South African Southern Ocean Research Programme

SASCAR

Programme developed by the Southern Ocean Committee
of the South African Scientific Committee for Antarctic Research (SASCAR)

SOUTH AFRICAN NATIONAL SCIENTIFIC PROGRAMMES REPORT NO

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PREFACE

South Africa is one of the twelve original signatories of the Antarctic Treaty and South Africans have been actively involved in Antarctic research since 1960. Research in the Antarctic is coordinated internationally through the Scientific Committee on Antarctic Research (SCAR) of the International Council of Scientific Unions (ICSU). The Council for Scientific and Industrial Research (CSIR) coordinates the scientific programmes of the South African National Antarctic Research Programme (SANARP) through a national committee called the South African Scientific Committee for Antarctic Research (SASCAR), which is also the National Committee adhering to SCAR. SANARP has four main research programmes - biological (mainly terrestrial) sciences, earth sciences, Southern Ocean sciences, and physical sciences.

This document describes the SANARP Southern Ocean sciences (physical, biological and chemical oceanology) programme, which SASCAR has recommended should be undertaken in the Southern Ocean south of southern Africa. It has been developed in consultation with scientists having a current Southern Ocean research activity within SANARP, with scientists having an interest, but not participating directly, in Southern Ocean research and with due regard to relevant international instruments (e.g. the Antarctic Treaty and the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) and research programmes (e.g. SCAR/SCOR Biological Investigation of Marine Antarctic Systems and Stocks (BIOMASS)). It also takes into account the manpower, scientific facilities and logistical support available in the country. It emphasizes research activities which can be undertaken with existing manpower, facilities and logistical support, as well as logical extensions to these. The objectives of the programme are *inter alia* to obtain an improved understanding of the structure and functioning of the physical, chemical and biological components, and the interrelationships between them, in selected areas in the Southern Ocean south of southern Africa.

The document is intended to direct and coordinate the efforts of those already involved in SANARP, be informative for those not involved, guide those who may wish to initiate an activity, and guide the policy and decision-making bodies in respect of future research activities and their financial and logistical requirements.

Similar descriptions of the SANARP biological sciences (mainly terrestrial) and earth sciences (including marine geoscience) research programmes have been published in this series. These are available from the publishers of this document. A future report in this series will describe the aims of the SASCAR physical sciences research programme.

ABSTRACT

This document describes the South African National Antarctic Research Programme's (SANARP) physical, chemical and biological Southern Ocean research programme. The programme has three main components: ecological studies of the Prince Edward Islands' marine ecosystems; ecological studies in frontal zones south of southern Africa; and ecological studies in four selected regions in the Southern Ocean.

SAMEVATTING

Hierdie dokument beskryf die Suid-Afrikaanse Nasionale Antarktiese Navorsingsprogram (SANANP) se fisiese, chemiese en biologiese Suidelike Oseaan navorsingsprogram. Hierdie program bestaan uit drie hoofkomponente: ekologiese studies van die Prince Edward-eilande se mariene ekosisteme; ekologiese studies van frontale sones suid van suidelike Afrika; en ekologiese studies in vier geselekteerde areas in die Suidelike Oseaan.

KEYWORDS

Antarctica, Southern Ocean, Prince Edward Islands, frontal zones, oceanology, marine ecology, South African Scientific Committee for Antarctic Research (SASCAR).

TABLE OF CONTENTS

TABLE OF CONTENTS (Contd)

TABLE OF CONTENTS (Contd)

LIST OF ACRONYMS USED

ACRP	Antarctic Climate Research Programme
AOSS	Antarctic Oceanographic Sciences Study
APF	Antarctic Polar Front
BIOMASS	Biological Investigation of Marine Antarctic Systems and Stocks
CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
CCAMLR SC	CCAMLR Scientific Committee
CCAS	Convention for the Conservation of Antarctic Seals
COPE	Cooperative Oceanographic Project on Ergoclines
CSIR	Council for Scientific and Industrial Research
EXCOR	Executive Committee of SANCOR
FIBEX	First International BIOMASS Experiment
FRD	Foundation for Research Development
FZS	Frontal Zones Study
ICSU	International Council of Scientific Unions
IWC	International Convention for the Regulation of Whaling
MOES	Marion Island Offshore Ecological Study
M.V.	Motor Vessel
R.S.	Research Ship
SAF	Sub-Antarctic Front
SANAE	South African National Antarctic Expeditions
SANANP	Suid-Afrikaanse Nasionale Antarktiese Navorsings-program
SANARP	South African National Antarctic Research Programme
SANCOR	South African National Committe for Oceanographic Research
SASCAR	South African Scientific Committee for Antarctic Research
SCAR	Scientific Commmittee on Antarctic Research
SCOR	Scientific Committee on Oceanographic Research
SIBEX	Second International BIOMASS Experiment
STC	Sub-Tropical Convergence
TOGA	Tropical Oceans Global Atmosphere
WCP	World Climate Programme
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
XBT	Expendable Bathythermograph

INTRODUCTION

South Africa, with its lengthy coastline along which two major ocean features meet - the Mozambique/Agulhas Current systems in the east and the Benguela system in the west - lends itself to oceanology. Coastal oceanology in particular is, and has been in the past 100 to 150 years, of great importance to the orderly growth and development of the nation's commercial and industrial sectors. Fundamental and applied research on the continental shelf region and in the Benguela, Mozambique and Agulhas systems is undertaken by a number of local and national agencies. An umbrella organization that has played, and continues to play, a significant role in promoting and coordinating both coastal and deep-sea oceanology since the early 1960s, is the South African National Committee for Oceanographic Research (SANCOR) of the CSIR.

With its geographically well-placed position, and its small but well developed community of oceanologists and marine biologists, the extension of South African oceanology into the Southern Ocean, was a natural development that has been an ongoing activity for many years. Replacement in 1978 of the 16 year old M.V. RSA by the new SANARP supply/research vessel M.V. SA AGULHAS, provided a much more suitable research platform capable of operating in these regions, and the effort gained considerable new momentum.

Physical, chemical and biological oceanology in the Southern Ocean has been recognized as a formal part of SANARP since 1984. SASCAR was therefore faced with incorporating an ocean science programme into SANARP, which at that time comprised three main programmes - biological sciences (mainly terrestrial), earth sciences (including marine geoscience) and solar-terrestrial sciences.

Each of these programmes is guided by a specialist committee of SASCAR, comprising the participants (i.e. those funded through SASCAR to conduct research) and a few non-participating experts in the fields being researched. In 1985 SASCAR created a committee to develop and guide an oceanological research programme. Amongst its most important initial tasks was the development of a research framework setting out the primary objectives of the ocean science (physical, chemical and biological) research programme over the next ten years or so. This framework is presented in the following pages. It reflects SASCAR's main interests in this field of scientific endeavour but it should not be seen to preclude absolutely requests to SASCAR for financial assistance for projects which do not fit into one or more of the primary components of this programme. It is intended to direct and coordinate the efforts of participants, guide those who may wish to participate and provide a point of reference for decisions on funding and policy. It is open to participation by any interested and sufficiently experienced individual scientist or group of scientists, provided the grant holder is resident in South Africa and permanently employed by an approved South African scientific institution. Practical advice as to how to go about participation is given in the last chapter.

The research programme outlined here takes due cognizance of existing national and international scientific priorities, as well as national scientific expertise and logistical support capabilities.

HISTORY OF SOUTH AFRICAN SOUTHERN OCEAN RESEARCH

From 1945, a number of *ad hoc* research projects were initiated to meet South Africa's own interests in the oceans immediately to the west, south and east of the country. Practical incentives included the exploration and exploitation of accessible marine resources, the development of the coastal zone, improved safety and economy in navigation, improved weather forecasting and a fuller understanding of climate. In the early 1960s the CSIR established SANCOR to coordinate these projects and promote new ones, and to develop oceanographic research in a nationally integrated, cooperative programme. The overall objective was to gain knowledge through scientific research of the basic structures, processes and relationships in the ocean and on the sea-bed around southern Africa. The SANCOR programme became fully operational during the 1970s. Its specific objectives were first described in *S. Afr. Natl. Sci. Progr. Rep.* No. 22, published by the CSIR in January 1978.

At the 27th meeting of EXCOR (Executive Committee of SANCOR) in November 1976, it was decided to review South African involvement in Southern Ocean research. This decision was promoted by a number of factors including the increasing international interest being focused on Antarctica and the surrounding Southern Ocean, and the plan to acquire a new supply/research ship for SANARP to replace the ageing M.V. RSA which was launched in 1960. This process of review culminated with the publication of the aims and objectives of the South African Southern Ocean Cooperative Research Programme (*S. Afr. Natl. Sci. Progr. Rep.* No. 38) in May 1979. This programme was developed by an *ad hoc* Working Group drawn from SANCOR and SASCAR and was guided by a steering committee reporting to both.

The new SANARP supply/research ship M.V. SA AGULHAS came into service in 1978. She provided a much-improved platform for deep-sea research by South African scientists. Her main function is to serve SANARP. This led in 1983 to the complete transfer of the SANCOR programme into SANARP as a new programme, adding to the existing biological sciences, earth sciences and solar-terrestrial physics programmes coordinated by SASCAR.

Since the implementation of the SANCOR Southern Ocean research programme in the late 1970s, numerous national and international developments led to the need to reconsider South African Southern Ocean research. Results from the SCAR/SCOR BIOMASS Programme, and developments such as CCAMLR, the extension of the SASCAR biological research programme at the Prince Edward Islands into the surrounding ocean (*S. Afr. Natl. Sci. Prog. Rep.* No. 50, July 1981), the implementation of the SANCOR Benguela Ecology Programme in 1982 (*S. Afr. Natl. Sci. Prog. Rep.* No. 54, March 1981), the implementation of the South African National Programme for Weather, Climate and Atmosphere Research in 1982, and the availability of ships' time for Southern Ocean research on the M.V. SA AGULHAS, resulted in the creation of the SASCAR Southern Ocean Committee to do this. The new research programme thus developed is described in the following pages.

It should be noted that the existing programmes on biological and earth sciences focus mainly on sub-Antarctic terrestrial biology and Antarctic continental geosciences respectively, with marine geoscience being incorporated into the latter. Thus, this programme focuses primarily on physical, chemical and biological marine sciences, recognizing that there are overlaps with the existing biological and earth sciences programmes.

THE RATIONALE FOR SOUTH AFRICAN RESEARCH IN THE SOUTHERN OCEAN

SCIENTIFIC INTERESTS

Scientific study of the Southern Ocean south of southern Africa is expected to yield results of broad general significance. The Antarctic Circumpolar Current is the only ocean current that circumscribes the globe. It affects the flow patterns of South Africa's west coast Benguela Current and the terminal region of the east coast Agulhas Current. Air-sea interactions near the Antarctic continent produce the Antarctic Bottom Water, which flows north to cover the floor of all the earth's major ocean basins, particularly those in the Southern Hemisphere. The segment of the Southern Ocean south of southern Africa is dynamically the most active of any portion of that ocean, and the strong oceanographic gradients here make the area particularly conducive to shipboard and satellite study.

Satellite pictures shown nightly on national television show very clearly to all South Africans that their weather is largely dominated by processes occurring in and over the Southern Ocean. The coupling between ocean and atmosphere in the Southern Ocean is an important factor in long-term climatic change for the whole of the Southern Hemisphere. A better understanding of the coupling processes is essential to improved accuracy in weather forecasting and providing a deeper insight into the longer term factors controlling climatic patterns.

The formation of Antarctic Bottom Water and its subsequent sinking presents to the marine chemist a rare opportunity to study the injection and dispersal in ocean waters of key elements. Perhaps of paramount importance, the relatively unpolluted Southern Ocean may serve as a baseline indicator for worldwide studies of the regional and global levels and transport of pollutants.

The Southern Ocean is one of the world's most biologically productive oceans. Antarctic krill *Euphausia superba* is close to the heart of a complex ecosystem. Although krill is patchily distributed throughout the Southern Ocean it is believed that major concentrations occur in areas reasonably accessible from South Africa. Because it is regarded by many as a fishable resource, a greatly improved knowledge of its behaviour and biology is needed in order to understand better its role in the whole ecosystem before its exploitation reaches significant levels. In the face of commercial exploitation of living resources in general (e.g. krill, fish, squid), a better understanding of the whole ecosystem and the interactions within and between its biological, physical and chemical components is essential. In addition, the entry into force of CCAMLR calls for additional knowledge on Antarctic marine living resources from signatory nations, of which South Africa is one. In some instances, ongoing research is likely to provide the required knowledge but in other cases the development of new research for this purpose will be necessary. An improved understanding of the dynamics of the Antarctic ecosystem is vital to the effective implementation of the Convention.

The fishes of the Southern Ocean are physiologically and ecologically adapted for cold water conditions and low or erratic food availability.

Their larvae, juveniles and adults have characteristics unlike those of fishes in warmer oceans, and are therefore of considerable theoretical interest. Many of the life-history characteristics of Southern Ocean fishes (e.g. their relatively slow growth, late maturation and low fecundity) suggest that they will be vulnerable to high fishing pressure. Fishes also form an important dietary item for marine birds and mammals. Therefore, studies of their biology and of their role in the ecosystem are necessary in order to facilitate the sound management of fisheries in the Southern Ocean.

Little is known about the processes involved in the maintenance of ocean fronts (Antarctic Polar Front, Sub-Tropical Convergence, Sub-Antarctic Front) in the Southern Ocean, or about the meridional heat fluxes across them, the formation of their water types, and their kinematic and dynamic characteristics. These fronts in turn play major roles in biological, chemical and physical processes, and influence the climates of nearby sub-Antarctic islands such as the Prince Edward, Gough and Tristan da Cunha islands, and of southern Africa.

Since the early 1970s considerable biological research has been conducted at the Prince Edward Islands which are South African possessions. The stage has been reached where it is essential to extend the research effort offshore, since much of the functioning of the terrestrial ecosystem is dependent upon or influenced by what takes place in the surrounding ocean.

Furthermore, because of the geographical location of South Africa relative to the Southern Ocean and some of its key features, South African marine scientists are in a favourable position to make significant contributions to a number of important international research programmes. In this manner, the avenue of scientific exchange and collaboration between local marine scientists and the world scientific community can be maintained to the advantage of all. Such international research programmes include WOCE, WCP, COPE, ACRP, etc.

ECONOMIC INTERESTS

When viewing South Africa's economic interests in the Southern Ocean, cognizance should be taken of the status of the Republic's traditional marine resources, the magnitude and accessibility of living resources in the Southern Ocean and the existing expertise in the fields of capturing and processing of marine living resources. Most of South Africa's present major fisheries are maximally exploited. Any new resources, for example, in the Southern Ocean, could lead to a diversification of fishing effort which in itself has many social and economic advantages. The Republic, with Chile, New Zealand, Argentina and Australia, is geographically well positioned to rationally exploit Southern Ocean living resources. In a world potentially facing severe food crises, these are matters which cannot be overlooked.

Another economic consideration of potential significance, in the event of a major international trend towards the exploitation of living resources in the Southern Ocean, is the need for harbour and associated infrastructural facilities to service such activities in these regions. Should exploitation develop into a significant multi-national activity, South African ports would be very well placed to provide some of these services and support.

OTHER INTERESTS

In addition to the above arguments for a South African research effort in the Southern Ocean, there are other considerations arising from South Africa's involvement in international instruments as well as its sovereignty over the sub-Antarctic Prince Edward Islands:

- Antarctic Treaty - South Africa is an original signatory of the Antarctic Treaty and is one of the presently 18 Antarctic Treaty Consultative Parties. While membership gives the country a voice in the decision-making process on all matters affecting the Antarctic, it also requires South Africa to contribute to the wise conservation of the Antarctic region south of 60°S in the interests of all mankind. The knowledge and insight required for such a responsible contribution are gained mainly through an active, thoughtful and ongoing research presence in the Treaty area.

- Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) - The Convention was negotiated within the framework of the Antarctic Treaty system and South Africa is, again, an original signatory and member. The Convention has as its primary objective to rationalize the exploitation of Antarctic marine living resources while safeguarding the integrity of the Antarctic marine ecosystem as a whole. This represents an attempt to break new ground in the realm of the management of marine living resources, which will require great wisdom and detailed knowledge to bring to fruition. Initially the Parties to the Convention have to rely largely on knowledge already available, and that becoming available from separate ongoing national, as well as international research programmes (e.g. BIOMASS), but it is not unlikely that the full achievement of its objectives will require new dedicated research from its signatories, independently and collectively.

- International Whaling Convention (IWC) - South Africa is an original signatory to this Convention which was formed in 1946. The Convention has as its aims "to provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry". Although the IWC has a worldwide responsibility for whale stocks, it has historically had a major interest in assessments of stocks within the Antarctic and this interest continues to the present. Recent significant moves by the IWC include an International Decade of Cetacean Research and declaration of a pause in all commercial whaling from the 1985/86 Antarctic season.

- Convention for the Conservation of Antarctic Seals (CCAS) - This Convention came into force in 1978 with South Africa as one of the original signatories. Its aims are "to promote and achieve the objectives of protection, scientific study and rational use of Antarctic seals, and to maintain a satisfactory balance within the ecological system". The Convention recognizes that every effort should be made to encourage biological and other research on Antarctic seal populations, and a close relationship with SCAR is envisaged.

- Prince Edward Islands - Although the Prince Edward Islands have been studied extensively over a long period, relatively little is known about their marine environments. Apart from the fact that such knowledge is required for the proper conservation of the island environs, the United Nations Convention on the Law of the Sea provides a framework for the declaration of an exclusive economic zone around the islands, should such ever be desired or necessary in the future. However, such a step would make it incumbent on South Africa to acquire a detailed knowledge of the resources contained within the zone. In the meantime, the former requirement already exists.

SUMMARY

The above combination of factors leads to the conclusion that the Southern Ocean, particularly that part of it lying to the south of southern Africa, is a region in which the country should develop and maintain an expanded scientific research programme. Furthermore, it is noteworthy that such a scientific activity should not simply be based on the resource potential of the region. Other considerations, such as the region's influence on the weather and climate of South Africa, are of equal and perhaps more immediate importance.

COMPONENTS OF THE RESEARCH PROGRAMME

The major components of the research programme proposed here, and outlined below, offer opportunities for a variety of activities which should make significant contributions to the requirements mentioned in the preceding chapter. Investigations at all levels are required, from basic exploratory and resource-orientated surveys over large regions to in-depth process-orientated work at specific locations or in specific regions of the Southern Ocean.

For each of the programme's major components, primary objectives have been identified. These are the objectives that research participants, each introducing their own type of expertise, are expected to work towards collaboratively. The research programme is not an entirely open one catering for individual research interests. High costs, and the restricted nature of logistical support available to serve the programme all but exclude the possibility of researchers participating simply to satisfy their own private interests without in any way contributing towards the achievement of the objectives outlined below.

1. MARION ISLAND OFFSHORE ECOLOGICAL STUDY (MOES)

1.1 Introduction

Historically, the earliest, and perhaps most noteworthy, study of the marine environment of the Prince Edward Islands (approximately 47°S, 38°E) was carried out by H.M.S. CHALLENGER in late 1873. Since then, and after annexation of the islands by South Africa in 1947/48, little offshore biological work was undertaken until the mid 1970s.

In 1976, South African scientists collaborated with French researchers on the eighth voyage of the French research vessel, M.S. MARION-DUFRESNE. A wide range of research was carried out in the vicinity of both the Prince Edward and nearby Crozet islands. A variety of disciplines was catered for on the cruise and study topics included benthos, various hydrological investigations, water chemistry, primary productivity, plankton, fish, and seabirds.

By 1978 SASCAR had recognized the need for offshore research at the Prince Edward Islands in order better to understand the functioning of the Island's terrestrial ecosystem which had been under investigation since the late 1960s. For example, information on the local distribution and availability of the principal prey items of the marine predators (seabirds and seals) which breed seasonally on the islands was meagre. Yet this information is essential to an overall understanding of the roles of these predators in both the terrestrial and marine ecosystems of the islands, and also to assessing the appropriateness of using seabirds and seals as agents for monitoring changes in the regional pelagic ecosystem, if not of the Southern Ocean itself.

Exploratory surveys in the offshore region were subsequently undertaken between 1980 and 1983. These augmented existing knowledge of the region and also reinforced the need for further interdisciplinary studies of the offshore ecosystem and on the interactions between the terrestrial and marine ecosystems. Such studies are essential to clarify many of the trophic links between terrestrial and marine components of such ecosystem interdependencies. In addition, the Prince Edward Islands occur in a region which has strong Antarctic as well as sub-Antarctic characteristics. Thus, for many reasons, the island's offshore zone presents a special opportunity for a cohesive and integrated environmental study of an important oceanic region.

Finally, with the recent ratification of CCAMLR, seen together with the still controversial United Nations Convention on the Law of the Sea, South Africa appears duty-bound to a committed programme of research and resource evaluation in the zone around the Prince Edward Islands.

1.2 Gaps in our knowledge

Knowledge of the offshore environment of the Prince Edward Islands is very patchy. Aspects of the plankton and the physical and chemical properties of the pelagic ecosystem have been studied, but virtually nothing is known about the distribution and abundance of the vertebrate predators and their prey. Even less is known about ecological processes affecting the structure and functioning of the marine communities in the open sea surrounding the Prince Edward Islands.

(a) Physical oceanology

Knowledge of the offshore region of the Prince Edward Islands, extending northwards to the Sub-Tropical Convergence (STC) and southwards to the Antarctic Polar Front (APF), is mainly descriptive. Important gaps in our knowledge relate to an understanding of the ocean dynamics in the region. Does an "island-mass effect" occur, and what influence does it have on the physical nature of the seas surrounding the Prince Edward Islands? Does wind-induced upwelling occur in the lee of Marion Island? The influence of the STC and APF on the islands' marine ecosystems is little understood. The APF lies close to the region, and Antarctic surface water may sporadically be advected into the islands' offshore ecosystem. Knowledge is required of the dynamics of such occurrences.

(b) Chemical oceanology

Again, research has been mainly directed at obtaining descriptions of the structure, rather than the dynamics, of the islands' offshore ecosystems. As above, studies are required to understand the possible roles of "island-mass effect", wind-induced upwelling or advection of Antarctic surface water within the offshore region of Marion Island. An important influence, at least close to the islands, may be the effect of "guano run-off" from the very large penguin breeding colonies. Elevated reactive nitrate concentrations have been observed close to the southeastern seaboard of Marion Island. Such elevated levels may be due to either guano run-off or the periodic advection of water with a different chemical "signature" (or both). Such elevations are likely to be ephemeral and the result of interaction between hydrological and meteorological phenomena. Knowledge of the frequency of occurrence of such events and the dynamics controlling them, is required.

(c) Biological oceanology

The waters surrounding the Prince Edward Islands show enhanced primary productivity, thought to be due to an "island-mass effect" (including guano run-off). These seas also support very large populations of foraging seabirds, especially penguins, as well as seals. Practically nothing is known of the distribution, abundance, life-histories and dynamics of the prey (fish, squid and crustaceans) of these predators, but it can be assumed that both a high biomass and a high productivity exist to support their numbers. Some hydro-acoustic and mid-water trawling work has shown a low abundance and biomass of zooplankton in winter. However, there is some evidence for very high biomasses of some benthic species (crustaceans and fish) which are known to be preyed upon by birds. Information on these prey species is almost totally lacking, and in several cases, even their taxonomic status is uncertain.

Biological enhancement is known to occur at fronts, but the reasons for this are not at all clear. The effects of such biological enhancement of the offshore region, require study. Lastly, studies are required of the foraging ranges and depths of land-based predators (birds and seals), as well as quantitative studies of seasonal and year-to-year changes of their diets. Such studies are fundamental, since knowledge of foraging ranges will be used to define the geographical limits of MOES.

(d) Sea-floor topography

The bottom topography and sedimentology of the area around the islands has not yet been well described. These are important factors to almost all aspects of this study. Therefore, one of the most pressing needs is the production of a fine scale bottom topography map of the immediate region, extending a little beyond the base of the sea mount which forms the islands. Extension of such a map beyond this area, to approximately 50 km offshore, should be aimed at by at least mid-way through this study.

1.3 Objectives

It is logical that MOES should comprise two basic thrusts, one focusing on the description of the structure of the offshore ecosystem and the other on the processes which maintain this structure. Each is defined below, based on the assumption that the region constitutes an ecologically distinct subsystem of the Southern Ocean:

(a) **Component 1** - Directed at describing the structure (physical chemical, biological) of the marine ecosystem of the islands and having the theme:

"To obtain an understanding of the taxonomy, distribution and abundance of selected biotic components, including the species of seabirds and seals that breed on the islands, and of factors affecting these components in the Prince Edward Islands' marine ecosystem."

(b) **Component 2** - Directed at obtaining an understanding of the processes that underpin the dynamics of the marine ecosystem of the islands, and having the theme:

"To obtain an understanding of the productivity of the Prince Edward Islands' marine ecosystem as influenced by climatic, oceanographic and terrestrial features."

1.4 Key questions

For any research programme to be realistic, the key questions must be limited, and should be meaningful with a real chance of solution, using the facilities available.

Five considerations have special relevance to the first key question but also apply to some of the remaining key questions listed below. These considerations are:

(i) Recent work has indicated that the benthos is an extremely important component of the near-island system. This appears particularly true for the decapod *Nauticaris marionis* which has been found in the diet of a number of predators. Furthermore, there is some indication that a very local circulatory mechanism may be sustaining a high benthos biomass in the channel separating Prince Edward and Marion islands. The implication, therefore, is that between-island hydrological phenomena might be reflected by the structure and productivity of the benthic community.

(ii) With a prey identification service now fully operational (at the Port Elizabeth Museum, funded by SASCAR), specific organisms, particularly those of greater importance than others to the diets of shore-breeding marine predators, can now be identified. Care must be taken to ensure that as much information as possible is gathered about such organisms. Although this may prove problematic initially, given sampling limitations (e.g. squid), sampling should be made using as wide a spectrum of sampling gear as possible. Much could also be learnt about the plankton community in this way even if sampling gear is only deployed in a simple, qualitative manner (e.g. from S A AGHULHAS). The use of a specialized research vessel (e.g. the R.S. AFRICANA) on an *ad hoc* basis should facilitate the necessary quantitative assessments in due course.

(iii) The fish community may have two components: an inshore community of largely sedentary benthic species, and an offshore community of nektonic or free-swimming midwater species. Some species may form parts of different communities at different life history stages. Fishes are the prey of land-based predators but are also predators and important members of the aquatic community in their own right. It is therefore important to sample fishes in the open ocean near the islands as well as in the shallow waters around them.

(iv) The foraging ranges of land-based marine predators during their breeding seasons will bear strongly on the limits of the geographical area to be covered by MOES. Therefore, every attempt should be made to set the 'boundaries' of the study area, even if only provisionally, as soon as possible. Satellite-tracking and other "high-tech" developments will, over time, enable more accurate determinations of foraging ranges.

(v) Every attempt should be made to assess seasonal effects on the hydrology, and perhaps more importantly, the biology of the region. There is a definite need to mount dedicated cruises to the region in mid-summer and also in mid-winter to obtain a full understanding of the dynamics of the system.

Five key questions appear to have priority and are likely to make the most pertinent initial contributions to an understanding of the Prince Edward Islands' offshore marine ecosystem. These are:

<u>Key Question 1</u>

Is there an "island effect" and what are its basic chemical, physical and biological signatures and their dynamics?

This question should be seen as the cornerstone of efforts to understand the offshore ecosystem. It should result in a definition of the topography, hydrology and biology of the inshore, nearshore and pelagic zones. Initially, attempts should be made to assess the status of the ocean close to the islands and to describe some of the possible effects of the islands on prevailing hydrological conditions nearby. Thus, the geographical limit of the study (see (iv) above) must also take into account the effective extent of any island-induced marine eddies or topographical effects.

Studies of both Component 1- and 2-types (see Section 1.3 (a) and (b)) are required. Much of the necessary Component 1-type data could be collected during a few dedicated interdisciplinary cruises (two to three weeks duration in the region each). However, great care must be taken to prevent the generation of excessive and irrelevant data which is often the result of comprehensive, descriptive-type surveys. Component 2-type studies could, in the meantime, proceed during island relief exercises.

Key Question 2

What is the influence of the Sub-Tropical Convergence (STC) on the Prince Edward Islands' marine ecosystem?

This key question, although important, could be regarded as ancillary to the more direct approach already outlined above. The STC region of the Indian Ocean is especially dynamic. There is an indication that considerable interchange of water and biological species occurs across its boundaries. To date, evidence from the Prince Edward Islands region suggests that effective violation of the STC frontier by marine organisms may be manifest as far south as the islands. Assessment of the local impact of this would entail study of the STC north of the islands in conjunction with a multi-disciplinary investigation of hydrodynamic events on either side of the front.

Although the STC is crossed regularly in transit to and from the islands, definition is local. At least two dedicated cruises would need to be set aside for a closer investigation of the front and any associated eddies or gyres. These would conveniently overlap with the needs of the Frontal Zones Study (FZS) described later in this document. The difference in objectives of MOES and FZS, namely that the latter is directed more at describing the STC itself rather than at its possible influence on nearby hydrological and faunal manifestations, should not be difficult to synchronize on such cruises. Since the most immediate gap in knowledge is of conditions close to the islands, any future STC study can, in the framework of MOES, only be seen as second priority to a more local investigation of island effects.

Key Question 3

What is the influence of the Antarctic Polar Front (APF) on the Prince Edward Islands' marine ecosystem?

This question is important for the same reasons given above for the STC. The difference is that the APF lies closer to and south of the islands, and is therefore likely to exert a stronger influence on the prevailing hydrology. Also for the same reasons, an investigation of the APF would be secondary to assessment of more direct island effects. However, it should be noted that there is some suggestion that certain island-based marine predators utilize the APF region as a feeding ground during their breeding seasons. This obviously requires verification and depending on the outcome, a more urgent priority may have to be given to investigation of the effects of the APF region.

Key Question 4

Is near-shore productivity elevated, and if so, why?

Recent research indicates that there is an increase in the rate of carbon fixation close to the Prince Edward Islands when compared with the surrounding ocean. The causes of this increase are largely speculative at present. One theory holds that modification of the surface manifestation of the Antarctic Circumpolar Current in the immediate vicinity of the islands, by the prevailing northwesterly winds, may entrain either phytoplankton or nutrients, hence the elevated primary productivity of the sea in the vicinity of the saddle between the two islands (i.e. an island effect).

The object is to determine the availability of this production, through horizontal and turbulent transport, to a diverse array of benthic, suspensoid and pelagic feeders which may occur some distance from this focus.

An investigation to answer this question would be aimed primarily at the interrelationships between the primary producers and the hydrographic regime in the immediate vicinity of the islands, and could be conducted during regular relief voyages.

Key Question 5

How, and to what extent, does the productivity of the island seas support the marine and land-based predators of the region?

An investigation designed to answer this question must be structured so as to examine the interrelationships between the various components of the food web. An important facet of such a study is the possible direct interception of the potential energy (e.g. particulate organic matter) fixed by the primary producers and benthic community, in view of the predominance of suspensoid feeding groups within this community.

In addition, part of this investigation should be dedicated towards a greater understanding of the interactions between marine predators and their prey. This would include determinations of the foraging ranges, both horizontally and vertically, of the predators.

1.5 Summary

It is proposed that an intensive study on the offshore ecosystems around the Prince Edward Islands be initiated, aimed at the above-mentioned five key questions in order to better understand the influence, if any, the islands may have on them and *vice versa*. Responding to them requires a broadly based, interdisciplinary initiative in which detailed process-orientated studies are embedded. Obviously, as the data base grows, so the emphasis will shift from descriptive- towards process-orientated studies. Similarly, the emphasis should shift from macro- to microscale studies with time.

2. FRONTAL ZONES STUDY (FZS)

2.1 Introduction

South Africa is geographically well-placed for research in the Southern Ocean. The border to this ocean is usually defined as the STC which lies well south of South Africa. A well-developed, unobstructed and uninterrupted set of ocean fronts, currents and gyres across the full meridional width of the Southern Ocean thus forms the setting for deep-sea oceanological research south of Africa.

Fundamental research on this ocean has been recognized in South Africa to be of national importance for a number of reasons (see Rationale). Some work, partly described in the introduction to the MOES programme, has already been carried out. Added to this, South African scientists have established the importance of some oceanic frontal systems in the Southern Ocean to the enhanced productivity and density of certain biota. The geographical location, surface characteristics and variability of all the frontal systems between Africa and Antarctica have also been qualitatively described, as has the detailed thermal structure of the upper ocean layer in that sector of the Southern Ocean which lies between southern Africa and Antarctica.

South African open-ocean research in the Southern Ocean has progressed through a number of identifiable investigative stages. The first may be described as the spot-reading stage where only a limited number of readings are taken when opportunity arises, outside any project framework. The second stage may be typified as the survey stage in which the geographical distribution, nature and variance of a particular oceanographic feature are studied in a given region. The investigation of the thermal fronts south of Africa over the past five years by ships of opportunity is a good example of such survey research. This is usually an important precursor to process-orientated research. Having established the location, the nature and the variability of a phenomenon, attempts are made in the process-orientated mode to establish the reasons for its location, nature and variability and its relationships with other factors.

From an overview of South African research in the Southern Ocean, it is clear that various disciplines in the spectrum of ocean sciences are presently at different research stages. In identifying gaps in present knowledge and in proposing the FZS research programme, the various research stages of different disciplines have to be borne in mind. An appropriate management framework for FZS must therefore take cognizance of these stages of, as well as the required linkages between, disciplines on research problems where interdisciplinary, process-orientated research is called for.

2.2 Gaps in our knowledge

(a) Physical oceanology

Knowledge on the APF, the STC and the SAF south of Africa is purely descriptive. Little is known about the processes involved in their maintenance, about meridional heat fluxes across them, the formation of water types at the fronts, or their kinematic and dynamic characteristics.

It is already clear that the characteristics of the various oceanic fronts exhibit strong geographical variability. So, for instance, the STC south of South Africa is a strong and well-defined front, whereas in the South Atlantic Ocean it is more amorphous. Little is known about the nature of this variability. Areas of special interest that have been identified concerning, for example, the STC are: how it relates to Tristan da Cunha and Gough islands in the South Atlantic Ocean; its relation to the Agulhas Current in the geographical area of its greatest temporal variability south of Madagascar; and, its possible influence from here on the Prince Edward Islands. Other areas of special interest are the APF and SAF, particularly in the general vicinity of the Prince Edward Islands.

(b) Chemical oceanology

Chemical processes play crucial roles in the behaviour of biota in the Southern Ocean. Up to 1984, chemical studies south of Africa have consisted mainly of a few hydrographic measurements of nutrients and trace metals.

It is generally surmised that the ecological system in the Southern Ocean is not nutrient-limited. The system may, however, in certain times and places be limited by the form of nutrients available. Studies on this aspect and on the regeneration processes of organic forms of nutrients are thus required, particularly at oceanic fronts. Biochemical processes at these fronts must also be investigated. This includes studies on the range and concentrations of pigments which may act as strong indicators of zooplankton feeding and also of the developmental stage of phytoplankton blooms.

An important climatological process is the so-called "greenhouse" effect in which the accumulation of CO_2 in the atmosphere, due to the burning of fossil fuels, may lead to an increase in global temperatures. Large amounts of CO_2 may be absorbed by the sea surface layers, may then subduct at ocean convergences and may thus be removed from the atmosphere. Whether the ocean acts as a CO_2 source or sink has not been unambiguously determined. The tracing of various water masses by their CO_2 content at oceanic fronts south of Africa, is thus an important oceanological and climatological investigation.

(c) Biological oceanology

Ocean frontal systems play important roles in the natural history of many species (e.g. they may be used as staging posts for different life stages of fishes). It has been shown that the frontal systems south of Africa are areas of enhanced biological activity. It is not understood why phytoplankton abundance is increased at fronts, why there is increased primary productivity, why there is increased zooplankton abundance, what the species composition is, and how it varies with time and place. It has been noted that there are increases in seabird abundance at fronts, which may be prey-related, but this has not been definitely established. Penguins form approximately 90 % of the avian biomass in the Southern Ocean and some species may congregate at the APF. This front is therefore of particular ornithological interest, especially if the pelagic range of the island-based penguins could be determined.

While the STC may pass through Tristan da Cunha on occasions and may thus have an important influence on marine and terrestrial biological systems and processes there, which might be seasonal, no such influence is to be expected at the Prince Edward Islands. These two areas may thus offer scope for important comparative studies.

South African work on the fish of the Southern Ocean has only recently started. The taxonomy of the endemic fish, their larval stages, and their distribution relative to fronts are all poorly known, as is their biology. The detailed study of fish otoliths may show variability of growth rates of certain fish species relative to seasonal phenomena such as the hypothesized seasonal passage of the STC through Tristan da Cunha.

2.3 Objectives

The FZS should follow a logical progression through an initial descriptive phase, where this has not already taken place, into a process-orientated phase.

(a) **Component 1** - Aimed at describing the structure (physical, chemical, biological) of selected frontal zones and gyres south of southern Africa and having the theme:

> "To obtain an understanding of the structure (physical, chemical, biological) of selected frontal zones and gyres south of southern Africa, and of factors affecting this."

(b) **Component 2** - Focused on the important processes in order that the dynamics of the selected areas can be understood. The primary theme of this component should therefore be:

> "To obtain an understanding of the dynamics of the selected frontal zones and gyres south of southern Africa."

2.4 Key questions

Three key questions on which South Africa could make significant scientific contributions have been identified. They are:

Key Question 1

What is the structure of the Sub-Tropical Convergence (STC) in the South Atlantic Ocean and how does it function?

Initially at least one, three-week, dedicated research cruise in this area is required to study the quasi-synoptic physical behaviour of this front including its relationships with the chemical and biological features noted previously. The cruise must be well-planned and goal-directed to answer a number of specific scientific questions. The cruise plan should be flexible, so that it can accommodate unexpected observations. Guidance on the location and behaviour of the front should be given by real-time satellite imagery, tracks of drifting buoys, and by historical data.

In the initial and subsequent cruises, physical measurements should include closely-spaced XBT readings and full hydrographic stations. Chemical measurements should include all nutrients, their different forms, pigments, trace metals, and carbon dioxide. Observations on birds, continuous measurement of sea-surface chlorophyll, potential primary production, and trawls for plankton and fish should be carried out simultaneously with the physical programme.

Whenever possible, biological data should be obtained concurrently with the physical and chemical measurements. In this manner a truly inter-disciplinary, rather than a multidisciplinary, research endeavour should result.

The longer term (Component 2) objectives will be to establish in quasi-synoptic time the kinematics of the STC over as wide a zonal band in the South Atlantic Ocean as possible. The relationships between the physical and chemical nature of the front and biological activity such as primary production, zooplankton abundance, seabird distribution and behaviour, and fish distribution are important complementary objectives that are closely linked.

Key Question 2

What is the structure of the Sub-Tropical Convergence (STC) in the South Indian Ocean, and how does it function?

The general organization and achievements of this will be similar to Key Question 1 above. The target area of the initial cruise should be such that the influence of the STC on the Prince Edward Islands, as well as the characteristics of this front in one of the world ocean's most highly variable areas, may be simultaneously studied.

The long-term objectives will be to establish the kinematics and dynamics of the STC in an area where these are totally unknown. In any one cruise as wide a zonal band as possible of the STC, over as short a time as possible, should be studied. Again the relationships between the physical and chemical nature and dynamics of the front, and between these and the biological structure and processes such as primary production, species composition, zooplankton abundance, seabird distribution and behaviour, and fish distribution, are closely linked complementary objectives.

Key Question 3

What are the structure and dynamics of the Antarctic Polar Front (APF) south of southern Africa?

Dedicated cruises are called for, planned on the same scale as those above and preferably in an area where the influence of this front on the Prince Edward Islands may be studied at the same time. It may be possible to append the ship's time required for this to relief voyages to Marion Island, because of the proximity of the APF to these islands.

The long-term objectives would be to study the quasi-synoptic distribution of kinematic and dynamic elements of the APF over as extensive a zonal band as possible. Such a study should produce important new insights into the physical and chemical processes involved. The relationships between the physical and chemical nature of the front and biological activity should be studied in the same manner as for Key Questions 1 and 2 above.

2.5 Summary

The above three key questions have been identified as FZS priorities which are within the scope of logistical support presently available. Responding to them requires a broadly-based, interdisciplinary initiative. As progress is made, the emphasis should be expected to move from a descriptive (Component 1) towards a more process-orientated approach (Component 2). Because relatively little is known about the structure and even less about the functioning of the frontal zones selected above, it will be important to obtain a descriptive understanding of these targets in support of in-depth studies on selected processes.

3. ANTARCTIC OCEANOGRAPHIC SCIENCES STUDY (AOSS)

3.1 Introduction

South Africa has participated in the SCAR/SCOR BIOMASS Programme since its inception in 1976. Research cruises dedicated to the BIOMASS Programme were undertaken by the S.A.S. PROTEA (10 February - 12 April 1978), the M.V. SA AGULHAS (pre-FIBEX, 28 February - 2 April 1980; FIBEX, 16 February - 10 March 1981; SIBEX-I, 24 March - 26 April 1984) and the R.S. AFRICANA (SIBEX-II, 20 February - 23 March 1985). In addition, an eight-year research programme on the detailed thermal structure of the upper ocean layers south of Africa has been carried out during the course of some 25 South African research and relief cruises in the area.

The above cruises have provided experience and schooling for South African deep sea oceanologists with interests in the Southern Ocean. In addition these have produced an expertise in the mounting of large interdisciplinary research cruises.

Given the central position occupied by krill in the Southern Ocean food web and its vulnerability to over-exploitation, it has come to attract considerable international attention, as are other potential living resources in the region. CCAMLR provides a legal framework through which rational exploitation and management of Antarctic marine living resources can be practised. In fact, it is the first international fisheries agreement to adopt an ecosystem approach in its terms of reference and to incorporate this into its Articles. For the Convention to be effective, however, its Scientific Committee (CCAMLR SC) still requires considerable data on, and advice about, the Southern Ocean marine ecosystem as a whole, particularly concerning the dynamics of trophic interactions between krill and other species. In the recent past the BIOMASS Programme has provided some of the more fundamental data required by the Convention. In view of South Africa's continued participation in, and obligations to, both CCAMLR and the Antarctic Treaty, there is a need to develop a national research programme for the continued study of the Antarctic marine ecosystem. Expertise developed through participation in the BIOMASS Programme can be well used to carry this out.

The WOCE Programme developed in response to a decision to give ocean circulation a high priority in the WCP of the World Meteorological Organization (WMO), is gaining momentum. It will be the first attempt to survey oceanic circulation globally for a brief period. It is expected that WOCE will carry oceanology into a new era of global analysis and modelling similar to the advance in meteorology as a result of the global weather experiment in the 1970s. South Africa's geographical position and its small but active community of physical oceanologists, places it in a position to make important contributions to WOCE, specifically with respect to circulation in the Southern Ocean south of southern Africa, an area identified in WOCE as being in urgent need of more detailed study.

The CCAS, developed by and implemented through the Antarctic Treaty, places South Africa under obligations with respect to Antarctic seals. One of the species identified as being rare and requiring full protection in CCAS is the Ross seal *(Ommatophoca rossi)*. Initial investigations by South African biologists have shown that this species occurs in relatively large numbers off the Fimbul Ice Shelf upon which SANAE is situated. South African biologists are in a potentially unique position to make major contributions to knowledge about this rare species, whose large numbers in this region may be indicative of the presence of other unique biological and/or physical phenomena.

These, and other considerations such as the identification of key biological monitoring areas by CCAMLR in the region south of southern Africa, indicate that a South African Southern Ocean research programme could make significant, if not major, contributions to the international programmmes and instruments concerned with the region, as well as to the improvement of mankind's knowledge of the Southern Ocean generally and its influence on the Southern Hemisphere (e.g. climate)

In view of the practical limitations that would be expected to act on such a programme it is proposed that it focus on specific problems in specific regions, with the selection of the key questions (see section 3.4) and the specific regions (see below) being made to maximize the value of the above-mentioned contributions. On this basis the regions that are selected are:

(a) the western Lasarev Sea (60°S to the ice shelf; 4°W-4°E)
(b) the area of the Weddell Gyre termination
(c) the Maud Rise area (63-66°S; 0-6°E)
(d) the Bouvet Island (54°25'S; 3°21'E) environs.

In each of these areas a research programme could be mounted with the expertise and facilities available.

3.2 Gaps in our knowledge

There are a number of critical gaps in the knowledge about the oceanic regimes south of South Africa. Most of these have already been identified either by international programmes such as BIOMASS, WOCE, WCP, etc, or by the research activities of South African oceanologists who have been working in the region. The main gaps are:

(a) Physical oceanology

Knowledge of the APF south of South Africa is essentially descriptive and therefore little is known about its kinematics and dynamics. Not only does the "African sector" of the Southern Ocean probably include the eastern extremity of the Weddell Gyre (between approximately 20-30°E) but the water dynamics of the region may be influenced by the topography of Bouvet Island and the Maud Rise. In addition, it has been postulated that a powerful surface-water circulation is responsible for the maintenance of a semi-permanent, cyclonic gyre in the Lasarev Sea. Such circulatory effects have also come to be implicated in the population dynamics and distribution of krill, especially in the maintenance of the postulated regionally localized stocks south of Bouvet Island and slightly to the east of the Lasarev Sea itself.

Sea-level records are virtually non-existent for the Antarctic coastal region south of South Africa. This reinforces the need to accrue suitable sea-level records for the determination of tidal constants and for climatological research, particularly as the latter may affect the South African subcontinent as a whole.

As has been mentioned elsewhere in this document, the coupling between ocean and atmosphere in the Southern Ocean is an important process influencing, or even controlling, climatic patterns in southern African and the rest of the southern hemisphere. The nature and position of the Weddell Gyre may, for various reasons, be an important element in the climatic patterns experienced in the south and west of southern Africa.

It has been shown that a large polyn̆ya (area of open water) develops in the sea ice during winters in the vicinity of the Maud Rise. It is postulated that this polynya represents a periodical frontal discontinuity extending from the Maud Rise itself to the northeast, so separating the Weddell warm and cold regimes. The periodical frontal discontinuity thought to be responsible for the Maud Rise polynya may also provide the hydrological conditions considered necessary for the regional localization of krill which apparently occurs in the region. Presently data are scarce and the oceanology of the Maud Rise region is attracting considerable international attention. This arises only from heuristic interest but also from the fact that the polynya may provide access for the study of many factors (e.g. sea ice dynamics, the food chain, etc) during the crucial winter months.

(b) Chemical oceanology

As discussed above, knowledge of chemical distributions and processes in the Southern Ocean is limited. Such studies can aid in the interpretation of both physical and biological questions. From a physical point of view, chemical tracers such as trace metals or gases, and nutrient/salinity relationships, are frequently useful in the interpretation of the dynamics of water masses and the establishment of water mass boundaries.

Chemistry can also help elucidate ocean/atmosphere interactions and their effects on climate. The Southern Ocean is an area where such interactions are particularly poorly understood, and more knowledge of the CO_2 distribution and exchange is critical in this regard.

Chemical processes which play crucial roles in the behaviour of biota also require investigation. These include, *inter alia*, studies of primary production and studies of biochemical processes, particularly near fronts. Similarly, investigation of the organic chemical constituents should throw new light on nutrient transfer processes and on primary production.

(c) Biological oceanology

Work undertaken by the "Discovery Investigations" during the 1930s gathered much information to suggest that the East Wind Drift (Antarctic Coastal Current) adjacent to Antarctica provides conditions suitable for the spawning and hatching of krill eggs, and for the development of larvae in the Continental Margin Region. Northward deflection of this coastal current (either topographically or atmospherically-induced) in certain regions, may act to enrich the essentially krill-poor West Wind Drift (Antarctic Circumpolar Current), thereby providing the conditions necessary for the regional localization of krill stocks. Thus, it has been proposed that enhanced krill abundance in the Atlantic sector of the Southern Ocean is the result of a north eastward extrusion of Weddell Drift water from the Weddell Sea, and that the eastern extremity (between approximately 20-30°E) of the Weddell Gyre then limits the eastern extent of krill "richness" in this sector. It is also thought that in certain areas in the Weddell Sea, interchange may occur between krill-rich coastal waters and the Weddell Drift. Understanding the physical and chemical dynamics of such phenomena is paramount in improving knowledge about the mechanisms underlying the distribution, dispersal and population dynamics of krill.

It is thought that a boundary zone may exist in the Lasarev Sea between the West Wind Drift and the East Wind Drift. This in turn may affect krill distribution by providing a mechanism for the maintenance of a localized East Wind Drift krill stock in an area slightly to the east of SANAE. If this is so, it might be analagous to the situation prevailing in Prydz Bay, and may therefore provide an interesting area for comparative study. The area is already of interest with respect to the Ross seal situation. In addition, both seasonal and more long-term changes in the southern ice-edge boundary may have a profound effect on the biological oceanography of the region as a whole.

To the northwest of the Lasarev Sea is Bouvet Island. This island not only lies directly within the influence of the Weddell Drift but may also exert a considerable topographical effect on hydrodynamic events nearby. It is possible, therefore, that both downstream and island-mass effects may directly influence krill distribution in the island's immediate vicinity. In view of the number of krill predators breeding on the island (both birds and seals), the CCAMLR SC has recognized that the island offers a unique opportunity to monitor the effects of various natural (as opposed to man-induced) phenomena in an area where no commercial exploitation of krill is currently being undertaken. Thus, it offers a comparative site for similar studies being undertaken at South Georgia and may provide a baseline for integrated future studies. It may be feasible to assist with such a monitoring activity in this region.

3.3 Objectives

In their broadest terms, the objectives of AOSS focus on selected areas of the Southern Ocean and on particular processes and species. With respect to the biological aspect of AOSS it has been agreed that these be centred on a krill biology theme.

As with both MOES and FZS, AOSS can be broken down into descriptive and process-orientated components.

(a) **Component 1** - Assuming that knowledge of the areas chosen for study is likely to be poor even at a basic level, this component would be directed at describing the basic structure (physical, chemical, biological) of the marine ecosystems in the areas concerned and having the theme:

> "To improve basic knowledge of the physical, chemical and biological structure of marine ecosystems in selected areas of the Southern Ocean".

(b) **Component 2** - Directed more towards a study of processes (both environmental and biotic) in the chosen areas in order that the dynamics of the marine ecosystems in those areas can be better understood, and having the theme:

> "To obtain a better understanding of the dynamics and functioning of selected systems and their biotic components in the selected areas of the Southern Ocean".

These two components are not necessarily mutually exclusive. Nevertheless, the meagre state of knowledge concerning Antarctic oceanology south of South Africa advocates a stepwise approach. This will involve structural descriptions of various systems concomitant with the development of an understanding of processes within, interrelationships between and, ultimately, the ecosystem dynamics of the AOSS selected areas.

3.4 Key questions

Given our present state of knowledge, key questions have been formulated so as to take account of both separate (geographical) and common (scientific) interests in the four selected areas of the Southern Ocean. In each area, a common approach has been adopted in order to study the prevailing physical and chemical oceanology and the distribution and abundance of krill and other important organisms (i.e. whales, seals, birds and fish). Being relatively accessible to South Africa, the highlighted areas are those most likely to be important should a krill fishery ever develop in the African sector of the Southern Ocean. The kinds of studies required to answer the various key questions presented below, should yield much of the information necessary for improving the efficiency of any future krill fishery and monitoring of the effects of this in terms of the various priorities recognized by BIOMASS and recently endorsed by the CCAMLR SC, and at the same time being appropriate to WOCE.

Key Question 1

What is the hydrography of the selected areas?

Initially at least one, possibly two, dedicated cruises will be required. Since all the areas fall more or less en route or close to Sanae, such cruises could well form part of the annual relief voyages to the South African base. The main cruise objective would be to define the quasi-synoptic movement of water within a particular area. This would be related on a variety of scales to the distribution of both biological and chemical phenomena outlined below.

In both initial and follow-up cruises, physical-oceanographic measurements have to include closely-spaced XBT transects and hydrographical stations. The latter should comprise chemical analyses of all important nutrient salts, pigments, trace metals, oxygen and carbon dioxide. Subsequent results will be used to identify specific water mass kinetics. In order to achieve a truly interdisciplinary approach, contemporaneous estimation of biological productivity must be integrated with oceanological observations (see below). Early cruises will probably be geared toward more descriptive appraisal of the areas concerned (i.e. Component 1). Longer term objectives will be more definitive and aimed at defining the dynamics of oceanological and biotic associations (i.e. more process orientated - Component 2). The latter will require the accrual of sufficient baseline data.

The establishment of a network of tidal stations will, among other achievements, directly support various international projects on satellite altimetry proposed for the late 1980s and early 1990s. The first objective would be to establish a full suite of tidal constants for areas where these are not presently available; secondly, to measure long term changes in sea elevation as related to ocean currents; and thirdly, to assist in satellite altimetery calibration. Particular sites should be selected taking full cognizance of presently operating or planned tidal gauges by the international community, the requirements of WOCE, the Tropical Oceans Global Atmosphere (TOGA), and other experiments. Tidal monitoring sites need to be accessible, either by ship or air, so as to provide for adequate servicing of instrumentation. Implementation of a South African contribution to the existing and planned network could be synchronized with field work related to the MOES and FZS components of this programme, and/or to the geodesy and cartography component of SASCAR's earth sciences research programme.

Key Question 2

What are the meso (c. *100 km) and fine scale* (c. *10 km) relationships between krill distribution/abundance and prevailing oceanological conditions in the selected areas?*

The approach to be adopted in answering this key question will entail integration of elements of both Components 1 and 2. The work plan will consist of an extensive areal assessment of krill distribution/abundance using hydro-acoustic techniques and systematic net sampling (both aimed and random). Contemporaneous hydrographical measurements, observations of other important organisms (e.g. birds, seals, whales and fish) and measurements of phytoplankton/primary production will form an integral part of each survey. Wherever possible, biological and physico-chemical parameters will be measured concurrently. Longer term objectives will be geared towards understanding variability in krill distributions with respect to oceanological conditions. This will be studied at a variety of scales and has important implications for improving our knowledge concerning interactions between krill and other important Antarctic marine ecosystem components.

Key Question 3

What are the demographic and trophic relations of populations of top predators in selected areas?

A dual approach is necessary to provide answers to this key question. In part, results will be directly relevant to the implementation of CCAMLR in terms of attempting to monitor important predator-krill interaction within the "whole ecosystem approach" espoused in Article II of the Convention.

The first approach involves monitoring important migratory predators both in the Convention area and off the South African coast. In particular, estimates of population size and/or population trends in baleen whales can most cost effectively be carried out where a species aggregates in a small area at any particular time, either for the purposes of feeding (minke whales - *Ballaenoptera acutorostrata)*, reproduction (right whales - *Eubalaena australis)* or while on migration (humpback whales - *Megaptera novaeangliae)*.

The second approach is to consider the abundance/distribution of important predators (including seals, seabirds and whales) in the selected areas in terms of their spatial/temporal associations with krill. The primary objective will be to assess selected predator abundances (Component 1) and to estimate their likely impact on krill stocks (Component 2). Both components entail sea-going and land (or ice) based censuses, analysis of stomach contents and contemporaneous estimation of krill distribution. The effective implementation of such studies is of critical importance to the International Ecosystem Monitoring Programme currently being formulated by a specialist working group of the CCAMLR SC.

It must be further emphasized that current knowledge of most of the top predators in all four geographical areas is severely limited. Therefore estimates of species diversity, abundance and distribution will constitute important studies in their own right. In particular, very little is known about ichthyofaunal distributions in the selected areas. It would be a relatively simple matter to include systematic sampling for fish (both larvae and adults) as an integral part of the studies to answer Key Question 2 above. Considerable additional information on Antarctic ichthyofauna could thus be gathered.

3.5 Summary

The four regions and three key questions above have been identified as important AOSS priorities and are within the scope of scientific expertise and logistical support currently available. As with the other studies outlined in this document, responding to the key questions requires a broadly based, interdisciplinary initiative. As AOSS progresses, emphasis will probably move from a descriptive (Component 1) to a process-orientated (Component 2) mode. In view of the paucity of information concerning the Southern Ocean south of South Africa, it is important that a sound descriptive definition of the physical, chemical and biological features of the selected areas are obtained to complement indepth studies of important processes. In some cases, both descriptive and process orientated studies could be conducted simultaneously, provided that variations in scale are sufficiently compatible.

ORGANIZATION AND ADMINISTRATION OF SANARP

Research in the Antarctic region is coordinated internationally through SCAR of ICSU. The CSIR adheres to ICSU, and therefore also SCAR on behalf of South Africa, and coordinates the scientific component of SANARP through SASCAR. This Committee is also the National Committee adhering to SCAR.

SASCAR has created four committees, one each for the programmes on biological, earth, Southern Ocean and physical sciences. Each of these committees is responsible for the guidance of a programme. Their membership comprises a mix of participants in SANARP (i.e. grant holders) and outside experts in the fields of research being undertaken, as well as representatives from state departments and the CSIR as relevant. *Ex officio* members of these committees are the Scientific Coordinator (also responsible for their administration) of the CSIR and representatives of the Antarctic Division of the Department of Environment Affairs responsible for SANARP logistics.

SCIENTIFIC COORDINATION

The overall scientific component of SANARP is managed and coordinated by a Scientific Coordinator at FRD of the CSIR. The scientists who participate in the programme are themselves responsible for project budgeting and the internal administration of their project personnel and allocated funds.

Participants in the SANARP programme are expected to maintain close liaison with one another. Scientific facilities available at the base stations and aboard research vessels, and ships' time, are shared by all participants.

Maintenance of scientific standards and research progress is largely the responsibility of the project leaders. SASCAR, on the advice of its committees, has a degree of guardianship over these aspects as well and reserves the right to withdraw support from projects if it is felt that suitable progress and sufficient standards are not being maintained.

Local workshops and symposia on selected topics are arranged, participants are sent to international SCAR or SCAR-related workshops, symposia and conferences when appropriate, and when possible overseas experts are brought to South Africa to visit researchers in the field or at their home bases.

Management of this programme

The Southern Ocean research programme of SANARP is guided by the SASCAR Southern Ocean Committee. The terms of reference of this committee are:

(a) to develop a South African programme of physical, chemical and biological oceanological research in the Southern Ocean south of southern Africa to contribute to fundamental scientific knowledge. The objectives should also take cognizance of South Africa's participation in international treaties, conventions and research programmes;

(b) to guide and manage this research programme on behalf of SASCAR and ensure the maintenance of a high quality scientific endeavour, and to liaise with other SASCAR and SANCOR programmes where relevant;

(c) to advise SASCAR on the allocation of funds for research in accordance with (a) and (b) above; and

(d) to advise SASCAR on South African involvement in international research activities in accordance with (a) and (b) above.

Membership of this committee comprises many, but not necessarily all, participants in the programme, outside experts in the fields of research being undertaken, and the *ex officio* members mentioned previously. Membership is by invitation, for three-year terms. The committee usually meets once or twice annually.

Participation in SANARP generally

Participation in SANARP is not confined to particular scientists or research groups. Individual or groups of researchers from any approved academic or scientific organization in South Africa are free to submit research proposals, provided these are designed to contribute towards the main objectives of the programme concerned. Scientists from other countries may also participate, provided that the grant holder is resident in South Africa and employed by a recognized scientific institution. Solicited and unsolicited research proposals are considered by the SASCAR committees in terms of the objectives of their programmes. If approved, projects are funded for fixed periods - normally between three and five years - provided satisfactory scientific progress and standards are maintained.

New projects are incorporated into the programmes as and when funds become available. Usually this occurs when current projects are brought to completion, making existing funds available for new projects.

Research proposals are submitted annually to FRD through the proposer's own research administration, by 30 June. The proposal is prepared on the FRD NP10 form, obtainable from the Scientific Coordinator, FRD, or from University Registrars or Museum Secretaries. Proposals take two forms - the first and original project proposal, describing the objectives, intended duration, techniques to be used, cost analysis, motivation for, and work plan of the project, and follow-up proposals submitted in each subsequent year of that specific project's duration. There is no set limit on the number of proposals a single project leader may submit, or on the number of projects a grant holder may be directing.

New proposals may be sent out for evaluation by FRD and are then considered by the relevant SASCAR committees, usually in September each year. The recommendations of the committees are then referred to SASCAR which meets annually, usually in October/November, for final approval.

Applicants are subsequently informed of the amounts, if any, they have been awarded for their projects usually in December/January. Funding is based on the financial year 1 April to 31 March. New or follow-up proposals submitted in June are therefore considered for funding from 1 April the following year to 31 March the year after. Funds are budgeted for and allocated on a yearly basis, and savings cannot be carried over into the next financial year. An audited financial statement from the grant holders' organizations, on each project funded by SASCAR in the previous financial year, is required by the Department of Environment Affairs by 15 May of each year.

Proper preparation of new and follow-up proposals is essential. Participants are advised to consult with the Scientific Coordinator prior to their preparation, particularly with regard to the preparation of budgets and work plans. Proposals that indicate insufficient familiarity with past and current work or with the programme objectives such as are set out in this document, and a lack of attention to experimental design, key questions, duration and costing will not be accepted for consideration.

Interim progress reports

Interim progress reports, covering the previous twelve months from July to June, are required with each follow-up proposal. They provide a means to assess scientific progress over the previous year and are therefore important supporting documents. A set of guidelines for the preparation of these reports is available from the Scientific Coordinator.

All interim progress reports submitted to SASCAR are distributed to participants in SANARP and to members of SASCAR and its committees in the form of an annual volume of "Progress Reports to SASCAR". These volumes provide participants with an insight into all research projects carried out in SANARP. The contents of these volumes are not for publication.

Final project reports

A final project report, describing the main findings of the project and outlining new aspects that should be investigated (and why), is required by SASCAR not later than two months before funding for the project ceases. Theses for post-graduate degrees are not acceptable as final project reports. These reports are in essence the products sought after by the organization(s) which funded the research, and their content must address directly with answers the original objectives of the project.

Final project reports are copied to other participants in the programme, to members of its committee, and to members of SASCAR. Where the contents of such reports are sensitive in nature, distribution may be restricted.

Grant holders are not usually permitted to commence work on new projects until the final report from a previous project has been submitted and accepted by FRD.

Guidelines on the preparation of final project reports are available from the Scientific Coordinator.

LOGISTICS

The Department of Environment Affairs is responsible for overall administrative control and financial and logistical support for the national Antarctic research effort. Provision and maintenance of laboratory equipment, special scientific supplies, secretarial services, computing services, etc., are the responsibility of the participating grant holders. The Department of Environment Affairs is also administratively responsible for the construction and maintenance of base station buildings.

The South African Antarctic supply/research ship, the M.V. SA AGULHAS, based in Cape Town, usually visits Marion Island twice annually. The first and longest visit, usually lasting four to eight weeks, takes place in autumn (April/May) and is the annual relief voyage. The second visit, generally of much shorter duration, usually takes place in spring (August/September) or summer (November/December). The ship visits Gough Island once annually for the relief exercise, usually in early summer (October/November) and the visit lasts three to six weeks. The annual relief of the Sanae Station (70°18'S, 02°24'W) on the Fimbul Ice Shelf, Dronning Maud Land, Antarctica, takes place from December to March, and the voyage lasts from six to twelve weeks. Following the off-loading of expedition personnel, construction/maintenance personnel, observers and supplies at the base station being visited, the ship then normally proceeds on oceanological surveys or may return to Cape Town. It then returns to the base to collect homeward-bound personnel and proceeds back to Cape Town.

The outward and inward voyages between the research stations and Cape Town are in themselves valuable opportunities for oceanological research. Special research cruises independent of base station relief or re-supply activities can be arranged. The SA AGULHAS, along with the R.S. AFRICANA and other research vessels, is part of the Department of Environment Affairs' research vessel fleet. Research time on these vessels is budgeted for and allocated by the Department's "Ships Committee". This committee comprises representatives of the various user-communities (e.g. SANCOR, SASCAR, Weather Bureau, Sea Fisheries Research Institute, etc). When a special research cruise is required by the SASCAR programmes the request for use of the chosen vessel is channeled to this committee through its member representing the SASCAR user-community. Because additional funding is usually required for such special cruises, planning for them must be initiated at least 18 months ahead of time.

Researchers and field assistants intending to stay at the stations between relief voyages are required to undergo medical examination and aptitude and adaptability tests before their appointment can be confirmed. They are also required to attend an orientation course prior to departure. These courses take place in February/March (for Marion Island), August/September (for Gough Island) and November/December (for Sanae). The Department of Environment Affairs organizes these courses. Those visiting the stations, or conducting oceanological research from the ship, for the duration of the relief periods or special cruises only are not normally required to undergo the selection tests. However, project leaders are advised to ensure that they are in sound medical and psychological condition, and able to stand up to the rigours of voyages across the Southern Ocean and/or life at the base stations.

SHIP-BASED RESEARCH

During any SANARP voyage (with the M.V. SA AGULHAS or other vessel) when one or more research groups will be conducting ship-based research, one of the accompanying scientists is appointed to the position of Chief Scientist for that voyage. His/her main task is to coordinate on-board research within the ship-based scientific complement, and between them and the other scientific or logistical activities (e.g. relief of base station) which maybe part of the overall voyage plan. A separate guide for Chief Scientists is available from the Scientific Coordinator.

About eight weeks prior to the advertized departure date of routine relief voyages, the Scientific Coordinator calls for details from those research groups planning to accompany the upcoming voyage. Project leaders are advised to respond promptly and fully to this call in order to ensure that their plans are included in the Sailing Instructions. Last minute, late requests are not usually accommodated due to the fact that by then the ship's schedule, facilities and capabilities have already been committed for that voyage.

Some three to four weeks prior to departure of each voyage, a document of "Sailing Instructions" is prepared. It outlines the aims and objectives of the voyage as a whole, and for each of the accompanying groups of people. This provides those responsible for managing and coordinating the total exercise with a checklist of the activities and requirements of all aboard, thereby assisting them with the day-by-day organization of the whole exercise.

TITLES OF CURRENT PROJECTS IN THE SASCAR SOUTHERN OCEAN RESEARCH PROGRAMME

<u>Percy FitzPatrick Institute of African Ornithology, University of Cape Town</u>

- Small-scale patterns of seabird distribution at sea in the African sector of the Southern Ocean (ending 1986)

  (Project Leader : W R Siegfried)

<u>Department of Analytical Science, University of Cape Town</u>

- Marine chemistry in the Southern Ocean (ending 1986)

  (Project Leader : M J Orren)

<u>Department of Applied Mathematics, University of Cape Town</u>

- Sighting estimates of the abundance of marine populations (ending 1986)

  (Project Leader : D S Butterworth)

<u>Department of Zoology, University of Cape Town</u>

- Survey of the benthos of the Prince Edward Islands (commencing 1987)

  (Project Leader : G M Branch)

<u>National Research Institute for Oceanology, CSIR, Stellenbosch</u>

- Southern Ocean fronts (ending 1987)

  (Project Leader : J R E Lutjeharms)

Department of Zoology and Entomology,
Rhodes University, Grahamstown

- An investigation of the distribution and production of plankton in the seas around the Prince Edward Islands
- The origins and distribution of potential energy production in the Prince Edward Island seas (commencing (1987)
- Characterization of the physical and chemical environment of the Prince Edward Island seas (commencing 1987)

(Project Leader : B R Allanson)

Department of Ichthyology and Fisheries Science,
Rhodes University, Grahamstown

- Atlas of Antarctic fish otoliths (ending 1986)
- Southern Ocean fish otolith project (commencing 1987)

(Project Leader : T Hecht)

JLB Smith Institute of Ichthyology, Grahamstown

- Taxonomy and biology of the fishes of the Southern Ocean (ending 1987)

(Project Leader : M N Bruton)

Port Elizabeth Museum

- Prey identification service (Phase 1) (ending 1986)
- Prey identification service (Phase 2) (commencing 1987)

(Project Leader : G J B Ross)

Mammal Research Institute,
University of Pretoria

- Right whale recovery (ending 1988)

(Project Leader : J D Skinner)

Sea Fisheries Research Institute,
Department of Environment Affairs, Cape Town

- Biology of krill (long term)

(Project Leader : D G M Miller)

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