PRINCE EDWARD ISLANDS' OFFSHORE OCEANOGRAPHIC STUDY: REPORT OF RESEARCH CRUISE APRIL-MAY 1997

By E.A. Pakhomov, P.W. Froneman and I. Ansorge

Focuses on the preliminary results of the second cruise of the Marion Island Oceanographic Study designed to provide oceanological observations off Prince Edward Islands from April 25 to May 28, 1997. Physical and chemical oceanographic results; Surface seawater temperature; Total chlorophyll-a distribution.

Isolated oceanic islands in the sub-Antarctic zone of the Southern Ocean strongly influence the physico-chemical structure of the adjacent oceanic environment[1,2] and are regions of intense biological enhancement.[3,4] The Prince Edward Islands group comprises two small volcanic islands, situated directly in the path of the easterly-flowing Antarctic Circumpolar Current (ACC),[1] between the sub-Antarctic (SAF) and Antarctic Polar (APF) fronts.[5] The Prince Edward Islands support a huge (more than 5 million) and unique community of seabirds and mammals.[6] The islands are also important in terms of their high conservation status, and economic and ecotourism potential. The recent proclamation of the 200-nautical mile exclusive economic zone around the Prince Edward Islands, coupled with the start of commercial exploitation of the Patagonian toothfish, Dissostichus eleginoides, on the islands' continental slopes further emphasises the need for offshore marine studies in their vicinity.

The uniqueness of the island ecosystem is the result of a close marine-terrestrial interaction known as the 'life-support system', which ultimately provides food for the entire community of seabirds and mammals.[7] The advection from the upstream region associated with the meandering dynamics of the ACC can supply much of the food necessary for the survival of the land-based predators. It is suggested that the position of the SAF in the vicinity of the islands is crucial in forming the macro- and mesoscale oceanographic conditions around them, both upstream and downstream.[4,8]

In the past, studies on oceanographic processes and zooplankton distribution were generally restricted to the interisland area and to the close proximity of the island shell[3,4] Only a single macroscale survey around the island group, which covered approximately 100000 km^2, was carried out during the second cruise of the Marine Offshore Ecological Study (MOES-H) in April 1989.[9] To establish the representativeness of these results, a second cruise of the Marion Island Oceanographic Study (MIOS-H) was, therefore, designed to provide oceanological observations and was carried out in April-May last year. This article summarises the preliminary results of this cruise.

The voyage, which began on 25 April and ended on 28 May 1997, was primarily concerned with the determination of the oceanographic structure of the seas in the upstream and downstream regions of the Prince Edward Islands. Two research groups, representing biological oceanography from Rhodes University and physical oceanography from the University of Cape Town, participated. Four main research aims had been set for the cruise. The first was to investigate the role of the Prince Edward Islands on the circulation patterns of the Antarctic

Circumpolar Current and their influence on plankton community structure. The second aim was to study the short-term variability in the position of the sub-Antarctic Front in the vicinity of the islands and its influence on plankton community structure and distribution. Another objective was to determine the spatial and temporal variabilities that may exist in the mesoscale activity downstream of the Prince Edward Archipelago. Finally, we wished to collect information on the distribution and biology of demersal fish and the swimming prawn, Nauticaris marionis, over the shelf area of the islands.

To accomplish these objectives, two surveys were conducted between 30 April and 18 May in the upstream, inter-island and downstream regions of the islands (Fig. 1). While en route to the study area, routine underway observations, including surface and subsurface temperature, salinity, size-fractionated chlorophyll, phytoplankton and acoustics, were conducted between the mainland and the islands.

Physical and chemical oceanography

The sub-Antarctic Front is predominantly a subsurface feature and as a result the positions of the surface and subsurface expressions may differ.[10,11] Repeat seawater temperature and salinity lines show that along the transect between the African continent and the Prince Edward Islands the subsurface position of the SAF lay within a narrow band between 43 degrees 51'S and 44 degrees 30'S, while the surface expression lay farther south in the vicinity of the islands between 45 degrees 25'S and 45 degrees 40'S. Preliminary results obtained on a large number of hydrographic stations, extending through the water column to a maximum depth of 1500 m, show that upstream of the islands, between 36 degrees and 37 degrees E, the SAF lay farther south at approximately 47 degrees 20'S (Fig. 2). This observation was not made during the MOES-II survey in 1989 and emphasises the great geographical variability in the position of the SAF upstream of the islands.[12] Further downstream, however, as a result of topographical steering caused by the shallow Prince Edward Island Plateau, the SAF was deflected meridionally around islands, forming to the north of them. Downstream of the islands, it continued to meander in the form of a Rossby wave between 45 degrees 40'S and 46 degrees 30'S (Fig. 2). Entrained in this wave, a deep-water cold-core eddy, extending to 1500 m and characteristic of sub-Antarctic Surface Water, was observed. A warm-core eddy was also found south of the islands (Fig. 2). The origin of this eddy is unknown, but it may be the result of the interchange of oceanic waters across the Subtropical Convergence.[8,13] In addition, at the southeastern and western corners of the survey area, intrusions of cold, relatively fresh and high oxygenated Antarctic Surface Water were observed, suggesting that the Antarctic Polar Front was also encountered. This is comparable to the previous survey, where Antarctic Surface Water was also seen south of the islands.[8]

Data from the MOES-II and May 1997 surveys show that the oceanographic regime in the region of the Prince Edward Islands is one of extreme mesoscale variability. During both surveys, however, a distinct Rossby wave and an eddy were observed downstream in the island's wake. The downstream region, therefore, appears to be a zone of enhanced meridional water exchange within the ACC. This may increase the vertical stability of the water column and consequently slow the mixing processes in the upper layer, which would provide favourable conditions for enhanced biological productivity in the downstream region.[8,14] Upstream of the islands during the 1997 survey in contrast to the 1989 cruise, the SAF was located much farther south at 47 degrees 20'S, evidence of the southward extension of warm-water masses. These conditions will undoubtedly play a significant role in plankton distribution and community structure in the seas upstream of the Prince Edward Islands.

Biological studies

These consisted of three components, underway sampling along a return transect between Cape Town and the Prince Edward Islands, two grid surveys conducted in the waters surrounding the islands, and ad hoc large (RMT-8) net tows within the inter-island region at night on an opportunistic basis.

Underway observations. Along the outward and return transects between Cape Town and Marion Island, total chlorophyll-a (chl-a) showed enhanced concentrations in the vicinity of the Subtropical Convergence (Fig. 3). In addition, elevated chl-a levels were recorded in the waters of the Prince Edward Islands along the Cape Town-Marion Island transect. Routine observations, therefore, did not show any substantial enhanced surface productivity in the vicinity of the SAF during April and May 1997.

Grid surveys. At the surface, total chl-a biomass varied generally between 0.3 and 0.5 mug 1^{-1} (Fig. 2). The spatial distribution was uniform throughout the surveys with slightly higher concentrations being recorded between and downstream of the islands. In the north-west part of the second survey to the north of the SAF, phytoplankton bloom with chl-a biomass reaching 2.3 mug 1^{-1} was recorded in the open ocean. With one exception, elevated chl-a biomass was observed to the north of the SAF. By contrast, the lowest concentrations were associated with the coldest waters in the southwestern and southeastern parts of the survey area (Fig. 2).

Surface size-fractionated chl-a and phytoplankton samples taken at each oceanographic station during both surveys showed that small algae (<20 mum) always dominated total chl-a biomass in areas with concentrations of <0.6 mug 1^{-1}. Where chl-a levels exceeded 0.6 mug 1^{-1}, however, large algae (>20 mum) accounted for more than 50% of total chlorophyll. The average contribution of large algae to total phytoplankton standing stock was higher in the downstream region than upstream, 16% versus 9%, respectively. This could probably be explained by the 'island mass effect', which favours the growth of larger algae in this region)

Ten microzooplankton grazing studies were conducted upstream and downstream of the islands during the second grid survey, in order to determine how the presence of the islands, through its effect on phytoplankton structure, modifies the partitioning of carbon between the various size-classes of herbivores (zooplankton). Preliminary results show that consumption rates of phytoplankton by microzooplankton differed between upstream and downstream regions. Upstream, phytoplankton consumption was higher than downstream, which can probably be related to increased contribution of large phytoplankton to total chlorophyll.

An extensive net sampling survey in the top 300-m layer revealed generally low zooplankton densities within the interisland area whereas high zooplankton biomass was apparent immediately downstream of the islands. Acoustic measurements showed that the back-scattering volumes (representing relative macrozooplankton-micronekton densities) were highest in the immediate proximity of the continental slope around the islands. Sample analysis indicated that meso- and macrozooplankton biomasses were similar to estimates obtained from previous years.[7,15] Copepods, ostracods, euphausiids, pteropods, hyperiids and chaetognaths dominated numerically. Preliminary results suggest that during the investigation the zooplankton community was typical of the sub-Antarctic origin. Some subtropical and Antarctic components were also represented, however, confirming that the mixing of different water masses has occurred. The RMT-8 catches were dominated by large euphausiids and saips, lantern fish and mesopelagic decapods, which are known to be the staple food of many land-based predators.[7]

A single 24-hour station that comprised midday and midnight series of tows in the different depth strata down to 400 m was occupied immediately upstream of the islands. Results showed that meso- and macroplanktonic crustaceans, for instance, euphausiids and hyperiids, undertake marked vertical migrations, rising to the surface or to the top 100-m layer during the night and descending to a depth of approximately 200-400 m during the day. Similarly, large decapods and lantern fish were generally found at a depth of 100200 m during the night, but were virtually absent from net tows undertaken during the day. Acoustic observations and target net tows conducted in the early morning hours revealed that small crustaceans are washed through the inter-island area and so become vulnerable to predation during the day.[7] No large decapods and fish were caught between the islands. These findings combined with the acoustic observations suggest that larger organisms, which are an important food source for many land-based predators, are washed around rather than drift between the islands. Elevated biomass of macrozooplankton-micronekton in the lee of the islands emphasises the urgent need for research in this area in order to understand the role of the downstream region in substantial build-up of terrestrial predators.

Ad hoc studies. Several near-bottom RMT-8 tows conducted between the islands were characterised by low plankton densities and dominated by juveniles of the nototheniid fish, Lepidonotothen larseni, the bottom-dwelling swimming prawn Nauticaris marionis and juveniles of bottom octopuses. Only in one tow conducted on Natal Bank were a significant number (approximately 2 kg in total) of N. marionis caught. Live specimens of the prawn were subsequently used for physiological studies to obtain the first estimates of respiration rates for this species.

Conclusions

In contrast with previous findings in the area, during April-May 1997 a marked interaction between the Antarctic Circumpolar Current and the Prince Edward Islands was associated with changes in the meso- and macroscale circulation patterns. Strong advective effects appeared to dominate the flow in the vicinity of the islands, which was unfavourable for the trapping of water between them. Biological productivity in the region was generally low compared to previous years, but similar to that observed in April 1989. This was despite the fact that the position of the SAF in the vicinity of the islands was substantially different.

The surveys clearly show that the position of the SAF plays an important role in determining the zooplankton distribution and community structure in the waters around the Prince Edward Islands. The possible significance of the downstream concentrations of macrozooplankton and micronekton as a food resource for land predators is becoming clearer.

We would like to express our sincere appreciation of the contribution which Captain R. Peters, his officers and crew made to the success of this cruise. The friendly and relaxed atmosphere they created on board ship contributed significantly to the completion of our work. The excellent cooperation with the officer-in-charge, H. Valentine, during the entire cruise is also most appreciated. We also thank each member of the Rhodes University and University of Cape Town groups for creating a helpful and considerate atmosphere during the surveys. Special thanks also go to the electronics officer, W. Houzet (Sea Fisheries Research Institute, Cape Town), for his enthusiasm and invaluable assistance throughout the entire voyage. We are grateful to the South African Department of Environmental Affairs and Tourism, Rhodes University and the University of Cape Town for providing funds and facilities for this study. Finally, we thank J.R.E. Lutjeharms for his invaluable comments on the manuscript.

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E.A. Pakhomov and P.W. Froneman are with the Southern Ocean Group, Department of Zoology and Entomology, Rhodes University, P.O. Box 94, Grahamstown, 6140 South Africa (e-mail: zoep@warthog.ru.ac.za). I. Ansorge is with the Ocean Climatology Group, Department of Oceanography, University of Cape Town, Rondebosch 7701.

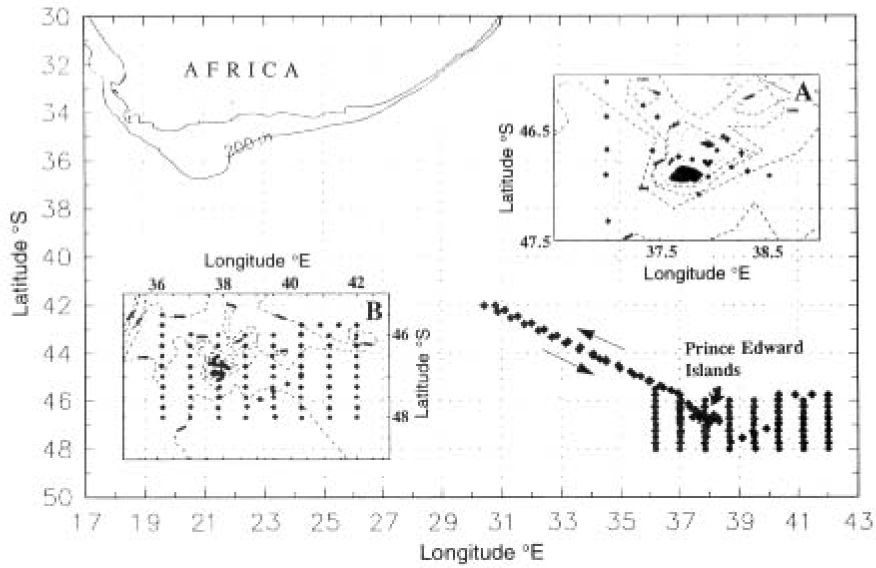


Fig. 1. XBT (diamonds) and CTD (circles) station positions occupied in the vicinity of the Prince Edward Islands during April/May 1997. Inserts represent: A, first grid survey, 30 April-5 May 1997; B, second grid survey, 8-18 May 1997.

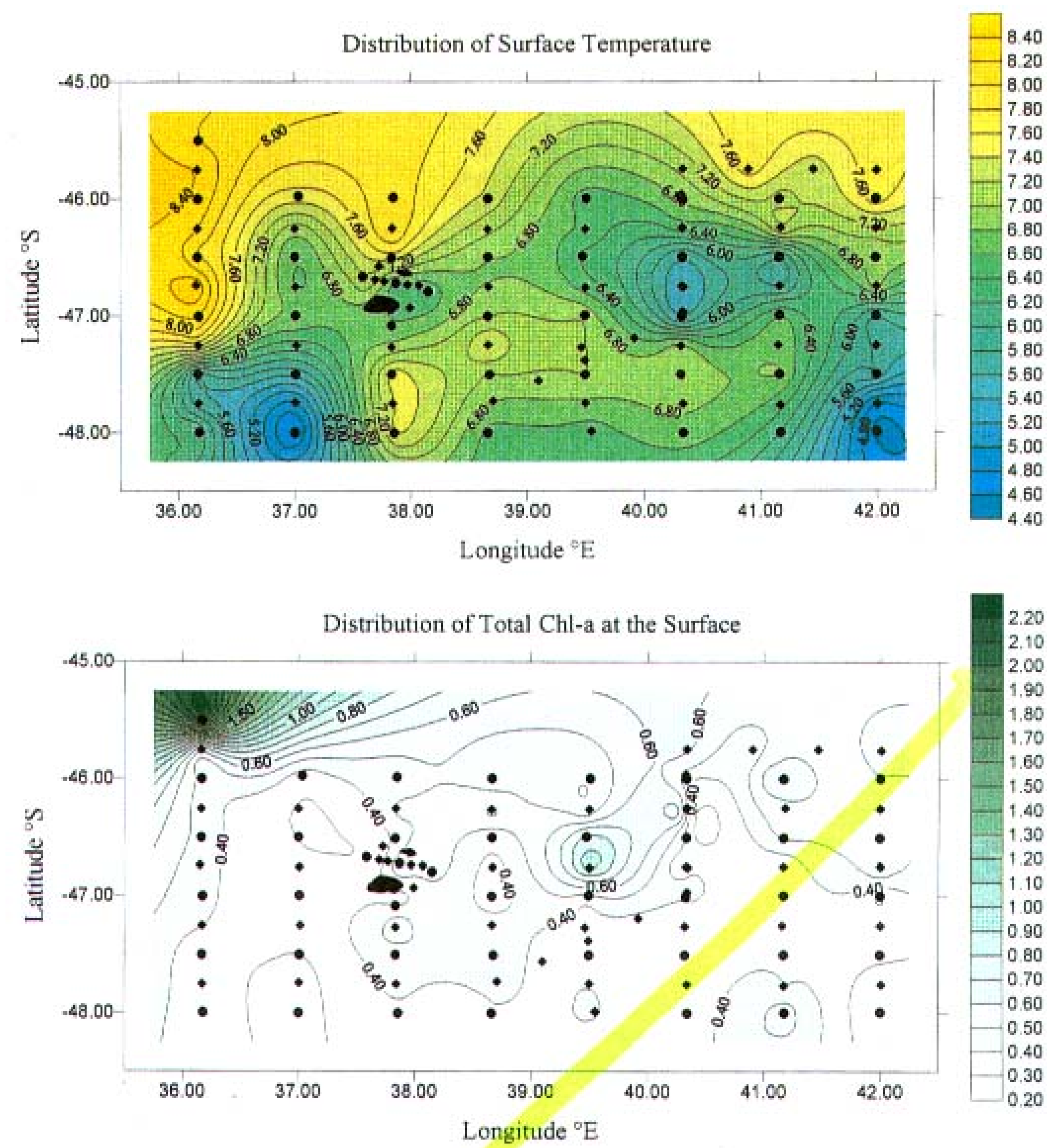
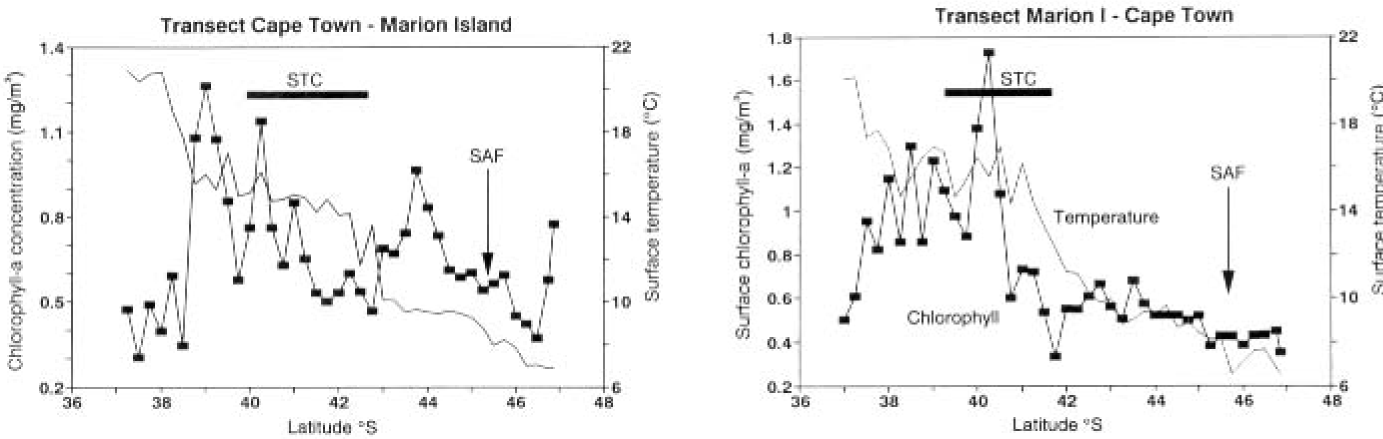


Fig. 2. Surface seawater temperature and total chlorophyll-a distribution during the second grid survey, 8-18 May 1997, in the vicinity of the Prince Edward Islands.



S: Fig. 3. Surface seawater temperature and total chlorophyll-a distribution along repeat transects between Cape Town and Marion Island during April-May 1997. STC, Subtropical Convergence; SAF, sub-Antarctic Front.