



A description of the

Benguela ecology programme

1982-1986

SANCOR

Programme developed under the aegis of the South African
National Committee for Oceanographic Research

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PREFACE

Development in South Africa is resulting in an increasing technological and socio-economic complexity, and hence in an ever-growing need for scientific knowledge and skills. The magnitude of this challenge, the limited numbers of scientists and the means at their disposal make the closest possible collaboration within the scientific community essential. The CSIR's Cooperative Scientific Programmes (CSP) offer mechanisms and means for such collaboration between organizations and between individual scientists in fields of national importance. One such national programme is the SANCOR Programme which includes amongst its programmes the Benguela Ecology Programme. Other constituent programmes currently recognized or being considered by the South African National Committee for Oceanographic Research (SANCOR) include Coastal Processes, Estuaries, Marine Pollution, Marine Line Fish and Open Ocean Science.

This document sets out the initial framework of the Benguela Ecology Programme. The programme has been structured by scientists who currently are active in marine ecological research dealing with natural systems and renewable resources in the Benguela Current region. The programme description, which is intended to be comprehensible to the non-specialist, draws on knowledge and experience gained in the past, and takes into account the manpower and facilities which are available at present- It is intended to serve as a focus for the efforts of scientists already involved in research in the Benguela system, and as a guide for scientists who may wish to initiate marine ecological research in the region during 1982-1986.

ABSTRACT

This document describes the Initial framework for a cooperative marine ecological research programme in the South African Benguela Current region, for the period 1982-1986. The programme is called the Benguela Ecology Programme. It is intended to serve as a focus for the efforts of scientists already Involved in research in the region, and as a guide for scientists who may wish to initiate marine ecological research in the region during 1982-1986. The programme places emphasis on research dealing with natural systems and renewable resources, especially shoaling fish of commercial importance, in the pelagic environment. The document outlines the motivation for South African marine ecological research in the Benguela Current region and indicates the objectives of suites of research projects which link together to comprise a cooperative, coordinated multi- and interdisciplinary research programme.

OPSOMMING

Hierdie dokument beskryf die oorspronklike raamwerk vir 'n kooperatiewe marine-ekologiese navorsingsprogram in die Suid-Afrikaanse Benguela Stroomgebied, vir die tydperk 1982-1986. Die doel hiervan is ener syds om te dien as 'n opsommende samevatting van die werk gedoen deur wetenskaplikes wat alreeds by navorsing in die gebied betrokke is en andersyds as 'n handleiding vir wetenskaplikes wat beoog om marine-ekologiese navorsing in hierdie gebied te onderneem gedurende 1982/1986. Die program beklemtoon navorsing wat gemoeid is met natuurlike sisteme en herwinbare bronne, veral skoolvormende visse van kommersiële belang in die diepsee-omgewing. Die dokument omlyn die motivering vir Suid-Afrikaanse marine-ekologiese navorsing in die Benguela-Stroomgebied en gee 'n aanduiding van die doelwitte van navorsingsprojek groepe wat bymekaar aansluit om 'n kooperatiewe, gekoördineerde multi- en Inter-dissiplinere navorsingsprogram te vorm.

TABLE OF CONTENTS

	Page
PREFACE	(iii)
ABSTRACT	(iv)
INTRODUCTION	1
THE BENGUELA SYSTEM	1
RATIONALE FOR THE RESEARCH PROGRAMME	3
GENERAL OBJECTIVE OF THE RESEARCH PROGRAMME	4
MANAGEMENT OF THE RESEARCH PROGRAMME	4
SCOPE AND ORGANIZATION OF THE RESEARCH PROGRAMME	5
STRUCTURE OF THE RESEARCH PROGRAMME BY PROCESS	5
A. Primary Production, Mineralization and Nutrient Cycling ..	5
B. Major Trophic Pathways to Selected Consumers	7
C. Fluctuations in Recruitment and Population Structure of Selected Species	8
D. Systems Analysis of Component Ecosystems	10
STRUCTURE OF THE RESEARCH PROGRAMME BY HABITAT	12
Inshore Research	12
Offshore Research	12
DESCRIPTION OF EXISTING PROJECTS	15
LIST OF ACRONYMS	29
APPENDIX 1	30
APPENDIX 2	32
TITLES IN THIS SERIES	36

INTRODUCTION

This document introduces a national cooperative programme of marine ecological research focused on the Benguela Current region of South Africa, roughly between Cape Agulhas in the south, around the Cape Peninsula, to the mouth of the Orange River in the north. Following on a brief description of the Benguela system, the document reports on the rationale, objective, scope and organization, and management of the Benguela Ecology Programme. It is envisaged that the programme will evolve and advance through a series of five-year phases, the first commencing in January 1982. This document covers the period 1982 to 1986.

THE BENGUELA SYSTEM

The coastal waters of the South Atlantic ocean off the western seaboard of southern Africa are strikingly different from the surface waters farther out to sea. The abrupt change from the blue oceanic waters to the greenish-brown coastal waters along the west coast is accompanied by sharp, horizontal temperature gradients and abrupt changes in the values of many other physical, chemical and biological properties. It is the strong, south-easterly winds which blow seasonally along this coast which are mainly responsible, since they move the surface waters away from the coast and expose the underlying cold, nutrient rich waters.

The general northward drift of these coastal waters in a complex and variable system of currents, countercurrents and eddies is known colloquially as the Benguela Current. The name was taken from the town of Sao Felipe de Benguela, south of Lobito Bay in Angola, from where the first coastal survey south to the Cape of Good Hope was carried out in January 1613. This survey makes reference to vast amounts of fish in the coastal waters, and led to the naming of the current. It is this richly productive biological system in the coastal waters which provides the focus of attention for the Benguela Ecology Programme.

The Benguela ecosystem contains a relatively narrow range of pelagic species. At the base of the food web are unicellular plants, predominantly diatoms. Populations of small crustaceans, mainly copepods and euphausiids, feed on the diatoms. The major components of the Benguela fish community are: lanternfish, lightfish, pilchards and anchovies, and their predators the tunas and snoek which all tend to live in the upper water layers; the hake which lives near the bottom but migrates upward at night to feed; and the horse-mackerel and red-eye which inhabit the intermediate water layers. Major predators of these fish include the Cape fur seal, Bryde's whale, dolphins, three seabirds (Cape gannet, jackass penguin and Cape cormorant) and, of course, man. The west coast of South Africa has one of the richest fisheries in the world; the total landed catch in 1979 being valued at R245 000 000.

The microscopic diatom cells which form the base of this biological system are often chained together to provide substantial particles for consumption by predators at the first step of the food web. This facilitates the existence of relatively large-bodied consumers just a

few "rungs up the ladder" and consequently the food chain is short - an arrangement that, coupled with a pulsed enrichment of nutrients through upwelling, makes it sensitive to artificial disturbances at either end. Moreover, because the juvenile pelagic fish do not have the necessary well-developed gill rakers for straining diatoms, the recruitment of young fish to the system is perhaps even more fragile in that, at this crucial phase, they probably rely on the less abundant copepods and euphausiids for food.

The decade that followed the end of World War II saw an unprecedented expansion of the fisheries in South African seas. Prior to and during the war, commercial line-fishing and whaling were practised and a relatively small bottom-trawling industry operated in the Benguela system but its huge shoals of pelagic fish were not exploited on a large scale until 1950. Initially, pilchards and horse-mackerel were the most important contributors to the catch and formed the foundation of the industry whose canned product was its most valuable commodity. The pilchard catch off South Africa reached a peak of 410 200 tonnes in 1962, and then declined due to poor recruitment of the population and overfishing. Subsequently, horse-mackerel catches also decreased. Over the last five years, pilchards have contributed, on average, 60 000 tonnes to the catch or 16% of the combined species quota allocated to the pelagic fishing industry. Since the collapse of the pilchard population, the anchovy has predominated with most annual landings exceeding 200 000 tonnes. As a consequence, the industry now produces mostly fish-meal and oil rather than the more valuable canned product-

Management of commercially valuable, pelagic fish populations in the Benguela system has been made difficult by the inability of scientists to predict accurately the occurrence of poor recruitment of young fish to the fishable population. The anchovy, particularly, is vulnerable to overfishing, because it is relatively short lived. Hence, it is important that scientific research be intensified so as to obtain an understanding of the recruitment fluctuations affecting the anchovy.

The west coast of southern Africa is exposed to large incoming swells generated by cyclones whose centres can be thousands of kilometres away in the South Atlantic. The surf is heavy, with individual waves reaching heights of seven metres. Much of the coastline consists of unstable sandy beaches. In the intertidal zone, the unstable substrata favour relatively mobile animals belonging to a few dominant species. The diversity of life is greater on the rocky shores, but overall it is considerably lower than that of shores that are washed by warmer, less turbulent waters. Several dominant organisms are especially abundant. Most striking are the large seaweeds, particularly the kelps which grow up from rocky bottoms in the infratidal zone to form "forests" in shallow water. These "forests" help to dissipate the energy of the large, incoming swells, allowing many more plants and animals which otherwise could not withstand the full impact of the swells, to occupy the area. Mussels, which feed on phytoplankton and detritus derived from kelp fragments, are abundant and, in turn, they sustain dense populations of rock-lobsters. The rock-lobsters are an important economic resource, the total annual take accounting for some R30 000 000, largely in foreign exchange earnings. In certain areas the

rock-lobster populations are severely depleted and quotas for fishing them have had to be reduced repeatedly.

RATIONALE FOR THE RESEARCH PROGRAMME

According to the objectives of the SANCOR Programme, scientific research in the Benguela Current region is justified on grounds of scientific interest and the economic importance of natural resources and their conservation. In this case, however, scientific interest and sound management of the resources are linked indivisibly together. For instance, a major interest of scientists is the rapidly pulsing character of the upwelling of water in the Benguela ecosystem, resulting in strong contrasts in sea temperature and biological productivity. This prevents equilibrium conditions from developing and provides a unique natural laboratory for studying the dynamics of upwelling and its influence on biological productivity, including the recruitment of young fish to commercially exploitable populations. Indeed, it is the very dynamic, complex nature of the Benguela ecosystem which adds a strong element of uncertainty in the management of its commercial fisheries. The populations of certain fish fluctuate considerably from year to year, and the causes of these fluctuations are not yet fully understood. A better understanding of these causes and the behavioural responses of the fish will aid in the management of the fishery.

South Africa has a shortage of skilled scientists. More particularly, the fields of marine ecology and fisheries science are experiencing a shortage of ecologists with advanced analytical and mathematical expertise. In addition to creating new contract posts in which promising young scientists can develop the necessary expertise under responsible supervision, the Benguela Ecology Programme aims to consolidate and channel the work of experts in a number of research institutes. This process of rationalization should help to offset the increasingly acute shortage of skilled manpower in a field of crucial concern to the nation.

The Benguela Ecology Programme should also enhance South Africa¹'s reputation in the international scientific arena. To date, studies in the Benguela Current region have not been integrated properly. Since a major (if not the main) objective of science is to generalize from the particular, South Africa should strive wherever possible to contribute scientific information which will be useful in international exercises aimed at synthesizing, through the comparative approach, knowledge that will reveal universal principles or paradigms useful in our understanding of how natural systems are structured and function. This is a reciprocal process leading to mutual benefits. In this context, the Benguela Ecology Programme fits in well with the objectives and scope of the SCOR programme on "Coastal Offshore Ecosystems Relationships" which has been approved by IABO and the UNESCO Division of Marine Sciences. There also are indirect links between the Benguela ecosystem, through whales and seabirds, and ecosystems in the Southern Ocean and, hence, there are links between the Benguela Ecology Programme and those operating internationally under SCOR, SCAR and the IWC in the Southern Ocean. In addition to these international relationships, there is a need for South Africa to continue to cooperate with, and to make

its scientific expertise available to, bodies charged with the task of promoting international fisheries science and the international management of commercially important fish populations. Such bodies include ICSEAF, ICCAT and the IWC

In broad outline, then, the Benguela Ecology Programme has four main interrelated aims: to create opportunities for research to meet current requirements of both national and international scientific importance; to promote training of skilled manpower which is needed but which is in short supply; to provide the knowledge necessary for a better scientific understanding of marine ecosystems; and, to contribute knowledge which may improve the wise management of marine renewable natural resources, especially pelagic shoaling fish.

The programme will be facilitated by past research work which has resulted in descriptions of components of the Benguela ecosystem and by recent studies which provide a further sound foundation. The Benguela Ecology Programme has the potential to make an international scientific and economic impact by addressing fundamental problems in marine ecology.

GENERAL OBJECTIVE OF THE RESEARCH PROGRAMME

The overall and ultimate objective of the Benguela Ecology Programme is to provide scientific information on the structure and functioning of constituent ecosystems, to complement the knowledge which is required for the management of the renewable natural resources of the Benguela Current region.

This objective will be approached by way of a range of projects which have been organized according to suites of guiding principles and key questions for research.

MANAGEMENT OF THE RESEARCH PROGRAMME

The principal organizations involved in the Benguela Ecology Programme are the Sea Fisheries Institute and the University of Cape Town. The CSIR, acting through SANCOR, coordinates and administers the Programme. The programme is directed by a Scientific Committee which reports to a SANCOR Programme Committee which determines broad policy for the Programme. The Chairman of the Scientific Committee is also Chairman of the Programme Committee. Each member of the Scientific Committee is responsible for a group of projects or field of research, and project leaders report directly to this committee. Project leaders are chosen for their experience, scientific skills and ability to lead research. Consultants are appointed where necessary to advise the project leaders or the Scientific Committee. The Scientific Committee normally meets monthly, and project leaders assemble for group discussions at three-monthly intervals. Regular seminars provide a forum for the essential scientific interaction, and serve to keep all participants informed about the progress of individual projects and the programme as a whole.

SCOPE AND ORGANIZATION OF THE RESEARCH PROGRAMME

Four major interrelated compartments encompassing ecological processes, each with its own sets of guiding principles and key questions for research, provide the "vertical structure" for accommodating currently active projects relevant to the programme. A habitat arrangement or "horizontal structure" of the programme is provided by groups of existent or proposed projects and tasks grouped conveniently under two main subheads (inshore and offshore research). Where necessary, further clustering of projects is employed to identify close relationships and/or themes of common interest to particular groups of researchers. The scientific institutions responsible for the administration of projects are listed (full names of these institutions are given in the list of acronyms at the end of this document). Projects having titles commencing with the name "* Benguela" are financed partially or wholly by SANCOR. A cross-tabulation between the programme subdivided by processes and the habitat arrangement of projects is given in Appendix 1.

STRUCTURE OF THE RESEARCH PROGRAMME BY PROCESS

A. Primary Production, Mineralization and Nutrient Cycling

Guiding principles

- A.1 Plant production is controlled by the supply of nutrients and by light.
- A.2 The supply of nutrients is replenished by pulses of upwelling in the Benguela Current region.
- A.3 The rate of primary production ultimately controls the productivity of other levels in food chains.
- A.4 Biodegradation of plant material by micro-organisms represents a major mechanism of mineral element recycling.

Attached macrophytes and phytoplankton, the two major contributors to primary production in the Benguela system, provide the basic food supply on which the carrying capacity of the ecosystem depends. Because nutrient enrichment, due largely to wind-induced upwelling, is sustained for long periods, primary production is much greater in the coastal zone than in adjacent oceanic waters, and is responsible for supporting the rich fisheries-resources of the region. However, the physical processes responsible for the nutrient enrichment, the mechanisms of "seeding" of bodies of upwelled water, the pathways of energy flow from primary production to consumer organisms, and the role of nutrient recycling are poorly understood. Thus, research is required which combines integrated studies of physical factors, associated with the upwelling and subsequent transport of enriched water, with a study of biological factors influencing growth and decay of macrophytes and phytoplankton. In upwelling areas, there is an apparent excess of primary production,

since plants grow faster than grazers can eat them. Consequently, consumer populations are influenced by the match and mismatch of their life-history stages with suitable food supplies. Studies dealing with fluctuations in primary production should, therefore, be linked to the feeding requirements of key consumers and carried through the food chains to selected species, as outlined in the second major compartment of the research programme.

Key questions

- A.1 What is the frequency of upwelling on the west coast and the Agulhas Bank?
- A.2 What are the seeding and colonization processes?
- A.3 What are the growth and primary production rates in relation to light, nutrients and temperature?
- A.4 What effects do advection, diffusion and turbulence have on primary production?
- A.5 What are the important processes causing the decay of the products of primary production?
- A.6 What is the rate of nutrient cycling in sediments and in the water column?

Current projects

	<u>Key questions</u>	<u>Institution</u>
* Benguela Inshore Ecosystems	A2,A3,A5,A6	UCT
Kelp Harvesting and Recolonization	A2,A3,A4	SFI
Inshore Phytoplankton Production	A2,A3,A4	NRIO
Oceanographic Responses to Macroscale Windfield	A1,A4	SFI
Effect of Mesoscale Windfield on Surface Temperature	A1,A4	SFI
Cape Peninsula Mesoscale Oceanography	A1,A2,A4	SFI
Cape Columbine Mesoscale Oceanography	A1,A2,A4	SFI
Small-scale Mixing in Upwelling Zones	A1,A2,A4	SFI
Nitrogen Cycling Environmental	A6	SFI
Monitoring Benguela Phytoplankton	A1,A2	SFI
Production Phytoplankton Colonization and Succession	A3	SFI
Phytoplankton Physiology	A2	SFI
Red Water Studies	A3,A5	SFI
Zooplankton Population Maintenance	A2,A3,A5	SFI
	A3	SFI

	<u>Key questions</u>	<u>Institution</u>
Zooplankton Feeding and Ecology	A5	SFI
Environmental Factors in Pelagic Fish		
Population Models	A3	SFI
Pelagic Shoal Fish Ecology	A3	SFI
* Benguela Detritus Studies	A5,A6	UCT
* Benguela Microbial Decomposition	A5,A6	UCT
* Benguela Physical Oceanography	A1,A2,A4	SFI
* Benguela Theoretical Oceanography	A1,A2,A4,A6	UCT, SFI
Remote-sensing in Oceanography	A1,A4	SFI, NPRL, NRIO, UCT

B. Major Trophic Pathways to Selected Consumers

Guiding principles

- B.1 Energy fixed by plants forms the basis of all food chains.
- B.2 At each step in the food chain there is a major loss of energy.
- B.3 Populations of animals tend to increase until they are limited by the availability of suitable resources (the "carrying capacity" of the environment), such as food.
- B.4 Populations may be limited by food supplies at certain critical times of their life cycles.
- B.5 Consumer populations generally respond more slowly than producers to changes in the environment.
- B.6 Predators influence prey populations and vice versa*

Little is known about "who eats whom" in food chains leading to top-order consumers, and the efficiency of food-transfer, in the Benguela system. Information on both of these key aspects is required for understanding energy losses at different trophic levels, and, hence, the carrying capacity of the system. The effects of top-order predators such as birds and mammals, on fish and other organisms are not understood, and knowledge of the influence of predators on the behaviour and demographic structure and potential yield of commercially important fish populations is required urgently.

Key questions

- B.I What are the main food chains to selected top carnivores, and how much energy flows along them?

- B.2 What processes affect the transport and availability of food-chain components?
- B.3 What is the efficiency of utilization of food materials?
- B.4 What processes limit the growth of important populations?
- B.5 How fast do the principal populations respond to nutrient pulses in the environment?

Current projects

	<u>Key questions</u>	<u>Institution</u>
* Benguela Inshore Ecosystems	B1,B2,B3,B4,B5	UCT
Inshore Zooplankton Studies	B1,B2,B3	NRIO
Inshore Avian Predators	B1	UCT
Oceanographic Responses to Macroscale Windfield	B2,B5	SFI
Effect of Mesoscale Windfield on Surface Temperature	B5	SFI
Cape Peninsula Mesoscale Oceanography	B2,B5	SFI
Cape Columbine Mesoscale Oceanography	B2,B5	SFI
Small-scale Mixing in Upwelling Zones	B5	SFI
Environmental Monitoring	B2	SFI
Phytoplankton Colonization and Succession	B5	SFI
Red Water Studies	B5	SFI
Zooplankton Population Maintenance	B1,B5	SFI
Zooplankton Feeding and Ecology	B1,B3,B5	SFI
* Benguela Anchovy Eggs and Larvae	B1,B2,B4,B5	SFI,UCT
Environmental Factors in Pelagic Fish Population Models	B2,B5	SFI
Pelagic Shoal Fish Ecology	B2	SFI
* Benguela Systems Analysis	B1,B2,B3,B4,B5	UCT
* Benguela Lipid Tracers	B1,B4	UCT
Remote-sensing in Oceanography	B5	SFI, NPRL, NRIO, UCT

- C. Fluctuations in Recruitment and Population Structure of Selected Species

Guiding principles

- C.I Populations and their recruitment may fluctuate, even when they are not exploited by man.

- C.2 A population that is exploited must be maintained in a condition in which, over a period, increases from recruitment at least balance losses due to mortality, to prevent its collapse.
- C.3 Populations can be affected adversely by both direct and indirect exploitation.
- C.4 Scientific advice is required as a basis for management aimed at preventing effects harmful to the exploited population and its ecosystem.
- C.5 The basic requirement for proper management is an ability to monitor and predict changes in the behaviour and demography of an exploited population in time to restrict catches from exceeding the population's production capacity.

A number of methods may be used to monitor change in size of populations; some provide absolute measures, while others provide only relative measures or Indirect Indices. All methods, however, suffer because of uncertainty of the validity of the assumptions on which they are based, or large variances in the estimates of demographic parameters. It, therefore, is important that as many independent methods as resources will allow, should be used to monitor a particular population. In addition to information on change in size of an exploited population, management requires information on the population's distribution, how its variation affects other species (which may themselves be exploited), and what determines recruitment and natural mortality. Research should concentrate on, first, testing the accuracy of methods that are available or may be developed for measuring changes in size and recruitment of populations and, secondly, Identifying those factors which largely determine changes in the size and recruitment of populations. The ultimate objective should be predictive models for commercially important populations subject to large recruitment fluctuations, permitting timely reduction of catches during periods of unfavourable recruitment.

Key questions

- C.1 What are the major populations of ecological and potential commercial importance?
- C.2 How do these populations behave and how are they distributed in time and space?
- C.3 What can be learned from past fluctuations of these populations?
- C.4 What are the natural dynamics of these populations?

Current projects

	<u>Key questions</u>	<u>Institution</u>
* Benguela Inshore Ecosystems	C1 ,C4	UCT
Kelp Population Dynamics	C2,C4	SFI
Lobster Population Dynamics	C2,C4	SFI
Lobster Ecological Energetics	C4	NRIO
Abalone Population Dynamics	C2,C4	SFI
Red Water Studies	C2	SFI
Anchovy Spawning and Early-stage Survival	C4	SFI
* Benguela Anchovy Modelling	C4	UCT
* Benguela Anchovy Acoustics	C1,C2	SFI
* Benguela Anchovy Genetics	C1,C2	SFI
Pelagic Shoal Fish Ecology	C1,C2,C4	SFI
* Benguela Anchovy/Seabird Predation	C4	UCT
Seabirds as Pelagic Fish Indicators	C3,C4	SFI
Past Fluctuations in Pelagic Fish	C3	SAM
Marine Mammal Studies	C1,C2,C4	SFI
Assessment of Hake, Lanternfish and Squid Populations	C1,C2,C4	SFI/SAM
Assessment of Snoek Populations	C1,C4	SFI
Assessment of Tuna Populations	C1 ,C4	SFI

D. Systems Analysis of Component Ecosystems

Guiding principles

- D.1 Ecological interactions often are complex.
- D.2 Ecosystem studies require the formulation of key questions which have scientific relevance.
- D.3 A "systems analysis" approach has an important role in the planning and management of research, and subsequent descriptions of ecosystems.
- D.4 Ecosystems tend to consist of loosely connected clusters or groups of tightly interacting species, which can be regarded as sub-systems.
- D.5 An ecosystem can be perturbed to a limit beyond which its characteristics change.

A number of large, multi-disciplinary, research programmes have made important contributions to our understanding of the structure and

functioning of the world's major ecosystems. Experience has shown, however, that financial expenditure and organizational difficulties involved in such programmes can be reduced by the use of a systems analysis approach to both planning and organization. Systems analysis facilitates formulation of key questions which identify factors controlling the functioning of the system as a whole. Thus, this approach is of considerable importance in the initial planning phases of large research programmes. It is intended that systems analysts will play a leading role in planning and organizing the Benguela Ecology Programme. Systems analysis can also be used to formulate policies for management of resources, in terms of "multiple goal" objectives where one or more related resources may be of commercial interest. With a proper understanding of ecosystems as functional units, for example, it is possible to show how an optimal yield can be obtained by the combined exploitation of more than one target species, as well as to predict some of the effects of perturbations in the system induced by environmental and other factors. A resilient ecosystem will be able to withstand certain perturbations, caused by exploitation, for example, and not change its nature completely, whereas one that is not as resilient may be altered to another state in which different species are dominant.

Key questions

- D.1 What species and processes control community structure?
- D.2 What is the number and nature of the essential sub-systems which make up the Benguela ecosystem?
- D.3 Are the sub-systems globally stable, or do any of them exhibit the potential for multiple stable states?
- D.4 What are the factors controlling ecosystem stability and resilience?
- D.5 What are the implications of this knowledge for multiple use of a sub-system?

It is envisaged that systems analysis and simulation modelling will be applied to identify gaps in knowledge and potential subjects for further research, as well as helping in determining options available to management, in all appropriate components of the Benguela Ecology Programme.

Current projects

	<u>Key questions</u>	<u>Institution</u>
* Benguela Systems Analysis	D1 ,D2 ,D3 ,D4 ,D5	UCT
* Benguela Consultants	D1 ,D2 ,D3 ,D4 ,D5	
* Benguela Anchovy Modelling	D1,D5	UCT
Environmental Factors in Pelagic Fish Populations Models	D5	SFI

STRUCTURE OF THE RESEARCH PROGRAMME BY HABITAT

Inshore Research

Although not necessarily of commercial importance, intertidal organisms are subjected to considerable pressure from man, both in terms of direct physical disturbance (bait collecting, recreation, etc) and from pollution. Work aimed at improving our knowledge of the dynamics of the populations of these organisms and the effects of perturbations (physical and chemical) to their environment is necessary for sound conservation-management. For instance, recent research has shown that some 5% of kelp bioraass is stranded annually and that much of this is utilized rapidly by intertidal organisms. Further research is needed to clarify the ecological effects of regularly removing cast-up kelp from beaches.

In the subtidal area attention is directed at three targets: rock-lobster, seaweeds of commercial importance and abalone. There is considerable variation in the productivity of rock-lobster populations in different areas. The reasons for this variation are not fully understood. In addition, while recent research has quantified the production of detritus from kelp and the feeding requirements of the ribbed mussel (the main food of the rock-lobster), more research is needed to reveal the importance of phytoplankton to the ribbed mussel and its dependence on micro-organisms for digestion of its food. Also in need of study are the roles of octopuses, as predators and competitors, and the position of these animals in the diet of seals. At present, studies dealing with seaweed production and related matters are well catered for, but research dealing with abalone should be expanded. Feeding behaviour, energetics and larval distribution and settling of abalone require further Investigation.

Offshore Research

The study of the offshore ecosystem should in the first instance be aimed at furthering our understanding of those ecological processes which are important to the main commercially exploited species. Bearing in mind the limited manpower, facilities and funding available, It would seem of dubious value to attempt to tackle superficially all the main species and all associated physical, chemical and biological features. It, therefore, is proposed that maximum effort be applied to studying one of the principal species, its dynamics and related ecological processes. There are two obvious targets, the hake and the anchovy.

The management of the hake fishery appears to be achieved fairly effectively on the basis of conventional population-dynamics techniques. The anchovy, on the other hand, being a small, short-lived pelagic fish, may well be more susceptible to collapse from over-fishing following environmentally poor years. Thus, it seems logical to direct the main thrust of the research at attempting to Improve scientific knowledge of the anchovy.

There are a number of elements around which research effort should be clustered, in order to reach the proposed goal of a better understanding of the ecology of the anchovy and, hence, to complement knowledge which is required for its management. These elements, not in order of priority (since all elements are important to the ultimate success of the research), are as follows:

Population status. Further knowledge of the number, size and distribution of reproductively isolated anchovy populations is desirable. Hydroacoustic, genetic and morphometric studies would be useful.

Population recruitment and behaviour. It appears that there are three crucial stages in the life-history of the anchovy: egg production by adults; survival of first-feeding larvae; and, behaviour of pre-recruits at shoal-formation. An initial review and synthesis of all available information should be made in an attempt to determine whether any one of these stages plays a predominant role in recruitment. Studies of the behaviour of the anchovy, particularly its shoaling behaviour, are needed urgently.

Indicators of historical population size. Information on historical guano production has been used as an indicator of the overall pelagic fish population and its fluctuations prior to the commencement of fishing activities. Palaeo-ecological studies (eg, otoliths from guano cores; fish scales in sediment cores) have the potential to yield this information for particular species, and merit further attention. This information can possibly be linked to climatic events (from study of tree rings, long-term air temperature data, rainfall records) which may provide insight into fluctuations in the fish populations induced by environmental change or other events.

Environmental factors and cyclical or episodic events. Anchovy recruitment may be affected by environmental factors (eg, above-average water temperatures). Some success has been achieved in California in incorporating relatively basic environmental parameters into models of pelagic fish populations, although the success with the anchovy has been limited. The bases for these models have been the assumption that food materials of the right type must be available for the larvae, that increased offshore transport reduces the probability of larval survival, and that increased upwelling generally implies increased nutrient supply and increased phytoplankton production. In South Africa, it is suggested that effort be directed at attempting to incorporate parameters, such as an upwelling index, wind-stress vorticity, and upwelling pulsing frequency, into the population models and monitoring exercises, as a first step. Further refinement could follow when more is known about the processes governing, for example, first shoal-formation. In this context, studies of the behaviour of anchovies, as it affects their dispersion, are crucial.

Allied to this will be further studies at a more fundamental level. Consideration of plankton dynamics will incorporate studies of small-scale physical processes, nutrient cycling and regeneration, seeding of newly upwelled water, phytoplankton growth and physiology, species' successions and zooplankton grazing. Work on eggs and larvae should try

to relate distribution, drift, feeding and survival to environmental parameters. To attempt to understand the mesoscale meteorological and physical oceanographic processes taking place in the Benguela ecosystem, projects providing basic information on the windfield, the coupling between the ocean and the atmosphere, rates and frequency of upwelling events, and advective processes necessary for successful recruitment are in progress and will continue. Satellites and remote sensing in general can play a useful role in the study of the various physical, chemical and biological processes.

Predation. Studies on predators, such as marine mammals (particularly seals, predatory fish (particularly snoek), and seabirds, should have a two-pronged input into the programme. First, seabirds are at the end of the pelagic food chain, and an ongoing assessment of the abundance of the main species of birds should provide a reasonably good idea of the state of the pelagic resource. Secondly, an improved understanding of predation could lead to an improvement in the estimate of natural mortality of the anchovy (and its density dependence) which will be of benefit for the assessment of the population. Thirdly, predation might be an important factor influencing variation in the shoaling behaviour of anchovies.

*Alternative resource strategy** In view of the possible collapse of the anchovy fishery, due to perturbations induced by nature or by man or by a combination of the two (the most likely case), it would seem logical to devote some effort to the identification and study of alternative resources. Lanternfish and squid have been suggested. Research on distribution, population size and other aspects of the biology of these potential resources should get underway as soon as possible.

DESCRIPTIONS OF EXISTING PROJECTS

This section encompasses very brief accounts of the main aims of all projects currently comprising the Benguela Ecology Programme. Titles of the projects are abbreviated, and supernumerals after the names of principal researchers (arranged in alphabetical order) indicate the source of their funding: 1 = NRIO, 2 = SAM, 3 = SANCOR, 4 = SFI, 5 = UCT and 6 = NPRL. A list of the full names of all institutions, principal researchers and their postal addresses appears in Appendix 2.

Inshore

* Benguela Inshore Ecosystems

Duration : 1982 - 1986

Principal researchers : Bennett³, Branch⁵, Griffiths⁵, Stenton-Dozey⁴

Institution : UCT

The project aims at determining the factors controlling intertidal and shallow-water community structure, and tracing the flow of energy from primary producers (macrophytes and phytoplankton) through these communities. Such analyses facilitate assessment of the significance of inshore regions as net importers or exporters of energy and, hence, should clarify their role in the wider Benguela system. Information on the dynamics and stability of these systems should allow prediction of the likely effects of human disturbance (bait collecting, recreation) and pollution in relation to relatively long-term natural fluctuations which may be a feature of these systems. Other studies include the role of biotic interactions (eg, competition, predation) in regulating community structure, the effects of collecting stranded kelp, and the ecological roles of fish in shaping community structure.

Kelp Harvesting and Recolonization

Duration : 1979 - 1986

Principal researchers : Jarman⁴, Simons⁴

Institution : SFI

The project commenced with a pilot study in which all kelp plants larger than 250 mm were cropped in contiguous belts across the kelp-bed at Soetwater, Kommetjie, to judge the effect of clearing kelp commercially. In the second experiment strips 30 m wide are being cleared, leaving 10 m strips of intact kelp between strips. The rate of recovery of cleared areas, the catchability of rock-lobster and other possible side effects, and the period needed before re-cropping, are being monitored and compared with uncleared areas.

* An asterisk indicates that the project is financed partially or wholly by SANCOR

Kelp Population Dynamics

Duration : 1974 - 1984
Principal researchers : Jarmarfi, Simons^
Institution : SFI

The project aims at estimating the standing stocks and growth rates of *Laminaria pallida*, *L. schinzii* and *Ecklonia maxima* on the west coast of South Africa. At selected sites and depths, longevity of individual plants and their productivity are being estimated, and the environmental factors responsible for distribution, reproductive viability and growth rates are being investigated.

Inshore Phytoplankton Production

Duration : 1979 - 1982
Principal researcher : Carters-
Institution : NRIO

The project aims at estimating the importance of phytoplankton as primary producers in kelp-beds, as compared to seaweeds. Previous studies have shown the dominance of filter-feeders in nearshore communities, but it has not been established whether these feed primarily on phytoplankton or on detritus derived from seaweeds- This is linked with the following project.

Inshore Zooplankton Studies

Duration : 1980 - 1986
Principal researcher : Carter^
Institution : NRIO

The project aims at understanding the role of zooplankton in kelp-beds. In particular, mysids occur in dense swarms but their role in food chains is not clear. How efficiently do they feed on phytoplankton, seaweed detritus or smaller zooplankton? Are they preyed upon by hottentot fish, sea wasps (cubomedusae), or what? How do they maintain position in a rapidly-flushed system?

Inshore Avian Predators

Duration : 1982 - 1986
Principal researcher : Siegfried⁵
Institution : UCT

The project aims at quantifying the role of birds as predators in sandy-beach, rocky-shore, and shallow-water communities. This is being done by monitoring densities of shorebirds, and by detailed studies on the feeding and activity and energy budgets of selected species.

Lobster Population Dynamics

Duration : 1968 - 1986
Principal researcher : Pollock⁴
Institution ; SFI

The project aims at monitoring rock-lobster populations in different areas, and estimating commercial exploitation, and growth, mortality and recruitment rates, as a basis for management of this heavily exploited resource.

Lobster Ecological Energetics

Duration : 1979 - 1986
Principal researcher : Zoutendyk[^]
Institution : NRIO

This is an extension of the previous project, in that feeding rates (energy gain), respiration, production, reproductive output, assimilation, and faecal production are being estimated experimentally in relation to size of animal and ambient temperature. The principal objective is a quantification of the flow of energy through a rock-lobster population.

Abalone Population Dynamics

Duration : 1980 - 1986
Principal researchers : Pollock[^], Tari⁴
Institution : SFI

The project aims at monitoring abalone populations in different areas, and estimating commercial exploitation, and growth, mortality and recruitment rates, as a basis for management of this heavily exploited resource.

Offshore

Oceanographic Responses to Macroscale Windfield

Duration : 1978 - 1983
Principal researchers : Kamstra[^], Nelson[^]
Institution : SFI

The project aims at providing information on the macroscale windfield along the west coast. This information is likely to be important for models of fluctuations in populations of environmentally-sensitive pelagic fish, and generally will assist several projects in the Benguela Ecology Programme.

Effect of Mesoscale Windfield on Surface Temperature

Duration : 1978-1984
Principal researchers : Holden[^], Kamstra[^], Nelson[^], Taunton-Clark.[^]
Institution : SFI

The project aims at describing the mesoscale windfields at a number of localities between Cape Agulhas and the Orange River, relating fluctuations to changes in sea-surface temperature. The information is necessary in describing the system generally, as well as in several other projects.

Cape Peninsula Mesoscale Oceanography

Duration : 1978 - 1986
Principal researchers : Ne Ison[^] > Shannon^{1*}
Institution : SFI

The project aims at understanding the dynamics of the upwelling system off the Cape Peninsula, a region which is seldom in a steady state owing to the pulsating character of the driving forces. Such knowledge is a prerequisite for a number of other projects, particularly those dealing with the survival of young anchovies which traverse the region in close proximity to the ocean front during a critical period in the species¹ life cycle.

Cape Columbine Mesoscale Oceanography

Duration : 1981 - 1986
Principal researchers : Holden[^], Nelson[^], Shannon[^]
Institution : SFI

The project aims at providing information on the main physical processes in the Cape Columbine area, as a basis for the study of nitrogen recycling and the study of anchovy at the stage of first-shoal information.

Small-scale Mixing in Upwelling Zones

Duration : 1981 - 1985
Principal researchers : Holden[^], Taunton-Clark[^]
Institution : SFI

Time series of continuous temperature/depth (CTD) readings will be taken at sites under differing weather conditions and differing histories of ocean circulation, in order to determine what vertical mixing and horizontal advection of phytoplankton is taking place.

Environmental Monitoring

Duration : 1950 - 1986
Principal researcher : Mostert^
Institution : SFI

The project aims at providing a series of statistically meaningful data on long-term fluctuations in physical features of the environment. This information is an essential contribution to several projects.

Nitrogen Cycling

Duration : 1981 - 1985
Principal researchers : Bailey^, Mostert^
Institution : SFI

The project aims at quantifying the amount of nitrogen recycled in the southern Benguela region. Recent indications are that in the St Helena Bay region there is considerable recycling of nitrogen both in the water column and in the sediment. As nitrogen appears to be the only significant limiting nutrient in the system, the study of the processes governing its supply and removal is of direct relevance to several other projects.

Benguela Phytoplankton Production

Duration : 1977 - 1983
Principal researcher : Brown^
Institution : SFI

The project aims at describing the growth and decay of phytoplankton blooms. The project provides a link between studies dealing with the supply and uptake of nutrients and those dealing with the development of zooplankton populations.

Phytoplankton Colonization and Succession

Duration : 1979 - 1983
Principal researcher : Olivieri^
Institution : SFI

Newly-upwelled water off the Cape Peninsula is characteristically poor in phytoplankton, yet within a few days dense blooms develop under near-optimal conditions of high light levels and abundant nutrients. Some 30-40 different species can dominate individual samples, and the question as to why certain species are more abundant than others arises. The project examines seeding and colonization processes, and attempts to determine whether a consistent pattern of colonization exists.

Phytoplankton Physiology

Duration : 1977 - 1986
Principal researcher : Barlow⁴
Institution : SFI

The project aims at investigating the physiological response of phytoplankton species to changes in nitrogen supply and light intensity. The response is monitored by measuring the active and inactive forms of chlorophyll *a*, by high performance liquid chromatography, as well as by the uptake of carbon and nitrogen tracers into various end-products of photosynthesis. The results of this study should provide a better understanding of the environmental factors controlling primary production, and the pattern of growth of phytoplankton in the Benguela upwelling region.

Red Water Studies

Duration : 1960 - 1986
Principal researcher : Horstman⁴
Institution : SFI

Stable water masses and the presence of suitable organic triggering substances lead to the formation of red water outbreaks of dinoflagellates around the south-western Cape coast. Since blooms occasionally are toxic to shellfish, periodic mass mortalities cause considerable changes in the subtidal populations of filter-feeding organisms, which in turn can affect man and rock-lobsters. Other blooms deplete oxygen in the water column and cause mortalities of large numbers of fish. This project examines factors contributing to red water outbreaks, reasons for the dispersion of blooms, and monitors toxicity levels in shellfish.

Zooplankton Population Maintenance

Duration : 1969 - 1986
Principal researcher ; Eutchings⁴
Institution : SFI

The important members of the zooplankton community in the upwelling region off the Cape Peninsula contend with peculiar problems in maintaining large populations within phytoplankton-rich water. Studies of the seasonal, vertical and horizontal distributions of selected members of the zooplankton will be linked to changes in current and wind patterns, in an effort to determine the factors affecting their life-histories. The project forms an intermediate step between the phytoplankton colonization process and the supply of juvenile stages of crustacea (eggs and nauplii) to the frontal zone where anchovy eggs and larvae are transported northwards.

Zooplankton Feeding and Ecology

Duration : 1979 - 2983
Principal researchers : flutehings^, Otivieri^
Institution ; SFI

The project alms at examining the role of zooplankton as grazers of newly developed, frequent, but sporadic, blooms of phytoplankton. The project links with studies of the feeding of pelagic fish and the growth of phytoplankton.

Centropages Biology

Duration : 1980 - 1984
Principal researcher : Borothers^
Institution : SFI

Centropages brachiatus is the commonest copepod in the southern Benguela Current; it has a short generation time and a high fecundity, and its juvenile stages may be an important food item for anchovy larvae. Its adaptations to the upwelling regime will be investigated, as part of a general study of factors potentially influencing the recruitment of anchovy.

Euphausia Biology

Duration : 1981 - 1984
Principal researcher : Pillar^
Institution : SFI

Euphausia lucens is one of the dominant, large zooplankton organisms in the southern Benguela Current, and it is one of the few euphausiids in the world which is adapted to the shallow neritic zone. It breeds within the upwelling zone where it is a potential predator of anchovy eggs and larvae. Adults and juveniles constitute an important food item for juvenile and adult anchovies, and juvenile hake. The project aims at investigating the adaptations and life history of E. lucens in relation to the development of phytoplankton blooms and to the system of currents and counter-currents.

Anchovy Spawning and Early-Stage Survival

Duration : 1977-1983
Principal researchers ; Eutchings^ , Shelton^
Institution : SFI

The project aims at relating the distribution of anchovy eggs and larvae to environmental and biological features, such as distance offshore, water depth, depth of the thermocline, water mass characteristics, zooplankton, phytoplankton and microplankton abundance. The project links with studies on the predation of anchovy eggs and larvae, and with projects dealing with the food of the anchovy.

* Benguela Anchovy Eggs and Larvae

Duration : 1981 - 1985
Principal researchers : Brownell[^], FieldP, Hutehings[^]
Institution : SFI and UCT

The project aims at investigating, using experimental techniques, the survival of anchovy eggs and larvae, and the environmental factors affecting survival. One of the main aspects of the study is the feeding responses of anchovy larvae (eg, what food is needed for their survival, what food concentrations are needed for satisfactory growth, and does starvation contribute significantly to larval mortality?). The other aspect to be studied is predation on anchovy eggs and larvae (eg, what are the important planktonic predators of anchovy eggs and larvae, what is the feeding behaviour of these predators, and how important is predation to their natural mortality?).

* Benguela Anchovy Modelling

Duration : 1982 - 1986
Principal researcher : Butterworth[^]
Institution : UCT

The project aims at providing advice on optimal methods for monitoring the size and recruitment of anchovy populations, as a basis for management. Mathematical models will be used in attempts to predict changes in anchovy populations. The impact of predators on the anchovy is an important part of such models. Thus, this project will draw on the results of those projects concerned with pelagic predation.

Environmental Factors in Pelagic Fish Population Models

Duration : 1976 - 1986
Principal researcher : Shannon[^]
Institution : SFI

The project aims at determining environmental factors suitable for incorporation into pelagic fish population models. It is known that the environment plays an important role in influencing the availability of fish (anchovy, pilchard, tuna) during fishing seasons, and it is probable that environmental factors are crucial in determining the recruitment of young fish into the fishery. The intention is to quantify these effects, initially on an empirical basis.

Pelagic Shoal Fish Ecology

Duration : 1979-1983
Principal researcher : Tromp[^]
Institution : SFI

The project aims at describing the behaviour of selected commercially important pelagic shoaling fish, and relating behavioural patterns to

the marine environment. Major aspects for study include: the depth distribution of shoals in relation to environmental parameters (daily and seasonally); the behaviour of different length/age classes of different species in mixed and pure shoals; and, feeding and spawning behaviour of pelagic shoal fish.

* Benguela Anchovy Acoustics

Duration : 1982 - 1986
Principal researcher : Hampton^
Institution : SFI

The project aims at investigating hydroacoustic methods for assessments of the size and distribution of both adult and juvenile populations of anchovy, using the new research vessel, R V Africana. Multi-frequency acoustic techniques will be developed to differentiate between acoustic targets by size, enabling discrimination between anchovy adults and recruits.

* Benguela Anchovy Genetics

Duration : 1982 - 1983
Principal researcher : Shetton^
Institution : SFI

The project aims at determining the number of genetically separate anchovy populations contributing to commercial catches off South Africa. This information is crucial for proper assessment of the size of anchovy populations.

* Benguela Anchovy / Seabird Predation

Duration : 1982 - 1986
Principal researchers : Duffy³, Fumess³, Siegfried^
Institution : UCT

The project aims at determining which avian species prey on pelagic shoaling fish, particularly anchovy, in certain sectors of the Benguela Current region. The diets and foraging behaviour of these predators will be studied in detail, to assess their potential impact on anchovy populations, and their breeding performance will be monitored concurrently. Selected species may be useful as indicators of changes in anchovy populations.

Seabirds as Pelagic Fish Indicators

Duration ; 1982 - 1986
Principal researchers : Berruti⁴, Crawford⁴, Shelton^
Institution : SFI

The project aims at determining how reliable seabirds are as indicators

of the size of fish populations. Variation in diet of selected species at their breeding colonies in relation to time of year and stage of the fish populations, will be determined. The effect on avian breeding success of change in the structure of pelagic fish populations will be examined.

Past Fluctuations in Pelagic Fish

Duration : 1982 - 1986
Principal researchers : Avery³
Institution : SAM

Evidence from fish scale and seabird guano deposits suggests that pelagic fish populations fluctuated widely prior to commercial exploitation. The project aims at investigating those factors which cause natural fluctuations and at determining the added effect of exploitation of fish populations.

Marine Mammal Studies

Duration : 1972 - 1986
Principal researchers : Best⁴, David⁴
Institution : SFI

Seal pup populations are assessed, using aerial-photography counts and tag-recapture methods, to provide information for rational exploitation. These assessments permit estimation of the impact of seals as predators on pelagic fish, using dietary information obtained from stomach samples. Bryde's whales are considered likely major pelagic fish predators, and estimation of their abundance using line-transect survey methods is planned. Other likely mammal predators of pelagic fish are the common, dusky, and Heaviside dolphins; information on their distribution, diet, and abundance will be collected.

Assessment of Hake, Lanternfish and Squid Populations

Duration : 1982 - 1986
Principal researchers : De Villiers⁴, Hulley[^]
Institution : SFI and SAM

The project aims at determining the distribution and size of hake, lanternfish and squid populations in the Benguela system. There are indications that lanternfish biomass may be extremely large. Hake may be important predators, and squid may be significant in the diets of a number of species of mammals, birds and fish.

Assessment of Snoek Populations

Duration : 1958 - 1986
 Principal researcher : Nepgen^
 Institution : SFI

The project aims at determining the distribution and size of the snoek population in the Benguela system, as well as growth and mortality-rates, and age at maturity of individual fish- The snoek may be a significant predator in the Benguela system.

Assessment of Tuna Populations

Duration : 1960 - 1986
 Principal researcher : Nepgen^
 Institution : SFI

Tuna are highly mobile, far-ranging predators in the Benguela system. Anchovy is considered to be an important item in their diets. The project aims at determining the distribution and size of tuna populations, as well as growth and mortality rates, and age at maturity of individual fish.

Inshore and Offshore

* Benguela Detritus Studies

Duration : 1982 - 1986
 Principal researchers : Field?, Griffiths**, Koop\$
 Institution : UCT

Nearshore ecosystems are generally believed to be based on seaweed detritus, and it also appears that in upwelling areas large quantities of phytoplankton decay to form detritus. Thus, pelagic detritus may be an important food source in food chains leading to pelagic fish and will be important in retaining all zing nutrients in the Benguela system. The project aims at investigating the quality (with emphasis on lipids and carbohydrates) of plant material produced, the role of detritus as food for consumer organisms and the rate of nutrient remineralization. Links will be formed with the following projects: Benguela Inshore Ecosystem, Benguela Phytoplankton Ecology, Benguela Microbial Decomposition and Benguela Lipid Tracers.

* Benguela Microbial Decomposition

Duration : 1982 - 1986
 Principal researchers : Davis³, Muir^, Robb⁵
 Institution ; UCT

Bacteria are essential to detritus formation but qualification of this role is inadequate, since the exact mechanisms and rates of degradation processes are unknown. The bacteria involved in sequestering kelp-

derived material will be investigated in some detail, forming a basis for studying nutrient cycling in offshore areas. Specific genetically marked strains of bacteria can act as tracers of the fate of incorporated Dissolved Organic Matter, and export of particles to other ecosystems. Thus, the project provides the microbiological input required to study detritus, and links closely with the following projects: Benguela Detritus, Benguela Inshore Ecosystems, Benguela Lipid Tracers, and Benguela Phytoplankton Ecology.

Remote Sensing in Oceanography

Duration : 1978 - 1986
Principal researchers : Brundrit[^], Iutgeharms[^] , Mostert[^], Nelson[^], Shannon[^], Walters[@]
Institution : SFI, NPRL, NEIO and UCT

The project aims to study, using remote sensing (land-based as well as from satellites and aircraft), the dynamics of those mesoscale and macroscale processes in the Benguela system which are not readily amenable to investigation by conventional oceanographic techniques, but which are nevertheless important (eg, frontal dynamics, thermal and phytoplankton plume development). This information will be useful to several other projects.

* Benguela Theoretical Oceanography

Duration : 1982 - 1986
Principal researchers : Brundrit⁵, Nelson^{^^} Van Foreest³
Institution : UCT, SFI

The project aims at studying problems of a physical oceanographic nature which arise in ecological projects of the Benguela Ecology Programme, with emphasis on theoretical studies supported by analysis of existing field data. The overall dynamics of the major features of the upwelling region will be the focus of attention in investigations of frontal dynamics, the effect of the wind-event cycle on the total dynamic structure, and turbulence under the action of variable wind stress.

* Benguela Lipid Tracers

Duration : 1982 - 1986
Principal researchers : Field^{**}, Horgan[^], Siegfried[^]
Institution : UCT

Certain fatty acids are essential in the diets of many animals and can only be synthesized in plants or micro-organisms. The fatty acids may be retained or recombined into different lipids in animals along food chains. If easily identifiable fatty acids are synthesized in unusual proportions by particular primary producers (eg, diatoms) it may be possible to use these as natural tags to trace food pathways. Lipids are likely to be particularly important in upwelling areas, since lipids are used as energy reserves by animals subject to a pulsing food supply,

and as a flotation mechanism by diatoms. The knowlegde of food pathways is fundamental to questions concerning fluctucations in fish populations, and this project links with those on seaweed ecology, detritus, microbiology, plankton, pelagic fish, seabirds and marine mammals*

* Benguela Systems Analysis

Duration : 1982 - 1986
Principal researchers : Bergh[^], Field?, Rumbak[^]
Institution : UCT

The project has two major elements. First, systems analysis of the programme as a co-ordinated whole, with information being gathered continually to aid the programme's Scientific Committee in planning and co-ordinating research. This work will include ongoing improvements of descriptive models of the functioning of component sub-systems, and balancing energy and material transfers. This will help to identify the key ecological processes requiring study to achieve the programme's objectives, identify gaps in knowledge, and promote compatibility between projects. Secondly, the project will involve research on physical and trophic transfers between components of the ecological system(s) involved. The main task will be to trace food chains and water movements where these are not being traced by other projects. Knowledge of the main food pathways is essential to understanding the structure and functioning of the constituent ecosystems of the Benguela region.

* Benguela Consultants

Duration : 1982 - 1986
Principal researcher : Newell[^]
Institution : UCT

Professor R C Newell and his research team at the Institute for Marine Environmental Research in Plymouth are engaged in parallel research, complementing that of the Benguela Ecology Programme. He is able to provide expert advice on the latest European and American research of interest to many projects of the Benguela Ecology Programme. It is intended that Professor Newell will visit Cape Town for two months in every year, and that he will assist in synthesizing the results of research projects.

* Benguela Workshop Services

Duration : 1982 - 1986
Principal researchers : Brundrit[^] & Hutchings[^]
Institution : UCT

The project aims at providing workshop services, to supplement those already provided by SFI and UCT. Specific instruments will be built under contract, as specified by programme projects.

* Benguela Computer Services

Duration : 1982 - 1986
Principal researcher : Brundrit^
Institution : UCT

The project aims at providing effective computer software support to all projects in the programme, but particularly to Benguela Theoretical Oceanography, Benguela Systems Analysis, and Benguela Phytoplankton Ecology. Specific software development will be contracted to freelance programmers through the UCT Computer Service. The main tasks will be in preliminary data validation for oceanographic instrumentation, statistical analysis and the presentation of data in graphic form suited to proper interpretation of results.

LIST OF ACRONYMS

BEP	Benguela Ecology Programme
CSIR	South African Council for Scientific and Industrial Research
CSP	South African Cooperative Scientific Programmes
IABO	International Association for Biological Oceanography
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICSEAF	International Commission for the South-East Atlantic Fisheries
IWC	International Whaling Commission
NPRL	National Physical Research Laboratory of the CSIR, South Africa
NRIO	National Research Institute for Oceanology, South Africa
SAM	South African Museum, Cape Town
SANCOR	South African National Committee on Oceanographic Research
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Oceanic Research
SFI	Sea Fisheries Institute, South African Department of Agriculture and Fisheries
UCT	University of Cape Town, South Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization

APPENDIX 1

Cross tabulation of key questions identified as needing answers by the Benguela Ecology Programme, and projects listed for the Programme in 1982. The key questions are discussed under, "Structure of the Research Programme by Process", page 5, while the projects are described under "Description of Existing Projects", page 15.

PROJECTS	INST	A					B					C					D									
		1	2	3	4	5	6	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5				
<u>Inshore</u>																										
*Benguela Inshore Ecosystems	UCT	*	*				*	*	*	*	*	*				*										
Kelp Population Dynamics	SF I														*				*							
Kelp Harvesting and Recolonization	SF I		*	*	*																					
Inshore Phytoplankton Production	NR IO SF I		*	*	*																					
Inshore Zooplankton Studies	NR IO							*	*	*																
Inshore Avian Predators	UCT							*																		
Lobster Population Dynamics	SF I														*				*							
Lobster Ecological Energetics	NR IO																		*							
Abalone Population Dynamics	SF I														*				*							
<u>Offshore</u>																										
Oceanographic Responses to Macroscale Windfield	SF I	*				*			*		*															
Effect of Mesoscale Windfield on Surface Temperature	SF I	*			*						*				*											
Cape Peninsula Mesoscale Oceanography	SF I	*	*	*	*				*		*				*											
Cape Columbine Mesoscale Oceanography	SF I	*	*	*	*				*		*				*											
Small-scale Mixing in Upwelling Zones	SF I	*	*	*	*				*		*				*											
Environmental Monitoring	SF I	*	*																							
Nitrogen Cycling	SF I							*	*																	
Benguela Phytoplankton Production	SF I			*											*											
Phytoplankton Colonization and Succession	SF I		*												*											
Phytoplankton Physiology	SF I		*	*	*										*				*							
Red water Studies	SF I		*	*	*	*					*			*				*								
Zooplankton Population Maintenance	SF I		*					*		*		*		*				*								
Zooplankton Feeding and Ecology	SF I					*		*	*	*	*		*		*			*								

APPENDIX 2

Names and addresses of scientific personnel in the Benguela Ecology Programme in 1982:

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