International Council of Scientific Unions

# SCAR report

No. 3

January 1988

Contents



Published by the

SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH

at the

Scott Polar Research Institute, Cambridge, England

SCAR REPORT No 3

January 1988

Report of a meeting of the

# SCAR GROUP OF SPECIALISTS ON SOUTHERN OCEAN ECOLOGY

(cosponsored by SCOR)

Paris, 27-29 May 1987

## 1. INTRODUCTION

### 1.1. Opening of meeting

Dr Hureau welcomed members (names and addresses at Annex 1) to this, the first meeting of the Group. Dr Sackshaug was absent on field-work and unable to attend. The present membership is that nominated by SCAR in June 1986, and it was greatly regretted that SCOR had not yet responded to the request to nominate two oceanographers as members.

If the Group is to make a critical and comprehensive view of Southern Ocean marine ecology, substantial input and advice on oceanography is essential.

The Agenda adopted is at Annex 2.

### 1.2. Background papers

The main documents used by the Group during the meeting are listed in Annex 3. Five papers (3-7) were prepared by members of the Group. The remaining documents relate mainly to existing or proposed multi-national collaborative undertakings (8, 9 and 19) or to planned national programmes (10-12, 14-16).

## 2. OBJECTIVES AND SCOPE OF THE GROUP OF SPECIALISTS ON SOUTHERN OCEAN ECOLOGY

### 2.1 Terms of reference

The Group's terms of reference, as drawn up by SCAR, are as follows :

a - To identify fields for research on Antarctic marine ecology and to propose co-operative studies, including multi-ship experiments.

b - To encourage and facilitate interdisciplinary studies in Antarctic marine ecosystems.

c - To further Southern Ocean ecosystem studies through workshops and other activities.

d - To respond through SCAR to requests for scientific advice and information by the Antarctic Treaty, CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) and other international organisations with interests in science, resources and conservation in the Southern Ocean.

e - To liaise with other relevant international research programmes.

### 2.2 Commentary

The Group discussed these terms of reference, in order to establish the most effective way of addressing them. The following observations were made:

(a)- Papers 3-7 offer numerous comments on research priorities and important research topics and themes. Details of the Group's deliberations and recommendations on research activities are set out in Section 3.

With reference to multi-ship experiments, these require clear and precise definition of attainable objectives and need co-ordinated planning over several years.

It was felt that it is premature to start planning any new multi-ship programmes because :

i) they should ideally build on the results of BIOMASS programmes, and a synthesis of these will not be available for several years.

ii) many nations are to make major commitments of shiptime and funds to the World Ocean Circulation Experiment (WOCE) but the nature and extent of these are uncertain at present.

iii) there has been extensive planning for an Antarctic Sea Ice Programme, which will need major logistic and financial commitments. It would be more appropriate to attempt to enhance the biological content of this programme than to develop new, and potentially competing, alternatives.

At present the Group felt that smaller-scale collaborative projects (perhaps including 2 or 3 national programmes) are likely to be the most productive. Indeed, a number of such projects are already in existence, or planned (e.g under the auspices of the European Science Foundation). It was felt that, in order to make the best use of available opportunities and to assist the development of new proposals, readily accessible summaries of all international collaborative projects will be essential. The Group agreed that SCAR should be asked to arrange for such summaries to be prepared and updated annually, through a national nominee within national Committees.

(b) - The Group reaffirmed the fundamental need to develop inter-disciplinary studies in marine ecology. While it was encouraging to see the initiation of process-orientated biological studies with physical and chemical oceanographic input, major programmes are still being planned without adopting a fully integrated approach.

(c) - Needs for workshops and similar activities should emerge from the review of the fundamental research requirements.

(d) -Careful consideration must be given to the best way of arranging links with CCAMLR and with other relevant international research initiatives that have developed, or are developing, as a result of BIOMASS.

As a consequence of its review of the terms of reference, the Group decided that it would confine its attention initially to a broad overview of the most important approaches, themes, and topics relevant to Antarctic marine ecology.

## 3. FIELDS FOR RESEARCH ON ANTARCTIC MARINE ECOLOGY

A most important outcome of recent Antarctic marine research has been the realisation that the Southern Ocean is no longer most appropriately treated as a single coherent ecosystem.

It is now clear that, within the geographical area of the Southern

Ocean (i.e bounded in the north by the Antarctic Polar Front), there are a number of recognisable systems, each characterised by a particular combination of physical, chemical and biological factors. These include distinctive assemblages of species, occurring in definable geographical areas and at particular spatial and temporal scales.

At present, only a very imperfect understanding of the structure and dynamics of these systems exists. The systems themselves are complex and the nature of their interrelations are poorly understood but are of particular scientific interest and significance.

Indeed the Group believed that the most profitable approach for the next phase of Antarctic marine ecological research will be to identify and quantify the energy fluxes within and between the major systems.

In addition there is a clear need to build on the initiatives and directions established by BIOMASS. The Group identified four major research directions:

Firstly, BIOMASS and related studies tended to concentrate on Antarctic krill (Euphausia superba) and particularly on its pelagic phase. While this should continue to be an important research theme, other major biota and components of the various systems should not be neglected. Indeed, even with respect to krill, little is known of its biology and demography in winter or in association with the sea-ice zone.

Secondly, much Antarctic marine research has concentrated on acquiring data on species and biomass distributions and on qualitative (or partially quantitative) descriptions of trophic links. There is now a need to focus research to quantify rates and processes, particularly with respect to energy fluxes and demographic parameters.

Thirdly, within a single trophic level, there will be profound species-specific variations in important processes, which require critical attention.

Fourthly, a key feature of Antarctic organisms is their physiological and biochemical adaptation to the physical environment. There is considerable scope for additional research, particularly if improved facilities for laboratory-based research, within the Antarctic and elsewhere, can be developed.

Based on the above considerations, the Group identified four ecological systems in the marine Antarctic and reviewed what it considered to be the most important topics for research within each. The Group believes that the systems chosen - Sea-ice, Continental Shelf, Open Ocean, Sub-Antarctic Islands - are the most important for future and current research. They also provide for a diversity of research activities and requirements.

There was no intention to produce reviews of comparable detail for each system. That on sea-ice is particularly extensive because the Group felt that research on this system, the one whose influence pervades most strongly the whole Southern Ocean, has been disproportionately neglected until very recently. The open ocean is treated relatively briefly because it was the focus of the BIOMASS Programme. Subantarctic islands are reviewed in summary form because there are already major national programmes operating at most of them.

## 3.1 SEA-ICE

Sea-ice is a key Southern Ocean habitat. During its annual growth and decay it sweeps an area of approximately $16 \times 10^6 km^2$ . While interannual ice variability may be substantial for individual regions, the overall variability for the Southern Ocean is probably less than 10%. The drifting pack ice comprises the majority of the ice cover and most of it is less than one year old. This annual ice is about 0.5 to 1.5 metres thick and has a variable snow cover usually of less than 1 metre.

Multi-year pack ice has survived two summers and is predominantly thicker and less saline than annual ice. It is often rafted and overlain with snow from 0.5 to 1.5 metres in depth. Multi-year pack ice is confined predominantly to the western extremes of the Weddell Sea. By contrast, continental fast-ice forms over relatively shallow waters and remains connected to the continent for most of its existence. Both pack-ice and land-fast-ice share common ice crystal structures; each containing large-grained (cm size) congelation ice and small-grained (mm size) frazil ice. Usually, pack ice is composed primarily of frazil ice and fast-ice of congelation ice. Each ice type is formed in a different way. While the sea ice is often thought of as a "two dimensional" thin skin covering the surface of the ocean, in reality there can be considerable vertical relief both above and below the water as a result of the formation of pressure ridges and rafted ice floes. This aspect of ice topography is of considerable importance to the organisms associated with it. This is because the ice represents the largest quasi-continuous surface within the pelagic realm. The ice crystal surfaces and the structures they form create a substrate for the growth of microbial biofilms on the small scale and provides a refugium for prey organisms on larger scales.

For the purpose of the present discussion, the Group agreed to define the sea ice biota as organisms at all trophic levels which live in, on, or are dependent upon the ice during part or all of their life cycles. Three groups of ice associated organisms can be identified: microbiota, macrobiota, and marine birds and mammals. The predominant group in terms of biomass is the microbiota (composed of bacteria, microalgae and protozoans). Macrobiota include : ctenophores, polychaete worms, copepods, amphipods, krill and several invertebrate larval forms. Adults of the fish *Pagothenia borchgrevinki* are known to live in sea-ice. Crabeater (*Lobodon carcinophagus*), Weddell (*Leptonychotes weddelli*), Ross (*Ommatophoca rossii*) and to a lesser extent, Leopard (*Hydrurga leptonyx*) seals spend most of their life associated with fast- or pack-ice. Of sea-birds, only the Emperor penguin (*Aptenodytes forsteri*) breeds in this habitat, but Adelie penguins (*Pygoscelis adeliae*) and many flying birds - especially Snow and Antarctic petrels (*Pagodroma nivea* and *Thalassoica antarctica*) - forage extensively in ice-leads, polynyas and at the ice edge. Blue (*Balaenoptera musculus*) and Minke (*Balaenoptera acutorostrata*) whales are known to associate with the marginal ice zone and deeper pack ice, respectively.

Ice microbiota may become associated with ice by either passive (physical) or active biological processes. The microbiota found in fast- and pack ice in part reflects the microbial assemblages present in the water column, or the benthos in shallow areas, over which the ice was formed. For instance, in continental pack ice areas neritic organisms and those associated with the benthos may be incorporated directly into the ice structure by physical processes such as ice nucleation scavenging or trapping. In shallow embayments at depths less than 30 m, where anchor ice is present, large (m size) patches of sediments, and associated organisms can be lifted from the benthos by the buoyant forces of anchor ice to the overlying canopy of floating sea-ice. Subsequent to physical incorporation, further biological growth of individuals or populations may occur within the ice matrix, particularly in brine tubes, chambers and channels, but always in a liquid water microenvironment.

Mechanisms by which microbes adhere to ice crystals and colonize their surface are unknown at present, but presumably some extracellular adhesive substances permit attachment. Following the initial colonization by bacteria and microalgae, dense biofilms cover the ice surfaces at the ice-water interface. The mechanisms whereby ice is colonized by a variety of organisms constitute an important topic for future study.

All research on sea ice biota should ultimately contribute to answering the following question :

How does the growth, presence and recession of sea-ice influence the biota of the Southern Ocean ?

We need to understand how the presence of sea ice and seasonal ice dynamics influence community structure, specifically the seasonal changes in horizontal and vertical distribution of organisms (from microbes to whales). We must understand also how ice influences the nature and rates of biotic process in the ice, on the ice, and in the water column beneath or adjacent to the ice, in the open waters of the marginal ice zone and beyond to waters uncovered during the annual retreat.

Such an effort requires knowledge of the geophysical features of sea ice from mesoscale features to the microstructure of the ice fabric, the organic and inorganic chemistry of ice and brine inclusions and the optical properties of sea ice. While these topics are generally the domain of physicists and chemists, biologists must be aware of and focus on those aspects of these topics likely to influence the sea ice biota.

In general, there seem to be two types of process which contribute to changes in the distribution of the biota. Physical processes appear to have significant influence on the lower trophic levels : ice nucleation, adsorption and trapping of individual cells are examples of small-scale processes. At larger scales the melting of sea ice, stabilization of the water column and seeding of the water with actively growing microbes provide appropriate conditions for a subsequent ice-edge bloom. Waters seaward of the bloom and under the ice have lower biomass and biological activity. We need to determine the factors controlling the seasonal changes in ice edge productivity in all Antarctic seas and large polynyas. We must understand how and how much ice-edge blooms contribute to overall system production. Biological processes also influence the distribution of organisms with respect to the ice. Thus the range and densities of sea-birds and seals vary seasonally with the waxing and waning of the pack ice habitat, but we know little about how their diet and foraging behaviour changes. The extent of the dependence of whales on the ice-edge zone is particularly poorly known.

The rates and types of biological processes related to the carbon cycle are substantially influenced by the presence and dynamics of sea-ice. This is best established for the microbiota, marine mammals and birds. Our knowledge is least for the ice macrobiota and we are still discovering what species, and in some cases phyla, are present in the ice.

Sea-ice microbiota are likely to be of considerable importance seasonally, because they provide a source of microbial biomass which is highly concentrated and available to microbial and metazoan grazers.

Topics of interest include:

1. Interactions between ice bacteria and ice algae
2. Photobiology of sea-ice microalgae
3. The dynamics of the microbial loop in ice

Primary and secondary microbial production is active seasonally even when under-ice water column production is nil. Fertile areas for research include how various physicochemical and biotic aspects of the sea-ice habitat act in concert to control the growth and development of sea-ice microbial communities.

Important physicochemical aspects are the influence of temperature, nutrients, light and salinity on rates of production. From the biological perspective we should investigate the physiological, biochemical, and molecular adaptations of the biota which have evolved to allow them to colonize and exploit the sea ice habitat.

Food web relations among the sea-ice macrobiota are also unknown. The microbiota may be grazed by amphipods and krill. Ctenophores have been observed near ice-floes actively feeding on small krill concentrated there. Little is known of the feeding ecology of the cryopelagic fauna or of the behavioural adaptations of epipelagic fauna which exploit the resources of sea-ice. Consequently there is little information on the diet and energy budgets of the seals, sea birds and whales characteristically associated with this zone. Dietary data from seabirds foraging in the pack-ice zone will also provide valuable information on the distribution of sea ice macrobiota where conventional sampling methods have failed.

The Group recognizes that much of the above information will not be collected without the development of suitable techniques for working in the ice. In particular, new methods are required for sampling the physical, chemical and biological properties in and under the pack-ice. Conventional open ocean sampling gear and methods are often totally inadequate for use in this zone. Future work is likely to rely increasingly on moored instruments (e.g. thermistors, fluorometers and current meters), on remote sensing from satellites and on specially designed packages, such as those which monitor diving behaviour of pack-ice seals.

In conclusion, the Group noted that there is now considerably enhanced research interest in Antarctic sea-ice. The proposals by the SCAR Group of Specialists on Antarctic Sea Ice for an Antarctic Sea Ice Zone (ASIZ) research programme could offer considerable opportunities for research on biological processes. It was expected that the formation of a SCOR Working Group 86 on the Ecology of Sea Ice (cosponsored by

SCAR) would focus further attention on research directions and priorities. Interchange of ideas between this group and the Group of Specialists on Southern Ocean Ecology is of great importance and will be facilitated by the presence of Dr Sullivan on both groups.

## 3.2 ANTARCTIC CONTINENTAL SHELF

### 3.2.1 Background

The continental shelf surrounding Antarctica comprises an area of about $2 \times 10^6 km^2$. Adjacent to the most parts of the continent, the shelf is narrow (less than 100 km) and deep (200-600 m). Major shelf areas are situated in the Ross Sea, Weddell Sea and Prydz Bay.

Both the benthic and pelagic habitats of the shelf are physically and biologically isolated from the other subsystems of the Southern Ocean (except for the overlapping sea-ice system) by deep oceanic basins and a pronounced hydrographic discontinuity (continental water boundary), respectively. In contrast to the other systems considered, environmental factors, although extreme, are more stable and predictable. Stable factors include temperature, salinity and currents, while the ice cover and the light regime are seasonally predictable. Certain organisms appear to be well adapted to such conditions, particularly in terms of their life history strategies. Nevertheless, the relatively poor faunal diversity of the pelagic zone may be attributable to the zone's young geological age compared to the benthos. This would have resulted from periodic glaciation of the shelf during the Pleistocene.

### 3.2.2 Current knowledge

The continental shelf and adjacent oceanic waters are some of the least investigated parts of the Southern Ocean. Locally, studies have been conducted mainly from shore stations, e.g. McMurdo Station, Scott Base, in the Ross Sea. Distribution and community structures of demersal and pelagic organisms are only roughly known. Recently, national programmes are being directed to the Southern Weddell Sea and the Prydz Bay Region. The first multinational investigation is projected for 1988/89 (European "Polarstern" study (EPOS) - leg 3).

Existing data on the high Antarctic shelf system show a diverse and abundant benthic community, dominated mostly by sponges and echinoderms. More than 50 species of demersal fish have been reported from the southern Weddell Sea. The zooplankton is dominated by copepods and E.crystallorophias rather than E. superba. The key nektonic species is the fish Pleuragramma antarcticum

### 3.2.3 Research requirements:

a) As in other Antarctic systems, basic knowledge on taxonomy, distribution and community structures has to be gathered, especially for the benthos.

b) Pelagic systems seem to be relatively simple and dominated by a few key species. Some of these, such as Emperor penguins and Weddell seals, depend on fish (especially Pleuragramma and various benthic-demersal species) and, to a lesser extent, cephalopods, Adelie penguins take fish but, at least in summer, depend on crustaceans, predominantly E. crystallorophias on-shelf and E. superba off-shelf. Crabeater seals may be less dependent on E. superba than previously assumed because fish, squid and E. crystallorophias have been recorded recently in their diet. We need more detailed and extensive dietary studies, especially in winter and particularly to determine seasonal and annual variations in the consumption of E. superba, E. crystallorophias, fish and squid.

c) The high Antarctic coastal current may provide a suitable mechanism for advection of essential nutrients utilized by sessile organisms. In these terms, the horizontal transport of energy may be more significant than sedimentation in the high Antarctic shelf system. At higher trophic levels, the variable availability of pelagic food resources may arise from both local enhanced productivity (i.e. in bays or inlets) and/or advection.

d) Extremely low, but constant, temperature and stable or predictable environmental conditions in general may have favoured the development of typical "Antarctic" adaptations in high Antarctic taxa. Zoogeography (e.g. of fishes) suggests significant differences between high Antarctic, Peninsula and subantarctic habitats. Studies of physiology, biochemistry and ethology of these taxa may yield valuable insights into evolutionary mechanisms in polar waters.

## 3.3 OPEN OCEAN PELAGIC ZONE

### 3.3.1 Physico-biological structure

The open-ocean pelagic zone comprises the surface-watermass (0 to ± 1000m depth) from the continental shelf in the south to the Antarctic Polar Front (APF) in the north. It is a seasonally ice-free ring of water surrounding the continent, with a characteristic thermohaline structure. Baroclinic circulation is weak while the predominantly cyclonic wind-field drives regional Ekman divergence and a poleward Sverdrup transport. This transport is balanced by northward flowing western boundary currents in at least three locations around the continent. These define the sub-polar gyres, perhaps the largest and most distinctive of which is the Weddell Gyre. At various localities there is also evidence that both horizontal frontal discontinuities (topographically or meteorologically induced) and vertical current shear interrupt the relatively weak surface geostrophic flow.

The dynamical balance and synoptic structure of the pelagic zone exert considerable influence on both the biotic elements and processes confined therein. Available data indicate very low phytoplankton stocks for a considerable period of the growing season. Such stock levels (0.05-0.2 um Chla/l) are characteristic of so called "blue-water" areas and associated primary production (c. 15 gC/m$^2$/yr) is also low. Therefore, despite enhanced local variability (i.e. at fronts and in the ice-edge zone), there are indications that large areas of the Southern Ocean may be relatively unproductive. It may prove that the traditional view of an exceptionally productive Antarctic pelagic system has arisen by generalisation from well-studied highly productive areas, such as those close to the Antarctic Peninsula.

Like other "blue-water" areas, the open ocean phytoplankton are predominantly small (possibly less than 5 um) thereby limiting the potential availability to macro-zooplankton (e.g. krill). Furthermore, Southern Ocean phytoplankton production is unlikely to be nutrient limited. The main influence on primary production is likely to be the interplay between vertical mixing and the time scale of phytoplankton light-adaptation rates.

### 3.3.2 Potential study topics in the open ocean pelagic zone

Because this system is one of limited physical variability, it will be difficult to relate biological features to particular aspects of the physico-chemical environment. It may be better to concentrate initially on areas of frontal discontinuity, which offer obvious environmental gradients to relate to the distribution of e.g. patchily distributed zooplankton. Furthermore, large scale advection may greatly influence the occurence, abundance and demography of key species and also the scale (e.g. duration) of interactions between them.

Nevertheless it is essential to view these frontal processes in the context of the whole system, which requires developing economic and logistically feasible ways of studying large-scale open ocean phenomena.

a) Primary producers

The development of a realistic phytoplankton growth model for the open ocean requires data on phytoplankton composition, biomass and photobiology at the species level. Changes in the open ocean light regime should be monitored in order to assess the seasonal and spatial variability in the photoenvironment. In addition to long term ship-based studies this needs the deployment of automated telemetry (e.g. buoys and moored arrays).

The best method for efficient determination of phytoplankton biomass on a large-scale appears to be remote-sensing. This would yield acceptable results providing that existing algorithms are modified for high latitude areas. Long term monitoring of continuous sea-surface profiles by ships-of-opportunity may also improve available data on both the temporal and spatial variability of phytoplankton distribution.

To improve understanding of the critical photobiotic relations, studies of the interactions between vertical mixing, ocean optics and phytoplankton growth should be encouraged. This would require innovative *in situ* experimental and laboratory studies.

b) Secondary producers

Improved quantitative information is needed on the trophic relationships of all important secondary producers. To date, most of our efforts have been directed at krill but other species may be more important in certain areas. Special attention should be given to fish (particularly myctophids), squid and other zooplankton (especially copepods).

The essential complement to this is investigation of the relative importance of microbial pathways in nutrient regeneration and as an additional food source for zooplankton. The limiting effect of the supply of organic carbon (i.e. the indirect effect of mixing on primary production) constitutes an important topic about which little is known.

In contrast to interspecies relations, comparisons are needed between important behavioural and physiological adaptations of dominant species at different localities. Comparisons between areas of obvious dynamic variations (e.g. near fronts as opposed to less structured waters) are of particular interest in this respect. The Group envisaged that many of the techniques developed and proposed for krill (see BIOMASS Report Series no 51) could usefully be adapted for other species (e.g. copepods). The need for more research on krill larvae was recognised.

c) Higher trophic levels

Higher-order predators (e.g. whales, sea-birds) may need to forage very widely in the open ocean system and at least some sea-bird species may exploit dispersed prey as much as aggregated ones. If so, the impact of these groups in this system (i.e. outside the shelf-slope and ice-edge areas) may be less than hitherto estimated.

Such predator-prey interactions will be difficult to study except with remote telemetry and recording devices. However, the extent to which prey may be concentrated by purely physical processes (e.g. currents, vertical advection) needs study.

## 3.4 SUBANTARCTIC ISLANDS

### 3.4.1 Background

This system was considered to comprise the islands located at, or near, the Antarctic Polar Front (specifically South Georgia, Bouvet, the Prince Edward Islands, Crozet, Kerguelen, Heard and Macquarie), together with their surrounding shelf and shelf-slope areas.

Special features of this system relate to two main effects.

1 - Hydrographic and biological features associated with the presence of an island (and its associated shelf) in the open ocean.
A similar phenomenon is created by the presence of sea-mounts, but these were not specifically considered.

2 - The provision by these few islands of:

a) breeding habitats for very large populations of high trophic level marine consumers which come ashore to give birth (e.g. seals, sea-birds).

b) Fjords and/or bay habitats (and water of appropriate depth) that form suitable spawning grounds for large populations of demersal and benthic-demersal fish and possibly also seasonally suitable feeding grounds for some species of shoaling squid.

Of particular interest is the extent to which there may be an effect of locally enhanced productivity and availability of zooplankton and/or benthos which can sustain the large populations of seals, sea-birds and fish (and perhaps squid). In the case of both seals and sea-birds the situation is potentially intensified during the breeding seasons, when adults are constrained spatially by the need regularly to provision their offspring.

Enhanced productivity in the nearshore zone may be attributable to the "island-mass effect" (see 1 above). This effect could include various combination of wind-induced upwelling, downstream eddy formation, the proximity of frontal systems and nutrient run-off derived e.g. from guano. While this generalised situation may be applicable to all SubAntarctic islands, the details of the processes, mechanisms and composition of the communities may differ significantly between them. Thus only at South Georgia is Euphausia superba the regular staple zooplankton prey of the most of the sea-birds and seals (and of many fish and squid species). At other islands, other euphausiid species (E. lucens, E. vallentini, Thysanoessa spp.) or even decapods (e.g. Nauticaris at the Prince Edward Islands) form the main crustacean prey of top predators while myctophid fish also play an important role.

The balance between "endogenous" production and advection of zooplankton will also vary greatly between islands, according to their location in relation to major current systems. The differing proximity to islands of the Antarctic Polar Frontal Zone may also promote different degrees of interannual variation in hydrographic and associated biological features. The species composition of top predator communities also has important consequences for the vertical and horizontal distribution of their foraging activities.

Nevertheless it is still possible to pose the following suite of questions for research, appropriate to most, if not all, components of the system.

### 3.4.2 Research questions

1) What are the physical, chemical and biological signatures of island mass effects ?

2) Is the availability of zooplankton, especially those which form the main prey of seals, sea-birds and fish elevated in the vicinity of islands ?

3) How is local prey availability maintained during the breeding seasons of the various top predators ? In particular

a) how much of the local production/potentially available prey is consumed by top predators and
b) how often is the prey supply replenished by advection ?

4) What is the importance of nutrient flux through benthic pathways and of the sedimentation process in particular?

### 3.4.3 Research programmes

To answer the above questions requires a major programme of integrated research including both shore-based and at-sea studies. A number of national programmes (chiefly France, South Africa, United Kingdom) are undertaking such research and the Group felt it was only necessary here to indicate the broad outline and the appropriate scope of such operations.

a) Physical and chemical oceanographic studies

Important processes and phenomena for study include bathymetry, geopotential topography, the nature and location of upwellings, eddies and gyres, the physical and chemical characterictics of discrete water masses and the water transport into and within the near-island zone. Knowledge of the position of frontal systems, perhaps using remote sensing techniques, is essential.

b) Microbial studies

The major research topics should include the distribution and the characterisation of the photoautotroph, microheterotroph and microphagotroph communities; the production dynamics within and between these, involving estimation of growth, of carbon and nitrogen fluxes and of nutrient recycling and remineralization involving protozoa; and the study of sedimentation rates.

c) Zooplankton studies

The principal aims should be to quantify zooplankton distribution, biomass and trophodynamics (including biochemical composition and its seasonal changes, basal and active metabolic rates, bioenergetics etc..) in relation to the physical and chemical environment and to the foraging activities of the main predators. At South Georgia a particular need is to define the biological characteristics of E. superba swarms and to determine the factors causing, or facilitating, swarming and dispersion. Similar studies of other euphausiids may be important in other areas.

d) Fish and squid studies

Priorities are to locate spawning grounds, to determine the seasonal distribution of populations, especially in relation to spawning time and food availability and to quantify trophic relationships. Knowledge of squid is almost entirely deficient in all these areas.

e) Sea-birds and seals studies

The main aim should be to quantify energy transfer to these top predators. This requires accurate estimates of: breeding population size; non-breeding populations (principally derivable from life-table data); dietary composition (and the main seasonal variations therein); including the age, sex, reproductive status and energy content of prey; and activity and energy budgets, especially including the location, timing and depth-distribution of foraging - ideally in relation to simultaneous data on the distribution and abundance of prey.

## 4. LINKS WITH THE BIOMASS PROGRAMME

### 4.1 Background

The SCAR/SCOR Group of Specialists on Southern Ocean Ecosystems and their Living Resources, which developed the BIOMASS Programme, was disbanded in 1985. The supervision of the completion of the analyses of BIOMASS data and of the synthesis of BIOMASS results is now the responsibility of the BIOMASS Executive, which is due to be disbanded in 1990.

The principal avenue for analysis of BIOMASS data is through the

BIOMASS Data Centre, housed at BAS Cambridge since 1984 (to be reviewed in 1989). The main data available for analysis are those collected during SIBEX in 1983/84 and 1984/85. Analysis of these data is planned to proceed via a series of workshops, viz :

1. Physical and Chemical Oceanography. This was held at Cambridge in April 1987 (convenors R.B. Heywood and M. Stein) (see document 18). It was a very successful meeting and established a sound environmental background against which to view the SIBEX biological data.

2. Phytoplankton/Zooplankton Relationships. This will be held in October 1987 at Sao Paulo, Brazil (Atlantic sector; convenors F.P. Brandini and S. Schiel) and Texas, USA (Pacific and Indian sectors; convenor S. Z. El-Sayed).

3. Fish Ecology. A data validation meeting was held at Cambridge in October 1986. The main workshop will be held at Cambrige in August 1987 (convenors J.-C. Hureau, K.-H. Kock and M.G. White).

4. Seabird Ecology. Guidelines for the conduct of data validation were developed at the FIBEX Seabird Data Interpretation Workshop (see BIOMASS Report Series n° 44). This operation should be concluded by the end of 1987 and the main workshop is likely to be held the following year. Co-ordination and organisation will be provided by the SCAR Bird Biology Sub-Committee.

A number of other workshops were originally projected by the BIOMASS Executive. That on krill catch-per-unit-effort (CPUE) is now essentially being co-ordinated by CCAMLR (see SC-CAMLR-IV, pp 25-29 for details). The workshop on krill physiology and biochemistry held in Canada in September 1986 (convenors A.Clarke, P.Mayzaud) was a broad-ranging review meeting almost exclusively discussing data not collected as part of SIBEX and other integrated multinational research operations (See Document 24).

There is a particular need for a workshop on krill acoustics, specifically to analyse SIBEX results, but this has been awaiting the results of target strength experiments.

There has been no progress with the workshops on krill larval ecology planned for spring 1987 and autumn 1988 because data were too sparse to justify such an exercise.

4.2 <u>Links with, and development of, BIOMASS initiatives</u>

A logical relationship between the BIOMASS Executive and the SCAR Group of Specialists on Southern Ocean Ecology might be developed along the following lines.

<u>BIOMASS Executive</u>

1. Planning and conduct of the SIBEX data analysis workshops (see earlier) and to ensure that these include one devoted to krill acoustics.

2. Organisation of a workshop integrating and analysing interactively the results of all the specialist SIBEX workshops.

3. Organising a BIOMASS evaluation meeting in 1990 and supervising the publications of its proceedings.

4. Arranging for the continued availability (after 1990) of the data (and management and analysis protocols) held within the BIOMASS Data Centre.

SCAR Group of Specialists

1. Responsibility for the further development of research and other initiatives started within, or stimulated by, the BIOMASS programme, but not directly relevant to FIBEX and SIBEX.
Developments and proposals of particular relevance here include :

a) Symposium and workshop on krill biology

The participants in the recent BIOMASS workshop on krill physiology proposed a meeting on the above theme for 1990 (See Document 24). Such a meeting should have profound influence on the future organisation and development of krill research and also for many related aspects of Antarctic marine ecology.

The Group believed that SCAR should strongly support this meeting and that the Group of Specialists should be represented in the planning of the scientific programme. To ensure this it was recommended that the proposed convenor of the krill biology meeting (Dr A. Clarke) attends the next meeting of this Group of Specialists.

b) Coordination of research on Antarctic fish ecology and physiology

Ichthyologists working on BIOMASS (especially SIBEX) fish data have felt the need for more co-ordination of and collaboration on such research. They proposed that an *ad hoc* group of Antarctic ichthyologists be established. The Group of Specialists, while recognizing the need for greater co-ordination of fish studies, were concerned to avoid the proliferation of *ad hoc* groups. It was agreed that an appropriate initiative would be for Antarctic ichthyologists to consider organising a symposium or workshop on Antarctic fish ecology and physiology, perhaps along similar lines to that proposed for krill. Drs Hureau and Hubold were asked to investigate this further.

c) Development of an integrated approach to research on pack-ice seals

The BIOMASS programme directed little research specifically at seals. The SCAR Group of Specialists on Seals has been concerned that the co-ordinated research necessary to improve knowledge of the biology and ecology of ice-breeding seals is not being developed.

In view of the increasing general biological interest in the sea-ice zone such a development would be highly appropriate. The Group of Specialists on Seals should be asked to prepare specific suggestions and to seek SCAR support.

d) Synthesis of results of the International Survey of Antarctic Seabirds.

Some 10 nations have current programmes collecting data on the distribution and abundance of Antarctic seabirds, especially penguins. This programme was started by SCAR and developed by the BIOMASS Working Party on Bird Ecology.

The SCAR Bird Biology Subcommittee has noted that a synthesis of results in about 1990 would be timely and suggested that a symposium or workshop would be an appropriate way of achieving this. The subcommittee should be asked to prepare detailed proposals and to seek SCAR support.

## 5. RELATIONS WITH CCAMLR

CCAMLR has a reponsibility for the management of all Antarctic marine living resources, including, therefore, harvested, harvestable and dependent species. At present the CCAMLR Scientific Committee is striving to develop a management scheme appropriate to this responsibility yet feasible in terms of demands on fields operations and data acquisition, analysis and interpretation facilities. The two main initiatives so far established are concerned with stock assessment and with ecosystem monitoring.

Data relevant to stock assessment and management come mainly from commercial fishery activities. Data pertaining to ecosystem monitoring come chiefly from the research conducted by national programmes.

The scope proposed at present for the CCAMLR ecosystem monitoring programme is very extensive indeed and would require substantial resources at shore stations and major commitments of shiptime and other resources at sea. This is because the programme involves monitoring a variety of predator and prey species and also requires collecting environmental and other data for interpreting trends and anomalies in the monitoring data and for distinguishing between changes resulting from commercial harvesting and changes due to environmental variability.

Until this programme is refined in more pragmatic terms its implications for existing national research programmes and for the research initiatives suggested here cannot be evaluated. Similarly, until general relations between CCAMLR and SCAR are clarified, it seemed premature for this Group of Specialists to suggest any formal collaborative links.

At present CCAMLR 's involvement with SCAR has mainly been confined to requesting data and specialist advice from members of the Group of Specialists on Seals and the SCAR Bird Biology Subcommittee. However, CCAMLR has also requested SCAR to consider the feasibility of promoting and coordinating as a matter of urgency the acquisition of quantitative information on diet, outside the breeding season, of predator species.

Some existing national programmes are already acquiring relevant data. Many of the proposals and themes developed earlier, especially those based on year-round studies of ice dynamics, would offer excellent opportunities. Whenever year-round programmes are started they should include provision for acquiring data on predator diets at times outside the breeding season and also from areas distant from breeding sites.

## 6. RECOMMENDATIONS

### 6.1 Membership

The elements of this report dealing with physical and chemical oceanography and with benthos need critical review by appropriate scientists. The Group recommends that the report be circulated widely to specialists in these disciplines and that three of these (ideally one physical and one chemical oceanographer and one benthic ecologist) should be nominated to the membership of the Group.

6.2 Liaison and information exchange

To assist its role in this, the Group recommends that SCAR arranges the provision of suitably detailed summaries of national research programmes in Antarctic marine ecology, highlighting those involving international collaboration. This review should be updated annually.

The Group also recommends that an appropriate scientist in each country be nominated to provide detail liaison with the Group concerning these research programmes.

6.3 Workshops

The Group recommends that BIOMASS Executive supports:

- the proposal for a krill biology workshop and symposium in about 1990. To facilitate this Dr Clarke should be asked to discuss with the Group of Specialists organising a planning meeting to coincide with XX SCAR in 1988.

The Group recommends also that SCAR supports:

a) initiatives seeking to co-ordinate collaborative research on Antarctic fish ecology and physiology. Drs Hureau and Hubold should be asked to prepare proposals for a workshop to promote this.

b) initiatives of the Group of Specialists on Seals to co-ordinate research on ice-breeding seals by holding an appropriate workshop.

c) initiatives of the Bird Biology Subcommittee of the Working Group on Biology in proposing a workshop in about 1990 to synthesize the results of the International Survey of Antarctic Seabirds.

6.4 Future meetings

The Group intended to meet in conjunction with the meetings associated with XX SCAR in Australia in 1988 and request SCAR to make financial provision for a meeting in 1989.

## ANNEX 1

### List of members of the Group of Specialists

John P. CROXALL
British Antarctic Survey
High Cross Madingley Road
CAMBRIDGE CB3 OET
United Kingdom

Gerd HUBOLD
Institut für Polarökologie
Olshausenstrasse 40
D-2300 KIEL 1
Federal Republic of Germany

Jean-Claude HUREAU (Convenor)
Museum national d'histoire naturelle
Ichtyologie générale et appliquée
43 rue Cuvier
75231 PARIS Cedex 05
France

Denzil MILLER
Sea Fisheries Research Institute
Private Bag X2, Rogge Bay
CAPE TOWN
Republic of South Africa 8012

Egil SAKSHAUG
Universitetet i Trondheim Museet
Trondhjem Biologiske Stasjon
Bynesvn. 46
7018 TRONDHEIM
Norway

Cornelius W. SULLIVAN
Marine Biology Research Section
Department of Biological Sciences
University of Southern California
University Park
LOS ANGELES California 90089-0371
U.S.A.

**ANNEX 2**

**Meeting of the Group of Specialists on Southern Ocean Ecology (PARIS, 27-29 May 1987)**

## Agenda

1 - Opening of meeting and adoption of agenda

2 - Objectives and scope of the Group of Specialists

3 - Review of research on Antarctic marine ecology

4 - Links with the BIOMASS Programme

5 - Relationships with CCAMLR

6 - Recommendations

7 - Other matters

## ANNEX 3

## Group of Specialists on Southern Ocean Ecology

### List of documents

1 - Provisional agenda

2 - Terms of reference and establishment of the Group

3 - The role of SCAR Group of Specialists on Southern Ocean Ecology in the organisation of research on Antarctic marine ecology (J.P.CROXALL)

4 - Important fields for research on Antarctic marine ecology (G.HUBOLD)

5 - Some thoughts on research activities to be co-ordinated by the SCAR Group of Specialists on Southern Ocean Ecology (D.G.M.MILLER)

6 - Outline of selected research topics (C.M.SULLIVAN)

7 - On future marine research in the Southern Ocean (E. SAKSHAUG)

8 - WOCE Core Programme 2 Workshop. The Southern Ocean

9 - SCAR Document for ASIZ Proposal

10 - IOS/BAS Paper submitted for inclusion as an appendix to the main report. The UK contribution to GOFS, a possible Southern Ocean study

11 - Offshore Biological Programme. Objectives and strategies for research

12 - Proposal for a Fine Resolution Antarctic ocean Model (FRAM)

13 - Final report of the BIOMASS Working party on Bird Ecology

14 - Projet ANTARES (Antarctic Research) 1988-1995

15 - European Polarstern Study. Preantares/FMO

16 - Programme S.O.C.R.A.T. (Suivi océanologique le long de Radiales en secteur Austral pour la valorisation de Transits)

17 - Future Biological Studies of the Southern Ocean: Research Plans and International Co-ordination (EL-SAYED)

18 - SIBEX Physical Oceanography workshop. BIOMASS Database Centre

19 - ESF Polar Sciences Network. Report of the EPOS Planning Group.

20 - Proposed terms of reference for an ad-hoc group of antarctic ichthyologists

21 - SCAR letter: Comments requested by CCAMLR Ecosystem Monitoring WG

22 - SCAR letter: Particularly Sensitive Sea Areas.

## SCAR Report

*SCAR Report* is an irregular series of publications, started in 1986 to complement SCAR Bulletin. Its purpose is to provide SCAR National Committees and others directly involved in the work of SCAR with the full texts of reports of SCAR Working Group and Group of Specialists meetings, which had become too extensive to be published in the *Bulletin*, and with more comprehensive material from Antarctic Treaty meetings.

## SCAR Bulletin

*SCAR Bulletin*, a quarterly publication of the Scientific Committee on Antarctic Research, is published on behalf of SCAR by Polar Publications, at the Scott Polar Research Institute, Cambridge. It carries reports of SCAR meetings, short summaries of SCAR Working Group and Group of Specialists meetings, notes, reviews, and articles and material from Antarctic Treaty Consultative meetings, considered to be of interest to a wide readership. Selections are reprinted as part of *Polar Record*, the journal of SPRI, and a Spanish translation is published by Instituto Antártico Argentino, Buenos Aires, Argentina.

## Polar Record

*Polar Record* appears in January, April, July and October each year. The Editor welcomes articles, notes and reviews of contemporary or historic interest covering the sciences and humanities in polar and subpolar regions. Recent topics have included polar aspects of agriculture, archaeology, biogeography, botany, ecology, geography, geology, glaciology, international law, medicine, politics, human physiology, psychology, pollution chemistry and zoology.

Articles usually appear within a year of receipt, short notes within six months. For details contact the Editor of *Polar Record*, Scott Polar Research Institute, Lensfiled Road, Cambridge CB2 1ER, UK: Tel (0223) 336567.

The journal may also be used to advertise new books, forthcoming events of polar interest, etc.

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Printed by The Chameleon Press Limited, 5–25 Burr Road, London SW18 4SG