PARTNERS IN SCIENCE

KENYAN - DUTCH CO-OPERATION IN MARINE RESEARCH - I

1992-1993

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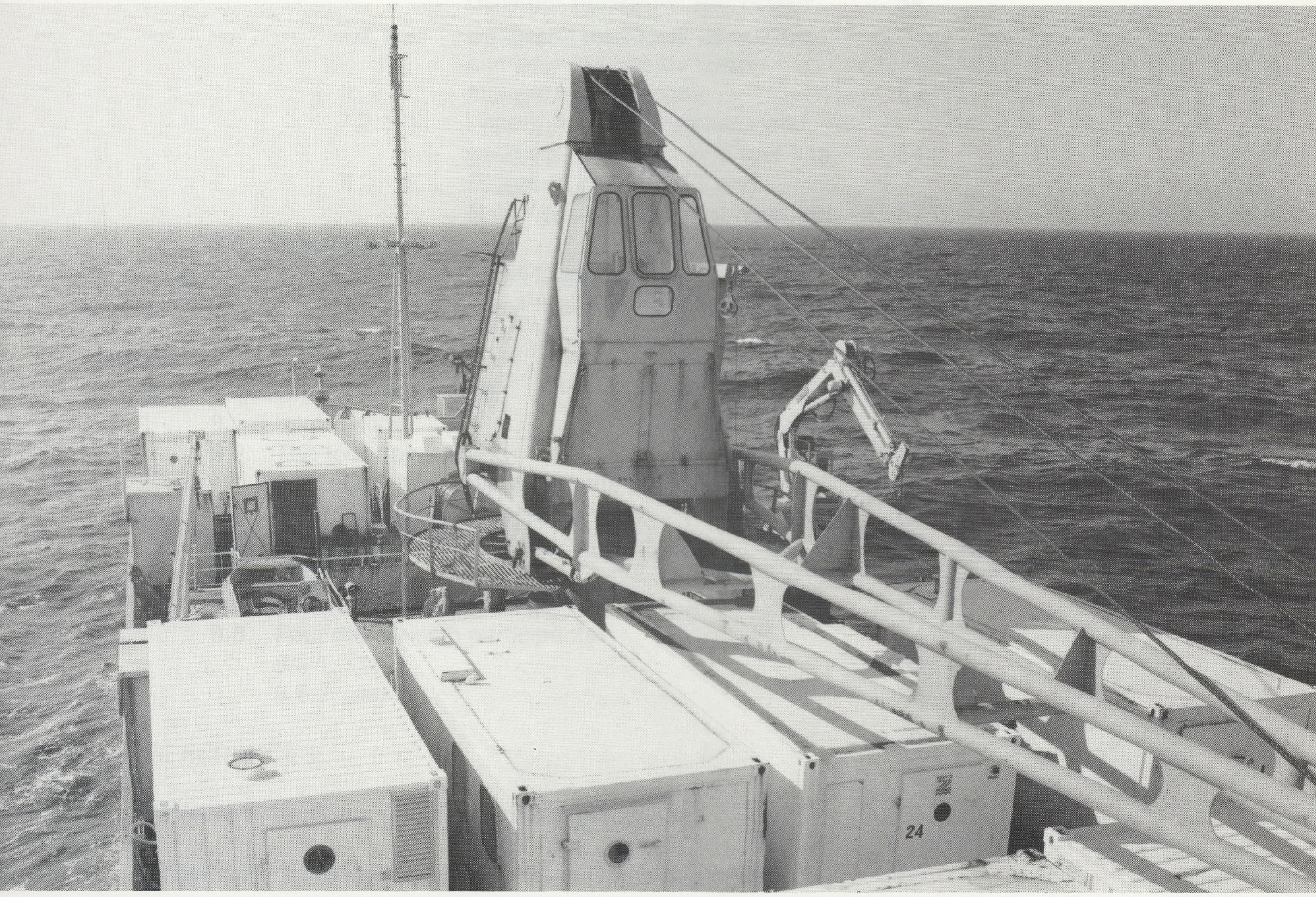
Mombasa, May 1992

Mwanzo kokochi, mwisho nazi
The beginning is a bud, the end is a coconut

Swahili proverb

Contents



1 Executive Summary

This document gives an outline of a partnership in marine science between Kenya and the Netherlands. It is a special part of the Dutch "Indian Ocean Programme" (IOP; 1990-1995). The central theme of the IOP is climatic change and its consequences. This theme fits in very well with a number of international research activities, such as the International Geosphere Biosphere Programme (JGOFS, LOICZ) and the World Climate Research Programme (TOGA,WOCE). The programme is also easily connected with on-going research in Kenya. It is a natural extension of the CEC-project "Study and management of Kenyan mangrove ecosystems". The present programme is a partnership between the Kenyan Marine Fisheries and Research Institute (KMFRI) in Mombasa and The Netherlands Marine Research Foundation (SOZ) of The Netherlands Organisation for the Advancement of Scientific Research (NWO) in The Hague.

In 1982 the Dutch government initiated a five year programme in marine science with the Indonesian government. The Snellius-II Programme (1982-1987) was successful. The Snellius-II approach, entailing transfer of knowledge and building infrastructure by the execution of a joint research effort, is internationally recognized as an effective management tool for sustainable development. The co-operation with Kenya is organized on the basis of this experience.

Inadequate infrastructure in Kenya has hindered the development of marine science. To develop marine science, funding for large scale marine projects and co-operation between Kenya and developed countries is needed. This report gives details of the first phase (1992 - 1993) of a seven year partnership. The philosophy of this endeavour is to sustain development through the execution of a joint research programme. The central theme of the present programme is "the study of the effects of the monsoonal regime on coastal marine systems". It consists of two main projects. One is based on board the Dutch research vessel 'Tyro' and will investigate processes on the Kenyan shelf and coastal ecosystems. The other is land-based near Mombasa and investigates coastal processes and pollution in the Kenyan coastal environment. Implementation of the seven year programme should allow Kenya to develop its present marine science capability in such a way that it can succesfully act as the regional centre, as proposed in UNEP's Eastern African Action Plan.

The Kenyan coast is an area of great physical beauty and rich in living resources. Palm beaches, clear turquoise waters and the colourful marine life of the coral reefs now attract about one million tourists yearly. Yet there are problems: local pollution, habitat destruction, tourism and the pressure of the growing population. Dams constructed or planned in the Tana river will effect the estuarine productivity in the estuarine and coastal area. Soil erosion as a result of deforestation and environmentally destructive agricultural practices inland, is effecting catches of fin fish and prawns in Ungwana (Tana river) and threatening the reefs around Malindi (Galana - Sabaki river). Mangroves are extensively cut for poles, firewood and charcoal. They are also effected by siltation and, due to upstream hydraulic works, by fluctuations in the amount of fresh water and sediment reaching them. Loss of the extent and vitality of mangrove forests may reduce marine biological productivity.

Sustainable use of the Kenyan coastal marine environment and its resources requires the development of management plans and the monitoring of pollutants. However, the basic knowledge for this is lacking. So far, nothing is known about the effect of the seasonally reversing monsoons and the linked unique reversal of the oceanic circulation on the marine ecosystems of the Kenyan coast. The interaction between the off-shore and coastal areas and the impact of the monsoons on this interaction is being studied in this partnership. Both the marine fauna and flora of the area and the physical, chemical and biological processes within it will be investigated. Despite the presence of several marine parks and reserves research on coral reefs is still fragmentary. The presence of an ocean going research vessel gives a unique opportunity to study remote and poorly known areas. There is no information on the benthic ecosystems beyond the reefs and also with respect to the pelagic domain only little information is available. Moreover, the sedimentology of the Kenyan coastal zone is unknown. Within this partnership in marine science Kenyan and Dutch scientists will be studying these as yet unknown areas. The activities described here will increase the basic know-how of the productivity of the Kenyan coastal marine environment, will give insight in the effects of inland erosion, siltation, inorganic and organic pollutants etc. and will assist KMFRI in its development towards a regional marine centre.

The two projects of the first phase of the Kenyan-Dutch partnership are being financed by the SOZ. The cost is about DFL 2.0 million. Within a research cruise of two months the Tyro will be made available exclusively to our Kenyan partners for a four day research and training effort. The programme for this exercise was developed by KMFRI. For the execution of the second phase funding outside the currently operating budgets of the partner countries has to be found. The programme for this phase will be formulated during the execution of phase one.

1 Introduction

General

Many human processes and activities increasingly have global and long-term effects: large scale burning of fossil fuels, clearing of vast tracts of vegetation, global dispersal of chemical and other waste, overgrazing and overfishing, etc. This is clearly expressed in the Bruntland Commission's report "Our Common Future", issued by the World Commission on Environment and Development. The report introduces the concept of sustainable development, i.e. economic growth maintained within the limits set by the environment in the broadest sense. Environmental protection and economic development are considered to be complementary rather then antagonistic processes.

Dutch environmental plans

In the Netherlands the environment is a subject of great public concern, and has become one of the cornerstones of national policy and also rates high on the political agenda. Recently this has been expressed in a number of policy papers such as the "National Environmental Plan", "Nature Policy Plan" and "A World of Difference", the latter issued by the Ministry of Development Aid. In the Netherlands environmental concern also touches on the marine domain and this is expressed by a substantial investment of capital and manpower in marine research. Marine research in the Netherlands is not just restricted to coastal waters, to protect the coastal zone and to preserve national livelihood and well-being but extends over the global ocean to monitor and understand its dynamics and to wisely harvest its vast resources. As a rich and responsible member of the brotherhood of nations, the Netherlands should share the knowledge thus gained for the benefit of all, not in the least the less developed nations.

Oceans

It is widely recognized that the world's oceans play a major role in global environmental change. To really understand the complicated processes in the sea and to predict their outcome over time scales of months, years or even decades, experts need to observe and describe them in detail. Sophisticated numerical models of the marine environment are vital for predicting changes. Satellites can provide some of the synoptic data needed, particularly from large areas of ocean previously unobserved. But these measurements need to be validated and complemented by reliable in-situ, ground-based, information. This demands that full advantage is taken of all technological advances in sensors, platforms, measuring systems and telemetry by means of internationally co-ordinated, cost-effective programs that ensure easy access to the data by all users. Man also urgently needs to establish the criteria for making the necessary choices among the many possible courses of action, and to implement the laws and create the institutions required to effect these choices. We must be able to correct mistakes caused by man's ignorance or greed. Among other things this means reducing - or preferably stopping - the discharging of effluents from towns, the dumping of radioactive waste and other hazardous substances, and accidents involving oil and chemicals.

African coast

The coastal waters of East Africa have some of the world's richest ecosystems such as extensive coral reefs and mangrove forests. As a result of the warm tropical climate and heavy rainfall, these waters are further enriched with nutrients from the land which enables them to support some of the most highly productive and diverse ecosystems on earth. Because of the economic opportunities in the coastal areas in East Africa, the population growth in coastal communities is higher than inland. The increasing population pressure and associated economic activities already has caused large-scale degradation and destruction of the ecosystems of the coastal areas. This, in return, is effecting the economic conditions and the quality of life of the coastal inhabitants negatively. This situation is mainly a result of the lack of knowledge in combination with ineffective or poor management of the coastal resources.

Coastal resources

It is essential to consider the coastal resources of the region as valuable assets that should be exploited on a sustainable and multisectorial basis. Unisectorial overuse of some resources will result in serious degradation of these and/or other resources. Indiscriminant and unregulated fishing activities, for example by using explosives and other destructive fishing techniques, will cause destruction of habitats and fish stocks. It also effects other activities, such as tourism, and may result in grave problems concerning coastal erosion. Indiscriminate cutting of mangroves for timber and fuel wood and for the conversion of land into aquaculture, may bring temporary gains, for example in the production of certain types of fish and shellfish of high commercial value, but in the long-term will result in losses in nursery areas of species of direct importance for the traditional fishery. Unregulated tourism is likely to result in destruction and degradation of productive habitats such as coral reefs, mangroves and estuaries. Indiscriminate logging and poorly managed agriculture in upland areas have proved detrimental to lowland activities such as fisheries and coastal industries dependent on tourism.

Kenyan - Dutch partnership

The aim of the Kenyan-Dutch partnership in marine science is to study coastal marine ecosystems. In the first phase fundamental knowledge of the effects of the two contrasting monsoonal weather patterns through their impact on erosion and river flow and the currents could be gained. Primary production and the growth of organic matter as well as the exchanges between the land and the deep ocean will be studied. Human impact (pollution, erosion, mangrove felling) on these processes will also be considered.

The following seasonal effects of climatic change on coastal ecosystems will be studied:

* The seasonality in productivity of surface waters and sedimentation.
* Inland erosion and erosion of degraded mangrove systems and increased siltation of coastal areas.
* Changes in growth of seagrasses and corals due to siltation, increased nutrient levels and temperature increase.
* Changing inputs of nutrients, particulate matter and inorganic pollutants from (semi-) terrestrial origin, including mangrove systems.

Historical rainfalls

The long-term changes that will be studied, are changes in rainfall over the last 10,000 years, production of greenhouse gases and changes in coral growth related with sea-level rise and sediment influx. These items are all part of the overall objectives of the climatic studies within Global Change. The first phase of the Kenyan-Dutch partnership in marine science is a major effort which partly coincides with a three year project of the Commission of the European Community i.e. the "Study and management of Kenya mangrove ecosystems". This project started at the end of 1989. It is a co-operative project between the Netherlands Institute of Ecology, Centre for Estuarine and Coastal Ecology (NIOO/CECE), the Catholic University of Nijmegen, a number of Belgian universities co-ordinated by the Free University of Brussels, the Kenyan University of Nairobi and KMFRI in Mombasa. The CEC-project resulted from the Kenyan-Belgian Co-operation in Marine Sciences; a co-operation which has been running since 1985. The advantage of this situation is that a scientific and logistic base exists in Kenya. A number of Belgian and Dutch scientists and a guest house are present in Mombasa.

The present first phase will be followed by a larger five year programme (1993 -1998) in which the development of Mombasa in to a regional marine centre will be an important element. Funding for this programme has to be applied for from national (Development Aid) and international (donor agencies, World Bank, Rockefeller Foundation, etc.) organisations.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2 Sustainable development in marine science

2.1. Introduction

Earlier Indonesian - Dutch partnership
From 1982 till 1987 the Dutch and Indonesian governments provided the way and means for the so-called Snellius-II Programme. Within this partnership in marine science The Netherlands Marine Research Foundation and the Indonesian Institute of Science executed the Snellius-II Expedition. The aim of the programme was to develop, execute and elaborate a joint research effort in the eastern Indonesian waters. The innovative element of this programme was that the transfer of knowledge and building of institutions were an intrinsic part of the overall programme, as well as the "translation" of the results for the public, politicians and scientists. The Snellius-II approach was a successful one and is internationally recognized as such.

Partners in sustainable development
In September 1989 a workshop on "Partnership in ocean sciences and services for sustainable development" was organized by IOC, UNESCO and the Federal Republic of Germany. The principal purpose of the seminar was to assess the need for and approach to the development and strengthening of partnerships between countries and agencies in order to improve marine science capabilities worldwide. The need for such partnerships in the face of global change, shared resources, and transnational marine problems was examined and the effects of the regime as envisaged under the Convention on the Law of the Sea were discussed in depth. This regime envisages and encourages partnership between nations in future marine research. These factors necessitate new forms and alternative directions for partnership in order to strengthen the technical, scientific, educational and service sectors of marine science. The seminar evaluated several possible new directions.

A holistic approach
It was concluded that a new holistic approach is needed for the cooperation between developed countries and developing countries. In this approach, which is similar to the one applied during the Snellius-II Programme, education in marine sciences is an intrinsic part of research and institution building. Moreover, open ocean issues should not be treated as distinct from those pertaining to coastal zones and global problems should be addressed together with national and regional concerns. The transfer of know-how should be a controlling theme within such joint programmes.

2.2. The role of the marine environment

Ocean resources

The marine environment is of vital importance to the continued well-being of mankind. Some forty percent of the world's animal protein is derived from the sea. Mariculture is expanding worldwide. Offshore oil and natural gas reserves are currently substantial sources of energy which are being tapped by using advanced technology. The potential of other undersea minerals is being explored and evaluated. Approximately two thirds of the world's population lives in coastal zones and over half of the world's coastlines are eroding. Much of society's waste ends up in the marine environment. It is obvious that especially the coastal zone itself is an important resource where the concentration of socio-economic activities frequently creates conflicting demands. This results in a degradation of this important resource. Human interference has major impacts on coastal zones.

Management of marine resources

The need for countries to develop coastal zone management plans are growing as the human population increases. Management of the marine environment presupposes a sound insight in and a good knowledge of the physical, chemical and biological conditions. Measures to reduce the effects of human activities require information on the sources of pollution and how these effect the environment. Effects and the measures taken to counteract them must be looked at in the context of the ocean's tolerance and capacity. Marine science addresses coastal protection as well as coastal ecosystem management, aquaculture and coastal pollution by providing a sound basis on which such management plans can be formulated. As a consequence, marine science has a vital role to play in achieving sustainable management of the ocean, coasts, shelves and deep sea, and in wisely harvesting its resources.

Human impacts/population pressure

The rapidly increasing human population also effects the global environment by increased exploitation of resources and its discharge of waste. Sustainable development requires a detailed and precise knowledge of the resources, their distribution, abundance and potential yields. In this regard it is important that each coastal and oceanic state develop an adequate capability in marine science if the health of the global oceanic environment is to be maintained and its resources not depleted or degraded.

In turn the global human population itself is also effected by the processes in the world's oceans. The world's oceans are an important factor in climatic change. The oceans are a fundamental component of the systems controlling global weather and climate. Major impacts of climatic change are expected to occur in coastal zones, near-shore areas and lowlands. Predicted impacts of climatic change may result in dramatic changes in ocean resource distribution and productivity, in coastal infrastructure associated with marine transportation systems and in an increased frequency and severity of natural hazards in the coastal zones of the world. Not only are developing countries vulnerable to such changes, but unlike the more industrialized nations of the world, many lack the necessary capabilities in marine science which will enable them to address and plan for the predicted adverse impacts of such changes. The challenges posed by these changes necessitate both increasing levels of investment in global marine research and monitoring infrastructure as well as increasing international co-operation. Only by 'pooling' our capabilities at an international level will we be able to understand the processes which link the climate and the oceans and, by this, understand how such changes and their potential impacts may be mitigated or avoided.

Resources of the next century

The oceans offer mankind a vast store of until now little-developed material resources. Modern marine research is generating new knowledge of what exists in and under the sea. New technology makes it feasible to reach and to extract or harvest natural resources that were previously inaccessible. Although the present level of exploitation of the oceans is growing rapidly, the potential is still enormous. Countries lacking an adequate marine science capability will easily be excluded from future exploitation of marine resources. As a consequence the knowledge gap with e.g. industrialized countries will rapidly increase.

Sustainable use of the sea

Man also urgently needs to establish criteria for making the necessary choices among the many possible courses of action. These criteria are also necessary to implement the laws and build the institutions required to implement these choices. We must be able to prevent and correct mistakes caused by man's greed and ignorance. Among other things this means reducing, or preferably stopping, the discharge of effluents, radio-active waste and other hazardous substances, and preventing accidents involving oil and chemicals. It seems that mankind's unwise use of the sea is about to reach the point of no return. This frightening situation has caused a new willingness to preserve this unique environment, as will be expressed at the upcoming Earth Summit in Rio de Janeiro (June 1992).

2.3. Sustainable development in marine science

Marine science: applied or basic?

It is important to realize that in marine science the dividing line between applied science, on the one hand, and basic science on the other, is tenuous at best. And taking marine issues into consideration immediately demonstrates that the two are inextricably linked and that attempts to separate them are artificial and ineffective. An important aspect of future directions in marine science must encompass the integration of open ocean research programmes with those on shelf seas and in the coastal zones. To study open ocean processes in isolation or separately from processes in coastal zones is counter-productive in the face of global climatic change and the possible rise of the sea level.

Science gaps?

Different countries have different needs and possibilities in marine science. The SOZ published a Marine Science Country Profile for The Netherlands in 1988. The report describes the scope of marine science in a national context and sums up the existing marine science capabilities. In some developing countries marine science capabilities are well established, in others funding is limited and is largely directed to the research of immediate, resource related problems. Little is invested, either nationally or internationally, in strengthening the capabilities of such countries to address more broadly based research problems. It is known that the limited national investment in science education in many countries frequently results in general shortages in skilled scientific and technical manpower.

Global dimensions of marine science

To participate as partners in marine science each country needs qualified personnel, an adequate infrastructure including equipment - as well as the capability to maintain it - research programmes and information systems together with a broad approach to marine science. This has to be based upon an internationally agreed on high level. By its very nature marine science is not confined within specific boundaries such as countries or regions. Marine scientists must therefore, be able to draw upon the scientific contributions from many countries if they fully want to participate in global activities and if marine science is to address global issues.

The need for a new approach

The need for partnerships in ocean sciences and services for sustainable development has a multiform and practical basis. This is among other things due to the transnational nature of marine problems, the effects of the regime under the Convention on the Law of the Sea, Global Change related programmes as well as other large international research programmes and the sharing of resources. These factors necessitate a new holistic approach to the co-operation between developed and developing countries. This approach is similar to the one applied during the Snellius-II Programme.

The development a marine science capability

The responsibility for the development of marine science capability rests ultimately with each individual country. Nevertheless, countries with well developed marine science capabilities have a responsibility to assist in the development of similar capabilities in less developed nations. Whenever industrialized countries support marine research in developing countries, the prevailing view seems to be that only applied research should receive support. Moreover, the needs in marine science are generally perceived along similar lines to the needs in other scientific and technological disciplines: more money, more trained and skilled manpower, more equipment, more training programmes - both formal and informal - , more scholarships, more overseas attachments, and a greater commitment on the part of the general public and politicians to the development of marine science. Frequently such inputs are not properly evaluated in terms of assessing their impact on performance, achievement and the development of marine scientific capabilities in developing countries. Often expensive equipment, including research vessels, is provided through donor agencies while problems of maintenance or recurrent budgets prevent its proper use in the development of marine science. However, there are a number of attractive and cost-effective ways, such as the use of mobile laboratories on land **and** on ships, for the development of a country's marine science capability.

In connection with the Dutch IOP two countries were selected for a partnership in marine science. These countries are Kenya and Pakistan. The pragmatic philosophy is that the overall 'return' of the planned IOP can be increased by combining the SOZ funded long-term basic scientific research activities with the more applied, shorter-term objectives of development aid related research activities. The approach in these partnership programmes stresses sustainable development, transfer of know-how and building infrastructure through the execution of a joint research effort.


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3 The East African Region

3.1. Introduction

The eastern African coast is an area rich in living resources. The area has vast mangrove forests, high coral cliffs, wide stretches of sand dunes, and numerous offshore and oceanic islands. However, pollution, habitat destruction, and the pressure of the growing population and tourism are causing problems. Therefore, the nine nations of the region are now working together within a Regional Seas Programme of the United Nations Environment Programme (UNEP). The eastern African region is one of the newest programmes of the Regional Seas Programme.
The region comprises four mainland and five islands countries. The mainland countries are Somalia, Kenya, Tanzania and Mozambique. The five island nations are the Seychelles (an archipelago of over 100 islands), the Comoros, Mauritius, Réunion (France), and the Malagasy Republic. Together, they have 12,000 kilometers of coastline, and a rapidly growing population of about 55 million people.

3.2. Wind and current regimes

Currents in the Southern Hemisphere
The hydrography of the Indian Ocean waters is strongly influenced by seasonal variations of the monsoon winds (Fig. 1.). In the Southern Hemisphere, the South Equatorial Current at about 12°S is the principal current flowing all year round from east to west. Part of this current branches off northeast of Madagascar to form the southward East Madagascar Current while the main stream splits up after the northern tip of Madagascar into a southward current, which flows through the Mozambique Channel forming the perennial Mozambique Current, and a northward flowing component which forms the East African Coastal Current. The latter is the main surface layer of water bathing the continental shelves of Kenya and Tanzania with nutrient-poor, mid-ocean water, resulting in low biological productivity along this coast. South of Madagascar, the East Madagascar Current and the Mozambique Current join at about 26°S to form the Agulhas Current. South of 30°S the West Wind Drift is predominant.

Currents in the Northern Hemisphere
The current flow in the Northern Hemisphere changes direction with the seasonal reversal of the monsoon winds. During the period of the South-West Monsoon (April to October, Fig. 2a.), an eastward flowing surface current, the South-West Monsoon Current, prevails, extending southward to about 7°S. The East African Coastal Current, which becomes the Somali Current, is influenced by the prevailing strong wind with a speed of over 600 cm/sec (over 10 knots) and causes the Somali

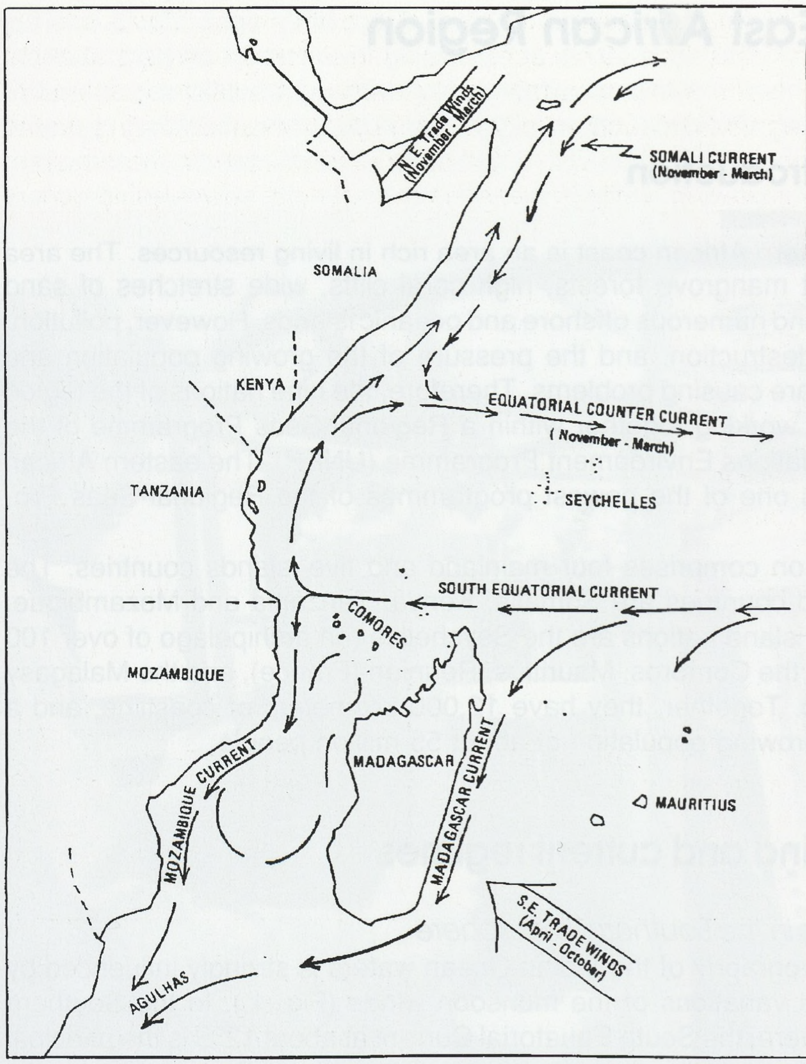

Figure 1: Ocean currents and winds in the East African Regional Sea

Current to continue its northerly flow, bending eastward off the Somali peninsula into the Arabian Sea. The fast-flowing Somali Current, with a speed of about 300 cm/sec (or over 8 knots), transports about 50-65 million m /sec of water, penetrating deep into the oceanic water mass and causing an upwelling along its left flank along the North-East Somali coast. The upwelling induces the comparatively high productivity off the Somali coast and is most intense between 5°N and 11°N. This turbulent phenomenon brings nutrient-rich, cold subsurface waters with temperatures below 20°C to the surface. The average temperature of the surface water during the upwelling period in this area is about 24°C and the salinity some 35.0 ppt.

During the North-East Monsoon (November to March, Fig. 2b.), the surface flow pattern is changed from its normal clockwise flow pattern to counter-clockwise in the northern Indian Ocean. The North-East Monsoon Current, sometimes called the North Equatorial Current dominates then, flowing in a westerly direction with its southern border at 3°S. The Somali Current, now less strong, partly reverses its flow to form the Equatorial Counter Current with its axis at 7°S and partly flows downwards to join the Mozambique Current. The turbulence of the waters is minimal because of the weakness of the Somali Current during this period (less than 10 cm/sec), and a thermocline develops at about 60-80 m depth, with the surface waters having a uniform temperature of between 28-30°C and salinity of 34.5 ppt. A weak upwelling on the right flank of the Somali Current is presumed to occur in the region of previous upwelling, while for reasons of continuity downwelling occurs on its left flank.

Thus the region may be divided into three hydrographic zones (Fig. 1.):
* Somali upwelling zone: North-East Somali coast.
* Monsoonal current zone: Tanzania, Kenya and Seychelles.
* Agulhas and Mozambique current zone: Mauritius, Madagascar, Comoros, and Mozambique. In this zone, the current flow patterns would be subject to seasonal cyclonic influence in the period December-April.

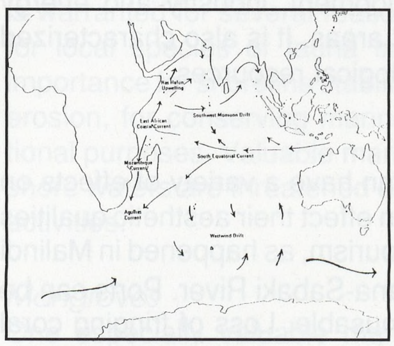

Figure 2a:
The South-West Monsoon current pattern in July

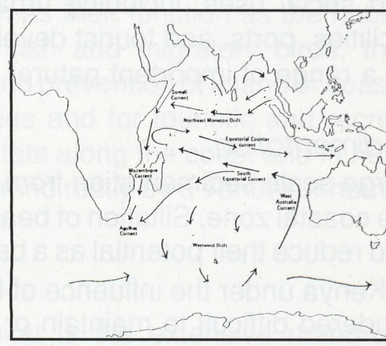

Figure 2b:
The North-East Monsoon current pattern in January

3.3. Continental shelves

The width of the continental shelf varies markedly throughout the region, but is generally extremely narrow. On most headlands and straight stretches of coastline there is a narrow shelf. Steep drop-offs begin only a few kilometres out to sea. The average width of the shelf is about 15-25 kilometres. The sediments of the East African shelf are generally sandy especially in shallower areas, changing to mud in deeper areas and in the vicinity of river mouth and estuarine areas. Shallower regions are characterized by extensive growths of coral, and there are numerous rocky outcrops. For these reasons, only a small percentage of the continental shelf is trawlable.

3.4. The coastal zone

The coast of East Africa is generally characterized by a coastal plain some 15-20 km wide rising to upland savannas and plateaus. This plain widens toward the south and in areas traversed by the valleys and floodplains of large rivers such as the Juba and Shebelle (Somalia), Tana (Kenya), Rufiji (Tanzania), and Zambezi (Mozambique).

Depending on rainfall and other factors such as the prevalence of the tsetse fly, the coastal plain is generally used for agricultural or pastoral activities. There is little irrigated land along the coast, however, and outside the floodplains there is rain-fed cultivation of cassava and maize as well as such export crops as cashew nuts, coconut, coffee, cotton, pineapple, sugar cane, and spices. Mixed cropping, as well as paddy rice cultivation, is practised in river plains. A variety of schemes including hydrodevelopment projects accompanied by irrigation works, centralized agricultural projects, integrated development plans and social and economic reorganization have been attempted in order to improve agricultural conditions along the coast and in the river plains. Apart from rural activities, the coastal zone is used for a variety of other economic and social uses, including urban development, industry and energy facilities, ports, and tourist development areas. It is also characterized by a range of important natural and biological resources.

Sedimentation

Large scale sedimentation from rivers can have a variety of effects on the coastal zone. Siltation of beaches can effect their aesthetic qualities and reduce their potential as a basis for tourism, as happened in Malindi in Kenya under the influence of the Galana-Sabaki River. Ports can be rendered difficult to maintain or even unusable. Loss of fringing coral reefs due to smothering and turbidity could lead to the loss of the protective values of these formations and result in coastal erosion, especially in areas subject to the forces of the open ocean or to severe storms. Formerly productive sea-grass beds in lagoons can be transformed into unconsolidated mudflats. Large-scale sedimentation can also radically increase the formation of deltas and sandwaves, altering the dynamics of sediment transport at the coastline and potentially leading to erosion.

On the other hand a decrease in sedimentation through upstream works can reduce the vitality of estuarine areas and even lead to erosion of deltas. Productive estuaries represent dynamic balances between the influences of the river and marine environments. Deltas are maintained in a highly productive condition through slow but constant growth that permits an orderly succession of colonial vegetation - primarily mangroves - to develop as land slowly becomes consolidated through the establishment of vegetation. Sudden loss of sedimentation or change of flow characteristics due to construction of dams or other major water-diversion projects upstream can disrupt the dynamic equilibrium of estuaries, curtail or reverse deltaformation, and effect the marine organisms where life cycles depend on certain flow and nutrient regimes. The major dams planned or being constructed in East Africa - the Bardera Dam on the Juba River in Somalia, the existing and planned dams on the Tana River in Kenya, the planned dam at Stiegler's Gorge on the Rufiji River in Tanzania, and the Cabora Bassa on the Zambezi and other planned dams in Mozambique - thus raise concern about the effects of these projects on estuarine productivity on the continental coastline.

3.5. Ecosystems

The coastal regions of East African Region fall within several biogeographic provinces. These determine the characteristic fauna and flora of the various biotopes that exist along the coast and in the near-shore environment. A number of characteristic biotopes can be differentiated. However, several should be singled out for special attention because of their special role in the ecosystem. These are: coastal dry forests, coastal dunes, coastal floodplains, fresh and brackish water marshes, mangrove forests, coral reefs, reef-back lagoons, sandy beaches and sea cliffs and nearshore islands. Protection of these areas is warranted for several reasons, such as their function as the habitat for local species of fauna including fish and migratory birds, their importance for shoreline stabilization and prevention of inland or coastal erosion, for conserving marine fisheries and for touristic and recreational purposes. Valuable marine habitats along the coast and in near-shore waters are threatened directly or indirectly by a variety of human activities.

Mangroves

One especially valuable marine habitat is the extensive mangrove forest. Mangroves are tropical coastal trees and shrubs which grow partially submerged or close to saline water. Seven species are known to occur in Kenya. They are found in sheltered coastal areas, in bays, creeks and estuaries. Mangroves are a critical habitat as nursery grounds for prawns which form such an important economic resource in countries with extensive mangroves. Mangroves also provide habitat for the fry of marine fish and a year-round habitat for various crustaceans, especially crabs. They also trap sediments released from rivers, binding some and releasing some nutrients at a relatively uniform rate into nearshore waters. The mangroves can also serve as a sink for pollutants from coastal and upland sources. Mangrove forests perform another important economic role. In addition to providing a nursery for fish and prawns, their rich waters provide a habitat for the large, edible mangrove crab and several important species of molluscs. Mangrove areas are cleared to form evaporation ponds for the making of sea salt in Kenya, Tanzania and Mozambique. Extensive clearing has taken place on the Ngomeni Peninsula, Kenya, for a prawn aquaculture project. Mangrove forests offer a wide array of valuable materials. Their wood, which is both insect and rot proof, provides fuel, poles used in house construction, and timber for boats and dhows. Lastly a fringe of mangroves helps to reduce coastal erosion.

The mangroves in East Africa are threatened by various activities. In Somalia, Kenya and Tanzania they are extensively cut for poles and for firewood and charcoal. A substantial portion of mangroves cut in this area is exported, under licence or illegally, to the Middle East. In other areas, including Mozambique and Tanzania, mangroves have been lost by the clearing of salt-pans. In Madagascar and other areas they are subject to a certain amount of usage as construction materials, a source of tannins for leathermaking, and for firewood. The vitality of mangrove swamps is also threatened by fluctuations in the amount of fresh water and sediment reaching them due to upstream hydraulic works. Mangrove areas are sometimes reclaimed and converted for salt ponds and occasionally to make way for other economic activities such as port expansion. Mangroves can also be threatened if siltation from rivers degrades protective reefs and exposes the shore to increased erosion. Loss of the extent and vitality of mangrove forests can reduce marine biological productivity of dependent species, especially shrimp. In summary, mangrove areas are threatened throughout the East African Region by over-exploitation, deforestation for development sites and pollution, by among other things, agricultural chemicals. There is a growing concern over future stocks of marine fish and prawns which use the mangroves as nursery areas. The need to conserve mangroves is internationally recognized.

Reefs

Another valuable marine habitat are reefs. A reef forms gradually over a long period as a result of the activities of both corals and algae. The growth of a coral reef creates a new living environment which gives shelter, protection and food to a variety of living organisms. The reef itself is a protective barrier against the force of the sea. In its natural state, a coral reef is one of the most productive marine ecosystems. Unfortunately these ecosystems are continuously disturbed.

Coral reefs are threatened by siltation of nearshore marine areas due to terrestrial erosion. Deforestation and environmentally destructive agricultural practices inland cause huge quantities of silt to be carried to the sea where it smothers the reefs. This is happening, for example, to reefs around Malindi effected by silt from the Sabaki River.

Reefs are also exposed to low-level oil pollution in some areas, especially in the vicinity of harbours. They are sometimes dredged or subjected to turbidity by dredging in connection with port improvement and maintenance, or land reclamation. Corals and associated marine life are collected as souvenirs, especially in tourist areas. Reefs are also subject to unknowledgeable and destructive fishing practices, such as dynamiting and poisoning. Explosives do not only kill the fish, but also other organisms, and break the structure of the reef itself. The balance of life in reef ecosystems can also be effected by overfishing of certain species. Changes in reef ecosystems could lead to depletion of the fisheries potential and to loss of aesthetic and recreational values. Other threats are the use of stone anchors and of dynamite for fishing. Stone anchors have smashed and destroyed large areas of coral. Sometimes coral reefs are also destroyed by dredging and mining.

Other coastal and marine habitat areas such as coastal dry forests, coastal dunes, coastal floodplains, fresh and brackish water marshes, reef-back lagoons, sandy beaches, and sea-bird rookeries, are also threatened by human encroachment. Severe loss of such habitats could seriously effect associated populations of coastal and marine animal species and related aesthetic values.

3.6. Living resources

Fish

The size of fish catches along the coast of the eastern African region is generally small, as it is in many parts of the Indian Ocean, because nutrient rich areas caused by upwelling do not exist. The one exception is the northeast coast of Somalia, the richest fishing ground in the region. Another factor that contributes to low fishing productivity is the narrowness of the continental shelf. A small zone for plant growth means little food for fish. However, diversity of fish species is high. In most countries small boats or canoes are used for fishing by line or by net just beyond the edge of the reef.

Prawns

Prawns are a significant resource for many countries in the region, yet the importance of mangroves as a vital habitat for these crustaceans is not fully appreciated. Prawns lay their eggs in deep water but the larvae migrate passively amidst the plankton, moving with ocean currents to the nutrient-rich water around the mangroves to feed and grow. They hide in the decaying leaves and feed on organic detritus to the sub-adult stage, when they migrate back into deeper water. Loss of mangroves effects prawn productivity, and countries of the region must accord their mangroves full protection if they wish to maximize prawn yields. Other commercially important crustaceans are the mangrove crab, important both as a protein-rich food for local people and a gourmet meal in tourist areas, and lobsters and crayfish which are mainly in high demand by tourists.

Oysters

Cultivating oysters could be an important mariculture activity as well as an extra justification for the protection of mangroves. Mariculture of oysters in mangrove creeks at Gazi in Kenya has demonstrated that oysters can be cultivated to a good size in such areas. Oyster culture can provide jobs, food and cash, all of which are needed in the region.

Plants

Marine plants, algae and seagrasses, which grow in profusion in many ecosystems, are among the most abundant renewable resources of the eastern African region. The rhizomes of seagrasses are harvested by people of the Lamu Archipelago in Kenya, who dry and then grind them into flour for cooking. Seagrasses are eaten by some herbivorous fish, while important carnivores like the emperor fish, feed on the molluscs, brittle stars and sea urchins which are part of the seagrass community.

Turtle grass is consumed by the herbivorous green turtle making it a plant of great importance. Several other species of seagrass are food for the dugong, once abundant in many parts of the region. Since the demise of the dugong, this enormous biomass of seagrass has been underutilized. Moreover, seagrass helps to stabilize the sea bed by holding down sand at times of rough seas and ocean turbulence.

3.7. Protected areas

One special feature of the region is the immense wealth in biological diversity. Outstanding achievements in conservation and protection are known from Kenya and the Seychelles. Kenya has established a number of marine national parks and reserves designed mainly to protect inshore ecosystems like coral reefs. In the north, the Funga National Reserve is a biosphere reserve under UNESCO's Man and the Biosphere (MAB) programme. The extensive Malindi-Watamu National Park protects some fine areas of coral and the Kasite Marine Park in the south encompasses islands, mangrove areas and coral reef. The Dodori National Reserve has both a terrestrial section and a marine area. This is in a wild, remote and beautiful area of Kenya's mainland, north of the island of Lamu, where you can see elephant and coral fish within the same reserve. The recently opened Mombasa Marine Reserve protects an area of the coast which has been under a lot of pressure from tourists. Plans are moving to open another protected area at Tenewi, south of Lamu, for dugongs, turtles and sea birds. Protected areas serve a number of vital functions:

* They can serve to restock areas under exploitation. For example, fish living within a protected area will move to and restock adjacent fishing grounds.
* They can protect critical habitats for feeding and breeding of organisms vulnerable to over-exploitation.
* They serve as a base line against which degradation effects in other areas can be compared.
* They can provide opportunities for research and education with out the interference of artisanal exploitation of the area.

3.8. Pollution

Forcing functions

The growth of coastal towns and industries, ecologically unwise farming and live-stock rearing practices, together with expanding agriculture and tourism are having undesirable effects on coastal zones and marine habitats. These effects are becoming more and more apparent as pollution increases and ecosystems deteriorate.

Soil erosion as a result of deforestation and unwise agricultural practices causes silt problems at the coast with serious socio-economic implications. In Kenya silt from the Tana river is effecting catches of both fin fish and prawns in Ungwana Bay. Silt carried by the Galana-Sabaki River down to the sea at Malindi is smothering coral reefs and sullying beaches, with serious consequences for fishing and tourism.

The use of pesticides and fertilizers

Agriculture, the livelihood of 90% of the population of the East African Region, is an economic priority. All countries in the region are striving for self-sufficiency in food crops and for increased productivity in cash crops like cotton, sugar, tea and coffee. As a result, pesticides and fertilizers are being used increasingly. Many areas of intensive agriculture are inland, and most pollutants from this source are carried by rivers down to the sea, thereby effecting the highly productive and fragile coastal ecosystems. Ecologically harmful organic pesticides include DDT, dieldrin, lindane and toxaphene. In general, pesticides are not biodegradable; they persist for a long time in the environment, are absorbed into living organisms and accumulate along food chains. Human health is threatened by these toxins reaching them through the food they eat.

Local pollution

Industrialization of the countries of the eastern African region is increasing, and with it, the rate of increase of pollution from industrial sources. Industries tend to be concentrated along the coast at particular sites. Mombasa is a major industrial site on the Kenyan coast. Local pollution problems are among other things, caused by textile mills, slaughter houses, sawmills and breweries producing important materials for local use.

Sewage discharges

The major problem caused by domestic pollution stemming from sewage discharges and excreta disposal along the coast are the bacteriological constituents. Due to the often very close proximity of discharge points and coastal recreational or shellfish areas, pathogens have a short-circuit back to the human target via the coastal environment. Endemic prevalence of infectious diseases with regularly occurring epidemic outbreaks are the result of this situation. Therefore domestic sewage discharge and excreta disposal are one of the major public health problems of the region.

Oil pollution

The East African Region is one of the busiest oil tanker routes in the world (Fig. 3.). Daily about 225 tankers move through the area. There are two main transport patterns: one route, served mainly by medium sized tankers of 20,000 - 100,000 tonnes, runs from the Middle East to the oil refineries of eastern and southern Africa, providing them with a total of 22 million tons of crude oil annually. After the tankers deliver their cargo, they return to the Middle East in ballast. The second route is via the Cape of Good Hope to Europe and America, using very large crude carriers of more than 200,000 tonnes. This trade is over 500 million tons a year.

Because of the relative calm of these waters, the absence of national surveillance capability, and the proximity to their loading ports, tankers returning by this route to the Middle East, routinely discharge oily ballast and clean their tanks in the region. The possibility of an oil spill from one of these huge tankers is the biggest single threat to the marine environment of the eastern African region. Unexpected spills in harbours or spills reaching the coast are a contingency that calls for prior planning and the availability of suitable equipment. Only Kenya now has a national contingency plan, detailing administrative responsibilities in case of a spill. Only Mombasa and Port Victoria (Seychelles) have operational contingency equipment.

Overexploitation of marine resources

Fish, shells, coral, bêche-de-mer, dugongs and turtles are all subject to overexploitation on a massive scale in many parts of eastern Africa, where agricultural land is in short supply and food is scarce. This overexploitation is due in part to burgeoning human numbers coupled with a shortage of land-based jobs. Kenya's population of 23 million for example - said to be the fastest growing in the world - is increasing at the unprecedented rate of 4.3% annually, and is expected to double around the turn of the century, with a consequential increase in demand for land, food, housing, water and social services. This situation strains both terrestrial and marine ecosystems to a breaking point.

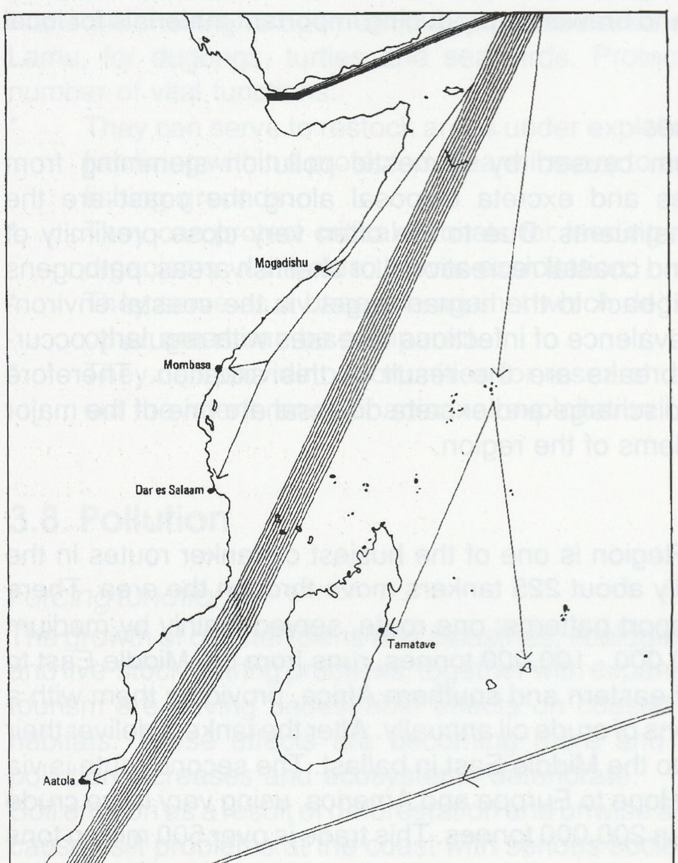

Figure 8 : Tanker routes of the region

Figure 3: Tanker routes of the East African Region

4 UNEP's action plan for the East African Region

4.1. Introduction

Marine problems neither start nor end at national boundaries. Neighbouring countries which share a common sea often face the same marine problems, and it makes sense for them to pool their financial and human resources together in order to approach and tackle these common problems on a regional basis. Setting out to address marine problems in a regional way, UNEP initiated the Regional Seas Programme in 1974 and has since established programmes in 10 different areas. These regional programmes concentrate particularly on the developing parts of the world. A plan for the eastern African region was developed during the early 1980's and, in 1985, the Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the eastern African region came into being. It was adopted by the representatives of the Comoros, France, Kenya, Madagascar, Mauritius, Mozambique, the Seychelles, Somalia and Tanzania (Fig. 4.).

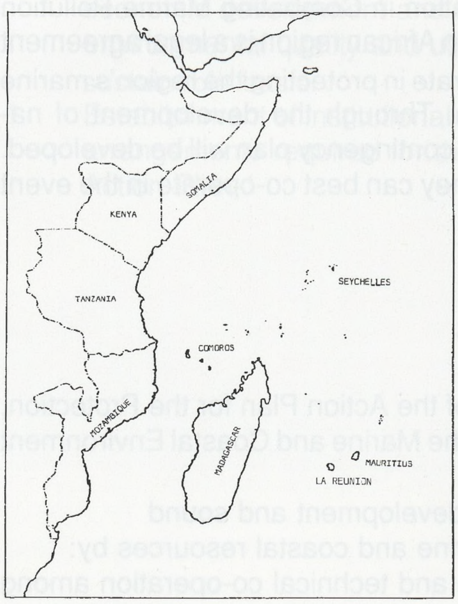

Figure 4: The East African Region

An agreement providing the legal framework for the Action Plan was signed the same year, together with two protocols: one concerning protected areas and wild fauna and flora in the region, the other concerning co-operation in combating marine pollution in cases of emergency. The Eastern African Action Plan provides a framework for regional co-operation on problems that beset the region. The region's key environmental problem is inadequate planning for an environmentally sound, sustainable socio-economic development and the rational utilization of natural resources. Therefore, one of the main objectives of the Action Plan is the provision for better planning so that the eastern African region may look to a healthier future for its marine and coastal environment, its ecosystems, its resources and its people.

The top priority of UNEP's Action Plan is to promote the protection and environmentally sound development of marine and coastal ecosystems in the region. This is to be accomplished through the establishment of a regional network of institutions or organisations that will concentrate and co-ordinate their activities. The members of this network will carry out a survey of coastal and marine ecosystems and produce information on species, habitats and ecosystems. This will involve on-site ground surveys, aerial surveys and remote sensing techniques. Based on this information, the particular coastal or marine areas that require the development of specific management plans will be identified. After a period of training, management plans will be drafted to conform with the Protocol Concerning Protected Areas and Wild Flora and Fauna in the eastern African region. At the same time a multimedia public awareness programme will be set up to enlighten the people of the region about their role in the management plan.

The second priority is to monitor pollutants, their sources, levels and effects in the region. This co-ordinated research and training programme will assist national institutions to monitor and combat pollution. A mission covering all research centres in the region has already identified suitable laboratories to be involved in pollution monitoring. Monitoring equipment for the participating laboratories has been purchased and is to be installed shortly.

The third priority is to assist countries to respond to maritime emergencies or marine pollution incidents which threaten the environment or the local people.
The Protocol Concerning Co-operation in Combating Marine Pollution in Cases of Emergency in the eastern African region is a legal agreement for the contracting parties to co-operate in protecting the region's marine environment from marine pollution. Through the development of national contingency plans, a regional contingency plan will be developed. States will then know in what way they can best co-operate in the event of such incidents.

4.2. Goals and objectives

The general goals and objectives of the Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the eastern African region are:

* To promote the sustainable development and sound management of regional marine and coastal resources by:
  - enhancing consultation and technical co-operation among the States of the region;
  - emphasizing the economic and social importance of the resources of the marine and coastal environment;
  - establishing a regional network of co-operation on concrete subjects/ projects of mutual interest for the whole region;
* To establish general policies and objectives and to promote appropriate legislation for the protection and development of the marine and coastal environment on a national and regional level;
* To prevent pollution of the marine and coastal environment within the region which originates from activities within the States of the region or from operations primarily subject to the jurisdiction of extra-regional States;

* To provide protection for and rational development of the living resources of the region - which are a natural heritage with important economic and social values and potential - through the preservation of habitats, the protection of species, and the careful planning and management of human activities that effect them.
* To strengthen and encourage, through increased regional col laboration, the activities of institutions within the region involved in the study of marine and coastal resources and systems;
* To improve training and assistance at all levels and in all fields relating to the protection and development of the marine and coastal environment;
* To stimulate the growth of public awareness, at all levels of society, for the value, interest and vulnerability of the region's marine and coastal environment.

The activities of the action plan are expected to result in:

* Assessment and evaluation of the causes, magnitude and consequences of the environmental problems, in particular assessment of marine pollution and studies of coastal and marine activities and social and economic factors that may influence, or be influenced by, environmental degradation.
* Promotion of methods and practices for the management of socio-economic development and activities that safeguard environmental quality and utilize resources wisely and on a sustainable basis.
* Establishment of institutional machinery and adoption of financial arrangements required for the successful implementation of the Action Plan.

5 The Netherlands Indian Ocean Programme (IOP)

5.1. Introduction

When the British Challenger undertook her famous round-the-world cruise from 1872 to 1876, she omitted the northern half of the Indian Ocean. The number of oceanographic expeditions in the early days of modern marine research is small. Noteworthy are the cruises by the Austrians aboard 'Novara' in the 1850's, the Germans aboard 'Valdivia' (1898-1899), 'Gauss' (1901-1903) and 'Planet' (1906-1907), the Dutch with 'Snellius' in the late 1920's and early 1930's, biological and physical research by the British 'Discovery II' on her way to and from the Antarctic in the 1930's and 1940's, the British John Murray Expedition on board the Egyptian 'Mabahiss' (1933), hydrographic surveys of the British Royal Navy, the Swedish deep sea expedition 'Albatross' (1947-1948) and work done by the Danes with 'Dana' (1928-1930) and 'Galathea' (1950-1952). Little of this research was done in a systematic way and sometimes twenty or thirty years elapsed between two observations in the same region. To overcome this situation the highly successful International Indian Ocean Expedition (IIOE), an initiative of the ICSU Scientific Committee on Ocean Research (SCOR), was conceived. The expedition took place during 1959-1965 and was co-ordinated by the newly established Intergovernmental Oceanographic Commission of UNESCO after its foundation in 1960. The expedition had a major scientific as well as social impact. It gave the first general overview of the Indian Ocean and laid the basis for the marine science infrastructure of the region's leading countries such as India and Pakistan.

Since the IIOE international research in the Indian Ocean has been limited. Exceptions, however, are the activities of the deep sea drilling programmes: DSDP, 1968-1975; IPOD,1975-1983; and the currently active ODP, 1985-present. Furthermore, research from especially French, German and British research vessels passing the area as well as research carried out by the USA, USSR and the Indian Ocean nations India and Pakistan, has been important. In the nineties a number of international initiatives related to Global Change will take place in this area. Several research groups are now discussing new programmes such as OMEX (Ocean Margin Exchange) and LOICZ (Land - Ocean Interactions in the Coastal Zone) and JGOFS (Joint Global Ocean Flux Studies) in the framework of the International Geosphere Biosphere Programme (IGBP). In the JGOFS-community it is recognized that the study of fluxes of carbon and associated elements in coastal oceans and marginal seas is a critical requirement for any programme dealing with global budgets. So far, the magnitude of the flux of organic matter from the coastal zone to the open ocean, which may be a significant sink of carbon, is uncertain.

5.2. Scientific programme

The Netherlands Indian Ocean Programme was developed by the Dutch marine scientific community. Representatives of this community and staff responsible for logistics and technical support form the national Indian Ocean Committee (see Annex 1). The overall scientific objective of the IOP is the study of the effects, on different spatial and temporal scales, of the monsoon on the marine ecosystem in the area. This paragraph gives a summary of the five main programmes. A detailed description is given in the Scientific Programme Plan of the Netherlands Indian Ocean Programme 1990/1995. An overview of the research area is given in figure 5.

A. Research of the continental shelf and the coastal ecosystems in Kenya

With this project we will be looking closely at the effects of the monsoonal system on the ecology of the coastal waters of Kenya. From November till March the North-East Monsoon prevails and from May till September the South-East Monsoon. In the northeast Indian Ocean the water circulation reverses with the change in wind direction: during the South-East Monsoon an East African Coastal Current heads north pushing great amounts of water with enormous speed from 4° S towards the Arabian peninsula; during the North-East Monsoon there is no East

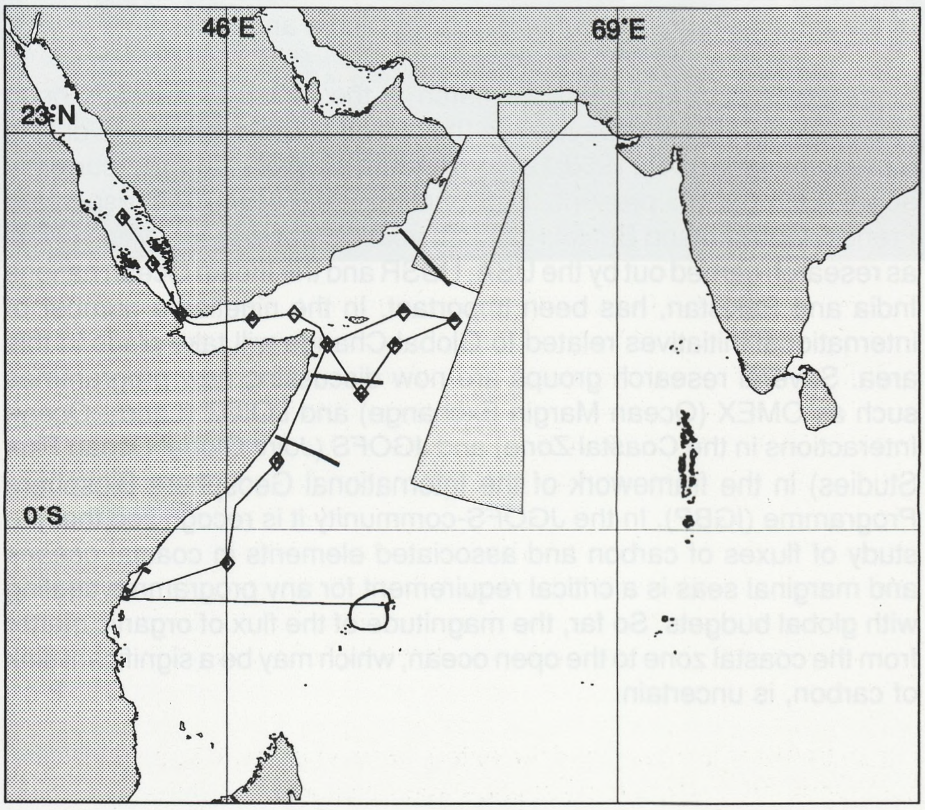

Figure 5: Netherlands Indian Ocean Programme

African Coastal Current, hence no upwelling. The South-East Monsoon and East African Current generate a strong upwelling on the coasts of Somalia and the southern Arabian peninsula. Cold, nutritious water from the deep is pushed to the surface, resulting in increased biological productivity. Although less constant and less powerful, upwelling also occurs off Kenya. During the North-East Monsoon the biological productivity diminishes in the coastal regions and conditions prevail that are akin to 'marine deserts'.

Nothing is known about the effects of this unique reversal of oceanic circulation on the ecosystems of the Kenyan coast. The project not only studies the marine fauna and flora but also tries to gain a clear understanding of the physical, chemical and biological processes in this region. The productivity of the Kenyan coastal waters and its determining factors such as current patterns, contents of nutrients and light penetration will be examined. An other area of research is the exchange of production between the coastal region and the deep sea, which is of great importance regarding the global effects of an increase in atmospheric CO_2.

The factors that determine productivity also include the influence of creeks and rivers. The mangroves along the banks are highly productive and act as nurseries for crustaceans and fish and provide coastal waters with nutrients. The exchange between these systems and coastal water is also seasonally determined (e.g. by the rainy season); specific effects, however, are unknown.

The research of the coastal waters as well as the exchange with creeks and rivers will be a supplementary executed research from the RV Tyro as well as from a coastal base near Mombasa. Close collaboration will be established with Kenyan research scientists of the Kenya Marine and Fisheries Research Laboratory In Mombasa.

B. Monsoons and pelagic systems

In the northwest Indian Ocean the monsoons reverse the surface circulation every half year. During the South-West Monsoon in the summer, strong upwelling occurs along Somalia and the Arabian peninsula. Massive algal blooms develop and are driven far into the open Arabian Sea. The organic material sinks below the productive upper layer and the decay of this matter decreases the oxygen concentration at intermediate depths. During the North-East Monsoon in winter, upwelling is absent and poor, unproductive blue waters prevail. The oxygen profile is very similar in the Red Sea but water temperature is above 20°C down to the bottom because the shallow Strait Bab-el-Mandab prevents cold, deep water to enter from the Indian Ocean.

The extreme seasonality and the extensive oxygen minimum zone in the northwest Indian Ocean are unique and invite a study of the dynamics of the pelagic systems. During the International Indian Ocean Expedition of 1959-1965 productivity estimates were scanty and plankton was collected from the upper 200m only. Therefore, a series of cruises is planned involving measurements with modern techniques of a large number of biological and chemical variables on water and plankton samples down to depths of 1000 or 2000m. The research plan comprises two main themes, a quantification of the carbon flux and biogeographical studies. In the latter, distribution and taxonomy of plankton will be studied to test whether species known from other oceans are really missing in the Indian Ocean. Overwintering populations of typical upwelling species will be traced at depths near the oxygen minimum (500-600m), and factors influencing their life strategies will also be examined. The plankton composition in Strait Bab-el-Mandab should be studied, to see whether the impoverished fauna of the Red Sea is due to mass mortalities of important species by high temperature, or by eventual lack of oceanic species in the summer undercurrent, with water originating from the upwelling areas.

The carbon flux part of the Programme is a pilot study for the Joint Global Ocean Flux Study in the northwest Indian Ocean (planned for 1994/1995) and will cover most of the core measurements of that international programme. Distribution and growth rates of different algal species will be related to hydrographical conditions, and monitoring of chlorophyll concentrations will facilitate the interpretation of satellite images for mapping phytoplankton booms. Recycling of nutrients by bacteria and by animal plankton will be compared with 'new' production caused by upwelling. Faecal pellets digested by larger plankton and by lantern fish and collected in traps floating below the productive zone, should give a measure of the loss of carbon at depth. This is of importance to estimate the buffering role of the oceans with regard to the concentration of carbon dioxide, the gas predominantly responsible for the present increase of the greenhouse effect. Special attention will also be paid to accurate determinations of dissolved organic carbon, a key variable in the capacity of the oceans to store CO_2. In addition, concentration and dynamics of N_2O, another gas contributing to the greenhouse effect, will be studied. The NW Indian Ocean is believed to produce a substantial part of global N_2O.

C. Tracing a monsoon induced upwelling system

The northwest Indian Ocean and the Arabian Sea have properties that are unique in the world, namely seasonally reversing monsoons and related upwelling (see before, under A). Upwelling systems are of great importance, as they are directly related to global climatic change, mineral and hydrocarbon exploration. This can easily be understood by realising that during the upwelling season the biological productivity increases enormously. After dying, organic matter sinks to the seafloor, where it disintegrates, consuming considerable amounts of oxygen ('oxidation'). The result is a so-called Oxygen Minimum Zone (OMZ) on the seafloor, a potential site for the formation of hydrocarbons. It is also

the place where high concentrations of minerals such as phosphates, opal and uranium may be found.
From previous deep-drilling in the ocean floor in this area, we know that the upwelling system, and thus the actual climatic conditions, were established some ten million years ago. The sediments and the incorporated skeletons of minute microfossils recovered during these drilling campaigns faithfully record subtle changes in upwelling intensity over this period. Careful studies of these sediments thus allow us to interpret past conditions and extrapolate the findings to the future.

Many signs contained in the fossil sediments are, however, still little understood. Bearing in mind the geological credo that 'the present is the key to the past', the scientific cruises described in this chapter, aim at a systematic and careful study of both the upwelling and the non-upwelling situations. This will be achieved by sophisticated sampling and measurement procedures throughout the water column and the uppermost part of the ocean floor. Techniques include CTD (conductivity, temperature, depth) measurements, plankton sampling by means of a multinet and determination of nutrient concentrations. Large funnel-shaped instruments (sediment traps) will be stationed at various depths in the water column, anchored to the seafloor. These will remain there for six months, enabling us, after retrieval, to quantify the amount of organic matter which descends to and eventually reaches the seafloor. The seafloor itself will be sampled from the ship by round boxes (box cores) and long tubes (piston cores) which sink into the soft clays and, upon retrieval, supply us with a core of undisturbed sediments. These 'books' of the earth history are the recorders of fluctuations in the upwelling system over a period covering the last 10-250 thousand years.

Integration of all data, collected on board and in the shore-based laboratories, will lead to a better understanding of the system, both in the past and projected towards the future.

D. The geological study of the Arabian Sea

1. Late Quaternary productivity and the dynamics of the Oxygen Minimum Zone in the northeast Arabian Sea.

The record of the climate in the past and of its transformation to that of today is locked in the sediments of the ocean floor. By carefully analyzing the sedimentological, geochemical and biological 'fingerprints' that are left in sediment cores taken from the bottom of the sea we should be able to establish changes in the physics, the chemistry and the biology of the northwest Indian Ocean. The latter provide clues to changing environmental conditions (climate, primary productivity, nutrients) over the lengths of intervals cored, i.e. back through time. The strongest imprint of environmental change is preserved in the zone of highest productivity, with the greatest numbers and variety in organisms, where consequently oxygen consumption is and was the highest.

These so-called Oxygen Minimum Zones (OMZ's) are found in water depths roughly between 200 and 1000 m and will be the focus of our attention. We thus will largely sample the continental slopes of Pakistan and Oman and the upper slopes of the Murray and Owen Ridges that reach up into the OMZ. The reason for working on both the Pakistani and Omani sides of the Arabian Sea is that in this way we will be able to distinguish and compare the effects of the North-East and of the South-West Monsoons which are expected to have been influenced differently by climatic change at the turnover from glacial to postglacial time.

2. Depositional architecture and sediment facies of the middle and lower Indus Fan

The internal structure and development of submarine fan systems, specifically their distal parts, are not understood in detail. Since submarine fans are potentially important hydrocarbon reservoirs, the study of these systems should help establish models for their exploration. The study entails the analysis of the internal structure of the southern Indus Fan by high resolution seismic profiling and by taking sediment cores from fan channels, channel levees and sheet deposits. This part of our cruise will be executed exclusively in international waters in the deeper parts of the Arabian Sea.

E. Biology of oceanic reefs, the Seychelles

The expedition to the Seychelles in the central Indian Ocean intends to examine the biology of coral reefs from different angles. The research in this 'umbrella-project' contains biogeographical, taxonomical, ecological and educational aspects.

The marine population dominated by coral will be explored along with the great variety of other habitats found in the reefs. From a biogeographical point of view the region shall be studied as an intermediate area between the Indo-Australian zone, East Africa and the Red Sea. This research will be based on the examination of various groups of organisms, in particular algae, sea grasses, sponges, sea anemones, stone corals, soft corals, worms, crustaceans and echinoderms. Of these groups taxonomical studies will also be made, which are to be connected with ecological aspects (such as local distribution patterns, population and the occurrence of symbiosis), biochemical studies and ecomorphology. The ecological research will be concentrated on distribution ecology by the study of the distribution of dominant organisms of the above mentioned groups.

Some special aspects will come up within this project, for example fisheries biology, the study of forms of symbiosis and the structure of population. The central topic in this project is: What distinguishes oceanic reefs from various, non-oceanic reefs that occur in the Indonesian waters and the almost similar reefs in the Caribbean? In previous years both areas were explored by the same group of Dutch scientists, facilitating this research. Such comparative research is of value for a better understanding of reef biology and tropical marine biology in general. The reinforcement of this understanding is essential for efficient control of the natural resources of the tropical seas and the protection of the marine environment.

Several items of the research programme will be realized in such a way that the results will be of optimal value for the aims of the Environmental Management Plan of the Seychelles 1990-2000 (published by the government of the Seychelles in October 1990). For this reason a more detailed programme will only be available after consultation with the departments responsible in the Seychelles, giving them the opportunity to put forward specific wishes and ideas.

During the expedition, next to scientific research, attention will be payed to underwater photography. Underwater videos will be made for educational purposes and for the general public.

5.3. Logistics

The SOZ is responsible for the Dutch IOP. The responsibility for the execution of the expeditions has been delegated to the Indian Ocean Committee (IOC) of the SOZ. Participation of scientists from other countries needs IOC's endorsement. Scientists from participating countries are considered members of the Dutch team. The SOZ has appointed an Operational Co-ordinator. The SOZ is also responsible for public relations. Visa, travel arrangements and custom facilities are in principle handled through the SOZ-office.

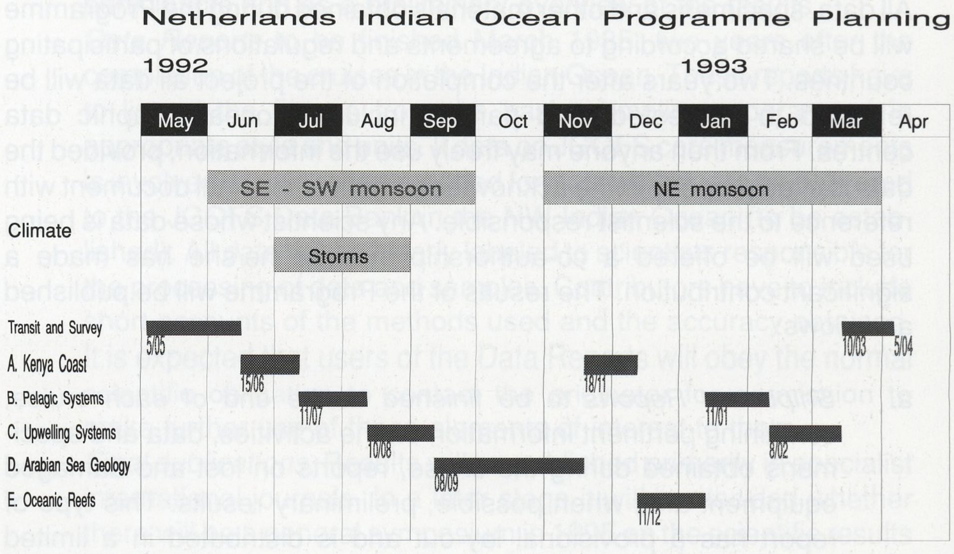

Figure 6:
Indian Ocean Programme Planning

The Programme will be carried out in the northwest Indian Ocean between May 1992 and April 1993 (Fig. 6.) and thus operations cover two monsoons: the North-East Monsoon (November - March) and the South-West Monsoon (June - September) for the northern part of the Indian Ocean and the North-East Monsoon and the South-East Monsoon for the southern part of the Indian Ocean. During the SE - SW Monsoon storms are active in July and August.

The main part of the Programme will be executed on board the RV Tyro. A land-based project is planned in June/July 1992 in the coastal area of the Republic of Kenya. During the Programme the Tyro will make port calls in Port Said (Egypt), Mombasa (Kenya), Djibouti (Djibouti), Victoria (Seychelles), and Karachi (Pakistan).

The Netherlands Marine Research Foundation (SOZ) will make available her complete pool of oceanographic equipment, including the containerised research vessel Tyro (Fig. 7.). All containerised laboratories will be used, not only on board ship, but also to set up a land-based laboratory facility in Kenya.

Besides the containerised laboratories a variety of oceanographic equipment will be available on board the Tyro. Maintenance and repair of the equipment as well as the technical assistance on board the ship is subcontracted to The Netherlands Institute for Sea Research (NIOZ). Apart from SOZ's equipment, participating research organisations will bring their own laboratory equipment as well.

5.4. Data and Publications

All data, specimens and other materials obtained during the Programme will be shared according to agreements and regulations of participating countries. Two years after the completion of the project all data will be released to interested third parties, including oceanographic data centres. From then anyone may freely use the information, provided the data is cited properly in the acknowledgement of the final document with reference to the scientist responsible. Any scientist whose data is being used will be offered a co-authorship in case he/she has made a significant contribution. The results of the Programme will be published as follows:

a. *Shipboard Reports* to be finished at the end of each cruise, containing pertinent information on the activities, data and specimens obtained during the cruise, reports on lost and damaged equipment and, when possible, preliminary results. This type of report has a provisional lay-out and is distributed in a limited number by the chief scientist to the SOZ and major participating institutes right after the cruise.

b. *Reports* on The Netherlands Indian Ocean Programme, a series comprising the following types of reports, for each of the five

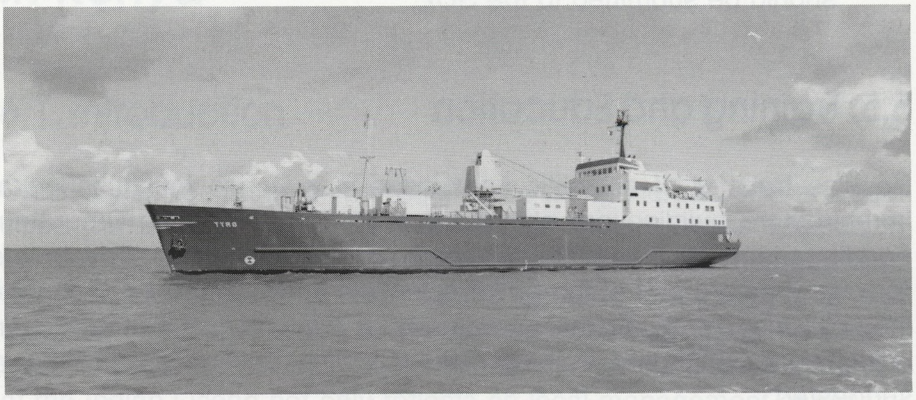

Figure 7:
R.V. TYRO

projects (NB. Part of the cover lay-outs may differ between projects, depending on bilateral co-operation and international context).

- *Cruise Reports* to be finished 6 months after the completion of the cruises of the project. A Cruise Report is the final version of the Shipboard Report, printed in a sufficient number of copies for distribution to all participants and interested parties. Projects with several cruises or parts will combine the separate reports into one definite Cruise Report.
- *Workshop Reports*, with a collection of presentations on the results obtained so far by participants. To appear shortly after a scientific workshop, scheduled for each project within 1 or 2 years after the completion of the cruises in March 1993. These reports are both meant for stimulating the preparation of papers by the participants and as a preliminary overview of the results.
- *Data Reports* to be finished March 1985, two years after the completion of the cruises in the Indian Ocean. These reports have to list all the figures from the basic sampling programme, in appropriate style and units. If data on JGOFS core measurements is involved, files in recommended formats will have to be delivered to the JGOFS Data Bank in the NW Indian Ocean (to be established). All data will be clearly labeled to scientists responsible for the processing of data and samples. Contributors have to include short accounts of the methods used and the accuracy obtained. It is expected that users of the Data Reports will obey the normal scientific obligation to contact the originator for permission to make further use of those elements of interest to them.
- *Final publications*. Results will be published primarily in specialist international journals. In a later stage it will be decided whether there will be a general symposium in 1995 on the scientific results of The Netherlands Indian Ocean Programme 1992/1993, or whether smaller symposia regarding specific issues will be preferred. Proceedings will be published in issues of appropriate journals, rather than appearing in a separate book. All publications should be written in English. Co-authorship between Dutch

scientists and scientists from the participating countries is encouraged. Five reprints (three for the SOZ and two for the counterpart) should be submitted to the SOZ.

5.5. Training and Education

Besides transfer of scientific knowledge, assistance in education and infrastructure building are objectives of the Indian Ocean Programme. Funding of this still has to be acquired from, among others, Development Aid. For the core part of this junior scientists and technicians of countries involved may be given the opportunity of education at Dutch research institutes, or on board training. The following training possibilities are suggested:

- *Pre-expedition Training* for junior scientists and technicians on specific techniques or methodologies that will be used during the IOP. The training should take place in 1992 in specialized Dutch institutes for a period of approximately 3 months.
- *Onboard Training* during the IOP for both junior scientists and technicians on sampling, operating equipment, labelling and preserving samples, data recording, etc.
- *Fellowships* for junior scientists during and after the IOP for analyzing samples, data handling, preparation of joint reports/manuscripts for publication.
- *Long-term Academic Scholarships* programme leading towards Master or Ph.D., with Dutch Universities for potentially capable candidates from the participating countries in the field of marine science, marine technology and other related fields.
- *Guest lectures* at Universities of the participating countries. Dutch scientists will give guest lectures as much as possible before, during and after the Programme.

6 Monsoons and coastal ecosystems in Kenya

6.1. Introduction

Only very limited research has been done along the East African coast since the large effort of the International Indian Ocean Expedition (1959-1975), which gave the first general overview of the Indian Ocean. Of a number of systems, such as the benthos, and of a number of dominant processes, such as primary production and sedimentation, nearly nothing is known. This lack of knowledge of the western border of the Indian Ocean not only reflects on local management of coastal areas but also has more general implications.

Ocean borders, which comprise estuaries, coastal, shelf and shelf-edge components, are a globally critical land-ocean interface controlling the anthropogenic and terrestrial fluxes and destinations of chemicals and biological production to and from the open ocean (Mantoura et al., 1991). The magnitude of the flux of organic matter from the coastal zones to the open ocean, which may constitute a significant sink of carbon, is uncertain. In a report of the JGOFS Planning Meeting in Paris, 1987, it is stated that 'the study of fluxes of carbon and associated elements in the coastal oceans and marginal seas would be a critical requirement for any programme dealing with global budgets'. The meeting agreed that the following topic should be considered among others: 'Temporal and spatial variability in primary production, its relation to satellite ocean colour measurements and to the balance between the production and consumption of organic matter'.

To bridge the existing gap in knowledge a number of initiatives has been drafted both in Europe and the United States to develop coastal oceanographic research and to put it in the context of Global Change and climate research. In the U.S. a national plan called Coastal Ocean Processes is in the making and has as scientific goal: 'to obtain a new level of quantitative understanding of the transports, transformations and fates of biogeochemically important matter on the continental border'. In Europe several groups are now discussing new programmes such as OMEX (Ocean Margin Exchange) in the framework of the IGBP (JGOFS and LOICZ). The Kenyan Coast Study of The Netherlands Indian Ocean Programme may be situated in this international framework.

It is obvious that the East African coast with its shallow shelf and its short distances between land and deep sea provides an extremely well suited location for studying exchanges along these borders.

6.2. International Co-operation

The project will be a major effort coinciding with the project Dynamics and Assessment of Kenyan mangrove ecosystems that started in 1990, a three year project of the Commission of the European Communities. This is a co-operative project between the CECE, the Catholic University of Nijmegen and a number of Belgian universities co-ordinated by the Free University of Brussels, the Kenyan universities of Nairobi and the KMFRI in Mombasa. This CEC project is a result of the current 'Kenyan-Belgian Co-operation in Marine Sciences' project which has been running since 1985. Because of this project a scientific and logistic base exists in Kenya. A number of Dutch and Belgian scientists and a guest house are available in Mombasa and will support the CEC and the SOZ.

The important added value of the project for Kenyan scientists will be the increased knowledge of the basic compartments of Kenya's coastal ecosystems which have been unknown until now. The expedition will mean for the Kenyan scientists that they will gain access to a modern oceanographic vessel and its application for the study of environmental issues. The expedition is planned as a part of a five year co-operation programme between The Netherlands and Kenya in which training and a follow-up of the expedition are essential elements.

6.3. Scientific Rationale

The magnitude on a global scale of the flux of organic matter from land to the coastal zones of the ocean and farther to the deep sea is not well defined. Terrestrial and littoral ecosystems may be a direct source of organic matter or may increase coastal production by exporting nutrients. Areas where freshwater input is small and where no upwelling exists are generally considered to be of little importance in the global carbon cycle. However, nitrogen inputs from rivers may be exceeded by other nitrogen sources such as nitrogen fixation or regeneration in sediments. Export from coastal systems with a narrow shelf may be much faster than from broad productive shelf areas where much of the organic material produced may be used on the shelf itself.

Although the East African coast is not likely to be an area where significant amounts of carbon are transferred, it is interesting for several reasons. It borders the western Indian Ocean along several thousand kilometers. The productivity of its coastal waters, limited mostly by nutrients and nutrient concentrations may be very different according to the season and depending on the monsoon. There are indications of upwelling occurring south of Somalia, but the contribution of new production relative to recycled production has not been investigated. Nitrogen fixation may be another non-negligible but unknown source of new nitrogen in these tropical areas. If, as expected, primary production is seasonal and strongly linked to the monsoon, there will be pulses of organic matter sedimenting to the benthos as well. The benthic productivity of the Kenyan shelf may therefore also be seasonal as well as the export of organic material, especially in areas where the shelf is very narrow, to the deep sea.

The Kenyan coast is a good environment to study coastal effects on productivity of oceanic ecosystems since two of the most important factors governing primary production, light and temperature, are nearly constant over the year. What varies is the composition of the oceanic water and the amount of fresh water which enters the coastal areas. On the Kenyan coast the main source of water is open oceanic water during the SE Monsoon and coastal oceanic water during the NE Monsoon. These two water types may have a very different composition as their contact with the coastal zone has a different duration. Especially the effects of various localized or diffuse land-based sources are much larger during the NE Monsoon than during the SE Monsoon. The amount of fresh water entering depends heavily on rainfall which is also linked to the monsoon.

Another last advantage of the Kenyan coast is that it has several well localized sources of material which may be studied in greater detail: the two larger rivers Tana and Sabaki and the numerous mangrove creeks.

6.4. Objectives and Applications

The aim of this research project is to study the effects of the monsoonal regime on coastal marine systems, in particular the changing effects of the two contrasting weather patterns through their impact on erosion and river flow and the reversing currents. Primary production and the fate of the organic matter produced as well as the exchange between the land and the deeper ocean will be studied. Human impacts (pollution, erosion, mangrove felling) on these processes will be considered as well.

The seasonal effects on coastal ecosystems to be considered are:

1) the seasonality in productivity of surface waters, the structure of pelagic and benthic systems and sedimentation and exchange processes;
2) inland erosion and erosion of degraded mangrove systems and increased siltation of coastal areas;
3) changes in growth of seagrasses and corals due to siltation, increased nutrient levels and temperature increases;
4) changing inputs of nutrients, particulate matter and inorganic pollutants from (semi-)terrestrial origin, including mangrove systems.

The contribution of coastal wetlands to the greenhouse effect through the production of mainly methane depends on climate since its extent is mainly governed by rainfall. Measurements of the production of greenhouse gases by mangrove and seagrass systems are scarce in general and non-existant in East Africa.

Deforestation and cattle ranching in the interior of Kenya has lead to an important increase of the sediment load of the rivers. The effects of sedimentation of silt on the reefs are especially visible in an expansion of the seagrass-beds (Giesen & van der Kerkhof, 1984) and a reduction of the corals (Blom et al., 1985; Van Katwijk et al., 1989). Effects on the productivity of the coastal waters have not been studied as yet. Such effects may be positive as well as negative: import of nutrients and oligo-elements may increase productivity but the increased extinction may decrease it.

Despite the presence of several marine parks and reserves research on coral reefs is still fragmentary. This is partly due to the poor accessibility of some areas and logistical problems. The presence of a research vessel gives a unique opportunity to visit less known areas, especially in the north of the country.

The Kenyan coast is of importance to the economy of the country, especially through the rapidly increasing tourism. The natural marits of the coast are outstanding: the intertidal areas are wintering grounds for palaearctic birds and local populations of several sea turtles, including the leatherback, and also the dugong. A number of marine parks have been established and are being well managed. These parks generate income for the local population and the country.

Human impact is expanding on the coast. Overfishing on the coral reefs (parrot fish and especially triggerfish) has lead to the expansion of the sea urchin (Echinometra mathei) population which preys on the living coral and therefore enhances erosion of the reef. The proximity of touristic infrastructure leads directly and indirectly to more human pressure by an increase in the amount of fisheries and the exploitation of corals and shellfish for decorative purposes.

The mangroves are under human pressure as well, due to increasing exploitation. The wood is used for the production of tannins, as fire wood and for the construction of houses; a trade between Lamu and Jemen for this material has existed for centuries. In some cases mangroves have been felled for touristic development and setting up ponds for aquaculture (e.g. in a FAO-sponsored project). The largest creeks in the country are the two creeks surrounding the fossil coral island on which Mombasa, the largest harbour of East Africa, is built. Both the Kilindili and Tudor creeks are used for discharging of domestic and industrial waste.

6.5. Monsoons, Current and Upwelling

A characteristic feature of the hydrography of the Indian Ocean is the seasonal switch in flow directions caused by the monsoon winds (Fig. 8.). These winds are influenced by the low pressure Inter Tropical Convergence Zone (ITCZ). The ITCZ moves to the north during the northern hemisphere summer due to the low pressure belt existing on the Asian continent at that time. From November until March the NE Monsoon blows, from May until September the wind direction is southwest to southeast (SE Monsoon).

The Indian Ocean basin can be divided into northern and southern sectors with 10°S as the dividing line. At this latitude a subsurface salinity minimum exists that extends from the north of Madagascar to the south of Java. To the north is the high salinity, high nutrient, low oxygen water of the monsoon gyre, to the south is the high salinity, low nutrient, high oxygen water of the subtropical gyre. The permanently west-flowing South Equatorial Current at 6°S to 20°S is partly diverted along the eastern Madagascar coast, becoming the Madagascar current. On approaching the mainland the SEC splits to form two coastal currents: the East African Coastal Current (EACC) to the north and the Mozambique Current to the south. That current later joins the Madagascar Current to form the Agulhas current.

During the SE Monsoon, the EACC has a high flow velocity, up to 200 cm/sec, particularly in the upper 200 m of the water column; water transport may be up to 65 million m3/s. This current causes an upwelling along the Somali coast, which is among the most extensive in the world and occurs in early summer. Upwelling is not restricted to the Somali coast. Ekman-type upwelling along the Arabian coast is also very extensive. According to CZCS images a maximum in surface chlorophyll is found in that region in August-September. Another more irregular upwelling occurs near the northern Kenyan coast and CZCS images show a maximum chlorophyll content there in January, during the NE Monsoon, which may be associated with runoff after the long rains. This also happens during the NE monsoon at the northern ends of the Arabian Sea and Bay of Bengal.

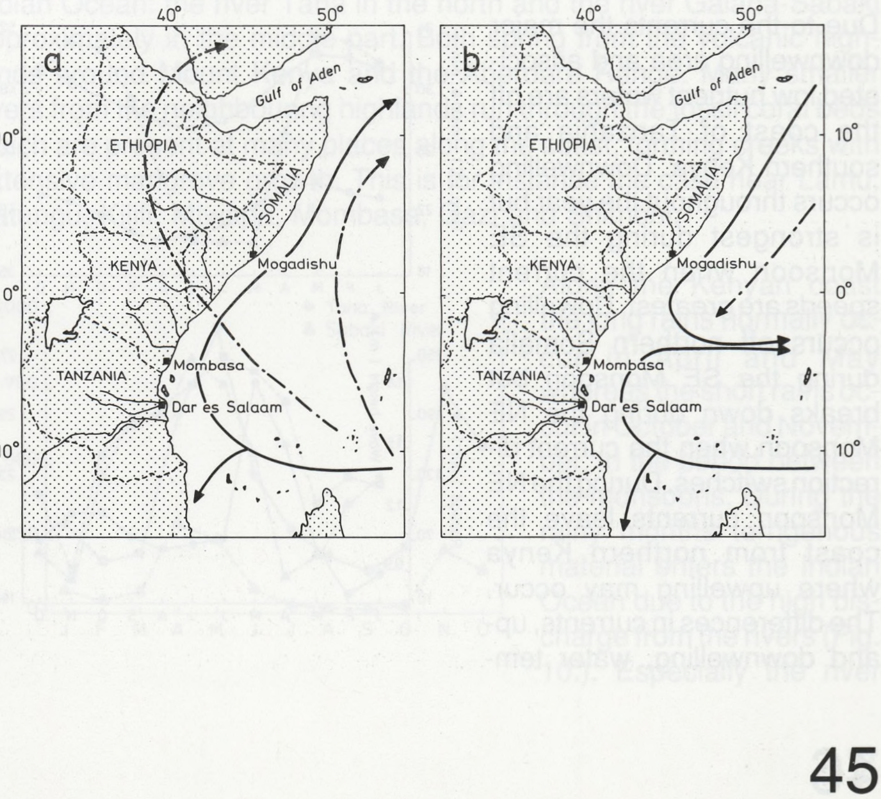

Figure 8: Current patterns (solid lines) and wind directions (dashed lines during (a) the SE and (b) the NE monsoons in the East African region

In the Somali region the primary productivity during the NE Monsoon is roughly equivalent to that of the Sargasso Sea, while during the SE areas of upwelling have a rate of primary production among the highest in the world's oceans. Seasonal contrasts in the primary production as based on the depth of the euphotic zone, are predicted to occur in the area, however, the area was one of the unsampled areas during the International Ocean Expedition in May-October. Pannikar (1970) shows abundant copepod biomass extending along the Somali coast in April-October. However, during the NE Monsoon increased copepod abundance is found southwards, along the Kenyan coast. Again river runoff is suspected to be the origin of this enhanced production.

The high productivity of the surface waters during the NE Monsoon in Somalia is not reflected by more organic matter in the sediments. This is because the shelf is narrow and the offshore currents are strong. The organic matter is probably not recycled but transported into the north-western basin and deposited at great depth. Whether this also happens in Kenya is unknown.

6.6. The Kenyan Coast

The annual migration of the Inter-Tropical Convergence Zone gives rise to the North-East and the South-East Monsoon in East Africa (Fig. 8.). Only off the Somali coast is the easterly air movement during the SE Monsoon overridden by a westerly flow towards the Asian continent. Along the Kenyan coast the NE Monsoon season is between November and March, the SE Monsoon season between April and October. The SE Monsoons are characterized by high clouds, rain, wind energy and decreased temperatures and light. During the NE Monsoons the situation is reversed (Fig. 9.).

Due to the currents the major downwelling area and associated low nutrient waters are off the coast of Tanzania and southern Kenya. Downwelling occurs throughout the year but is strongest during the SE Monsoon when the current speeds are greatest. Upwelling occurs off northern Somalia during the SE Monsoon but breaks down during the NE Monsoon when the current direction switches. During the NE Monsoon currents leave the coast from northern Kenya where upwelling may occur. The differences in currents, up- and downwelling, water tem-

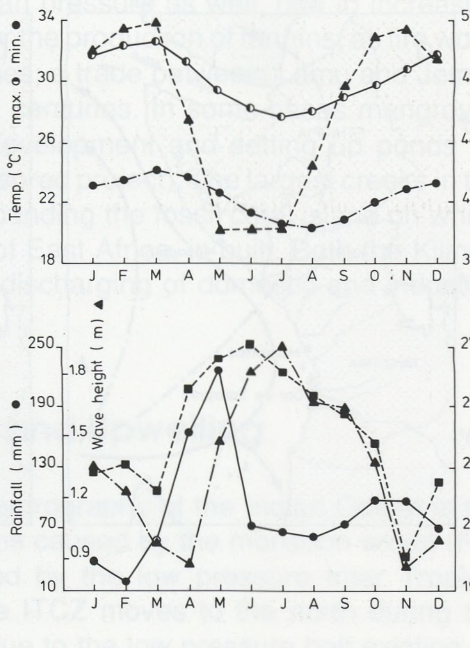

Figure 9: Meteorological parameters in Mombasa.
a: air temperature and solar radiation
b: rainfall, wind run and wave height

peratures and nutrients cause a North-South division between the ecosystems along the coast. The southern section (Tanzania-Kenya) is dominated by coral reefs and benthic productivity associated with low-nutrient water. The northern sector (Somalia) has cooler nutrient-rich water and a greater predominance of plankton productivity.

The coastal ecosystems in Kenya consist of: (1) a shallow shelf area; (2) coral reefs (fringing reefs) along the entire coast, with extensive areas of seagrass beds on the sheltered parts of the backreefs and in lagoonal areas; (3) mangroves on the shores of the brackish parts of rivers and creeks along the coast; seagrass beds also occur here.

The continental shelf is narrow and the ocean is very deep close to the Kenyan coast. There is no information on the benthic ecosystems beyond the reefs and also about the pelagic domain only little information is available; the classic picture is that these areas combine low productivity with high diversity but there is evidence of upwelling and higher productivity in northern Kenya during winter. The interaction between the offshore and coastal areas and the impact of the monsoon on this interaction is unknown. How much material is introduced into the ocean and where it goes is unknown. The sedimentology of the Kenyan coastal zone is also unknown. Because the tidal amplitude is relatively large (approximately 4 m near Mombasa), there is an extensive intertidal zone between the reefs and the coast at many places; the substrate in this zone mainly consists of carbonate sands derived from eroding reefs. The productivity of these back reefs is determined predominantly by the presence of seagrasses and microscopic benthic algae. On many places along the Kenyan coast, substantial seepage of freshwater occurs; as a result brackish water is often found in areas of seagrass beds. The system of reefs and seagrass beds along the Kenyan coast is interrupted in a number of places. Two large rivers debouch into the Indian Ocean: the river Tana in the north and the river Galana-Sabaki approximately in the middle part. Both spring from the volcanic highlands around Mount Kenya and the Aberdare Range. Many smaller rivers from the neighbouring highlands run through the fossil coral beds which are present at many places along the coast, forming creeks with extensive mangrove growth. This is for instance the case near Lamu, Katungu, Kilifi, Mtwapa, Mombasa, Gazi and Shimoni.

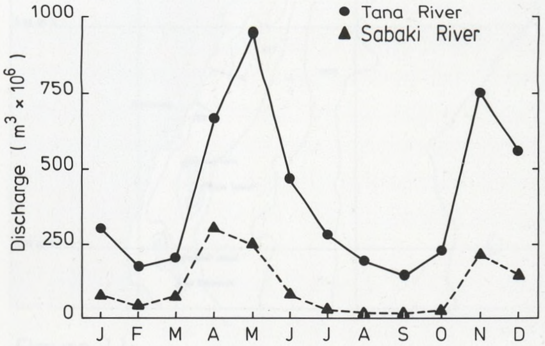

Figure 10: Average monthly discharge from Kenyan Rivers Tana (1948 to 1979) and Sabaki (1952 to 1979). (Tana River Development Authority).

Along the Kenyan coast the long rains normally occur in April and May whereas the short rains occur in October and November, in the period between the monsoons. During the rainy months terrigenous material enters the Indian Ocean due to the high discharge from the rivers (Fig. 10.). Especially the river

Tana and the river Galana-Sabaki transport huge quantities of silt originating in the interior. The silt spreads along vast stretches of the coast and into the Indian Ocean. In the estuaries and the smaller creeks an extensive brackish water zone is often found; the residing time of the water in these systems is generally short.

The mangrove ecosystem, characteristic of these silty brackish transition zones, mainly consists of woody plants associated with a characteristic fauna and flora. The salinity gradient resulting from the mixing of outflowing river water and incoming sea water, regulates the presence of the various mangrove species. The system is open, with input of nutrients from the land and export of organic material to the sea. This organic material originates from a complex detrital food chain and is an important source of energy for numerous brackish water and marine organisms (oysters and other bivalves, peneid shrimps and crabs, mullets and other fish species). Mangroves are nursery areas for several commercially exploited species.

7 Research Projects

The IOP in the Kenyan coastal waters consists of two main projects, one based on board the Tyro to study processes on the shelf and one land-based in Mombasa to study the coastal processes.

7.1. Offshore Cruise

7.1.1. Effects of the monsoon on the Ecosystem of the Kenya Shelf (Project managers: C. Heip (NIOO) and M.M. Nguli (KMFRI))

The following questions will be addressed:

1) What is the productivity of Kenyan coastal systems and how does it change according to the monsoon? How is the organic material produced used in the food web and how does the structure of the pelagic ecosystem depend on season?
2) Are the expected contrasts in pelagic productivity reflected in changing benthic metabolism? Is there export to the deep sea?
3) Is the productivity of coastal waters dependent on export from rivers, seagrass and mangrove areas? How does this change according to season and what is the human impact on these processes?
4) Are the size and biomass spectra of benthic communities in tropical areas different from those in temperate and boreal areas?
5) What are the dominant zooplankton and benthic species on the Kenyan shelf?

Three transects perpendicular to the coast are proposed (see Fig. 11.):

1) Gazi transect
2) Tana transect
3) Kiunga transect

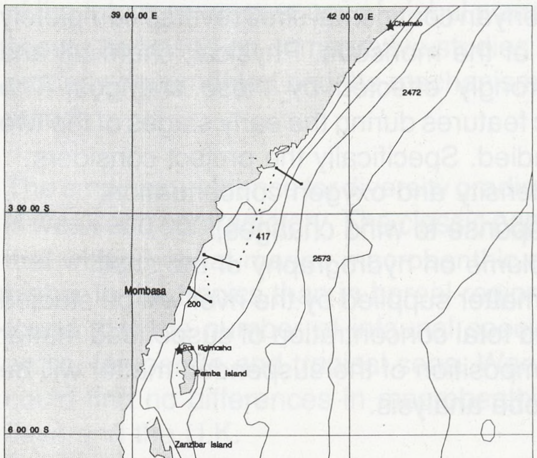

Figure 11:
Area map, showing the three transects Gazi, Tana and Kiunga.

The Gazi transect in the south will provide the link with the land-based mangrove studies. Gazi is also well south of the South Equatorial Counter Current, in an area where neither upwelling nor significant river input exists. The Tana transect covers the mouth of the Tana river, one of the two main Kenyan rivers. This transect provides the link with the land-based coral reef studies. The Kiunga transect is in the north of the country, in an unexplored area where the shelf is relatively broad and where upwelling exists at times. At each transect three stations (with depths of probably 100, 1000, 2000 m) will be studied. At each station a standard set of oceanographical parameters will be determined using the CTD/Rosette sampler with Niskin bottles at different depths. Light intensity, chlorophyll and oxygen measurements are necessary as well. The plan is to attempt current measurements using profiling current meters and by deploying floating sediment traps in a string down to 150 m deep.

Use will be made of meteorological observations. No wind measurements are made in Ungwana Bay and north of Lamu. The intention is to install, in addition to the two existing meteorological stations at Mombasa and Malindi, two stations at Gazi and Kiunga with the aid of WMO/VAP (Voluntary Aid Programme). The variables and the principal rates necessary to obtain an adequate and comprehensive picture of the pelagic system will be measured. This comprises nutrients, the microbial food web, phytoplankton and primary production, zooplankton and grazing.

The benthic systems will be studied by deploying box-corers, the NIOZ benthic lander and the benthic bottom profiler. The composition of species and the biomass of the benthos will be studied as well as sediment profiles, community respiration, fluxes of nutrients and other chemical components. The rate of sedimentation will be studied from 210 Pb measurements of cores. The study must be supplemented with the relevant remote sensing data.

Hydrography and General features

The current systems on the Kenyan continental shelf reverse completely with the change in direction of the monsoon. Physical, chemical and biological processes are strongly effected by these changes. The variability of the hydrographic features during the early stages of the two monsoon regimes will be studied. Specifically the project considers:

1) temperature, salinity, density and oxygen concentration,
2) current variability in response to wind changes,
3) influence of the Tana plume on hydrography of the shelf.

The dispersal of suspended matter supplied by the river will be studied in both seasons. Turbidity and total concentration of suspended matter will be measured and the composition of the suspended matter will be determined by SEM Microprobe analysis.

Plankton

Primary production will be measured along the three transects. The growth limiting factor in both seasons will be studied. Nutrient availability will be assessed by nutrient uptake assays, including the measurement of nitrogen fixation. The physiology of the phytoplankton populations at different depths will be studied by measuring photosynthesis using both the oxygen technique and the 14C technique. The distribution of 14C and 35S-SO_4 in the different macromolecular pools will be followed in order to study C-turnover and net protein synthesis as a measure of growth. An estimate of the rate of new production relative to regenerated production will be made using 15N measurements.

Species composition, biomass and distribution of the phytoplankton will be investigated. The deeper benthic algal flora on hard substrates will be studied from box corers and underwater TV. The importance of the microbial foodweb will be studied. Estimates of bacterial growth will be made in different water masses. The part of the primary produced material that will enter microbial populations directly, will be determined. The control of bacterial populations by heterotrophic nanoflagellates, protozoa and ciliates by grazing will be measured by direct counting and labelling of bacteria with a radioactive marker. Grazing on algae and how it determines phytoplankton population size and nutrient turnover will be estimated by determining the standing stock of zooplankton. Direct measurement of grazing is also envisaged. An inventory of dominant species will be made.

Benthos

The rate of sedimentation and deposition of organic material on the bottom will be studied by analysis of the benthic community (box-core, beam trawl), metabolic activity of the benthic system (bell-jar, bottom lander) with measurements of oxygen profiles in the sediments and nutrient exchange between bottom and water. For these experiments the benthic lander and the benthic bottom profiler will be used.

The structure of the benthic communities will be studied by determining biomass, densities and species composition of meio- and macrofauna. Major changes occur in the structural and functional attributes of shallow water marine environments between high and low latitudes. A prediction of the future consequences of global warming in specific climatic zones should be based on comparative studies so that these differences are properly documented and the mechanisms controlling them are understood.

The empirical evidence for diversity gradients in the marine environment is weak and contradictory. The classic paper of Sanders (1968) showed that within-habitat marine macrobenthic diversity for soft bottoms was higher in the tropics than in boreal regions. However, Thorson (1952) found that the number of infaunal species was roughly the same in arctic, temperate and tropical seas. Warwick and Ruswahyina (1987) could find no differences in macrobenthic diversity between sites on Java and the U.K.

On the meiobenthos there is no comparative information but since the mechanisms of diversity maintenance are probably different, a comparative study may provide a firm basis for mechanistic hypotheses.

Comprehensive collections of benthos at different latitudes could also be used to examine hypotheses relating to other attributes of community organisation, specifically size and biomass spectra. For example the conservative bimodal pattern in temperate latitudes should be unimodal at high latitudes and strongly bimodal in the tropics.The biomass spectrum should be bimodal throughout the entire gradient.

The Community Ecology Group of the Plymouth Marine Laboratory has already collected strictly comparable data on community structure of the macrobenthos and the meiobenthos from representative sites in high latitudes, temperate and tropical zones and would welcome the opportunity to analyze material collected in the same way from the Kenyan shelf.

Past and present sediment distribution along the Kenyan coast
Sediments in the western Indian Ocean have been studied. Preliminary investigations of the lithology and composition of the sediments are presented by the International Indian Ocean Expedition. A few samples taken along the shore off Somalia and Kenya consist of calcareous sands. Recent work shows that after the last glacial period, precipitation in eastern Africa was extremely high resulting in numerous floodings of the river Nile. The discharge of the river Nile was at that time so high, that a fresh water layer developed in the eastern Mediterranean. This caused water stratification, anoxic bottom water conditions and even deposition of organic rich layers (so called sapropels) in the eastern Mediterranean.

The Tana and Sabaki rivers have been bringing sediments from the Kenyan Highlands to the Indian Ocean for millions of years. The high precipitation after the last glacial in East Africa must have resulted in larger discharges of these rivers to the sea. To document the higher rate of discharge the sediments will be dated by oxygen isotope stratigraphy and 14C AMS datings on forams. Cores with higher sedimentation rates will be studied in more detail (oxygen and carbon isotopes) to determine climatic changes in the recent geological past. The results will be compared with studies carried out on Mount Kenya, and with investigations on the erosion of volcanic minerals in the rift valley.

Finally the chemical composition of the sediments will be determined to quantify the relative contribution of lithogenous, biogenous, anthigenic, dissolution residue and hydrothermal phases to the chemical composition of the sediment. With these analyses origin and source of sediments can be determined.

Levels of potential pollutants in Kenyan waters
Marine pollution research and monitoring is a priority area in the KMFRI programmes necessary for pollution management and decision making. Until now pollution studies have been concentrated in the vicinity of Mombasa harbour and nearby creeks where oil spills have occurred and which are suspected to be contaminated by municipal sewage. The influx of fresh water into creeks around Mombasa island, particularly during the rainy season, has been shown to result in higher nutrient

levels and probably also pesticide residues. The monsoon may therefore result in waves of pollutants entering the ocean.

Although pollution studies are not part of the Tyro programme, samples will be collected to investigate the distribution and levels of hydrocarbon pollutants and trace (heavy) metals in the water and the sediments. The analysis will be done by the KMFRI scientists.

7.2. Inner shelf programme

7.2.1. Kenyan coastal ecosystems and their interrelations
(Project managers: M.A. Hemminga (NIOO) and J.M. Kazungu (KMFRI))

Going from the coast seawards, a number of characteristic ecosystems can be successively found along the Kenyan coast: a zone with mangroves is followed by a zone with seagrass vegetation in backreef lagoons; these lagoons are bordered by a belt of coral reefs; beyond the coral reefs the open ocean begins. In the ship-based research programme described above, the pelagic system of the open ocean water of the Kenyan shelf is the central issue. The coastal project presented here is complementary to this programme: research focus is on the adjacent mangrove, seagrass and coral reef systems. These marine ecosystems are connected by the tidal water which carries both abiotic and biotic elements to and from the systems. The relation between mangroves, seagrass beds and reefs (in terms of dissolved nutrient and seston fluxes and shuttle movements of fish) is the central theme of the coastal project. Very little is known about the interlinkages between the coastal ecosystems in the East African Region. However, information is indispensable for a rational management of the coastal ecosystems and their resources.

Attention will also be given to the emission of greenhouse gases by the mangrove sediments. Quantitative data on the emission of these gases by tropical wetlands are scarce, and more data is needed to improve the estimates for emission of greenhouse gases by natural wetlands on a global scale.

The coastal research programme will be carried out in Gazi Bay (see Fig. 12.), about 50 km south of Mombasa. This site has the advantage of the presence of nearby laboratory facilities at the Kenya Marine and Fisheries Research Institute in Mombasa, and facilitates the participation of Kenyan scientists in the project. Furthermore, Gazi Bay is the location where a research project focussing on the ecological functioning of mangroves is currently being carried out. This project is financially supported by the European Community (EC). Kenyan, Dutch and Belgian research parties participate. Concentrating the research work of both the European Community project and the coastal pro-

gramme in Gazi Bay will be scientifically profitable, as the data resulting from the two projects can be joined to give a more thorough understanding of the functioning of a tropical coastal area. The integration of both projects, furthermore, will be advanced by the involvement of EC-scientists in some subprojects of the coastal programme. Moreover, one of the three transects of the ship-based research described in the previous section, is off Gazi Bay, giving the coastal programme a connection with the offshore research.
The coastal programme consists of four parts which are described separately below.

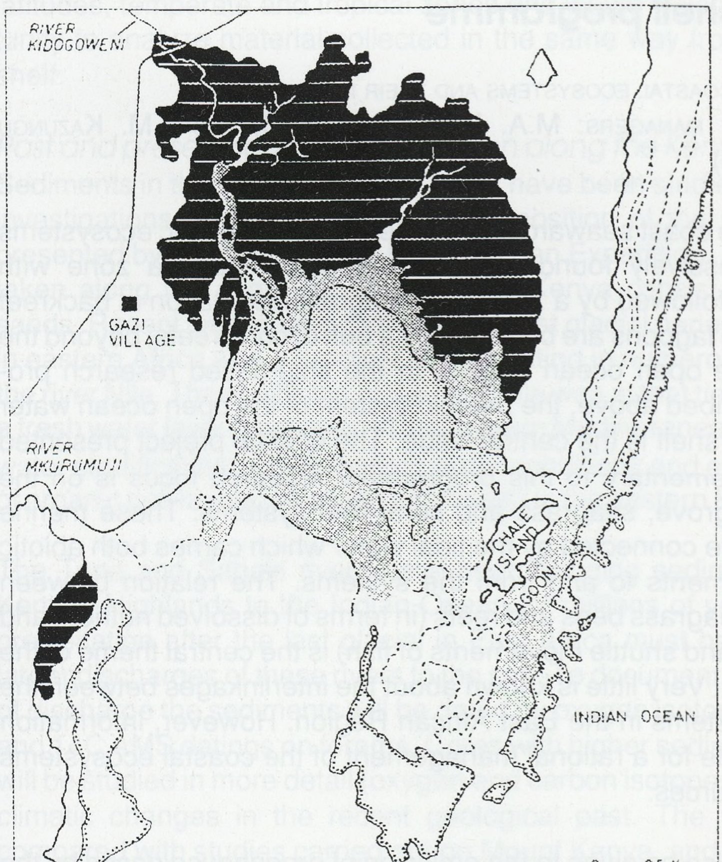

Figure 12: Gazi Bay, the research area of the land-based programme.

7.2.1.1. Isotope composition of mangroves and of seston in tidal currents between mangrove and ocean (M. Hemminga (NIOO), J. Nieuwenhuize (NIOO), J.M. Kazungu (KMFRI), E. Slim (NIOO/EC), A.F. and Woitchik (VUB/EC))

To understand the influence of the Kenyan coastal ecosystems on each other, we propose to study the transfer of organic matter between systems with the stable carbon isotope technique. Stable isotopes are very useful for studies of ecosystems if there are two dominant isotopically distinct sources of carbon. Mangroves and seagrasses have 13 C-values of -27 and -10%, respectively, while the standard error in determining the 13 C-value is about 0.1-0.3%. It is also possible to use the isotope ratios in organisms to trace the origin of carbon actually assimilated into body tissues. They give no information on individual organisms consumed, but on the organic matter assimilated over several days, weeks or months. In determining the origin of animal organic matter, trophic levels must be taken into account: carbon isotope ratios of animals are an average of 1% more positive than that of their food.During ebb and flood tides, outcoming and incoming water in mangroves, over seagrass vegetations and near coral reefs will be sampled and the seston in the water will be collected with a continuous centrifuge. In each system animals will be collected for the isotope studies. Bottom sediment samples in the coastal area surrounding the mangrove will be taken to assess the contribution of outwelling mangrove organic matter to sediment composition.

7.2.1.2. SEAGRASS MEADOWS AS NUTRIENT AND SESTON TRAPS BETWEEN MANGROVE AND OCEAN (M. HEMMINGA (NIOO), E. SLIM (NIOO/EC), P. DE KOEYER (NIOO), A.F. WOITCHIK (VUB/EC), P. GWADA (KMFRI) AND J. KINYAMARIO (UoN))

Seagrass leaves are capable of capturing nutrients from the ambient water. In addition, the seagrass canopy tends to trap seston particles from the water column. Leaf uptake and sedimentation probably are essential for the persistence of seagrass vegetations: a number of processes lead to nutrient losses from the seagrass beds (e.g. export of leaf material with currents, leaching processes, denitrification); obviously the continued existence of seagrass beds depends on mechanisms effecting a continuous replenishment of nutrients; uptake of nutrients by the leaves, and sedimentation, together with N_2-fixation, are responsible for counterbalancing these nutrient losses.

Their relative importance is unknown: combined measurements of these processes have not been carried out in any seagrass system. From an analysis of literature data, however, leaf uptake emerges as a proces of potential major importance (Hemminga et al., 1991). The position of extensive seagrass vegetations between mangroves and coral reefs, and the processes associated with seagrass canopies mentioned above, imply that these systems may function as a trap which reduces the extent of the fluxes of seston and nutrients between mangrove and ocean. Such a phenomenon would be of considerable ecological interest.

The research concentrates on two questions:

1) What is the relative importance of leaf uptake, sedimentation and N_2-fixation for nutrient input into the seagrass meadow of a backreef lagoon?

The permanently submersed coastal plain in Gazi Bay between the mangroves and the coral reefs is dominated by dense stands of the seagrass Thalassodendron ciliatum, and the investigations will be carried out in plots of these vegetations. Leaf uptake will be measured in experimental chambers. N_2-fixation will be determined using the acetylene-reduction technique. Measurement of N_2-fixation is an important component of the EC-mangrove project and will be in operation during the Kenya expedition. Sedimentation will be measured using coloured particulates applied in permanent plots. Cores of the marked sediments will be collected during the expedition and later on, by participants in the EC-project.

2) Do seagrass meadows change the nutrient and seston content of tidal water flowing between mangrove and reefs?
To answer this question, the tidal water mass flowing to or from the mangrove will be sampled and flow velocities will be measured when the tidal water passes the seagrass vegetations. Water samples will be taken on several depths, and analysed for particulate matter content and nutrient concentrations. Standing nets will be used to assess transport and catchment of larger (>1mm) particulate mangrove detritus. In addition, soil cores will be taken in the seagrass meadows, to investigate whether sediment composition shows gradients going from the mangrove side to the ocean (coral reef) side. Stable isotope techniques will be used to trace the origin of organic matter in the sediment (see also section 7.2.1.1.).

7.2.1.3. IMPORTANCE OF MANGROVES AND SEAGRASS BEDS FOR CORAL REEF FISH (G. VAN DER VELDE (KUN), P.J.M. BERGERS (KUN), P. VAN AVESAATH (KUN), M. VERSTEEG (KUN), M. VAN KATWIJK (KUN), J. MUTERE (KMFRI), A. MELLES (FAME, VUB), N.J. NTIBA (UoN), M. BOREL-BEST (NNM; ADVISORY PARTICIPANT))

Mangroves and seagrass beds are known to be nursery grounds or feeding areas for many fish species. Some species occur as juvenile and as adult in these biotopes but others are only present there as juveniles, while they are present as adults in other biotopes such as depth zones on the coral reef. Although seagrass beds and mangroves often occur in adjacent zones, their fish fauna is mainly studied separately. Studies in which fish of coral reefs, seagrass beds and mangroves are studied together are very scarce. This is, in part, due to methodological problems. Several researchers have indicated a positive influence of seagrass beds on the species composition and standing crop of the fish population on the coral reef. Also the mangroves can have a large influence on the occurrence of coral reef fish.

During a study of the Lac lagoon on Bonaire, where the fish community of adjacent mangroves, seagrass meadows and coral reefs was investigated, we developed a visual census technique, which seems satisfactory for the study of fish which are easy to identify and not too shy or in hiding. With drop nets day and night activity can be followed, while by means of these nets density and length estimations can be checked. With the drop net method also more complete fish lists can be obtained.

The field work in Gazi Bay will comprise several elements:

1. A description will be made of the structure of the coral reefs, by means of sampling, line transects and an echosounder. (The structure of mangroves and seagrass meadows in Gazi Bay is being studied within the framework of the EC-project and this information will be available)
2. Fish will be caught in permanent plots over the gradient by means of drop nets to investigate the species composition, the length distribution of the various species and the densities over the various zones.
3. Fish will be caught by means of drop nets during various times to study migratory movements and activity patterns during day and night (see also 2).
4. The various species of fish will be counted by means of a visual census technique in permanent areas by two divers in the various zones. Their lengths will be estimated.

7.2.1.4. Fluxes of gaseous C- and N-compounds to the atmosphere (G. Klaver (NIOO), J. Nieuwenhuize (NIOO), technician (NIOO))

Several gases are released as the result of decomposition processes in tidal wetlands. Among these, CO_2, CH_4 and N_2O are greenhouse gases which are rapidly increasing in the atmosphere. N_2O is not only a greenhouse gas but it destroys the ozone layer as well. The sources and sinks of the above gases are reasonably known, but the individual contribution of each source to the global emissions can only be estimated. For instance the estimates for the emission of methane from natural wetlands vary almost by an order of magnitude. The estimates can be improved by increasing the number of gas-flux measurements. The research has two objectives:

1) To estimate the annual production of the above mentioned gases.
2) To study the impact of short-term precipitation and inundation patterns on the release of CH_4, N_2O and CO_2.

In Gazi Bay a number of sites will be selected. During the expedition the release of gases will be intensively monitored to document the variation in gas fluxes due to flooding and precipitation. Gas fluxes will be estimated using chambers connected to a gas monitor. In addition soil salinity, nitrate concentration of the flooding water and organic carbon content of the soil will be determined.

7.3. Project Specifics

7.3.1. PARTICIPANTS AND CLASSIFICATION

Project management:

Prof.dr. C. Heip & Dr. M.A. Hemminga
Netherlands Institute of Ecology,
Centre for Estuarine and Coastal Ecology,
Vierstraat 28, 4401 EA Yerseke
(tel. +31-1131 1920)

Participating institutes and responsible scientists:

Centre for Estuarine and Coastal Ecology, Yerseke
- M.A. Hemminga - seagrass studies, mangrove studies
- E. Slim - mangrove studies
- Microbiologist - geochemistry, mangrove studies
- J. Kromkamp - primary production
- N. Goosen - microbiology
- V. Escaravage - zooplankton

Laboratory of Aquatic Ecology, Catholic University, Nijmegen
- G. van der Velde - coral reefs fish

Netherlands Institute for Sea Research, Den Burg, Texel
- W. Helder - marine chemistry
- P.A.W.J. de Wilde - benthic metabolism

National Museum of Natural History, Leiden, The Netherlands
- M.B. Best - stony corals (advisory participant)

Free University of Brussels, Belgium
- L. Goeyens - pelagic system
- A.F. Woitchik - mangrove and seagrass studies
- A. Melles (FAME) - coral reefs ecosystem
- Mengesha (FAME) - new production studies

Kenya Marine and Fisheries Research Institute, Mombasa, Kenya
- J. M. Kazungu - marine chemistry
- P. Gurada
- M. Osore
- J. Mutere

University of Nairobi, Kenya
- N.J. Ntiba -

Plymouth Marine Laboratory, United Kingdom
- R. Warwick - benthic system

Classification

Disciplines and subdisciplines:
- marine ecology, biology, geology and chemistry;

Areas of application:
- fisheries, coastal zone management;

7.3.2. Methods, Equipment and Facilities

The pelagic systems will be studied on each station by the following analyses and measurements:

- Vertical distribution of nutrients, chlorophyll and oxygen.
- Photosynthetic measurements using the oxygen technique on concentrated samples and the 14C technique.
- Nutrient uptake measurements using concentrated samples of nitrogen, possibly phosphorus and iron. Also 14C-methylammonium can be used as an ammonia analogue.
- Nitrogen fixation measuring acetylene reduction by gas chromatography.
- Measurement of new production by incorporation of 15N-nitrate and 15N-ammonium (planned).
- Assimilation of 14C-CO_2 and 35S-SO_4 to determine C-turnover, carbohydrate to protein ratios and net protein synthesis during the photo- and scotophase.
- Bacterial activity using 3H-thymidine incorporation.
- Grazing of bacteria by protozoa, ciliates and heterotrophic flagellates by labelling bacteria.
- Estimates of population sizes of picoplankton, bacteria, ciliates and protozoa, phytoplankton, nanoflagellates and zooplankton.
- Grazing and vertical migration by zooplankton.
- Distribution of POM and DOM.
- Sedimentation by using sediment traps.

The rate of sedimentation and deposition of organic material on the bottom will be studied by analysis of the benthic community (box core, beam trawl), metabolic activity of the benthic system (bell-jar, bottom lander) with measurements of oxygen profiles in the sediments and nutrient exchange between bottom and water. For these experiments the benthic lander and the benthic bottom profiler will be used.

The structure of the benthic communities will be studied by determining biomass, densities and species composition of meio- and macrofauna. In combination with the studies of the benthic system bottom sediment will be analysed.

In the coastal programme various techniques will be applied. The stable isotope technique will be used to assess the significance of mangrove and seagrass material in the coastal foodweb (7.2.1.1.). Collection of the samples (seston, animals and plants) will be carried out during the expedition; seston samples will be collected with the use of a continuous centrifuge. The actual isotope analysis will be carried out in The Netherlands and Belgium. For the research on seagrasses (7.2.1.2.), samples of seagrass material and of undisturbed sediments from the seagrass meadows will be taken by scuba-divers. Nutrient uptake by the leaves will be determined experimentally with the use of incubation chambers kept in a temperature-controlled water bath. N_2-fixation will be determined using the acetylene-reduction technique. Nutrients in the water samples will be stored frozen and their concentrations will be determined after the programme with an auto-analyzer on board the Tyro, or in The Netherlands.

For the study on coral reef fish (7.2.1.3.), a description will be made of the structure of the coral reefs, by means of sampling, line transects and an echosounder. Furthermore, fish will be caught by means of drop nets to investigate species composition, length distribution, densities in the various zones and migratory movements. Fish will also be counted by means of a visual census technique in permanent areas by two divers in the various zones. The fluxes of gaseous C- and N-compounds from the mangrove sediments (7.2.1.4.) will be measured by fastening polypropylene domes on the selected sites; these domes are connected to a gas-analyzer, which will continually measure the levels of the various gasous compounds in the domes. In the sediment of the sites, salinity of the interstitial water and organic carbon content will be determined.

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Note: The figures in this chapter have been redrawn after McClanahan, 1988

8 Training Programme R.V. TYRO

8.1. Introduction

The training programme within The Netherlands Indian Ocean Expedition (1992-1993) consists of four elements i.e.: pre-expedition training, on-board training during a research cruise of two months, post-expedition training and a four day regional on-training on board the Dutch research vessel Tyro.

The pre-expedition training programme is being financed by the SOZ and concerns three Kenyan junior scientists, Mr. P. Wawiye (biologist), Mr. M. Mwaluma (biologist) and Mr. K.K. Kairu (geologist). They will attend a three month training course in The Netherlands. During this course they will get acquainted with the Dutch research techniques and methodologies.

The two month on-board training will be carried out along the execution of Gazi, Sabaki and Kiunga transects off the Kenyan coast. This training will involve two of the pre-expedition trainees (Mr. Wawiye and Mr. Mwaluma) as well as two other Kenyans Mr. M.M. Nguli (oceanographer) and Mr. Abuodha (geologist). The total Kenyan participitation during the ocean going expedition will be four people.

The post-expedition training will follow as soon as possible after the completion of the 1992 research activities. This training aims at a joint analysis of the data, joint publications and will also offer post-graduate marine studies.

The details of the four day regional training on-board the RV Tyro are discussed below.

8.2. The four day training

During the June 1992 port call of the RV Tyro to Mombasa the vessel wil be made available to the Kenyan and regional scientific community for a four day training course by KMFRI. This course is being funded by the SOZ, KMFRI, SAREC and UNEP. The aim is to boost KMFRI's development towards a regional marine scientific centre. The course offers junior scientists from the East African Region the possibility to visit the RV Tyro and to participate in an on-board research training effort during three days. The programme is being developed by KMFRI and will be executed in the 4 transects off the Mombasa area (see Fig. 13.). The day-to-day programme for the training is as follows:

8.2.1. Day for public visit to the RV Tyro

The vessel will dock on June 12th, 1992 at Kilindini ready for public visit. The public will be welcomed aboard by the scientists. The aim of the visit will be to educate the public on research operations at sea and the economic value of such work. Specifically the scientists will brief the public on:

1. Goals aims and objectives of such an expedition.
2. Research methodologies.
3. The use of the equipment employed in research or data collection; a demonstration will be given.

(A more detailed programme will be issued a few days before the visit.)

8.2.2. Three day on-board

The training will involve 24 junior scientists (see list). Most of them will come from Kenyan institutions and at least 4 from Mozambique, Tanzania and the Seychelles.

8.3. The Cruise

RV Tyro

The practical training will consist of a cruise on coastal waters off Mombasa Island (Mombasa offshore area). A series of oceanographic stations will be occupied along four transects taken perpendicular to the coast (see Fig. 13.). The actual cruise track will consist of 2 legs. Leg 1 will cover the two transects north of the Mombasa entrance and leg 2 those to the south of it. Each leg will take 1 days.

8.4. The shuttle

RV Maumba

Since the Tyro can only take 12 participants at a time, the RV Maumba (KMFRI) will be used to shuttle the participants to and from the Tyro. The Tyro will anchor near the Mombasa Harbour and the RV Maumba will ferry the other 12 participants to join the RV Tyro for leg 2 and bring ashore the 12 participants of leg 1. After completion of leg 2, the RV Tyro will disembark the 12 participants at Kilindini and pick up the 5 Kenyan participants before sailing for the offshore cruise.

During the 3 days the junior scientists will be trained on:

1. Specific techniques or methodologies
2. Sampling
3. Operating equipment (e.g. CTD)
4. Labelling and preserving samples
5. Data recording
6. Partial data analysis while on board

The following aspects will be considered during the research training program:

Physical Oceanography
- Water masses (salinity, temperature and density)
- Dissolved oxygen
- Thermocline identification
- Computation of currents
- Windstress
- Correlation of windstress and surface

Chemical Oceanography
- Distribution of Nutrients (phosphate, cilicate, nitrate and ammonia).

Biological Oceanography
- Biomass.
- Plankton distribution (zooplankton) and phytoplankton.

Geological Oceanography
- Bottom sediment distribution.
- Bottom morphology (by echo sounding).
- Sediment analysis techniques

8.5. Output from the training

Specimens and data
Some of the information obtained from the training is to be processed aboard the Tyro. A copy of the data will be given to KMFRI. Specimens that are not analysed on board will be taken back to KMFRI laboratories for further analysis. A data report will be compiled following the training exercise and copies sent to the participants. A mini-workshop will be organised at least 8 months after the training to report and discuss the results.

It is expected that the scientists will attempt to answer simple questions such as what is the salinity and temperature structure off Mombasa like during the training period? How does it compare with data collected in previous work? What is the chemical structure of these waters? And what is the distribution pattern of plankton? Are these structures/ patterns/changes influenced in anyway by the tidal outflow of the Tudor and Kilindini harbours (or inlets).

8.6. Four day training participants

8.6.1. Leg 1

1st group

1.	Mr. M. Odido	(Physical oceanography)
2.	Mr. B. Ohowa	(Chemical oceanography)
3.	Mrs. H. Oyieke	(Macro algae)
4.	Mr. Mwangi	(Macro biology)
5.	Mrs. Owili	(Micro biologist)
6.	Mr. Manyala	(Fisheries)
7.	Mr Ojuok	(Fisheries)
8.	Mr. Odero	(Fisheries)
9.	Mr. Getabu	(Fisheries)
10.	Mr. Oberth Mwaipopo, Tanzania	
11.	Mr. Maurice Mgendi, Tanzania	
12.	Scientist from Mozambique	

8.6.2. Leg 2

2nd group

1	Mr. Wakwabi	(Fisheries)
2.	Mr. Mwachireya	(Fisheries)
3.	Mr. S. Omolo	(Ecophysiology)
4.	Miss J. Mutere	(Coral reefs)
5	Miss D. Anyona	(Zoologist)
6.	Mr. A. Yobe	(Pollution studies)
7.	Mr. Kazungu K.M.	(Nutrients)
8	Mr Kamau	(Technology)
9.	Mr. P. Gitui	
10.	Mr. B. Kaunda	
11	Mr. Joel Souyave, Seychelles	
12.	Scientist from Moi University	

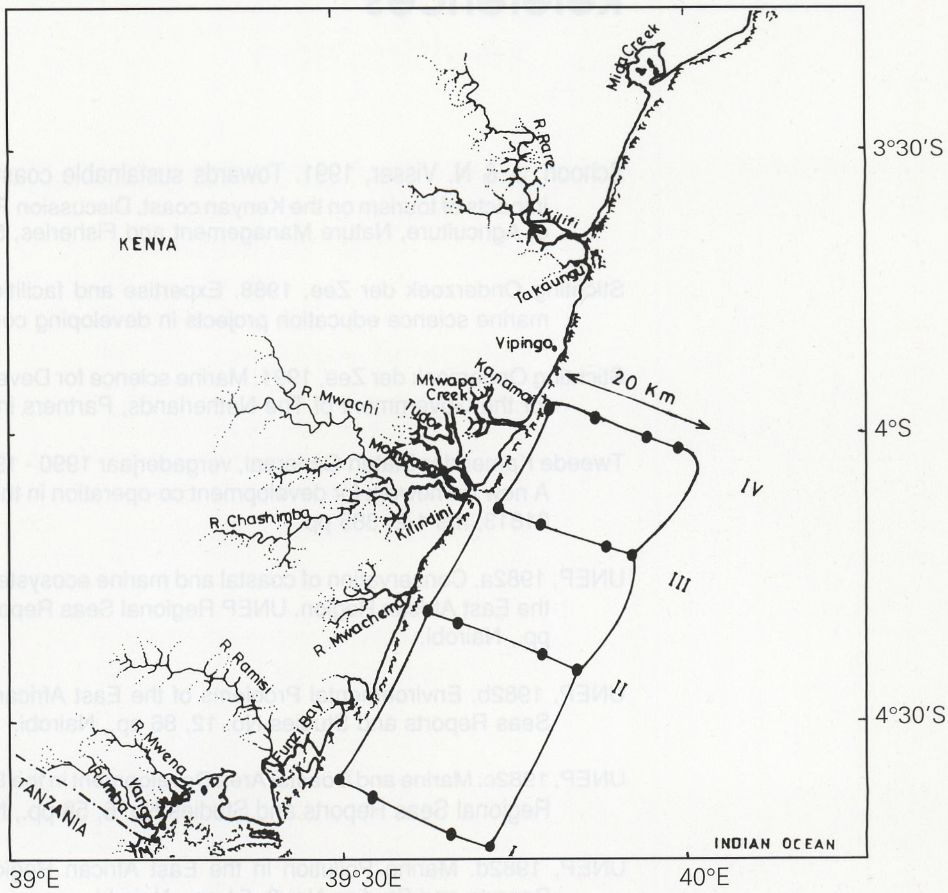

Fig. 13. Proposed cruise track for 'Tyro' in June 1992 during 4 day training showing Oceanographic transects and stations.

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ANNEX 1. Members of the organizing committees

The Netherlands Indian Ocean Committee
* Dr. J. van der Land (chairman)
* Dr. J.H. Stel (secretary)
* Mr. E. van Abs
* Dr. M.A. Baars
* Mr C.N. van Bergen Henegouw
* Prof. dr. C. Heip
* Dr. M.A. Hemminga
* Dr. S.R. Troelstra
* Dr. T.C.E. van Weering
* Prof. dr. Ch. van der Weijden

The Netherlands-Kenya Committee
* Prof. dr. C. Heip (chairman)
* Dr. J.H. Stel
* Dr. M.A. Hemminga

Kenya-The Netherlands Committee
* Dr. E. Okemwa (chairman)
* Dr. M. Ntiba
* Mr. R. Nzioka
* Mrs. H. Oyieke

Joint Management Committee
* Prof. dr. C Heip
* Dr. J.H. Stel
* Dr. E. Okemwa
* Mrs. H. Oyieke
* Prof. dr. P. Polk (advisor)

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ANNEX 1. Members of the organizing committees

The Netherlands Indian Ocean Committee
* Dr. J. van der Land (chairman)
* Dr. J.H. Stel (secretary)
* Mr. E. van Abs
* Dr. M.A. Baars
* Mr C.N. van Bergen Henegouw
* Prof. dr. C. Heip
* Dr. M.A. Hemminga
* Dr. S.R. Troelstra
* Dr. Tj.C.E. van Weering
* Prof. dr. Ch. van der Weijden

The Netherlands-Kenya Committee
* Prof. dr. C. Heip (chairman)
* Dr. J.H. Stel
* Dr. M.A. Hemminga

Kenya-The Netherlands Committee
* Dr. E. Okemwa (chairman)
* Dr. M. Ntiba
* Mr. R. Nzieko
* Mrs. H. Oyieke

Joint Management Committee
* Prof. dr. C Heip
* Dr. J.H. Stel
* Dr. E. Okemwa
* Mrs. H. Oyieke
* Prof. dr. P. Polk (advisor)

ANNEX 2. List of involved Kenyan and Dutch authorities

- Netherlands Marine Research Foundation
- Netherlands Institute of Ecology, Centre for Estuarine and Coastal Ecology, Yerseke, The Netherlands
- Netherlands Institute for Sea Research, Texel, The Netherlands
- Catholic University of Nijmegen, The Netherlands
- State University of Groningen, The Netherlands
- Free University of Amsterdam, The Netherlands
- State Museum of Natural History, Leiden, The Netherlands
- Free University of Brussels, Belgium
- State University of Ghent, Belgium
- Kenya Marine and Fisheries Research Institute, Mombasa, Kenya
- Government Chemist's Laboratories, Mombasa, Kenya
- The University of Nairobi, Kenya
- Plymouth Marine Laboratory, United Kingdom

ANNEX 3. List of abbreviations

BOD	Biological Oxygen Demand
CECE	Centre for Estuarine and Coastal Ecology, The Netherlands
CTD	Conductivity Temperature Depth
DOC	Dissolved Organic Carbon
IGBP	International Geosphere Biosphere Programme
IOC	Intergovernmental Oceanographic Commission
IOP	Indian Ocean Programme
JGOFS	Joint Global Ocean Flux Study
KMFRI	Kenya Marine and Fisheries Research Institute
KNAW	Royal Netherlands Academy of Sciences and Arts, The Netherlands
KUN	Catholic University of Nijmegen, The Netherlands
LOICZ	Land - Ocean Interactions in the Coastal Zone
MAB	Man and Biosphere
NIO	Netherlands Institute of Ecology, The Netherlands
NIOZ	Netherlands Institute for Sea Research, The Netherlands
NWO	Netherlands Organisation for the Advancement of scientific research
RUG	State University of Groningen, The Netherlands
SAREC	Swedish Agency for Research Co-operation with developing countries
SEM	Scanning Electron Microscope
SOZ	Netherlands Marine Research Foundation
TOGA	Tropical Oceans Global Atmosphere (WCRP)
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UoN	University of Nairobi
VU	Free University of Amsterdam, The Netherlands
VUB	Free University of Brussels, Belgium
WCRP	World Climate Research Programme
WOCE	World Ocean Circulation Experiment

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