visible at depths between 50 and 60 m at most stations (Fig. 4). This corresponded well with the maximum depth of the euphotic zone.

With the exception of marked elevation in phytoplankton standing crop and primary production at Station 03-05 (Fig. 1), the levels of both these parameters fell within ranges normally associated with such latitudes in the Southern Ocean. Station 03-05 was situated in shallow water (336 m) close to the continental ice-edge. It could therefore be considered to lie in the near-shore zone which is favourable to elevated primary production, given suitable light and weather conditions (El-Sayed & Taguchi 1981).

Substantial quantities of chlorophyll-*a* occurred below the euphotic zone (Fig. 4) although C_{14} assimilation was substantially reduced at these depths.

Most of the chlorophyll-*a* and C_{14} uptake was attributable to cells larger than 20 μm. Nanoplankton (<20 μm but >1 μm) contributed only a relatively small percentage of the total phytoplankton biomass (29 %) and primary

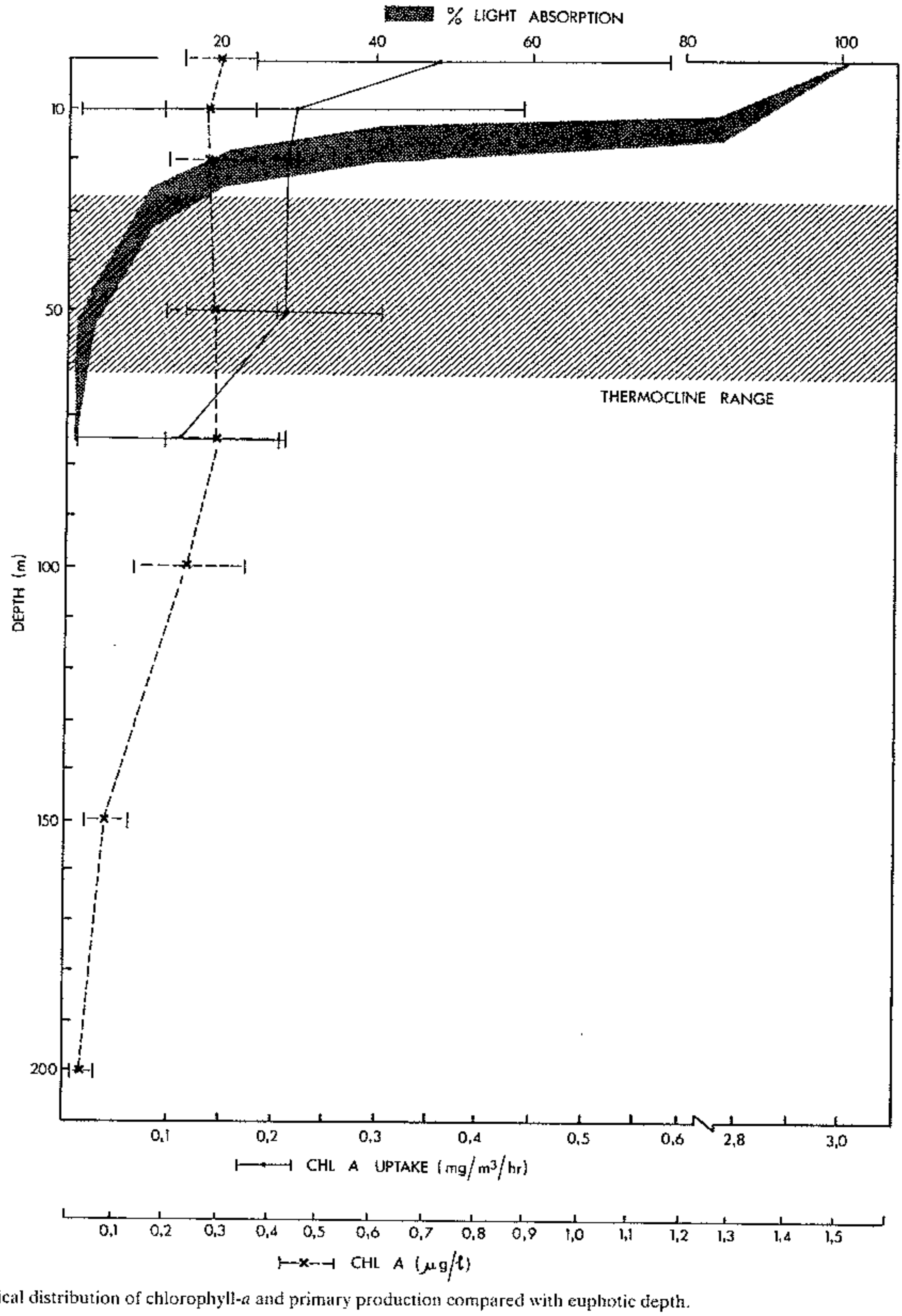

Fig. 4. Vertical distribution of chlorophyll-*a* and primary production compared with euphotic depth.

productivity (43 %). The amounts of either chlorophyll or C_{14} uptake detected in cells less than 1 μm in size were, in most cases, insignificant. This was in direct contrast to most other areas of the Antarctic where nanoplankton contribute most to primary productivity (e.g. *cf.* von Bröckel 1981, Yamaguchi & Shibata 1982, Witek *et al.* 1982).

Diatoms were predominant in the phytoplankton samples and the silicoflagellate *Dictyocha speculum* occurred in moderate quantities at most of the stations. In terms of relative abundance, the most abundant and ubiquitous diatom species were (in descending order) – *Nitzschia kerguelensis*, *Thalassiothrix longissima* (var. *antarctica*), *Nitzschia seriata*, *Rhizosolenia hebetata* (f. *semispina*) and *Chaetoceros criophilus*.

Ichthyology

A total of 127 fish larvae representing seven species was collected during Phase 1. The most abundant species were *Notolepsis coatsi* (38 % of the total catch), *Electrona antarctica* (28 %) and *Electrona* sp. (26 %). *N. coatsi* or *E.*

antarctica dominated individual catches and both these species were present at all but two of the Phase 1 stations. Three adult myctophids were collected - two *Electrona antarctica* and one *Gymnoscopelus braueri*. It should be noted that larvae collected during Phase 1 were similar to catches taken in the same area during SIBEX-I and with larvae from the Lasarev Sea (Efremenko 1983).

The five 16/41 samples yielded *E. antarctica*, a juvenile *Dissostichus mawsoni* two nototheniid larvae, five channichthyid post-larvae and one unidentified bathydraconid, all mixed with krill. The first blind haul for fish (depth 55 m) yielded *E. antarctica* and six specimens of the unidentified species described above. The second haul (to 500 m) was dominated by *E. antarctica* and *Bathylagus antarcticus*. Apart from these, specimens of three lanternfish species (genus *Gymnoscopelus*), 14 adult *N. coatsi*, one adult *Pleurogramma antarcticum*, one flat fish of the species *Mancopsetta maculata*, a single *Benthalbella elongata*, one *Paradiplospinus gracilis* and another specimen of the above bathydraconid species were collected. Of the 11 species contained in this haul, the most unusual result was the presence of the typically benthic flatfish *M. maculata* 1200 m above the sea bed. Other uncommon species included *P. gracilis* and *B. elongata* and their presence provides the southernmost (66°20'S) record to date for all three species in the Indian Ocean.

Ornithology

During the transit journey from Cape Town to the survey area (20/2-27/2), a total of 24 hours of 10-minute cards was completed. Twenty-seven species of seabirds were recorded.

From 1/3-5/3 (Phase 1), a total of 14 hours of cards was completed while underway and a further eight hours was completed between 6/3-8/3 (Phase 2). Between 1/3-7/3, a total of 35 10-minute cards was completed while the ship was on station. The range of cards per station varied between 3-6 with a mean of 4,4. The number of species per station varied from 0-8 and the number of individuals from 0-134. During Phase 1 the most consistently numerous species observed were prions (*Pachyptila* spp.), sooty shearwaters (*Puffinus griseus*) and whitechinned petrels (*Procellaria aequinoctialis*). Diving petrels (*Pelecanoides* sp.) were also common and these observations extend the southerly range of this group of species (Harrison 1983).

During Phase 2, 11 species were observed and sooty shearwaters were again predominant. For a variety of reasons (e.g. ship's speed, mist etc.) no 10-minute cards were completed on the return journey to Cape Town. However, daily observations continued and these documented the disappearance of "southern" species along with the appearance of "northern" species by latitude. A white southern giant petrel (*Macronectes giganteus*) (c. 65°S; 60°E) and a colour-dyed greyheaded albatross (*Diomedea chrysostoma*) (c. 60°S; 52°E) were observed. The latter probably originated from South Georgia, some 4000 nautical miles to the west.

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