Unesco reports
in marine science 66

Coastal systems and sustainable development in Africa

Proceedings of a UNESCO Regional Seminar on Human Impacts on Coastal Ecosystems, their Response and Management Problems
ROSTA, Nairobi, 5-9 April 1993

comar

IUGS
UNESCO
IGCP

UNESCO 1995

ISSN 0253-0112

Published in 1995
by the United Nations Educational,
Scientific and Cultural Organization,
7, place de Fontenoy, 75352 Paris 07 SP
Printed in UNESCO's workshops.

PREFACE

UNESCO Reports in Marine Science are designed to serve specific programme needs and to report on developments in projects conducted in the context of UNESCO's marine science-related activities.

Designed to serve as a complement to the *UNESCO Technical Papers in Marine Science*, the systematic distribution of *Reports* **is restricted to libraries** of oceanographic institutions and governmental authorities, and documentation centres. Individual requests from specialists will, however, be examined by the Marine Information Centre and dealt with on a selective basis.

Requests for specific titles or additions to the mailing list should be addressed to:

Marine Information Centre
UNESCO
1 rue Miollis
75732 Paris Cedex 15
France

Abstract

The UNESCO Regional Office for Science and Technology in Africa (ROSTA) has compiled, within this issue of UNESCO Reports in Marine Science, various scientific papers presented during the Regional Seminar on Human Impacts on Coastal Systems, their Response and Management Problems, held at ROSTA (United Nations Office, Gigiri, Nairobi, Kenya) from 5 to 9 April 1993.

The objectives of the Seminar, convened within one year of UNCED's adjournment, were inter alia: to bring together a selected group of scientists to exchange ideas and to discuss their achievements, problems and future strategies; to recommend measures aimed at mitigating adverse human impacts in order to improve the balanced co-existence of coastal populations and marine ecosystems; to contribute to the further promotion of marine science and management of the coastal zone in the region by the publication of the Seminar's proceedings, as well as to give added impetus to the objectives and relevant conclusions of UNCED.

Résumé

Le Bureau régional de science et de technologie de l'UNESCO en Afrique (ROSTA) présente, dans ce numéro des Rapports de l'UNESCO sur les sciences de la mer une compilation de certaines communications faites pendant le séminaire régional sur les "Répercussions des activités humaines sur les systèmes côtiers, la réaction des systèmes et les problèmes de gestion correspondants". Le séminaire s'est tenu, du 5 au 9 avril 1993, au ROSTA (Bureau des Nations unies, Gigiri, Nairobi, Kenya).

Un an après l'ajournement de la CNUED, le séminaire avait pour principaux objectifs de réunir des scientifiques pour qu'ils échangent des idées, exposent leurs résultats, leurs problèmes et leurs stratégies futures; qu'ils proposent des mesures propres à réduire les effets indésirables des activités humaines, de façon à rétablir un équilibre acceptable entre populations côtières et écosystèmes marins; qu'ils contribuent au progrès des connaissances en sciences de la mer et à la gestion de la zone côtière africaine par la publication des actes du séminaire; et qu'ils favorisent ainsi la réalisation des objectifs et les conclusions de la CNUED.

Resumen

La Oficina Regional de Ciencia y Tecnología para Africa (ROSTA) ha compilado en este número de Informes de la UNESCO en Ciencias del Mar, varios de los trabajos científicos presentados durante el Seminario Regional sobre Impactos Humanos en los Sistemas Costeros, su Respuesta y Problemas de Gestión, que tuvo lugar en ROSTA (Oficina de las Naciones Unidas, Gigiri, Nairobi, Kenya) del 5 al 9 de abril de 1993.

Los objetivos del Seminario, convocado en menos de un año de la clausura de la CNUMAD, fueron inter alia: reunir un selecto grupo de científicos para intercambiar ideas y discutir sus logros, problemas y estrategias futuras; recomendar medidas destinadas a mitigar los impactos humanos adversos, a fin de mejorar la co-existencia racional entre las poblaciones costeras y los sistemas marinos; contribuir a aumentar la promoción de las ciencias del mar y de la gestión del área costera en la región por medio de la publicación de los resultados del Seminario, así como dar nuevo ímpetu a los objetivos y conclusiones relevantes de la CNUMAD.

Резюме

Региональный оффис ЮНЕСКО по науке и технике в Африке (РОСТА) собрал в данном сборнике Отчетов ЮНЕСКО по морским наукам различные научные статьи, заслушанные в ходе Регионального семинара по вопросам воздействия человека на береговые системы, их реакцию на эти воздействия и проблемы управления. Семинар был проведен в РОСТА (оффис ООН, Гигири, Найроби, Кения) 5–9 апреля 1993 г.

Задачи семинара, который был проведен менее чем через год после конференции ЮНСЕД, сводились, в частности, к следующему: собрать вместе группу ученых, с тем чтобы они обменялись мнеииями и обсудили имеющиеся достижения, проблемы и будущую стратегию; рекомендовать меры по уменьшению отрицательного влияиия человека, с тем чтобы улучшить баланс в сосуществовании народонаселения в береговой зоне и прибрежных экосистем; внести вклад в дальнейшее развитие морских наук и управления береговыми зонами региона путем публикации данного сборника статей; а также чтобы внести дополнительный вклад в достижение целей и выполнеиие соответствующих решений ЮНСЕД.

مستخلص

تولى مكتب اليونسكو الاقليمي للعلوم والتكنولوجيا في افريقيا (روستا) بتجميع أوراق علمية مختلفة، في هذا العدد من تقارير اليونسكو في علوم البحار، وقد قدمت هذه الأوراق العلمية خلال الندوة الاقليمية عن تأثير النشاطات البشرية على النظم الساحلية ومدى استجابتها لها وعن المشاكل الادارية. عقدت الندوة في مقر روستا (مكتب الأمم المتحدة - جيجيري - نيروبي - كينيا) خلال المدة من 5 الى 9 ابريل 1993.

كان من أهداف الندوة التي عقدت بعد مرور سنة على مؤتمر الأمم المتحدة للبيئة والتنمية UNCED : التقاء مجموعة مختارة من العلماء ليتبادلوا الأفكار وليناقشوا انجازاتهم ومشاكلهم واستراتيجية المستقبل وليوصوا بما يجب اتخاذه من معايير تهدف الى الحد من التأثيرات السلبية للنشاطات البشرية، ولتحسين التعايش المتوازن للسكان الساحليين وادارة المنطقة الساحلية وذلك من خلال نشر وقائع الندوة وكذلك اعطاء دفعة اضافية لأهداف ونتائج مؤتمر الأمم المتحدة للبيئة والتنمية.

文　摘

在本期《海洋科学报告》中，教科文组织非洲地区科技办事处（ROSTA）对一九九三年四月五日至九日在ROSTA（即位于肯尼亚内罗毕几几里的联合国办公室）召开的“人类对海岸系统的影响地区研讨会”上所做的各种科学讲演进行了汇编.

此次研讨会是在联合国环境与发展大会之后的一年内召开的. 其主要目的是: 召集一个精选的科学家小组，以交流看法并讨论所取得的成就、问题和未来战略; 就如何减轻人类的不良影响从而改善海岸地区人口与海洋生态之间的和谐共处提出措施建议; 通过研讨会论文集的出版为进一步促进该地区海洋科学的发展和海岸带管理做出贡献，并为推动联合国环发大会的宗旨及有关结果的实施进一步注入活力.

Table of contents

Foreword

The UNESCO Regional Office for Science and Technology in Africa (ROSTA) has compiled, within this special issue of UNESCO Reports in Marine Sciences, various scientific papers presented during their Regional Seminar on Human Impacts on Coastal Systems, their Response and Management Problems, held at ROSTA (United Nations Office, Gigiri, Nairobi, Kenya), from 5-9 April 1993.

Coastal areas are the site of complex natural systems where intense interactions occur between land, sea and atmosphere. They comprise a variety of highly productive ecosystems that differ in nature, magnitude and importance from one another, and from one coastline to the other. Yet these ecosystems are extremely vulnerable, particularly to increasing human activities in the coastal zone. In this context, and in part to meet the objectives of the United Nations Conference on Science and Technology for Development (1979), UNESCO formally launched, in 1986, the "UNESCO Manor Interregional Project on Research and Training leading to the Integrated Management of Coastal Systems (COMAR)" which has regional components on all continents, including Africa, and whose activities are closely co-ordinated with those of other relevant UNESCO programmes, such as the programmes of the Intergovernmental Oceanographic Commission (IOC), the Man and Biosphere Programme (MAB), the International Hydrological Programme (IHP) and the International Geological Correlation Programme (IGCP), as well as with those of other relevant UN Agencies.

During recent years, a number of scientists in the African region have been encouraged, under UNESCO's and other UN Agencies' sponsorship, to conduct research on various marine coastal ecosystems with a view to providing the scientific basis for their proper conservation and management. Between 1988-92, fifteen coastal States of the region actively participated in the African component of COMAR, the UNESCO/UNDP Regional Project (RAF/87/038) for Research and Training on Coastal Marine Systems in Africa (COMARAF). Most of these have also participated in relevant activities of the IOC within the framework of the IOC Regional Committees for the Central Western Indian Ocean (IOCINCWIO), and for the Central Eastern Atlantic (IOCEA), as well as of UNEP, such as the Action Plans for the protection and development of the marine environment and coastal areas of the West and Central African Region (WACAF); and of the East African Region (EAF); while the island states are equally participating in Project 7 of MAB – Ecology and rational use of island ecosystems. Furthermore, issues raised at the recently concluded United Nations Conference on the Environment and Development (UNCED, Brazil, 1-21 June 1992) are also being addressed.

Therefore the objectives of the Seminar, called within one year of UNCED's adjournment were inter alia to bring together a selection of scientists to exchange ideas and to discuss their achievements, problems and future strategies; to recommend measures aimed at mitigating adverse human impacts in order to improve the balanced co-existence of coastal populations and marine ecosystems; to contribute to the further promotion of marine science and management of the coastal zone in the region by the publication of its proceedings, as well as to give added impetus to the objectives and relevant conclusions of UNCED.

Overview on human impacts on coastal ecosystems

SAHA Ruby V.L.
Planning Division
Ministry of Housing, Lands and Town & Country Planning
Edith Cavell Street, Port Louis
Mauritius

Abstract

The paper highlights the interdependency between the terrestrial and marine environment and gives examples of major impacts of human activities upon the marine environment, drawn mainly from the Eastern African experience. It is likely that these impacts are going to be further intensified in the near future, with trends in population pressure and corresponding resource needs. The author spells out some of the major issues which include the high vulnerability of tropical marine environments; their economic and critical ecological roles, the low level of awareness of the interdependency between marine and terrestrial sectors; the almost non-existent level of environmental impact assessment on terrestrial activities affecting the marine environment. Recommendations relate to the need for greater staff capabilities which would lead to more effective stewardship of the environment, closer policy/science linkages, greater public awareness. An integrated management approach is called for at a national level and the collaboration and support of the international community needs to be strengthened.

Introduction

It is a great pleasure and privilege for me to have been requested by Unesco-Rosta to make an overview presentation on the issue of human impacts on coastal ecosystems. Please note that I have not been trained in the marine sciences. I am, by training, a land use planner, the bulk of my experience having been in terrestrial issues, the *dryside* as opposed to the *wetside*, including national physical development planning, a level of planning which involves the formulation of policies at the territorial level of a and therefore greatly influences locational decisions of those terrestrial activities which may have a major impact on critical coastal habitats.

My interest in coastal issues was triggerred off in 1989, when I became part of a multi-sectoral regional Team set up by UNEP, which reviewed the likely socio-economic implications of climate changes upon the Eastern African Territory and when I had to communicate *meaningfully* for the first time, in numerous meetings, with various marine scientists from both the region and from the OCA-PAC Division of UNEP, just across the way from our Conference Room today.

Furthermore, in 1991 I led a coastal Zone Management Mission comprising a fisheries expert and a Professor of Oceanography into seven of the coastal countries of Eastern Africa and, during the process of project formulation, had the opportunity of meeting representatives of various multi-sectoral (including fishery) institutions in Kenya, Tanzania, Mozambique, the Seychelles, Mauritius, Comores and La Reunion, to discuss coastal Zone Management issues. It has been confirmed through my field experience in Eastern Africa, that **the institutional linkages between the terrestrial and marine sectors of their economies in decision making are weak.** I have, unfortunately, no knowledge or experience of either Central or Western Africa, but I am convinced that the same institutional constraints of **compartmentalised and line** thinking, inherited from past colonial regimes, would also persist there, perpetuating the scission in real communication that exists between the two areas and that, unless checked, is likely to maintain a constant threat to the longterm sustainability of our coastal ecosystems which are in the main highly vulnerable.

The other major issue which is relevant here is the limited perception at the policy level of the longterm threats to the sustainability of coastal ecosystems by terrestrial activities. The coastal waters are often readily and openly used as a sink. What is not readily visible to the naked eye does not have an impact and furthermore there is a dearth of baseline data and monitoring in respect of the coastal environment.

This limited perception can be traced back not only to decisions made at country level, but also to those with international collaboration, it being a well known fact that institutions such as the World Bank who have funded heavy infrastructure projects in the region have only begun to incorporate environmental concerns into their thinking since the late 1980's.

Furthermore, although higher learning and research institutions have now been established in our countries, the fact that the marine sciences initially received low priorityhas subsequently created cumulative setbacks in terms of relative numbers. Therefore *the relative impact in comparison with other sectors* that can be made upon locational decisions of terrestrial activities is relatively small. **The linkages between marine science and policy makers have been limited**. I also quote Bryceson (1990):

> *"Even within the recently started marine science centres, emphasis has been given to aspects other than pollution....Scientific personnel capable of conducting marine pollution research and monitoring are yet to be trained in adequate numbers and to sufficient levels. Measuring instruments and analytical equipment are in meagre supply, and air-conditioned laboratories where such equipment should be maintained are few...."*

Since environmental management is an art that prospers in direct proportion to the scientific knowledge on which it is based, **national planning policy has been relatively little influenced by marine policy as opposed to other sectoral policies.** The aggressivity from the marine side occurs as a single sector issue in its own right, for example in terms of fishing or other policies concerned specifically with the *wetside*. **It is, however, missing as an input into decisions located on the *dryland*, as the impact of such decisions is not perceived as influencing the longterm sustainability of coastal or other marine resources and the marine voice is often not aggressive enough.**

We also note that Fisheries Ministries do not often exist in their own right, but often as part of larger Ministries where the Fisheries issue may be relatively submerged under other important, ***perhaps conflictual,*** policy issues of its own Ministry. The sharp boundaries between Ministerial and legislative authority and marine and terrestrial areas also make the task of co-ordination even more complex.

The support for environmental stewardship of coastal areas would also not be forthcoming from many **local communities** due to of poverty issues. Unless people can have time off from survival issues, they cannot be expected to care and fight for the environment. *In Africa, sustainable development involves much more than just the environment alone.* Furthermore, the communities have insufficient awareness of the complexities of the various interrelationships.

Yet events which have been taking place in all coastal areas around the world and no less in this region, such as the serious environmental degradation brought about by the polarisation effects of the coast and the continued use of coastal waters for ***sink functions***, dictate otherwise and this is the subject of my talk today.

The modification of terrestrial areas on the coast and upstream has a high potential for adverse effects on coastal ecosystems and **the linkages are such that it is not possible to have effective management of coastal resources without a concurrent management of land habitats, *with the specific objective of coastal management stewardship in mind.***

To begin, let us look at the specificity of the geographical area we are referring to.

The coastal zone: specificities

Coastal zones constitute some of the world's most productive areas. The offshore sectors provide valuable marine resources including high protein food while the onshore sectors feature amongst the most sought after for areas in terms of residential settlement and trade as well as other business opportunities.

The definition of the *coastal zone* can be as elusive as that of *sustainable development*. There can be several hundred definitions. In the context of this seminar, which highlights the impact of human settlements, the boundaries would need to be tailored to capture major coastal zone management issues.

In some areas, depending on geographical features, the inland boundary could be quite narrow. In others, it could reach extensively inland. Generally, however, such a boundary would include, *"all coastal areas that are subject to storm flooding by the sea; all intertidal areas of mangrove, marsh, deltas, salt flats, tideflats and beaches; all permanent shallow coastal water areas such as bays, lagoons, estuaries, deltaic waterways and nearcoast waters that include seagrass meadows, coral reefs, shellfish beds, submerged bars; the nearshore coastal waters and all small coastal islands"* Clark (1990).

To focus more specifically on our region, we note that tropical marine environments are characterised by high species diversity which are less tolerant of changes in their surroundings. *"The sum effect of their characteristics generally result in tropical organisms and communities being more susceptible to disturbances or pollution than their corresponding counterparts in temperate seas (Sanders, 1968; Johannes & Betzer, 1975)"* (Bryceson, 1990).

Within the Eastern African region, Bryceson conveniently divides the inshore marine environments into separate biotopes: coral reefs, rocky intertidal platforms, cliffs, sandy beach slopes, sandy/muddy tidal flats, seagrass beds, mangroves, estuaries/deltas, each of which is inhabited by its own characteristic fauna and flora with their own susceptibility to particular forms of environmental degradation. However, critical habitat types concurrently exist as components of larger coastal systems and **they perform vital economic as well as critical ecological roles,** both singly and as part of the overall larger ecosystem.

The shallow tropical coastal areas have traditionally supported very productive ecosystems from which aquatic resources are harvested. These systems support multiple valuable services in addition to their natural defence functions against coastal erosion.

Examples of specific multiple functions include **the coral reef** which gives shelter, protection, food and anchorage to a variety of living organisms. The reef itself becomes a protective barrier against the force of wave action and protects the coastal area from erosion, while the lagoon that it protects provides a tranquil environment for other marine organisms. The coral species themselves and the other creatures that inhabit the reefs – fish, shellfish, anemones – are an important source of food, a major tourist attraction, and a source of scientific and cultural interest.

Mangrove swamps and forests, estuaries and mudflats are silt binding. They reclaim land from the sea in the long term and protect outer lagoons and coral reefs from sedimentation. Their wood is insect and rot proof and provides fuel and poles used in house construction as well as in the construction of boats and dhows. On top of that, they also provide a nursery ground for prawns and fish and a suitable habitat for crabs, plankton and molluscs. A food chain through plankton, larvae and fish continues with the many species of birds found in the foliage of the trees.

Another example include **the seagrasses** which are amongst the most abundant renewable resources of the region. Lagoons and creeks are characterised by vast meadows of seagrasses and they provide a nursery area for fishes, crustaceans and turtles. In addition to providing anchorage, food and shelter for various marine organisms, seagrass helps to stabilize the seabed by holding down the sand at times of ocean turbulence.

The coastal areas of East Africa contain some of the world's richest ecosystems including extensive coral reefs, mangrove forests, lagoons and estuaries. They support wide biodiversity and the coastal populations derive many economic benefits from these systems. However, within the context of development pressure, poverty, food security, as well as ineffective planning, management and lack of environmental awareness that many parts of Africa faces today, the healthy survival of all these critical ecological areas cannot be but threatened.

There is a lack of understanding of coastal resources and their interaction with terrestrial processes. The level of research work carried out on the coastal zones of Africa is extremely limited on account of a shortage of research capabilities and funds. The data for planning is insufficient and relatively little monitoring is carried out. The imponderables include not only the terrestrial/marine interface, but also the interactions amongst different resource uses within the marine environment themselves.

We need also to look ahead. With Africa's growth rate running at above 3.5% and an urbanisation rate running at 5%, the pressures upon areas which are not adequately protected by law, institutions and even the community because they are unaware of the basic and intrinsic values, could become quite dramatic. We shall now review the state of human impacts upon the coastal area.

Human impact on the coastal zones

The coastal zones all over the world are the focus of much developmental activity. It has been an inevitable process since the days of exploration and the setting up of maritime links and trade throughout the world. More than half the world's population lives within 60 kms of the coastline and this figure is predicted to rise to three quarters by the year 2020.

In Africa, the coastal development process has been accentuated by the carving up of the continent by previous colonial powers into territories that favoured an export oriented economy based on agricultural products and the import of manufactured goods. Except for the landlocked countries and countries with a strong internal capital like Kenya, there is a considerable amount of focus on the coast. Many of the ports which are there are also the capital cities, the business and industrial centres, the areas for job opportunities, while the hinterland, often extending down the coasts are the source areas for additional shelter, food and fuel as well as the dumping grounds for wastes disposal. Parts of the marine area are also used as convenient dumps.

Ineffective planning and management of coastal zones, the absence of environmental impacts assessment, inadequate incorporation of environmental issues into feasibility projects, population pressure as well as economic expansion are threatening the integrity of the natural ecosystems. All over the coasts of East Africa, ther are examples of indiscriminate use of coastal resources which are leading to diminishing returns as well as the degradation of environmental quality.

We shall seek to probe into the human impact issues on the coast further.

The coastal pull and urbanisation

Stewardship of the coastal environment and its critical ecological systems has to reckon with *trends and therefore* with the coastal pull factors as well as rapid urbanisation that exist within our cegion. Factors contributing to this coastal pull would be various and include, for example, the existence of traditional ports (Mombasa) which in turn have created multiple other opportunities and in turn drawn more and more people from the rural hinterland; alternative economic opportunities based on the exploitation of the beauty of the coastline and leisure opportunity (Seychelles, Mauritius); fishing opportunities (Comores); influx of people from inland to the coast due to adverse conditions (war, drought: Mozambique).

Within Africa, this coastal pull would be compounded by the strong urbanisation process that typifies our continent which, out of all five continents, shows the most rapid rate of growth. For various reasons linked to a general geography of disparities, African cities display a phenomenal rate of urbanisation based nowadays *(on account of an already large population base)* on both migration and natural increase, and the coastal cities are no exception.

The urbanisation process itself is a heavy resource consumer and, in view of pressure and poverty as well as the absence of effective urban management, isnot very caring towards the environment. In the African context it is over exploitative and constantly extends the construction of shelter and accompanying infrastructure, both basic and social, into new areas, often with inadequate forward planning. The inability to *manage* and cope with increasing wastes stemming from rapid urbanization magnifies the problem of coastal pollution.

Land development involves substantial resource use, not only in terms of land unit area, but also in terms of the natural materials which go into the building of the shelter and the infrastructure needs, including glass production and filter bed material.

Exploitation of non-living marine resources

The exploitation of *sand* is an example of a marine resource with important ecological functions which is heavily used in the overall urbanisation process, to the detriment of environmental processes and quality.

The need for cyclone-proof housing in Mauritius, for example, has caused significant sand depletion in various areas of the island, accentuating coastal erosion and increased risks of flooding in areas where the removal of sand dunes has increased the vulnerability of the coast. Yet sand extraction is incompatible with beach conservation, essential in a tourist oriented economy. In the Kunduchi area north of Dar es Salaam, quarrying of siliceous sands behind the beach crest has caused severe coastal erosion which has been arrested only by the construction of groynes.

On the African mainland, degradation of *the mangrove areas* are a major issue. The mangroves are vulnerable to new settlement and also to over-exploitation of their resources. *Large areas of mangroves have been cleared in Kenya, Tanzania and Mozambique for the production of salt by evaporation. Destruction of expensive mangrove forests for salt production has also caused concern in Tanzania* (Bryceson, 1990). Other destructive activities affecting mangrove systems include rice cultivation, aquaculture ponds, charcoal production and removal of firewood. The selective cutting of poles for local house construction is not considered a threat if adequately controlled.

Semesi (1992) spells out that "*commercial activities can be harmful because they are done with little or no planning or control by Government management bodies and in many cases the activities are illegal... Furthermore, there is little co-ordination between the branches of Government which issue the permits. It might be possible for one Government office to issue a license to construct a saltpan in the mangroves without even consulting the forest or fisheries department as to the impact of such a project on other resources.*"

Tourism

Other economic opportunities such as tourism development or major industrial infrastructure are also over exploitative of coastal resources. coastal tourism is dependent upon the beach for its infrastructure and upon the adjoining coastal waters for its recreation.

Tourism is however in a peculiar position. Whilst it is exploitative of the natural resource of the coastline, it is also dependent upon the continued quality of that physical raw material for its own survival. Therefore the tourism sector is generally more vigilant and caring in its approach. In the absence of a strong urban management structure with appropriate enforcement and pollution control, industry has been traditionally much less concerned with environmental stewardship and its processes often feed upon the *drawing* of clean water from aquifers or surface reservoirs and the *disposal of soiled waters, often of unrevealed composition*, into disposal areas which find their way eventually to the sea. This is discussed next.

Disposal of waste waters

The disposal of urban and industrial wastes waters into the coastal waters creates perhaps the most significant loading factor that the marine environment has constantly to reckon with. The overwhelming majority of States in the Eastern African region lack basic sewage treatment facilities and discharge nutrient-rich sewage directly into the Ocean. Industrialization results in highly toxic effluents being discharged directly into bays and lagoons, later reaching the ocean.

> *"The degree of treatment of sewage is low and industrial wastes are also mainly untreated and unchecked, and therefore there is occasion for serious concern for localised instances of pollution from raw or insufficiently treated domestic sewage and from untreated toxic and deleterious wastes from industries.*

> As summarised by Unep (1982):

> *Most of the factories often discharge their wastes without treatment directly into estuaries, lagoons, bays or the sea. Some discharge their wastes into rivers which flow into coastal waters. Little attention seems to be given to the question of pollution. Moreover,*

there are no effluent guidelines or discharge criteria for industrial wastes. Hence, industries discharge their wastes carelessly into the nearest water-course.

Due to paucity of information on the capacity of the various factory plants and corresponding volume of effluents discharged, the load of industrial waste discharged into rivers, the coastal environment or the sea cannot be calculated." (Bryceson, 1990).

There are innumerable examples of severe localised problems of wastes and sewerage disposal on the coastal area of the Eastern African region: in Mombasa, a number of industries discharge their mainly untreated wastes into Tudor Creek and river, while municipal waste water is discharged into the sea off Mombasa Island; In Dar es Salaam, some 15% of the population is sewered, whilst most of the population use soak-away pits and septic tanks, which create serious problems of overflow during the rainy season. *Septic tank wastes are discharged into stormwater drainage systems, causing serious pollution problems in the outfall areas such as Msasani Bay, which has poor flushing* (Bryceson, 1990).

There are also serious cases of industrial pollution by industrial effluents, usually via streams and rivers. The Msimbazi River receives large amounts of untreated or insufficiently treated wastes from industries in addition to domestic sewage. Other industries like the Mufindi Pulp and Paper, located well inland, threaten aquatic life downstream.

On the sugar cane growing islands, areas near sugar factories are subject to smells, smoke, and effluent containing residuary liquor and hot water and the aquatic life in the vicinity is completely destroyed.

The impacts caused by effluent disposal extend much further inland than is normally anticipated. The Port Louis (Mauritius) harbour and basin was used as a case study in the UNEP/IOC Workshop on Marine Pollution Monitoring which was held in 1990 in Mauritius and it was realised that the water front was not the receiving body for just the obvious factories located in Port Louis, but also for a vast agricultural and industrial hinterland, based respectively on the use of pesticides and fertilizers and dyestuffs through 22 dyehouses connected to the Port Louis Sewerage system.

Solid wastes

In our region, solid wastes are often disposed in dump sites, with little funds available for sanitary landfills. Some of these sites are directly on the sea, but even where they are not, leakage and seepage can result in the conveyance of pollutants to waterways and eventually to the sea. Solid wastes are not considered by Bryceson (1990) to be a major source of marine pollution in the Eastern African region, but there may be further risks in the future.

Intensive exploitation

Urbanisation and the concurrent growth of population in quest of fuel and food, also gives rise to further intensification in the use of soils. In Africa, the primary use is agricultural. Destruction of forests for fuel and clearance for agriculture places additional strains on vegetation cover and soils, disrupting ecological balances.

Population pressure combined with the shortage of agricultural inputs induces malpractice which in turn leads to increased soil erosion and siltation problems. In the Malagasy Republic, up to 300 tonnes of silt per hectare are estimated to be lost annually to soil erosion.

Subsequently, the siltation process finds its way to the sea, smothering coral reefs and sullying beaches, with serious consequences for fishing and tourism. Agricultural practices making use of chemicals induce agro-chemical pollution. The deployment of pesticides and fertilizers has not been accompanied by adequate environmental awareness. Munga (1985) has made some measurements of pesticide concentrations in the Tana River, Kenya (Bryceson, 1990). Current fish decline in some countries is attributed partly to pesticide pollution. As for fertilizer runoff, it increases the supply of nutrients in lagoons and estuaries, causing algae to bloom artificially and decay, using up oxygen needed by marine organisms.

Manipulation of hydrological cycles

The construction of dams for the storage of water and for the harnessing of hydro-electric power is taking place throughout the region. They are valid projects in view of the tangible benefits which are achieved such as savings in the foreign exchange bill due to decreased importing of oil.

However, there are definite negative impacts insofar as the marine environment is concerned, relating to the total trapping of alluvial sediments which results in sediment supply impoverishment at river mouths and deltas. This induces recession of shorelines and can have an impact upon the spawning and growth cycles of marine fish and prawn species as well as upon fisheries further offshore.

Marine transport of oil and other hazardous substances

Another major hazard comes from the passage of tankers concerned with the transportation of oil along the coast. *Visual observations of offshore oil slicks are common in the East African region* (Levy *et al*, 1981). There is a lack of surveillance capacity and tankers routinely flush out their tanks in the region. Tar balls on beaches are the most visible form of oil pollution in the area.

The possibility of an oil spill from one of the huge tankers moving around the region is the biggest single environmental threat to the marine environment. A major oil spill at the mooring buoy outside Dar es Salaam totally destroyed the area of mangroves south of the harbour entrance in 1981. *Many fishes, invertebrates, algae and seagrasses were observed to be dying immediately after the spill, but the death of the mangrove tresse became apparent after three to four weeks. All the mangrove trees were completely dead after three months and there were no signs of regrowth seven years later in 1988* (Pers. obs. of Bryceson, 1990).

Oil threatens the environment in many ways. Oil slicks can poison aquatic life and smother corals. *As oil breaks down, its chemical components affect the feeding and reproduction of many organisms... Chemical dispersants, used to break down oil slicks, can create another form of pollution* (UNEP, 1989).

Huge cargoes of hazardous materials being transported long distances are a real threat to marine life and ecosystems.

Exploitation of living marine resources

Within the Eastern African region, fishing is a victim of pollution rather than a source of it; however the fact remains that utilization of marine resources takes place without concern for the interactions between different components of the marine environment.

Two major issues must be mentioned: first, industrial fishing carried out by foreign fishing fleets which have negative effects on habitats and stocks, and second, the over-exploitation of marine resources attributable to rising human population, degradation of land and shortage of land based jobs, *in short* the depletion of resources and the poverty cycle. This induces malpractice, including the widespread use of dynamite for fishing off the coral reefs which is another serious cause for concern. *The explosions smash the coral and destroy the habitat of fish and other reef-dwelling organisms. Through repeated blasting over a long period of time, extensive areas of coral reef are destroyed and the fisheries productivity of the reefs decline... The rubble of smashed coral is subject to wave erosion and is reduced to sand: noticeable increases in sand accumulations on the reefs off Dar es Salaam have been observed to smother parts of the remaining reef* (Bryceson, 1990).

A new popular area of intervention is aquaculture development. But these need to be closely monitored in the light of the harmful effects through the accumulation of food wastes at the bottom, which could lead to nutrient overloading. *Particular care should be exercised when considering the introduction of exotic species. Selective breeding for genetic characteristics suited to aquaculture may cause problems if escaped individuals breed in the wild and degrade natural genetic stocks* (Bryceson, 1990).

Issues

This overview of human impacts upon coastal ecosystems brings to light the following major issues:

- The coastal Zones constitute some of the world's most productive areas in terms of fishery and other marine living resources and other non-living resources, agricultural production, leisure opportunities as well as business and other economic opportunities. But the productivity and quality of these coastal Zones is seriously threatened by the degradation caused by human activities and rapidly increasing population growth.
- Tropical marine environments are characterised by high species diversity all of which perform vital economic and critical ecological roles.
- Many of the ecological areas are highly sensitive to change. Under normal conditions of development, such critical ecological units adapt to nature, but when the rate of change is rapid, adaptation is difficult and there can be serious environmental degradation.
- The level of funding and research devoted to the stewardship of the marine environment is despondently low.
- Activities carried out on land have a strong bearing upon the coastal environment. Depending upon relief factors, this influence can extend fairly extensively inland. So long as human populations were low, nature could keep pace and remain sustainable. Examples of *hotspots* occur all round the Eastern African region, but the development *trends* are such that these *hotspots* could become more persistent unless mitigative measures are sought to address the problems.
- Industrial activities are at a relatively low ebb within the region, but as investments expand, the industrial problems will become proportionately higher.

- Concurrent utilization of marine resources without concern for the interaction between different components of the marine environment threaten the functional integrity of natural coastal ecosystems and could mitigate againgt the long-term sustainability of coastal resources as well as the livelihood of coastal populations.
- The intricate relationship between marine and terrestrial sectors calls for the *two sides* to be managed as a single whole; however, the paradox is that not only are both sides treated as separate units, but there are no linkages at institutional level to promote the effective management of marine and estuarine resources through concurrent management of adjacent land habitats. The institutional linkages between the two sectors in decision-making are weak.
- The jurisdiction of the land habitats in the coastal region would come under local government planning authorities (in some countries, like Mauritius, a strip of coastal land fronting the sea is also state land, but it is a fairly thin strip), whilst the water area would come under the ministry responsible for fisheries.
- The Fisheries portfolio is often a smaller segment of a large ministry looking after a bigger sector, sometimes agriculture. In cases where there are conflicts, the more powerful sector may prevail.
- There is a lack of understanding of coastal resources and their interaction with terrestrial processes. The development of marine science in Africa is of relatively recent origin and their level of research and monitoring capacity is obviously limited. It has not yet quite kindled the active interest of policy makers, preoccupied with issues of immediate survival such as hunger, debt, job creation and so forth. The interest in fisheries *exists,* but as a *single sector issue*, not as an issue dependent upon concerted action within the wider economy.
- Furthermore, some may be aware of the interdependency, but may ignore it because it suits them to do so.
- The involvement of the local communities in the protection of their local areas and the rights to a continued livelihood could be of paramount importance, but the communities are, more often than not, poor and have to reckon with survival issues like population pressure, drought, and *sometimes* war. Their level of awareness of environmental relationships would also be limited.

Recommendations

It is imperative to bring remedial action to the key pressure points. It is noted that under Agenda 21, coastal States are requires to *"commit themselves to integrated management and sustainable development of coastal areas and the marine environment under their national jurisdiction".* In Rio, protection of the coastal environments to ensure sustainable use of the natural resources was at the top of the agenda for action. UNCED also highlighted the need for coastal states to develop national policies and management capabilities for integrating the development of multisectoral activities in the area. Specific recommendations could take the form of a range of synergistic actions.

Staff capabilities generally:

There is a clear need to augment staff capabilities to deal with the overall environment within the region. I repeat *with the overall environment,* because if we are to achieve multisectoral communication, there is a need for trained staff from various multidisciplinary groups that can dialogue meaningfully with one another.

Staff capabilities, marine science:

At the same time, there is a need to redress the staff capabilities in terms of marine science. The status of research on the resource base, the limitedness of systematic ecosystem monitoring and pollution investigation in the region, tied to the scarcity of staff and resources, demands that there be an ambitious training programme. To that end, the collaboration of the international community for a longterm support programme, *including the need to train more graduates in various aspects of marine science* needs to be obtained. There is a call for quantifying these needs over the long term so as to be in a position to devise the most cost effective strategy.

Marine environmental management plan:

Side by side with the augmentation of skills, the fundamental absence of linkages between science and policy can be addressed through an intensified specific programme for the marine sector, leading to the formulation of a marine environmental management plan, based on a thorough study of the resource base, and the systematic marine ecosystem monitoring and investigation of marine pollution.

Science and policy linkages:

The constraints, opportunities and vulnerabilities stemming from the findings should be presented to as wide an audience as possible including multisectoral groups, land use planners, environmental groups, local communities, and those *dependent upon the coast for their living and to policymakers.*

Public education and awareness:

Part of the strategy of this plan should be to educate the public about the need to protect the environment and the effects of their activities upon it.

Integrated management approach:

At the same time, it is imperative that Governments should recognise the need to manage the coastal environment comprehensively. Ideally, the coastal environment should be managed as a single unit, but in many countries, this may give rise to *territoriality* problems between ministries, owing to historical demarcations between the land side and the wet side.

Environmental impact assessment:

These institutional difficulties may be tackled differently. It is noted that African Governments are committed to the protection of the environment and that they are at varying stages in the process of evolving national environment policies and national environmental action plans. **The issue is whether the interaction between land and sea *or even amongst different components of the marine environment* is being taken care of.**

It is vital that the process of environmental care at the national level be consolidated with an imperative need for **environmental impact assessment** in respect of a list of ***scheduled*** activities that should be worked out jointly by a multidisciplinary team with a strong contingent of marine ecologists. The marine scientists should be heavily involved in the screening and appraisal of projects. Staff-time should be allowed for that input.

Environmentally sound planning

The region is likely to develop further, with growing economic expansion. It is important that environmental concerns are integrated into the development process and that industrial and other effluents are disposed of in an environmentally sound way. Close attention needs to be given to the appropriate siting of industries and major infrastructure. This calls for a co-ordinated approach to investment and also for spatial planning to be integrated into the national economic framework.

Legal and institutional framework:

At the same time, the legal and institutional framework for protecting the marine environment should be strengthened.

Role of the international community:

The need for support in capabilities from the international community to tackle the marine environment effectively has already been highlighted. There is also a need to strengthen the efforts of the organisations already playing a catalytic role in the area, such as UNEP (regional Seas Programme) and the International Oceanographic Commission. A significant effort is being made by these organisations in establishing networks, training, supply of equipment and so forth, but the resources available are limited when compared with the needs.

Promotion of regional co-operation:

The Protection of the coastal Environment is an area which calls for much regional co-operation in terms of enforcement and surveillance by patrol boats.

References

Bryceson, I. *et al* (1990). State of the Environment in the Eastern African regional *UNEP regional Seas Reports and Studies* No 113, UNEP.

Clark, J. (1990). Integrated Management of coastal Seas Resources, Draft Report prepared for FAO.

Semesi, A. (1992). The Mangroves of the Eastern African region, UNEP.

The World Bank, (1990). Environmental Monitoring and Development Project, Mauritius, Staff Appraisal Project.

UNEP, (1989). A coast in common – an Introduction to the Eastern African Action Plan.

Human impacts on biodiversity in African coastal ecosystems: an overview

Matens Els E.
Department of Zoology, University of Nairobi
P.O.Box 30197, Nairobi, KENYA

Abstract

The coastal ecosystems of many African countries contain some of the most biologically diverse and productive habitats but they are also the most vulnerable as well as the most abused marine zone. coastal ecosystems are not only an important source of essential products for consumptive, commercial and recreational use, but also provide ecological services that directly benefit the people. Due to the many living and commercial opportunities it offers, the coastal zone contains densely populated areas. Those areas especially are seriously threatened by human activities with consequent loss of their biodiversity. The direct mechanisms include habitat loss and fragmentation, physical alteration, over-exploitation, pollution, introduction of alien species and global climate change.

Human impacts on coastal ecosystems are widespread. Habitats are changed or lost by the urbanization, development of tourist facilities and industrial installations, land reclamation and conversion, dredging and mining activities. Land-based and upstream activities alter sedimentation and freshwater input in downstream estuaries and coastal biotopes. Contamination from domestic and industrial sewage disposal and from agricultural runoff is also rapidly increasing and leading to eutrophication and chemical pollution. Disposal of solid wastes, especially plastics, not only causes a litter problem but also widespread mortality in marine species. Some types of exploitation of living marine resources may damage habitats and alter food webs, while mariculture generates its own pollution and may upset ecological balances by the introduction of alien species.

Human activities have dramatically increased the intensity, pace and types of environmental changes with an impact upon the coastal habitats and the resources they sustain. These changes may lead to the drastic decline of coastal fisheries and loss of biodiversity. The main root cause which drives these human activities lies in the high rate of human population growth, economic policies that fail to value the ecological services of the environment and its resources, insufficient scientific knowledge, and weakness in institutional and legal systems.

Introduction

Biodiversity is the term used to describe the total variety of living organisms at different levels: genetic, species, ecosystem diversity, which are closely interrelated in a complex way. Most species can only survive if the genetic diversity within their population is maintained at a sufficient level so that their capacity for adaptation to environmental changes is not impaired. Genetic diversity can only be maintained if the population of a species is kept above a minimum critical size. Species diversity is dependent upon the maintenance of ecosystem diversity, while survival of an ecosystem may rely upon the presence of particular species.

The coastal waters of many African countries have some of the world's most diverse ecosystems characterized by coral reefs, seagrass meadows, mangrove forests, estuaries and floodplain swamps. These coastal ecosystems also have a high diversity in functions benefitting the people (Dugan, 1990; IUCN, 1990; Martens, 1992). They have a role in maintaining essential ecological processes and life support systems such as the protection of coastlines, soil regeneration, nutrient recycling, water purification. Because of the economic benefits that can be derived from them, the coastal zones teem with human settlements. And with no doubt, the greatest risk factor for marine ecosystems is being close to high concentrations of humans.

The rapid increase in human population and the intense activities to meet its economic needs and growing aspirations have placed an immense pressure on the natural resources, and have led to misuse or abuse of available resources. Human activities have dramatically increased the intensity, pace and kinds of environmental change, posing severe adaptive challenges to marine organisms. Anthropogenic destruction of resources, fragmentation and change of habitats, release of pollutants, introduction of species and climate change, are now more rapid, intensive and widespread than natural changes.

The coastal zones of most African nations are subjected to increasing pressures due to urbanization, industrialization, fishing, coastal aquaculture, mining, waste disposal, oil drilling, shipping traffic and tourism (Jaccarini & Martens, 1992; Martens, 1993; Martens, in press; Saenger *et al*, 1983; Salvat, 1987; UNEP, 1982 a,b; UNEP, 1984a,b; UNESCO, 1979; UNESCO, 1986). This mix of water-based and land-based economic activities has put considerable stress on the coastal resources which are the very basis of the viability of these activities. The fast pace of technological development and economic activities has generally not allowed for the evolution of appropriate attitudes and structures to minimize resource exploitations that pose a threat to marine biodiversity. Also, the scientific and socio-economic information necessary for proper resources management has remained patchy and inadequate so that competing human uses have often remained unrelated and unplanned. It is also a fact that the main part of the population subsisting on coastal systems are rural poor communities who's livelihoods are linked to the sustainability of coastal resources. Any change will therefore affect them first.

The scenic beauty of these coastlines as well as their wildlife attract many people worldwide. Tourism generates important foreign-exchange income and job opportunities but also creates high additional pressures.

A sustainable use of coastal resources can only be induced by integrated coastal management that recognizes the interdependency and linkage between terrestrial, coastal and marine systems, and which ensures the protection of some natural areas.

Biodiversity in marine ecosystems

Although fewer marine than land species have been described, marine ecosystems are far more diverse than terrestrial ones. Of the 33 extant animal phyla, only 11 occur on land while are found in the seas. Fifteen of them are exclusively marine and another 5 make up more than 95% of the species marine. The coastal and marine biotopes host nearly the entire extant diversity of basic animal body plans, and also contain far greater diversity in body size, from whales to picoplankton, than is found on land. Further, it has been shown that filter feeders create extra levels in aquatic food chains that tend to be more complex than terrestrial ones (Margulis & Schwartz, 1988; WRI/IUCN/UNEP, 1992).

Marine biodiversity is for most groups considerably higher in tropical regions than in co-oler waters, while within the tropics many taxa reach highest species diversity in the Indo-West Pacific. In contrast to the open ocean, the coastal strip including the intertidal area and the immediately adjacent land, is the most vulnerable as well as the most abused marine zone. Measures of changes in biodiversity, either by a shift in the species abundance distribution or an increase in dominance, are often used as indicators of the health condition of ecosystems and of the need for conservation actions. Several aspects of marine systems however complicate the task of conservation: **(1)** coastal waters and their organisms have no boundaries, **(2)** coastal ecosystems are at the receiving end of drainage from land, and most wastes eventually concentrate there, **(3)** reproduction of marine organisms can be very uneven in space and time, **(4)** some species require more than one habitat during development and are threatened by activities in any one of those.

Although a relationship between human population increase and environmental change has long been recognized, attempts have been made only recently to assess the cumulative impacts of development in the coastal zone by recording their physical, chemical and biological consequences. Damages that would be readily observed on land, were seldom noticed: wastes simply seem to disappear. Also, there is no tradition of managing marine areas for conservation as exists on land, and the pollution of coastal systems may often originate in the open seas outside the jurisdiction of states.

However, preserving genetic diversity is a matter of both ethics and economical survival. Genetic diversity is needed to sustain and improve agricultural and fisheries production, to keep future options open, to guard against harmful environmental change, and to secure the raw material for scientific and industrial innovation (Salm & Clark, 1984).

Threats to marine biodiversity

The ways that humans threaten marine biodiversity can be grouped into proximate threats that are driven, in turn, by root causes such as the increasing population, its preferential settlement in the coastal zone and the resulting industrialization. However, concerns may differ from region to region, reflecting local situations and priorities.

Proximate threats

The main types of human activities that damage marine organisms and ecosystems are: **(1)** over-exploitation, **(2)** physical alterations and habitat loss, **(3)** pollution, **(4)** introduction of alien species and **(5)** global climate change.

(a) Over-exploitation

Coastal ecosystems are an important source of essential products for mankind, such as foods, medicines, raw materials and recreational facilities (Martens, 1992; Saenger *et al*, 1983; UNEP, 1985). The ever growing exploitation of the coast and its resources is a reflection of the steady population increase, the most important root cause for biodiversity loss, especially in coastal areas.

Tourist populations, generally concentrated in few areas, enhance this local exploitation tremendously, particularly for such specific species as oysters, lobsters, crabs, prawns.

In theory, virtually any marine organism, even the slowest maturing or least fecund species, could be exploited sustainably as long as the population is left above the critical size, which varies depending on the species. However, today's exploiters are far more numerous and their technologies more powerful. The global catch of marine fishes, crustaceans and mollusks in 1989 totalled about 86 million metric tons. Because of population growth, another 19 million mts may be needed within this decade.

Current fishing activities exceed sustainable yields on a large number of traditional fishing grounds, especially in coastal areas and on continental shelves. Most commercially valuable marine populations are now over-exploited, while many other aquatic species are under pressure because of incidental exploitation as bycatch. As most fishing methods are unselective, large numbers of invertebrates, fishes, sea turtles and marine mammals are captured along with target species, and then discarded. Industrial fishing technologies especially, such as gillnetting and bottom trawling, have generated widespread concern over the effects on biodiversity of overfishing, unselectivity and bycatch. For most fisheries however, data on incidental catch and its effects are very limited (Sanders *et al*, 1990).

Other unselective techniques are dynamite fishing and poisoning to take coral reef fishes. Dynamite fishing is widely used throughout the tropics despite being illegal in most areas. The explosions kill everything near to the blast, including corals and thus destroy also the habitats. Fish collecting for the aquarium trade often involves poisoning reefs with sodium cyanide, rotenone or bleach, having an effect on corals and other invertebrates (Salvat, 1987).

Although living marine resources are harvested largely for food, some species are utilized for other purposes. Many marine species, including corals, sponges, mollusks, echinoderms, puffer and trigger fishes, and turtles, are collected widely for curios or jewelry. The overharvesting of shallow inshore populations particularly can have serious effects locally on these species and their habitats. Other marine products being highly exploited are stony corals for building material and mangroves for fuelwood, timber, and alternative land uses such as aquaculture and agriculture (Wells, 1988; Martens, 1992; Salm & Clark, 1984). These activities have contributed to the decline of the species and have caused structural damage of the habitats, having detrimental effects on their living communities.

Over-exploitation not only reduces specific populations and causes lower economic returns as shown by the declining catches despite higher fishing efforts, but it also causes genetic impoverishment in the exploited populations and alters the trophic relationships among species. Marine organisms are part of intricate food webs, with high species interdependence involving multiple trophic levels at several spatial and temporal scales. Removal of certain species frequently leads to losses of other species, to changes in the food web communities with shifts in key species or to impairing the functioning of ecological processes (Beddington, 1984; Martens, in press; McClanahan & Muthiga, 1988).

(b) Physical alterations and habitat loss

Because organisms are adapted to specific abiotic conditions, the conditions in each place are crucial in determining the community of species that live there. If conditions are altered, there will be corresponding changes in the composition of the biological community.

Vast areas of mangroves, estuaries, flood plains, watersheds and beaches have been cleared to make way for coastal development, industrialization, aquaculture or agriculture (UNEP, 1990). Not only does it destroy rich mangrove and estuarine fisheries, but many commercially valuable species depend on these coastal habitats as nursery grounds (Martens, 1992; Martsubroto & Naamin, 1977).

Coastal erosion is aggravated by man-made alterations to lagoon channels for port facilities, while bottom trawling is a profound disturbance to the seabed affecting benthic communities both directly and indirectly. Direct effects include damage to all species on the swept area from contact with the gear and physical alterations of the structural complexity of the habitat. Indirect effects are resuspension of sediment, nutrients and toxic chemicals. Communities dominated by benthic photosynthesizers, such as corals, algal beds and seagrass meadows, are particularly susceptible.

Upriver deforestation and careless agricultural practices and over-grazing in the catchments increase the runoff of sediments that are deposited into the sea. The addition of anthropogenic sediments, especially silts and clays, threatens coastal systems by smothering or burying marine organisms, clogging their feeding or respiratory organs, coating photosynthetic surfaces or increasing turbidity that reduces the light available for photosynthesis. After settlement, longer-term effects can follow from changes in the particle size of the substrate with consequences to the structure of the benthic fauna. Shallow coastal ecosystems that flourish in clear waters, such as seagrass beds and fringing coral reefs, are especially vulnerable to siltation. Increases in sedimentation usually decrease coral species diversity and the percentage living under coral cover, which leads to a decline in diversity and the number of fishes that the reef can sustain. Siltation also causes long-term shallowing of estuaries with a consequent reduction in the nursery grounds of many reef species.

> **eg**. The silt load of the Sabaki river (Kenya) increased from about 58,000 tons/year to 7.5-14.3 million tons/year in about 20 years time, affecting the beach and coastal ecosystems nearby (Giesen & Van der Kerkhof, 1985).

On the other hand, reduction in sediment and the nutrient supply from altered freshwater input due to the modification of river basins can also lead to important losses of downstream estuarine and coastal habitats causing a rapid decline in the populations they sustain. Estuarine ecosystems depend on constant or frequent freshwater inputs, which determines their productivity and diversity and without which they are replaced by marine communities due to salt water intrusion. Constructions of dams for irrigation, power generation and water supply projects alter the flow regimes of many rivers and the flushing characteristics in down river estuaries. Such changes reduce sediment and detritus inputs from the catchment area, limiting food resources and lowering estuarine productivity whilst blocking spawning migrations and recruitment of marine species. In West Africa alone, 114 major dam projects are underway or planned (Dugan, 1989; IUCN, 1990).

> **eg**. Before the Aswan High Dam was built the Nile River discharged about 150 million mt/year of sediment, but since the dam was completed the sediment discharge is virtual nil, and the coast adjacent the Nile is now subject to erosion. Due to salt water intrusion vast areas of mangrove swamps have been destroyed, while the total fisheries landings dropped by 80%.

Other activities causing physical alterations are coastal mining for building materials and minerals (many West African countries), mangrove clearing and destruction of fringing vegetation for agriculture and aquaculture, constructions on coastal borders, dynamiting of reefs causing serious beach erosion, dredging of inshore waters, and tourism impacts by trampling, boating and anchoring on the coral reefs.

> **eg**. The dredging of the Lagos estuary (Nigeria) and deposition in mangrove swamps caused the collapse of the oyster fishery and the erosion of beaches in Nigeria since port developments (jetties and breakwaters): 10-25 m/year, in Abidjan up to 20 m of a cleared shoreline was washed away in the course of one storm (UNEP, 1989).

(c) Pollution

A series of anthropogenic pollutants poses serious threats to estuaries and coastal waters. Uncontrolled development of the shoreline and alongside estuaries increase the pollution potential. Waste products from human activities enter the coastal zone as runoff from fertilized agricultural and silvicultural lands, from sewage effluents including domestic and industrial waste discharges, riverine transfer of pollutants from land, dredging, dumping and oil pollution by vessels at sea and atmospheric deposition.

Domestic sewage.

Human sewage (together with pathogenic organisms) and agricultural runoff (with inorganic fertilizers and pesticides being used on an increasing scale to improve agricultural outputs), which are particularly rich in nitrogen and phosphorus, form the major source of pollution in coastal waters.

In most developing countries sewage is for a large part discharged untreated or only partially treated into rivers, lagoons and coastal waters via short outfalls, most of which were installed with little attention to advance planning. Compared to the rapid urban and industrial development, coupled with extending informal communities, sewage treatment facilities that do exist are too small and serve only limited areas (GESAMP, 1990; UNEP, 1989, 1990).

Disposal of sewage into estuaries with a limited capacity to assimilate the high organic loads induce localized pollution problems and a serious increase in pollution of the coastal zone may thus be anticipated. The biological process initiated by such organic enrichment, known as **eutrophication**, can have far reaching effects: increased primary production, changes in plant species composition, dense and often toxic algal blooms, changes in the structure of benthic communities and conditions of hypoxia or anoxia with adverse effects on fish and invertebrates. The contamination of inshore waters by sewage also causes adverse effects on fisheries resources, especially of molluscs, leading to serious public health problems.

> **eg**. In one lagoon in Lagos an estimated 25-30 million liters of untreated sewage was dumped in 1974 which caused fish kills along the Nigerian coast and contamination of mollusk cultures (*Crassostrea gasar*; *Perna perna*) (UNEP, 1989) leading to the infection of consumers with typhoid, cholera and hepatitis.

Nutrient pollution can have adverse effects even before oxygen is depleted. Coral reefs grow only in clear waters with low nutrients, and are very sensitive to nutrient additions because algal blooms cloud the water and limit the sunlight reaching the corals. Moreover, higher nutrient levels favor benthic algae at the expense of corals, thereby reducing biodiversity.

Inputs of pollutants from industrial sources.

Many industries discharge their effluents directly into the nearest water bodies, causing additional organic and inorganic pollution.

Trace metals, radionuclides and petroleum residues, become toxic environmental contaminants when discharged in excessive concentrations. Synthetic compounds are becoming ever more important chemical pollutants in the sea. Among the most persistent ones are organochlorine pesticides (PCB's, DDT) used in agriculture, dioxins from incinerators and paper mills, organotins (TBT) used as antifoulings in marine paints and oil dispersants that are toxic and cause the oil to sink onto benthic communities.

The main concern for toxic chemicals are their long-term effects as many of them are persistent in the environment and become concentrated through the trophic chain. In exposed marine organisms, toxics can cause death, disease, reduced reproductive success and developmental aberrations. Communities in contaminated ecosystems generally have reduced species diversity, as more sensitive species are affected in the first place and tolerant species, relieved of competition or predation, proliferate.

Solid wastes.

In many coastal communities household rubbish and industrial solid wastes are dumped in nearby estuaries and coastal waters or on the beaches. When dumped in mangrove creeks and estuaries there is a risk of flushing into creek and coastal waters and of leaking of organic and toxic chemicals.

The nature and volume of solid wastes vary in different countries depending on the level of industrialization and population pressure. With the increased use and subsequent disposal of plastics, solid wastes are now more than a litter problem as plastic debris cause widespread mortality in marine species through entanglement ("ghost fishing") or ingestion (Carr, 1987). Marine mammals, sea birds and turtles are among the animals at risk.

Plastic wastes are discharged into coastal waters via sewage systems and storm drains, coastal littering contributed by rivers, ships and beach users, and plastic processing facilities. Because of their strength, buoyancy and durability, they account for more than 50% of all anthropogenic debris items found at sea and on coastlines.

> **eg**. On West African beaches up to 200 g/m2 solid wastes were measured near coastal settlements (UNEP, 1989); in Mombasa (Kenya) about 50% of the 100,000 mt/year solid wastes from domestic garbage is dumped in an uncontrolled landfill of the Makupa mangrove creek.

(d) Introduction of alien species

Introduced species are responsible for many species extinctions, especially on islands since their indigenous biota usually lack the necessary defensive or competitive capabilities.

Many marine organisms are transported by human activity, intentionally as for aquaculture and private collections, or accidentally from fouling or ballast water from ships. Some of them are now dominant species in other coastal communities where they caused the disappearance of native species. Often parasites and pathogens moved along with them. Introductions that lead to fundamental alterations in the structure of natural communities may have serious economic and social consequences, e.g. toxic marine phytoplanktons leading to the closure of shellfish operations and human health repercussions (Carlton, 1989).

(e) Global climate change

A massive side-effect of air pollution and global warming may have profound effects on oceans by the human-caused increases of greenhouse gases (esp. carbon dioxide and chlorofluorocarbons) into the atmosphere. The greenhouse effect will not only cause an increase in global temperature by 1 to 4.5 °C, but also change the heat distribution which will alter patterns of ocean circulation, precipitation and storm tracks. Warmer temperatures will also cause rising sea levels – about 20-140 cms during the next century – by thermal expansion of the water itself and by the likely melting of ice-bound areas (GESAMP, 1990; IOC, 1992; WRI/IUCN/UNEP, 1990). This will increase flooding and salinization affecting the coastal systems directly. Together, these changes could have serious effects on the coastal biodiversity. Many African countries are more vulnerable to these effects as the majority of the people depend on agriculture (including fisheries) for their livelihood and agricultural production depends a great deal upon climatic patterns.

Rapid environmental change is a common cause of impoverishment of nature which often favors small-bodied rapid-producers, and depresses larger-bodied longer-living organisms. Increase in water temperature will affect specific temperature dependent processes such as reproductive and growth processes, eg. coral bleaching. The coral reefs, however, are themselves key players in the greenhouse scenario and may be as important as tropical rain forests in reducing greenhouse gases.

As sea levels rise, coastal erosion and severity of flooding will increase so that coastlines will recede unless stabilized by dikes or sand influx. Changes in rainfall patterns, salinity distributions and temperatures will alter rates of river delta sedimentation and coastal currents and upwelling patterns are likely to shift geographically and change in intensity. A common consensus is that global warming will make the dry areas drier and wet areas wetter, bringing about a climate of extremes.

Coastal wetlands are likely to suffer the most visible impacts as their landward movement may be hindered by the ever growing development of coastlines. With the loss of this coastal fringe, the species it contains will be lost too.

Many of the islands would be completely submerged by the more extreme projections of sea level rises.

Root causes

Biotic impoverishment is an almost inevitable consequence of the ways in which man has used and misused the environment. The main root causes of human impacts on biodiversity lie in the **(1)** ever growing demographic pressure and unsustainable use of natural resources, **(2)** economic policies that fail to value the environment and its resources, **(3)** insufficient knowledge and its application, **(4)** weakness in legal and institutional systems and collaborations.

(a) Human population growth and unsustainable use of resources

The global human population is quickly rising toward the 6 billion mark. Almost 70% of it lives near aquatic systems, especially coastal zones. In most countries with high fertility rates, such as most African countries, about half of the population is under 16. The resulting demographic momentum in coming years, due to this large number of people reaching their reproductive age, means that the global population will continue to grow for at least the next half century. As numbers have increased, the demand and consumption of renewable and non-renewable resources has an even higher rate of increase.

The recreational use of coastal waters is increasing in some areas, representing the major or even the only industry. coastal tourism generally show high peaks in concentration at certain times of the year and in certain areas, especially the ones with high diversity such as coral reefs. These high numbers are putting an additional pressure on the coastal biodiversity through excessive food, energy and water consumption, physical alterations of the environment (tourism development projects, boating, trampling) and cultural alterations. Ironically, this environmental degradation and congestion may destroy the main natural assets on which tourism development is based.

(b) Economic systems and policies that fail to value the environment and its resources.

Many conversions of natural systems to farmlands or industrialization are economically and biologically inefficient. They happen partly because of the urgent need for economical land use, regardless of how sustainable it is, and partly because natural habitats are commonly under-valued economically. There are several reasons for the misvaluation of biological resources. Many resources are consumed directly and never enter the markets, such as food, fuelwood and medicinal plants harvested by local people, and many valuable coastal biotopes do not have markets, such as water purification, storm surge protection, nursery grounds for fisheries products. Because these values are "free goods" they tend to be ignored in economic calculations which decide whether such biotopes should be conserved or developed. The result is a systematic bias favoring development and hence the degradation of coastal ecosystems.

Economic policies in many African countries are contributing to environmental degradation. The need to increase their foreign exchange earnings often forces them into increased environmental exploitation, such as increasing export of wood, minerals, and marine products.

Another aspect is the inequity in ownership and in the flow of benefits from both the use and conservation of biological resources. Too often the local communities dependent on the natural resources are left out but at the end pay the price.

(c) Deficiencies in knowledge and its application

Scientists still do not have adequate knowledge of coastal ecosystems and their innumerable components (Martens & Jaccarini, 1990). Even where information exists, it does not flow efficiently to decision-makers, who have often failed to develop policies that reflect the scientific, economic, social and ethical values of coastal biodiversity (McNeely *et al*, 1990). Except for research on commercially important resources, most marine studies till recently had scientific and not resource management goals. Few databases on marine subjects exist that are accessible or informative enough for policymakers, especially on a regional and international scale. An additional difficulty in co-ordinating information collection and transfer relates to overlapping jurisdictions and competition among agencies concerned with marine resources.

A final difficulty is often public reluctance to accept policies that reduce excessive resource consumption, which shows an urgent need for more public awareness campaigns.

(d) Weak legal and institutional systems

Most countries have different institutions responsible for managing coastal resources, but each of them focussing on only one of the aspects, such as agriculture, fisheries, tourism...

Ecological realities however clearly call for a cross-sectorial approach including local participation. It is only quite recent that multidisciplinary and institutional collaborations come through which are the basis for information exchange among all groups concerned, including the local communities, and for an integrated management approach that takes into account marine and terrestrial sectors.

Many developing countries also lack an adequate system of environmental laws and enforcement instruments to ensure protection of the environment and the sustainable use of its resources. National policy-making and planning processes are often non-existent or ineffective, and do not take into account long term cost-benefit evaluations. Largely because of these institutional and legal constraints, biodiversity conservation and management has typically been fragmented and restricted to specific protected areas or species.

Conclusions

Although some loss in coastal and marine biodiversity is inevitable and can even benefit man, much is both detrimental and avoidable. Increasing economic activities and the unsustainable use of coastal and marine resources has put considerable stress on the ecosystems with consequent loss of biodiversity and detrimental effects on the socio-economic well being of the people. There is an urgent need for **measures to mitigate or prevent the impacts** of these human activities.

Only by increasing **awareness** of the value of coastal ecosystems and designing **economic incentives** which encourage local communities to support conservation will the rate of biodiversity loss be subsequently reduced. Appropriate **research programmes** that provide necessary information for developing **conservation and management strategies, environmental education** to augment staff capabilities, **cross-sectorial collaboration** and **environmental impact assessments** are needed to provide a sound basis for an **integrated coastal management policy** that includes both the marine and terrestrial systems. As coastal waters have no boundaries, **regional and international approaches** should be strengthened.

References

Beddington, J. R.(1984). The response of multispecies systems to perturbations. In May, R.M. (Ed.) Exploitation of marine communities. Springer-Verlag: 209-225.

Carlton, J. L. (1989). Man's role in changing the face of the ocean: Biological invasions and implications for conservation of near-shore environments. *Conserv. Biol.* 3: 265-273.

Carr, A. (1987). Impact of non-degradable marine debris on the ecology and survival outlook of sea turtles. *Mar. Poll. Bull.* 18: 352-357.

Dugan, P.J. (1990). (Ed.) Wetland conservation: a review of current issues and required action. IUCN, Gland, Switzerland. 96 pp.

GESAMP, (1990). The state of the marine environment. *UNEP regional Seas Reports & Studies* No. 115.

Giesen, W. & Van der Kerkhof, K. (1984). The impact of river discharges on the Kenyancoral reef ecosystem – the physical processes. II: Effect on the Malindi-Watamu coastal environment. Research Report, Laboratory of Aquatic Ecology, Catholic University of Nijmegen, The Netherlands, 82 pp.

IOC, (1992). IOC-SAREC-KMFRI regional Workshop on Causes an consequences of sea-level changes on the Western Indian Ocean coast and Islands. Workshop report No. 77.

IUCN, (1990). Biodiversity in Sub-Saharan Africa and its Islands. IUCN Species Survival Commission Paper No. 6, 242 pp.

Jaccarini, V. & E. Martens (Eds.) 1992. The Ecology of Mangrove and Related Ecosystems. *Hydrobiologia* 247, Kluwer Academic Publishers, Dordrecht, The Netherlands, XII + 266pp.

Margulis, L. & Schwartz, K.V. (1988). Five Kingdoms: An illustrated Guide to the Phyla of Life on Earth. W.H. Freeman & Company, N.Y.

Martens, E. E. (1992). coastal wetland utilisation. In Crafter S.A, Njuguna S.G. & Howard G.W. (Eds) *Wetlands of Kenya*. Samara Publishing Ltd, Dyfed, SA43 2 JG, UK. VIII + 183 pp.: 115-134.

Martens, E. E. (1993). Pollution and loss of biodiversity in aquatic ecosystems. Green Belt Movement Report, Nairobi, 20 pp.

Martens, E. E. (in press). Causes of biodiversity loss in coastal ecosystems. In Conservation of Biodiversity in Africa. Kenya National Museums, Nairobi.

Martens, E. E. & Jaccarini, V. (1990). The ecology of mangrove and related ecosystems: Declarations issued by the International Symposium, September 1990. Mombasa. Report University Nairobi, 10 pp.

Martosubroto, P. & Naamin, N. (1977). Relationships between tidal forests (mangroves) and commercial shrimp production in Indonesia. *Mar. Res. Indones.* 18: 81-86.

McClanahan, T.R. & Muthiga N.A. (1988). Changes in Kenyan coral reef community structure and function due to exploitation. *Hydrobiol.* 166: 269-276.

McNeely, J. A., Miller, K.R., Reid, W.V., Mittemeier, R.A. & Werner, T.B. (1990). Conserving the world's biological diversity. IUCN, Switzerland. 193 pp.

Saenger, P., Hegerl, E.J. & Davie, J.D.S. (1983). Global status of mangrove ecosystems. IUCN, Switzerland, 88 pp.

Salm, R.V. & Clark, J.R. (1984). Marine and coastal protected areas: a guide for planners and managers. IUCN, Switzerland, 302 pp.

Salvat, B. (1987) (ed.). Human impacts on coral reefs: Facts and recommendations. Antenne Museum E.P.H.E., Fr. Polynesia. 253 pp.

Sanders, M.J., Gichere, S.G., & Nzioka, R.M. (1990). Report of Kenya marine fisheries subsector study. *FAO RAF/87/008/DR/65/E*, 44 pp.

UNEP, (1982a). Marine pollution in the East African region. *UNEP regional Seas Reports and Studies* No. 8, 58 pp.

„ (1982b). Environmental problems of the East African region. *UNEP regional Seas Reports and Studies* No. 12, 86 pp.

„ (1984c). Onshore impact of offshore oil and natural gas development in the West and Central African region. *UNEP regional Seas Reports and Studies* No. 33, 67 pp.

„ (1984b). Socio-economic activities that may have an impact on the marine and coastal environment of the East African region: National Reports. *UNEP regional Seas Reports and Studies* No. 51, 277 pp.

„ (1985). Management and conservation of renewable marine resources in the Kuwait Action Plan region, IUCN/UNEP. *UNEP regional Seas Reports and Studies* No. 63, 64 pp.

„ (1989). State of the marine environment: West and Central African region. *UNEP regional Seas Reports and Studies* No. 108, 34 pp.

„ (1990). State of the marine environment in the Eastern African region. *UNEP regional Seas Reports and Studies* No. 113, 46 pp.

UNESCO, (1979). The mangrove ecosystem: scientific aspects and human impact. *UNESCO Reports in marine science* No. 9, 46 pp.

„ (1986). Human induced damage to coral reefs. *UNESCO reports in marine science* No. 40.

Wells, S.M. (1988). (ed.) Coral reefs of the world. 3 Volumes, UNEP/IUCN.

WRI/IUCN/UNEP (1992). Global Biodiversity Strategy. 244p.

Influence des structures de protection d'un canal portuaire sur la morphologie de la côte: le Canal de Vridi en Côte d'Ivoire

Influence of protection structures of a port access channel on the morphology of the coast: the Vridi Channel in Côte d'Ivoire

ABE Jacques et BAKAYOKO Souleymane
Centre de Recherches Océanologiques
B.P. V 18 Abidjan
COTE D'IVOIRE

Résumé

Le canal de Vridi représente la voie d'accès au port de la ville d'Abidjan. Son débouché en mer situé au point de changement d'orientation de la côte a nécessité des travaux de protection contre l'ensablement. Le musoir Ouest et l'épi d'arrêt des sables dont les constructions datent respectivement de 1943 et 1972 ont eu pour effet de bloquer l'important transit sédimentaire évalué à 800 000 m^3 an, à l'origine de l'engraissement observé à l'Ouest du canal. Il s'en est suivi une profonde modification de la morphologie de la plage sous marine dans cette zone. A l'Est du canal la côte subit dans le même temps une sévère érosion évaluée par endroits à 1.5 m/an.

Abstract

The Côte d'Ivoire littoral zone can be divided into two lithological units which are:

– a rocky and sandy coast spreading from the Liberian boarder to Fresco areas. It is characterized by granitic and metamorphic (gneiss and migmatite) caps and sandy coves;

– a sedimentary basin in the eastern part composed of continental clayey sands and Holocene sandy barrier beaches lying between lagoon system and the sea.

The presence of San Pedro port on the Western coast does not create any major problem. However, due to protection structures of its entrance, a local erosion of the adjacent eastern sandy coast is observed. It concerns the coast of a Nautical Club where the erosion rate is about 1.5 m per year.

The Abidjan area has the most worrying erosion rate of the whole Ivorian coastline. Indeed, located at the change point of the coastline orientation, it presents a shelf cut by an important submarine canyon (bottomless pit). On the other hand, the dredging of the access channel to the port and the protection structures result in trapping of sediments coming from the littoral drift. This sediment deficit results then in severe erosion of the coast at the eastern part of the canyon. This phenomenon is emphasized by the concentration of the swell at certain areas of the coast. Data (bathymetric, sedimentological and slope maps) were collected for a physical model construction.

Introduction

A l'heure actuelle, la grande majorité des plages a tendance à démaigrir et à reculer (Paskoff, 1983) ou tout au plus est en équilibre. Toute intervention humaine modifie profondément cet équilibre soit en accélérant l'érosion, ou en provoquant l'effet inverse conduisant à l'accumulation de sédiments. Ce phénomène est visible dans la zone du canal portuaire de Vridi. Le dit canal a été creusé en face du canyon du Trou Sans Fond sur le plateau continental ivoirien, (Fig.1) où l'on espérait alors piéger les sables provenant de la dérive littorale. Les aménagements réalisés à cet effet (construction des musoirs d'une longueur de 450 m pendant les années 1943 à 1950) ont été très vite saturés et l'on a retrouvé des accumulations de sable à l'entrée du canal. Pour arrêter cet ensablement, la Direction du Port Autonome d'Abidjan a entrepris depuis 1972 d'édifier une digue d'arrêt des sables de 350 mètres. Elle est située à 500 mètres à l'ouest du musoir Ouest et fut terminée en 1975.

Une question importante alors se pose; elle concerne les modifications morphologiques actuelles consécutives à la présence de cet épi. En effet, les études antérieures menées par Tastet, 1985 et 1987 ont montré qu'avant tout aménagement, la dérive littorale d'Ouest en Est avait une capacité de transit de 800.000 m^3/an à l'Ouest du canyon et de 400.000m^3/an à l'Est. L'observation de ces valeurs suggérerait que l'excédent de sédiment aboutirait dans le canyon (Varlet, 1958). Les dernières études (Tastet, 1983; Quelennec, 1984; Tastet, 1987) indiquent qu'une partie de ces sédiments s'accumulant en tête du canyon, y constituent un talus instable qui peut glisser dans ce canyon à l'occasion de fortes houles ou d'ébranlements sismiques.

Pour montrer le comportement hydrodynamique actuel des sédiments dans la zone, nous avons comparé des cartes bathymétriques de 1972 et 1990 .

Les documents bathymetriques

Les principaux documents bathymétriques utilisées pour cette étude sont ceux d'avril 1972, d'avril 1990 et de juillet 1990, dressées par le Service Hydrologique et Topographique du Port Autonome d'Abidjan.

- *La carte de 1972* (Fig. 2). La minute de sonde a été réalisée au 1/2000 par le service précité. Au cours de ce sondage, les radiales ont été choisies perpendiculaires au trait de côte et séparées les unes des autres de 100 mètres. Les isobathes élaborées ont une équidistance de 1 m. L'observation de cette carte montre une bathymétrie régulière à l'Ouest du musoir et une flèche de sable individualisée orientée SSE qui marque la limite Ouest du canyon.

- *La carte de 1990* (Fig. 3). Tout comme celle de 1972, les minutes de sonde sont réalisées à la même échelle et les isobathes sont tracées avec une équidistance de 1 mètre sur la plage aérienne et la plage sous-marine. La présence de l'épi d'arrêt des sables a eu pour conséquence une avancée du zéro marin de la côte vers le large.

La carte bathymétrique de juillet 1990 à l'échelle 1/500 présente l'épi d'arrêt des sables dans son état actuel. Cette carte est dressée à partir des levés topographiques et sondages jusqu'au zéro hydrographique. Les radiales sont perpendiculaires à l'épi et donc parallèles à la côte. Afin de les

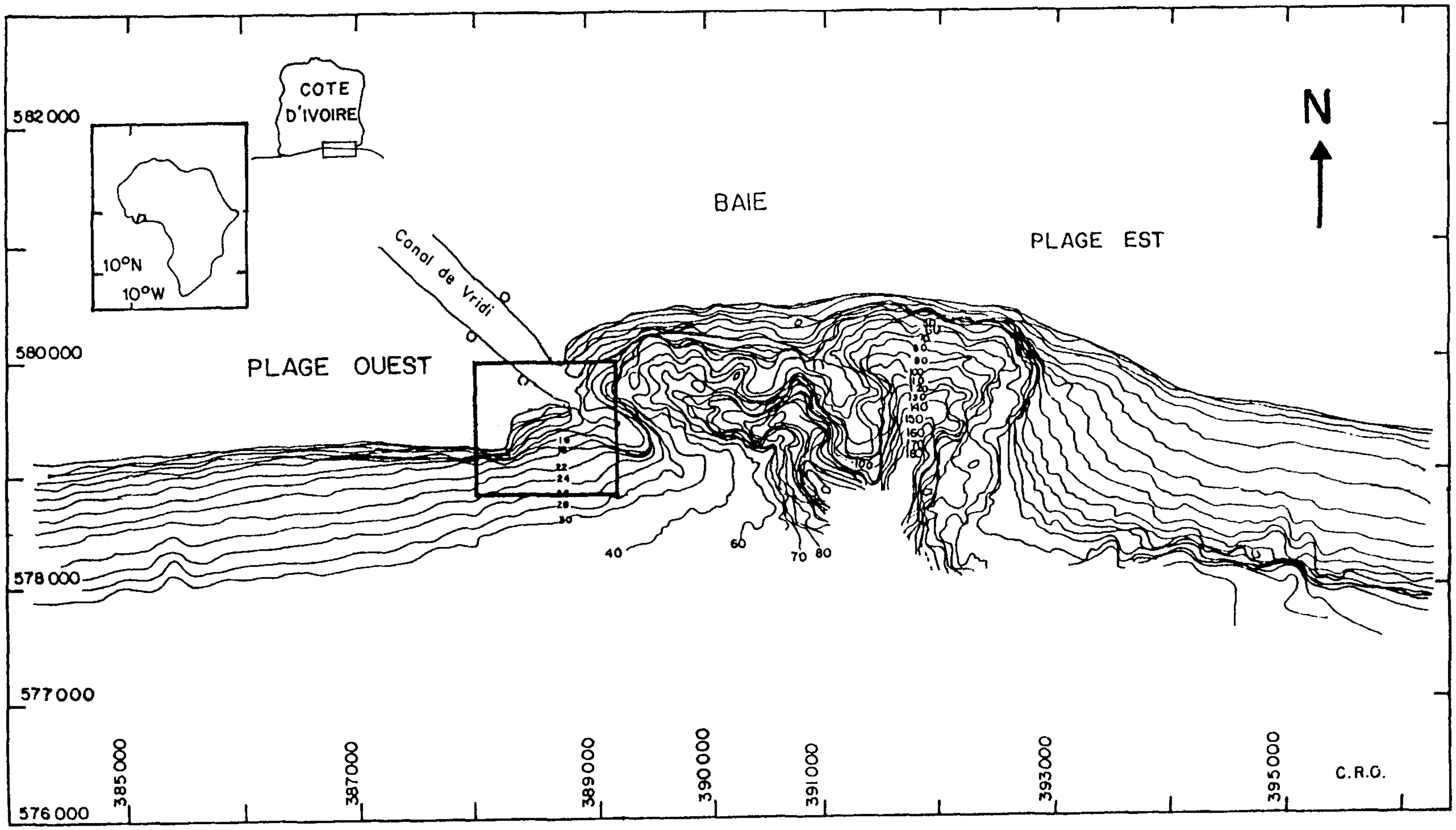


Fig. 1 : Localisation du secteur d'étude.
Location of the study area.

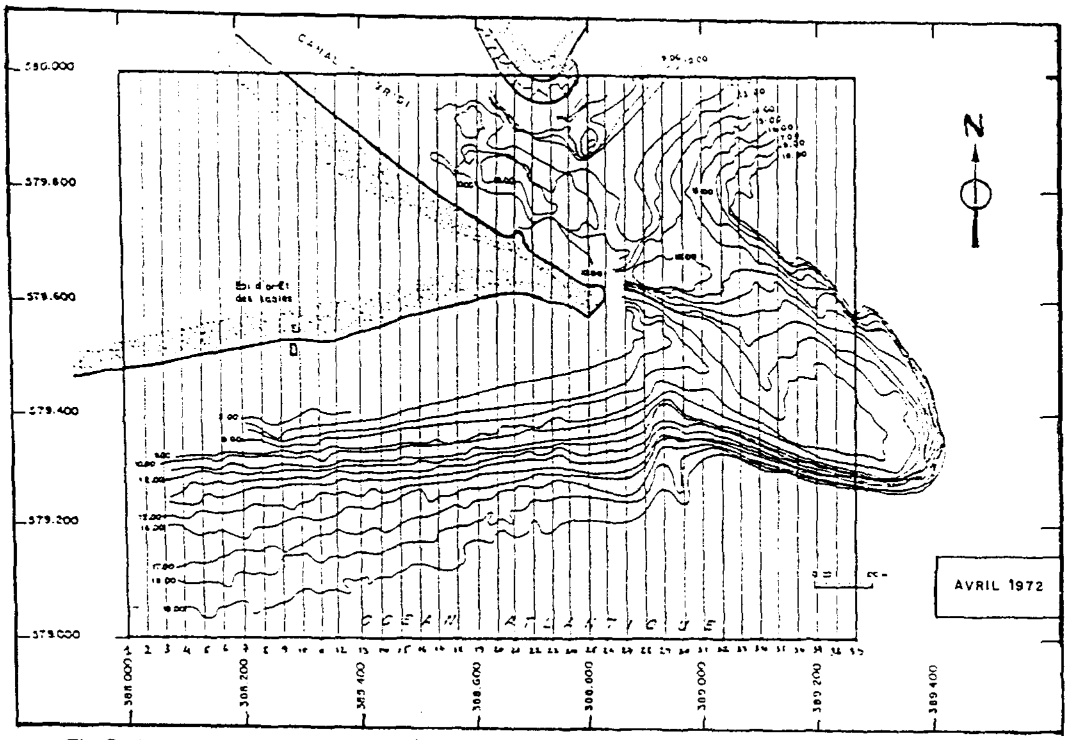


Fig.2: Bathymetrie de la zone étudiée · (1972)
1, 2, 3, ... 36, 37, 38, 39 : Radiales bathymétriques.

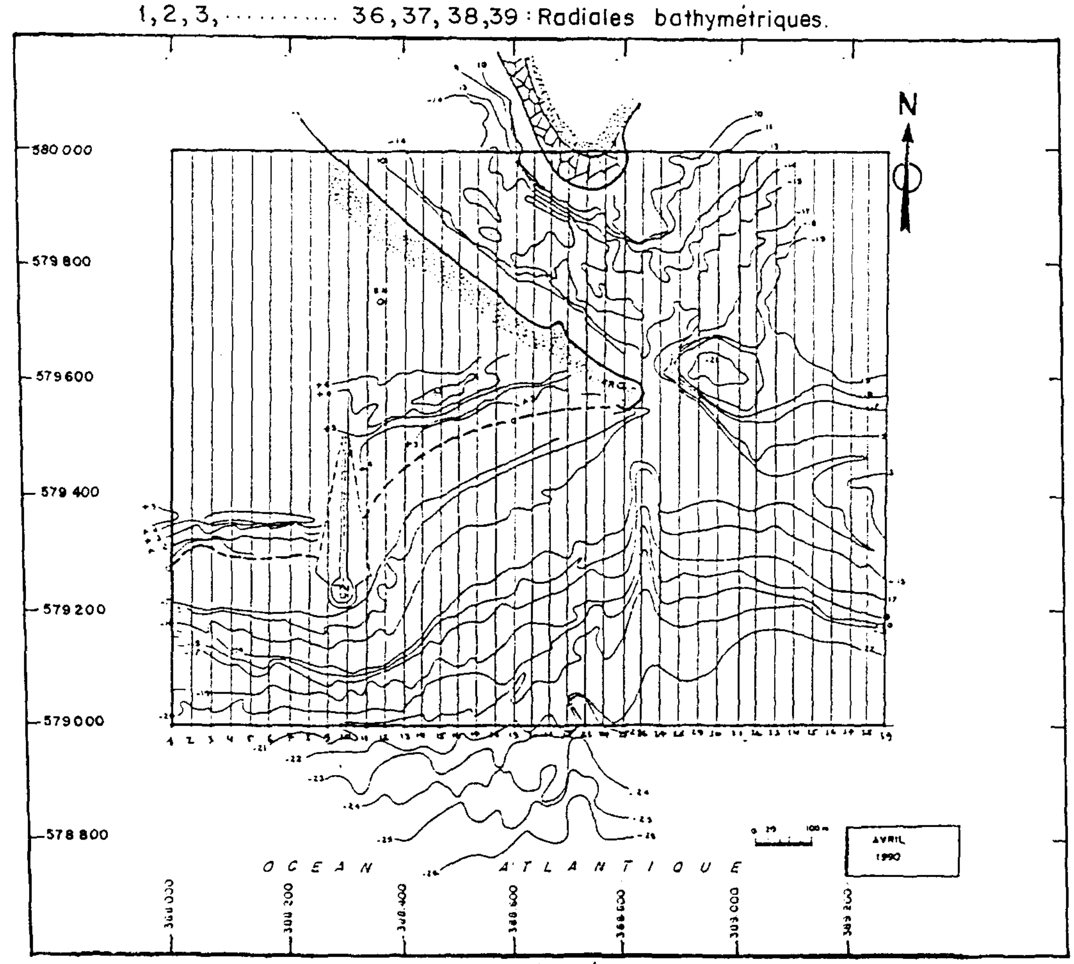


Fig. 3: Bathymetrie de la zone étudiée (1990)
1, 2, 3, ... 36, 37, 38, 39: Radiales bathymétriques

comparer, toutes ces cartes ont été ramenées à la même échelle avec une très grande précision et elles se superposent parfaitement.

Les calculs volumetriques

Les calculs volumétriques ont été effectués par comparaison des deux cartes bathymétriques de 1972 et 1990 .

(a) les courbes d'égal exhaussement et d'égal approfondissement ont été tracées manuellement avec une équidistance de 1 m, par superposition des documents cartographiques (Froidefond *et al.*, 1983). Il découle de ces observations que les zones d'exhaussement sont exclusivement localisées à l'Ouest de l'axe du canal portuaire. Des zones d'approfondissement ont été localisées dans le secteur étudié; celles orientées Nord-Sud se trouvent au bout du musoir Ouest; et celles que l'on observe dans le canal sont le résultat des actions conjuguées de travaux de dragage et des courants de marée. Ces dernières peuvent être assimilées à des chenaux de marée (Fig.4). Sur la bordure Ouest du canyon (face Nord de la flèche littorale), elles suggèrent des déplacements de sédiments sous l'action de la gravité. Le contournement de l'épi d'arrêt par les sables de la dérive est effective; les isopaques qui atteignent 10m à l'épi s'amenuisent progressivement jusqu'à s'estomper à 500m à l'est.

(b) Les coupes topobathymétriques

Sur les cartes bathymétriques de 1972 et de 1990 une série de 39 radiales orientées Nord Sud ont été tracées. Elles sont parallèles entre elles et équidistantes de 25 mètres. L'intersection de ces radiales avec les courbes bathymétriques a permis de tracer les coupes topobathymétriques (Fig.5). Les coupes d'une même radiale superposées font apparaître des section d'exhaussement et d'approfondissement.

(c) Les calculs volumétriques

Les surfaces d'exhaussement et d'approfondissement obtenus après superposition ont été évaluées par planimétrage et présentent les caractéristiques suivantes:

- A l'ouest de l'épi d'arrêt des sables, au niveau de la radiale 4 (Fig.5a), on constate un engraissement très important qui atteint 11 mètres d'épaisseur. Cette accumulation de sédiments s'estompe dans les fonds de 20 mètres, marquant ainsi la limite de la zone d'influence de l'épi en son état actuel.

- Entre l'épi d'arrêt des sables et le musoir Ouest, la radiale 20 (Fig.5b) indique un équilibre entre zones d'exhaussement et d'approfondissement qui n'excèdent pas 3 mètres. Sur cette même radiale, le secteur canal présente une alternance de zones érodées et engraissées.

- A l'entrée du canal, la radiale 27 (Fig.5c) met en évidence une zone entièrement érodée. Les épaisseurs de sédiments atteignent 8 mètres, au droit du canal portuaire.

- Plus à l'Est, la radiale 31 (Fig.5d) fait apparaître une zone d'engraissement située au-delà de 19 mètres de profondeur. Au dessus de ces fonds, on assiste à une forte érosion jusqu'à la côte.

La Figure (5) présente les courbes d'égal exhaussement et d'égal approfondissement séparées par une équidistance de 1 mètres. Sur cette carte sont délimitées les zones d'engraissement situées

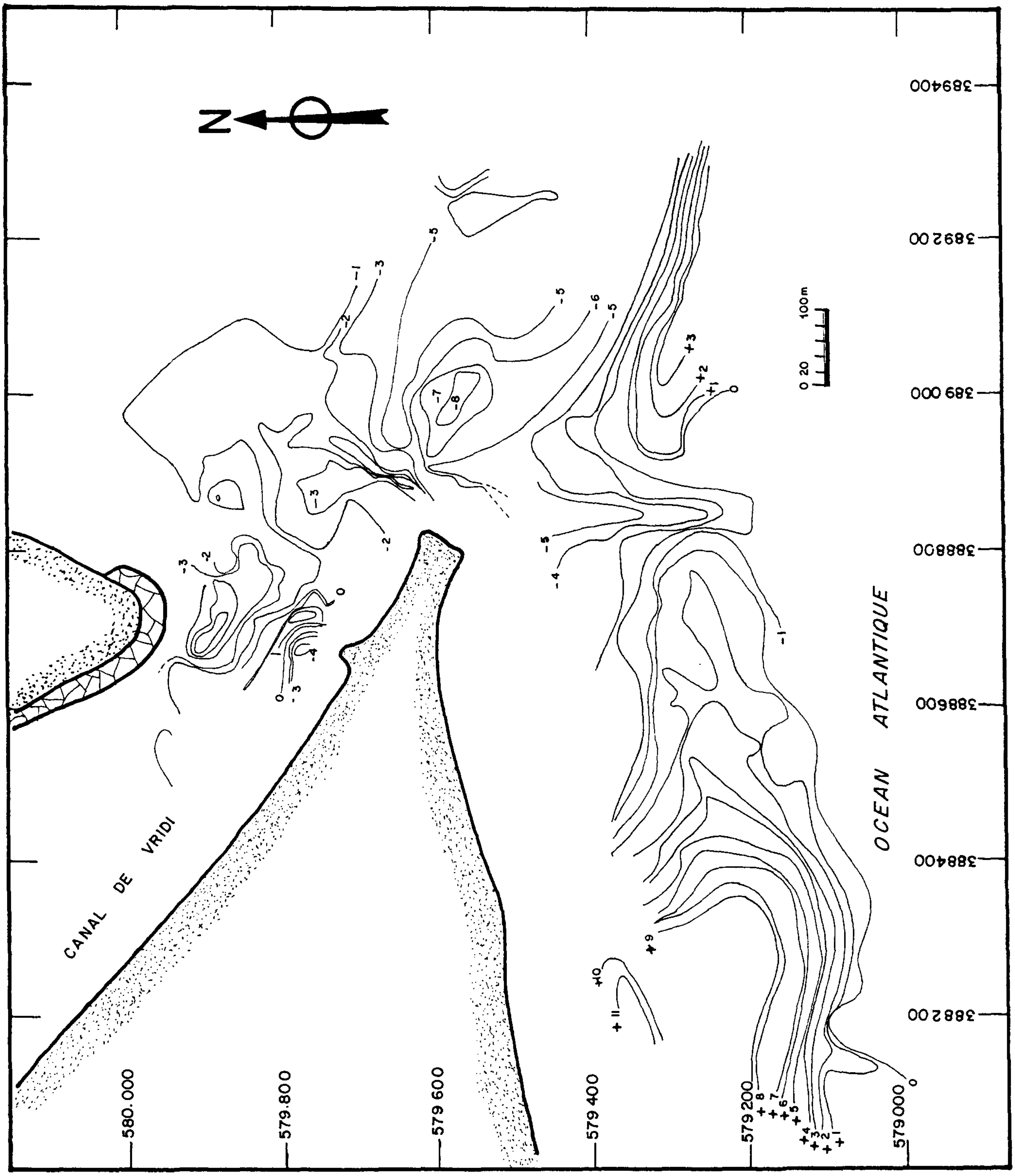


Fig. 4. Carte des chenaux et des zones engraissées et érodées.

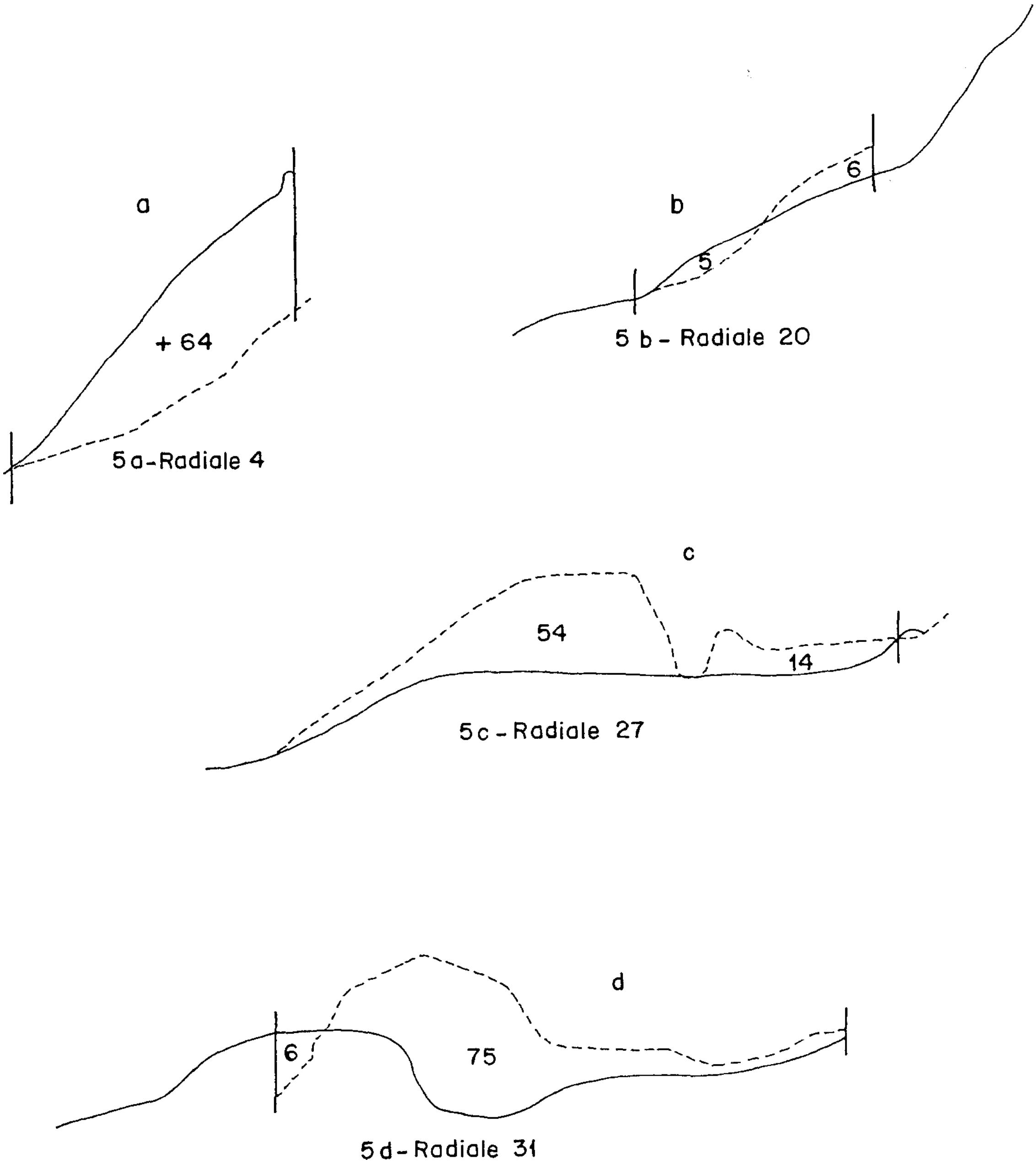


Fig.5 : Niveaux d'exhaussement et d'approfondissement.

____________ en 1990

\- - - - - - - - - en 1972

préférentiellement à l'Ouest du canal et au Sud de la flèche de sable. Alors que la zone du canal et le secteur Est sont en érosion.

Les volumes sont calculées en multipliant la surface-bilan sur chaque radiale par 25 mètres. Les résultats des bilans volumétriques sont les suivants:

Volume des exhaussements en mer	: + 996.467m^3
Volume des approfondissements en mer	: – 892.033m^3
Bilan des approfondissements en mer	: + 104.434m^3
Bilan des approfondissements au niveau du canal	: – 93.315m^3
Bilan global	: + 11.119m^3

Ces résultats démontrent que pour la zone d'étude et sur une période de 18 ans, environ 996.467 m^3 de sable ont été retenus par les aménagements. Dans le même temps, 892.033 m^3 de sédiment ont migré de leur position. On remarque que les pertes de sédiment sont équivalentes aux apports.

L'approfondissement observé au niveau du canal est le résultat des travaux de dragage conjugués aux effets des courants de jusant.

Nature et repartition des sediments selon la carte de 1987

Les sédiments de surface ont été prélevés selon des profils perpendiculaires à la côte, en haut estran et bas estran. Les échantillons lavés, séparés des fines, sont séchés décarbonatés et tamisés à sec sur une colonne de tamis répondant aux Normes AFNOR. Le traitement des échantillons de plage a été réalisé dans le cadre du programme d'étude de l'évolution du littoral Ivoirien (Abé, 1992). Ceux de la plate-forme interne ont été analysés à la faveur de l'étude sédimentologique du littoral de Vridi-Port-Bouet (Koffi, Abé & Affian, 1989).

Certains des échantillons sus-cités ont fait l'objet d'analyse morphoscopique (Howa, 1989). Il résulte de toutes ces études que les cordons sableux qui séparent les lagunes de la mer ont été mis en place par la dérive littorale il y a environ 5000 ans; ce qui indique que ceux-ci ont été constitués bien avant l'ouverture du canal. Dès lors, le matériel détritique qui le compose est partout le même. Il est composé pour l'essentiel par des grains de quartz dans la proportion de 80%; le reste (20%) regroupe quelques grains de feldspath et de nombreux minéraux lourds tels que ilménite, rutile, grenat.

Depuis la construction du canal portuaire, si la composition minéralogique des sédiments reste inchangée, la morphologie des grains de silice par contre se différencie quelque peu, selon que l'on se situe à l'Ouest ou à l'Est du canal.

En effet, depuis Grand-Lahou jusqu'aux structures de protection à l'Ouest du canal, les grains de quartz sont de plus en plus arrondis, tandis que dans la baie de Port-Bouet voisine, ils sont plus anguleux. Cette coupure au niveau du canal est encore plus franche si l'on considère la granulométrie des sédiments. Ceux-ci s'avèrent plus grossiers dans la baie de Port-Bouet qu'à l'Ouest du canal où ils ne sont au plus que des sables moyens (Fig.4).

Conclusion

L'objectif de cette étude était d'évaluer l'effet de la construction du canal et de ses structures de protection sur le comportement dynamique des sédiments dans la zone Vridi Port-Bouet. Il en résulte un déséquilibre dynamique qui se traduit par une accumulation de sable à l'Ouest de l'épi et une érosion en quantité équivalente à l'Est. Lors de la saturation de l'épi de protection, les sables de la dérive littorale contournent celui-ci et migrent vers l'Est.

Cette interruption se traduit par la différence de la morphologie des grains de quartz qui sont plus anguleux à l'Est du canal qu'à l'Ouest.

Le rétablissement de l'équilibre de la zone nécessite un apport sédimentaire (beach nourrishment) par by passing à l'Est du canal. Mais cette solution s'avère onéreuse dans la conjoncture économique actuelle.

Bibliographie

Abé J. (1992). Etude préliminaire de l'érosion côtière du littoral Ivoirien., 28th IGC, 1989. *Newsletter of the Association of geoscientists for international development*: 28-31, 3 Fig.1 tabl.

Froidefond J.M., Castaing P., Weber O. (1983). Evolution morpho-sédimentaire de la tête du canyon de Capbreton d'après les cartes de 1860 et de 1963, utilisation des méthodes informatiques. *Bull. Soc. geol. France*, t.XXV, n°5: 705-714.

Howa H., (1989). Un exemple d'utilisation de l' analyse exoscopique en sédimentologie côtière, *J. Rech. Oceanogr*. vol.1 et 2: 21-38.

Koffi, Abé, Affian, (1989). Etude complémentaire du littoral de Vridi Port-Bouet: morphologie et sédimentologie. NDR n°3/89, C.R.O Abidjan, 25 p., 4 Fig.

Paskoff, R. (1983). L'érosion des plages. *La Recherche* n°140, vol.14: 20-28.

Quelennec, R.C. (1984). Identification des problèmes sur le littoral sabbleux de Côte d'Ivoire. Propositions d'actions prioritaires, *Doc. BRGM*, 46 p., 19 Fig.

Tastet, (1985). La dynamique sédimentaire littorale devant Abidjan. Impact des aménagements, *Annales Univ. Nat.* Côte d'Ivoire, PAA, 39 p., 13 Fig., 4 ph.

Tastet, (1987). Effets de l'ouverture d'un canal d'accès portuaire sur l'évolution naturelle du littoral d'Abidjan (Afrique de l'Ouest). *Bull. Inst. Géol. Bassin d'Aquitaine, Bordeaux*, n°41: 177-190.

Varlet, (1958). Le régime de l'Atlantique près d'Abidjan (Côte d'Ivoire), Essai d'océanographie littorale, *Extrait des Etudes Eburnéennes, t.7*, 222 p., 43 Fig., 39 tabl.

Répercussions de la mise en eau des barrages de Diama et Manantali sur l'environnement estuarien du fleuve Sénégal

Impacts of the Diama and Manantali dams on the estuarine environment of the River Senegal

Bâ M., Diouf B., Barusseau J.P., Descamps C., Diop S., Monteillet J., Rue O. & Saos J.L.

Département de Géologie, Faculté de Sciences
Université Cheikh Anta Diop
B.P. 15063 Dakar
SENEGAL

Résumé

- *Le fleuve Sénégal, au nord du Sénégal, est régulé par le barrage anti-sel de Diama depuis 1985 et par le barrage réservoir d'eau de Manantali depuis 1988. La mise en fonction de ces deux barrages a entraîné des modifications sur l'ensemble de l'écosystème estuarien. Une étude pluridisciplinaire, menée depuis 1989, a permis d'obtenir les résultats suivants:*
- *l'embouchure s'est étendue sur plus de 6 km vers le sud en 6 ans et une barre d'embouchure s'est formée illustrant ainsi le passage d'un régime fluvial dominant à un régime marin dominant;*
- *le littoral adjacent est affecté de changements morphosédimentaires qui se manifestent par des alternances d'érosions et de dépôts dérivant généralement vers le sud sous l'action de houles de nord-est;*
- *la faune malacologique représentée de plus en plus par des formes polyhalines montre une tendance à l'accentuation de l'influence marine en aval du barrage vers l'embouchure. Plus en amont, la faune se raréfie sous l'action de lâchers d'eau sporadiques. Dans la retenue du barrage la faune oligohaline s'est mise en place au détriment des formes mésohalines;*
- *l'hydrodynamique est modifiée: en aval du barrage de Diama, on observe des changements brutaux de vitesse de courant et une réduction dans le temps soit du flot soit du jusant en fonction des ouvertures et des fermetures de vannes. La durée de la crue est réduite ainsi que son intensité;*
- *des lâchers d'eau douce, en période d'étiage, entraînent une dilution brutale des eaux marines. Ces lâchures ralentissent la progression de l'intrusion saline et maintiennent la salinité à des valeurs intérieures ou égales à celle de l'eau de mer;*
- *le pourcentage de saturation en oxygène dissous ainsi que le pH diminue en période d'étiage dans le réservoir d'eau douce tandis que les nitrites et les nitrates augmentent.*

Abstract

The Senegal River, in the North of Senegal, is regulated by the anti-salinity dam of Diama since 1985 and by the dam of Manantali which stores freshwater since 1988. The functioning of these dams has brought about profound changes in the estuarine ecosystem. The results of a multi-disciplinary study which started in 1989 are as follows:

- *the mouth of the River now extends 6 kms further out than it used to, six years back;*
- *there are morphological and sedimentological changes on the adjacent shoreline, as witnessed by the shifting occurences of erosion and silt accumulation;*
- *the marine influence is becoming more dominating in the molluscan fauna as shown by the prevalence of polyhaline species nearer the mouth; in the dam itself, oligohaline fauna replace the mesohaline species;*
- *hydrodynamics have been modified: downstream, there are vital changes of the current speed and a decrease in the duration of the flood tide or the ebb tide as the sluices of the Diama Dam are opened or closed; the duration and the intensity of the river flood also decrease;*
- *releases of fresh water during the lowest water level cause severe dilution of sea water. These releases reduce salt water intrusion and salinity decreases to below that of the sea;*
- *the saturation percentage of dissolved oxygen as well as the pH decrease in the freshwater reservoir during the lowest water level, while nitrites and nitrates increase.*

Introduction

La sécheresse, que l'on observe dans le Sahel depuis 1968, a entraîné dans les estuaires du Sénégal tels que le Saloum, au centre, et la Casamance, au sud, une sursalinité des eaux extrêmement préoccupante pour l'avenir de ces zones. Au nord du Sénégal, dans la vallée du fleuve Sénégal, la situation est différente puisque, d'une part, les apports d'eau douce venant du Fouta-Djalon en Guinée sont beaucoup plus importants et, d'autre part, deux barrages ont été construits l'un, le barrage de Diama à 50 km de l'embouchure pour stopper l'intrusion saline et acumuler des réserves d'eau douce, l'autre, le barrage de Manantali à 800 km de l'embouchure, pour permettre de réguler le débit du fleuve (Fig. 1).

Ainsi le fleuve a subi de fortes modifications depuis plusieurs années, sous l'action:

– du phénomène de sécheresse

– de l'artificialisation de tout le système hydrologique avec les deux barrages.

Cadre general

Cadre climatique

Le nord du Sénégal est soumis à un régime sahélien à faible pluviosité (100 à 400 mm/an). Depuis le début de la sécheresse, en 1968, la diminution de la pluviosité, à parfois moins de 100 mm/an (Fig. 2), s'accompagne d'un raccourcissement de la saison des pluies de 4 mois à 2 ou 3 mois suivant les années.

Le taux d'évaporation moyen annuel est de l'ordre de 2 360 mm et par conséquent, l'évaporation ne peut être compensée par la pluviométrie (environ 200 mm/an). Ceci entraîne un fort déficit hydrique pendant la saison sèche dans la vallée du fleuve Sénégal.

Cadre hydrologique

Le régime du fleuve Sénégal dépend des pluies dans le haut-bassin et des ouvertures des barrages de Diama et Manantali. C'est une alternance de période de hautes eaux (août à novembre) et de période de basses eaux régulées par les barrages :

- le barrage de Diama, barrage anti-sel, est fermé pendant la saison sèche de novembre à juin et ouvert progressivement lorsque l'onde de crue arrive, vers la fin du mois de juillet, afin de garder un niveau d'eau constant nécessaire pour les cultures de décrue et l'irrigation, mais n'entraînant pas d'inondation dans la vallée du fleuve ; ce barrage fonctionne depuis 1985,

- le barrage de Manantali est un barrage réservoir d'eau. Des lâchers d'eau sont faits pendant la crue en fonction des besoins agricoles et de la recharge du Lac de Guiers dont l'eau est acheminée jusqu'à Dakar pour la consommation d'eau potable ; ce barrage fonctionne depuis la fin 1988.

Dorénavant l'estuaire du Sénégal est scindé artificiellement en deux parties distinctes pendant environ huit mois de l'année : l'aval envahi par la mer, l'amont en eau douce. Toutefois, des lâchures plus ou moins importantes ont lieu sous diverses contraintes, pendant l'étiage, permettant un mélange des eaux marines et douces.

Cadre socio-économique

L'économie, dans l'estuaire du fleuve Sénégal, repose essentiellement sur l'agriculture, l'élevage, la pêche ainsi que la culture industrielle avec la Compagnie Sucrière Sénégalaise (CSS) exploitant la canne à sucre et les usines de concentré de tomates (SOCAS, SNTI).

L'agriculture est surtout constituée à l'heure actuelle de riziculture, de culture de tomates et de canne à sucre. Trois modes de cultures sont pratiqués : les cultures sous pluies (en très nette diminution à cause de la sécheresse), les cultures de décrue et les cultures par irrigation qui se développent sous l'influence des barrages.

L'élevage de zébus, répandu dans la zone, est pratiqué sous forme d'élevage pastoral par les peulhs.

La pêche est en nette régression dans le delta du Sénégal et est devenu marginale au profit notamment des activités agricoles.

L'utilisation de l'eau

Dans les zones riveraines, l'eau est utilisée en grande partie pour les cultures (industrielles ou non) avec le développement des cultures irriguées.

L'eau du fleuve Sénégal est utilisée aussi pour l'alimentation en eau potable de la presqu'île du Cap-Vert par l'intermédiaire du lac de Guiers.

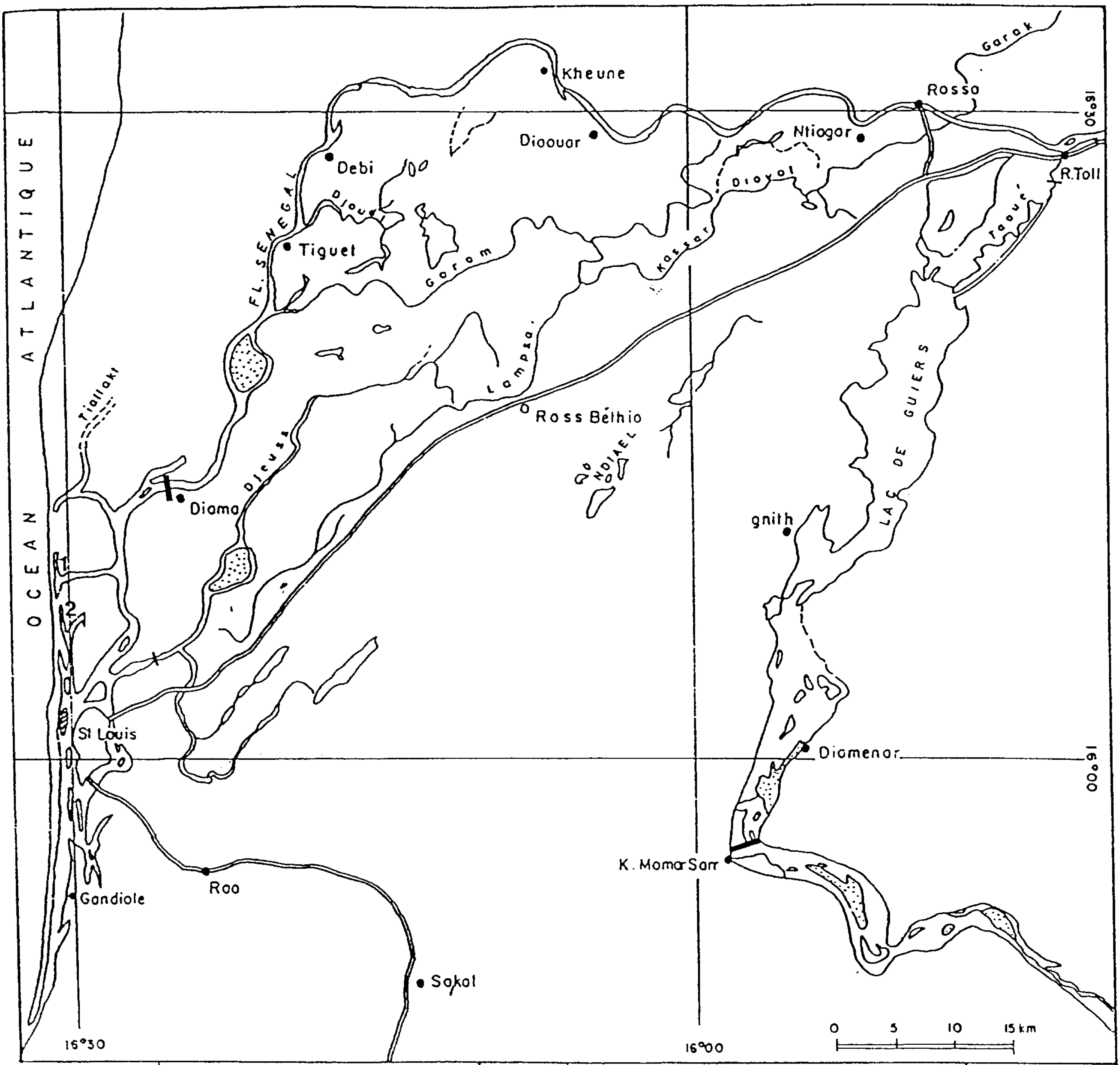
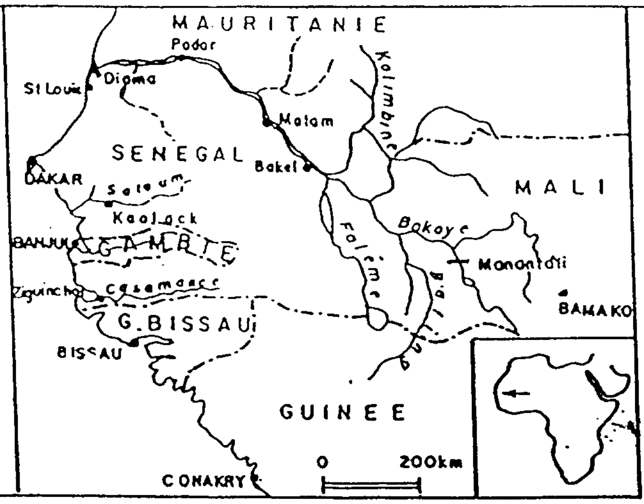


Fig. 1 : Carte de situation

de la zone étudiée



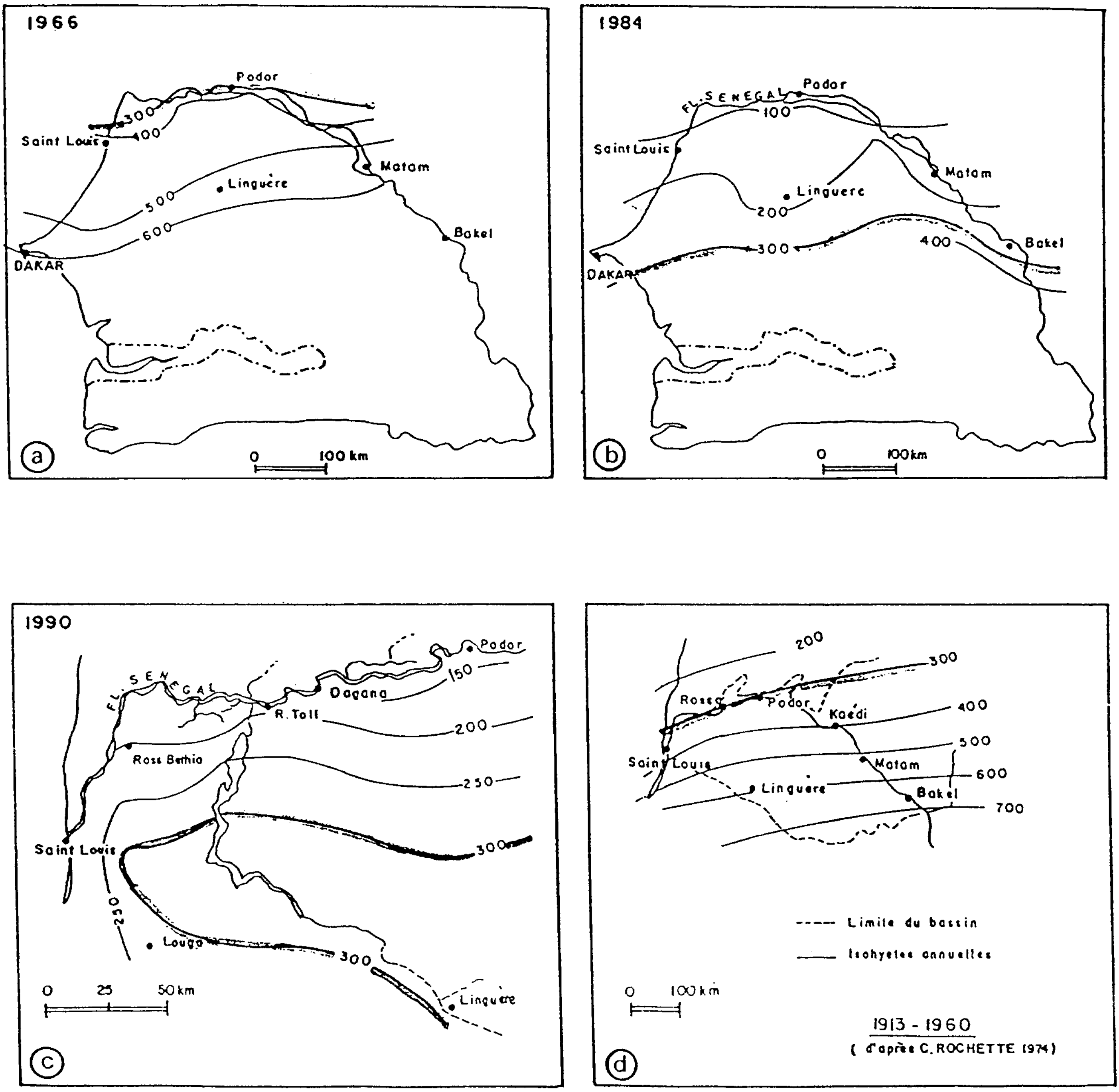


Fig. 2 : Les isohyètes annuelles (a,b, c) et interannuelles (d) au nord du Sénégal

Repercussions des barrages sur l'environnement estuarien

Géomorphologie

D'un point de vue purement physique, nous remarquons, grâce à des photos satellites prises en 1986 et 1990, une extension de la Langue de Barbarie vers le sud et un épaississement de l'extrémité de cette flèche (Fig. 3). Par contre la flèche sableuse de la lagune de Mboumbaye, située en face de la Langue de Barbarie, s'est raccourcie d'environ 2500 à 3000 m entre 1986 et 1990. Actuellement, la partie nord de la flèche de Mboumbaye s'est accolée au rivage, ainsi la lagune est complètement isolée du système estuarien (Diop *et al.*, 1992). Ces variations de la morphologie du littoral sont étroitement liées à l'hydrodynamique de l'estuaire.

La formation d'une barre d'embouchure, émergée à marée basse, matérialise le passage d'un régime fluvial dominant à un régime marin dominant.

Hydrodynamique

En aval du barrage de Diama, on observe des changements brutaux de vitesse de courant et une réduction dans le temps soit du flot soit du jusant en fonction des ouvertures et des fermetures du barrage (Bâ, 1992).

En étiage, lorsque le barrage est fermé, nous observons un système homogène avec un type de fonctionnement lagunaire (Fig. 4).

Entre la fin de l'étiage et le maximum de la crue, le régime estuarien est complètement inversé: l'eau de mer, peu chargée en matière en suspension, est expulsée et l'estuaire est totalement envahi par de l'eau douce très turbide. En crue, le passage d'un milieu marin homogène à un milieu sous dominante fluviatile se fait beaucoup plus rapidement qu'avant le barrage. La durée de la crue a diminué dans la partie aval.

Le débit du fleuve en crue a diminué sous l'action du barrage de Diama et l'influence marine se fait sentir même lors des débits maximaux à environ 10 km en amont de l'embouchure (Fig. 5). Ceci est très important pour les transport de sédiments.

Les matières en suspension

Les matières en suspension varient d'environ 20 mg/l en période d'étiage à environ 400 mg/l au maximum de la crue (Fig. 6). Les eaux passent d'une couleur bleue-vert en étiage, à l'aval du barrage, à une couleur jaunâtre en crue dans tout l'estuaire. L'essentiel des débits solides a lieu pendant la crue. En fait, il est vraisemblable que les concentrations les plus importantes soient en début de crue grâce à l'apport des matières en suspension par les eaux superficielles dues aux premières averses ainsi que la remise en suspension des sédiments déposés par les parties basses des berges par le clapotis lors de la dernière crue (Gac, 1979). En décrue, les débits solides sont rapidement dégressifs et on atteint, en étiage, une concentration relativement stable d'environ 20 mg/l. En fait, il y a décantation rapide d'une grande partie des sédiments fins.

Les bilans sédimentaires ont changé et les quantités de sédiments expulsés en crue sont très inférieures aux quantités expulsées avant le barrage, le débit ayant diminué. Le bilan sédimentaire montre également actuellement un piégeage des sédiments dans les zones marginales entre Gandiole et le barrage.

Sédimentologie

En amont du fleuve, on a des dépôts de boue fluviatile de 30 cm d'épaisseur dans le chenal c'es-à-dire dans la zone où le transport des sédiments est maximal. Le barrage, comme on l'a vu, réduit le débit même ouvert et limite l'auto-curage du lit. La tendance à long terme est donc à la sédimentation dans le lit et au développement latéral des zones humides.

En aval du barrage, entre le barrage et St-Louis, on observe une vase noire argileuse sous le dépôt récent de crue et donc déposée antérieurement. Ces dépôts non tassés indiquent que la compétence du fleuve en début de crue n'a pas été suffisante pour entraîner ce dépôt plus ancien (avant-dernière crue).

Ainsi le bilan sédimentaire semble devenir progressivement excédentaire et la tendance de ce bief estuarien est au colmatage par sédimentation fine.

Dans la zone de l'embouchure, par contre on a un domaine sableux qui correspond au domaine des eaux marines. La granulométrie du matériel augmente vers l'embouchure et à également augmenter ces dernières années, ce qui correspond à la variation géomorphologique observée plus haut (Rüe, 1992).

Salinité

La salinité est un facteur extrêmement important et préoccupant dans les estuaires du Sénégal où un fonctionnement en "estuaire inverse" (Pritchard, 1967) a été décrit dans les estuaires de la Casamance (Pagès, 1986) et du Saloum (Saos, 1985) dont la salinité augmente vers l'amont.

En période d'étiage, d'une part, la remontée saline est stoppée par le barrage de Diama prévu à cet effet, d'autre part, bien que les eaux marines pénètrent dans l'estuaire pendant toute la période d'étiage et que la salinité augmente globalement depuis la fermeture des vannes jusqu'à l'ouverture lors de la crue suivante, les salinités restent toujours inférieures ou égales à celles de l'eau de mer. Un phénomène de dilution est provoqué par des lâchers d'eau douce au barrage. Ainsi l'estuaire est dans des conditions très différentes de celles observées avant le barrage (Bâ, 1992). En effet, avant le barrage les eaux marines atteignaient Podor à 300 km de l'embouchure, et des taux de salinités supérieures à celui de l'eau de mer (35 %) étant observés jusqu'au km 70 en juillet 1982 (Gac *et al*, 1986).

L'ouverture du barrage a lieu après l'arrivée de la crue à Diama de façon à maintenir le plan d'eau en amont du barrage à la cote d'environ + 1,50 m. A ce moment l'eau douce descend vers le littoral diluant les eaux marines.

A Gandiole, les variations saisonnières de la salinité dépendent directement du barrage de Diama et de la remontée des eaux salines montrant un maximum en juillet (35 %) et un minimum en septembre et novembre (0 %). La zone située en amont du barrage de Diama est maintenant en permanence en eau douce.

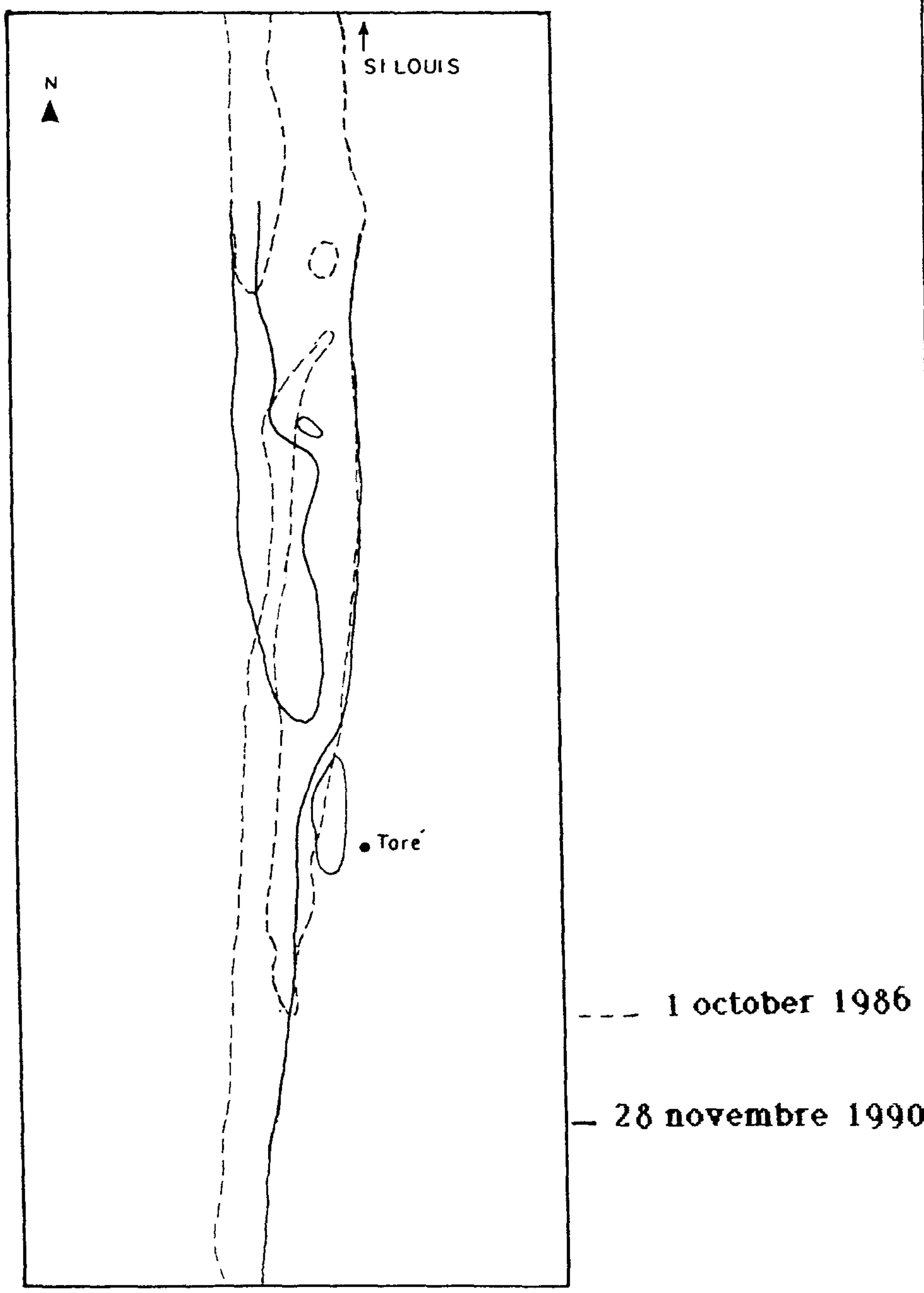


Fig. 3 : Evolution de la flèche de la "Langue de Barbarie" d'après les images satellitaires SPOT du 1er Octobre 1986 et du 28 novembre 1990

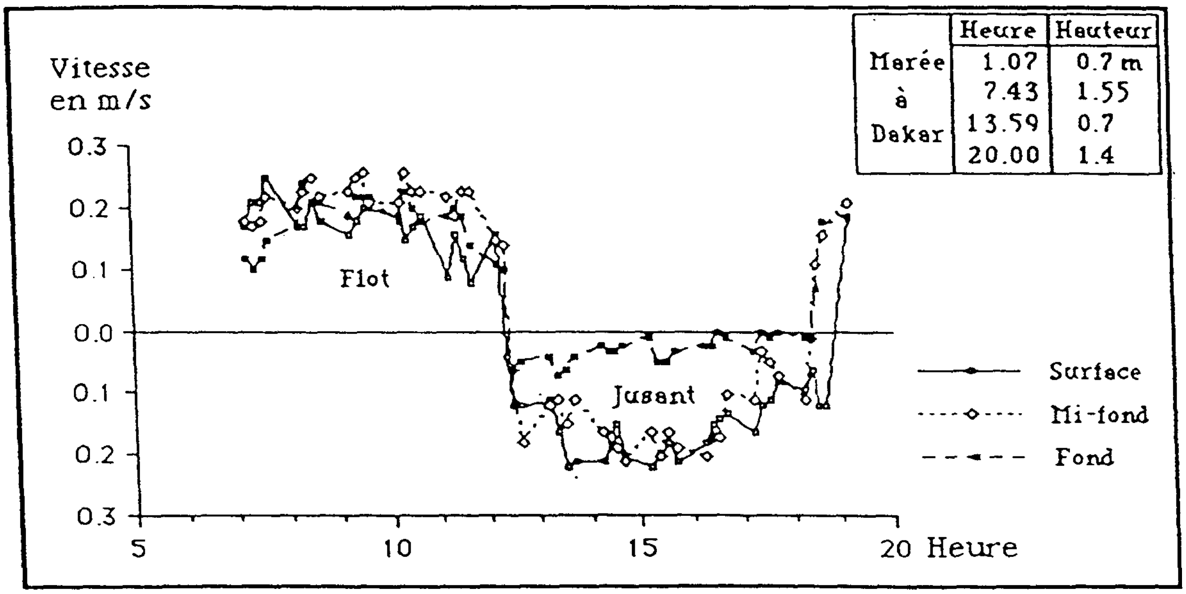


Fig. 4 : Vitesse de courant - Gandiole - 24 juillet 1991

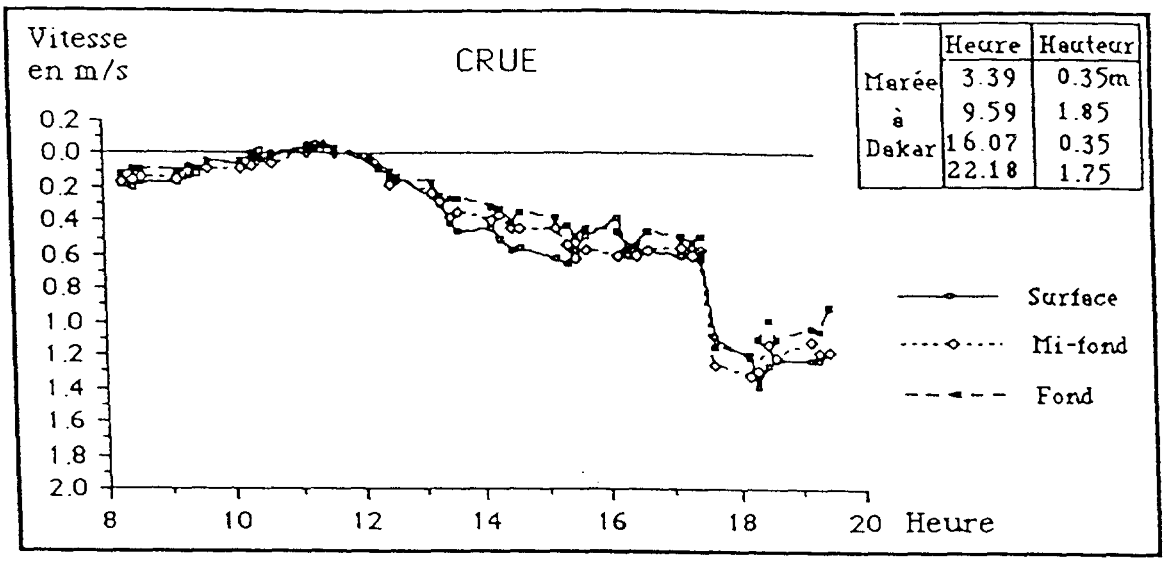


Fig.5 : Vitesse de Courant - Gandiole - 10 septembre 1991

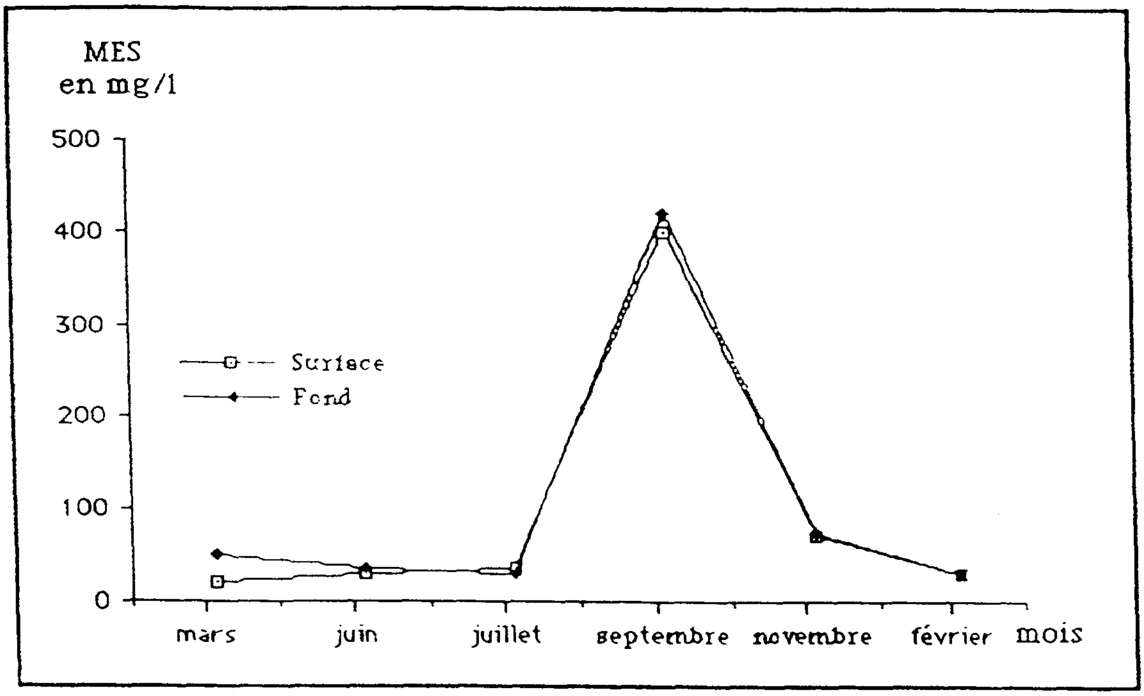


Fig. 6 : Variations saisonnières des M.E.S. à Gandiole

Caractéristiques hydrochimiques

- <u>Le pH</u>

Dans le delta du Sénégal, le pH est compris entre 6,7 en amont du barrage de Diama et 8,3 à Gandiole.

A Gandiole, le pH diminue pendant la période de crue à cause de l'apport en eaux douces moins alcalines que l'eau de mer. A Diama – amont, le pH est plus faible au fond qu'en surface où la photosynthèse est plus active grâce à l'ensoleillement. En fin d'étiage, la baisse du pH s'accentue dans les eaux profondes (Fig. 7, 8).

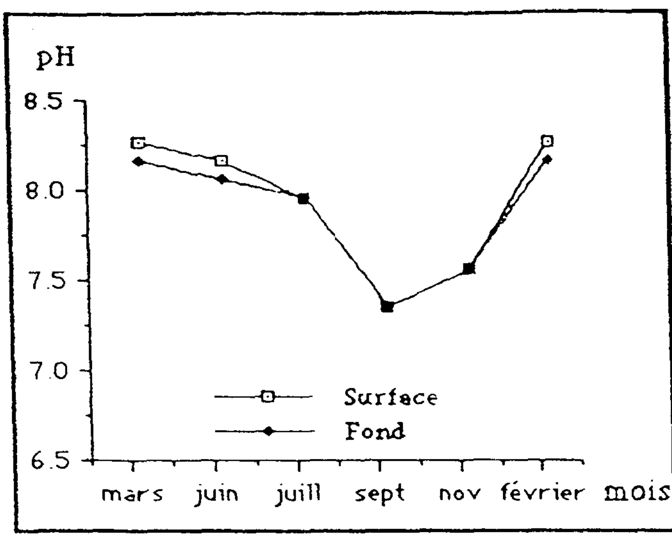


Fig. 7 : Variations saisonnières du pH à Gandiole

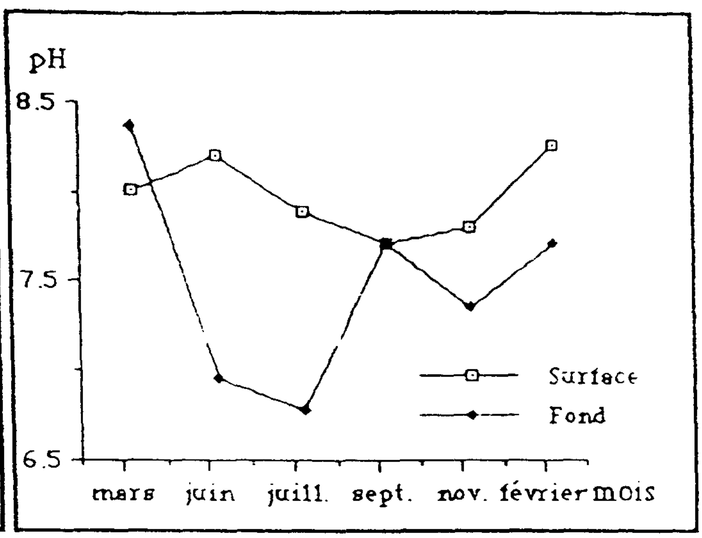


Fig. 8 : Variations saisonnières du pH à Diama (amont)

- L'oxygène dissous

Les valeurs à Gandiole sont généralement comprises entre 80 et 110 % et augmentent au cours de la journée quelque soit la saison et quelque soit la transparence de l'eau.

Les eaux sont mieux oxygénées à Gandiole qu'en amont du barrage où nous remarquons même des valeurs très faibles de l'ordre de 20% de saturation au pied du barrage (Fig. 9, 10).

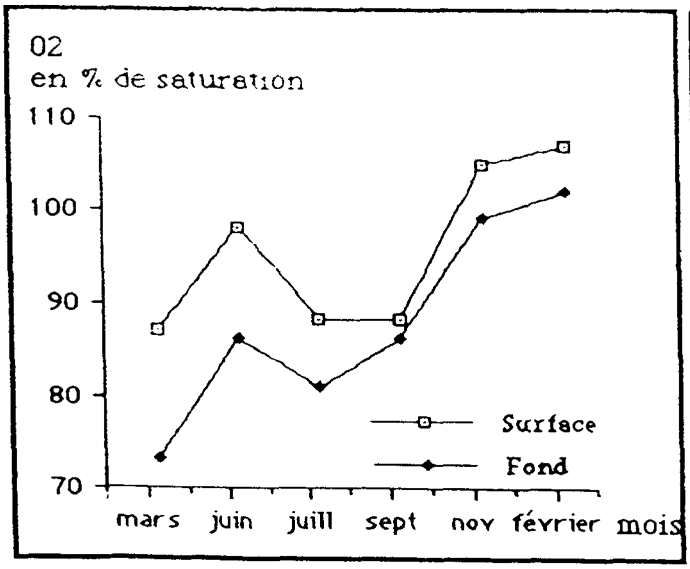


Fig. 9 : Variations saisonnières de l'oxygène dissous à Gandiole

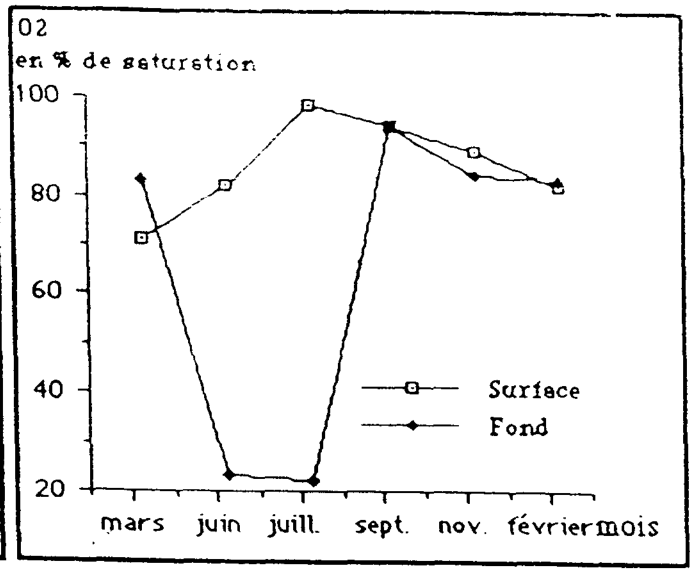


Fig. 10 : Variations saisonnières de l'oxygène dissous à Diama (amont)

En effet, le barrage de Diama constitue un piège pour l'ensemble des détritus, composés en partie de matière organique, venus de l'amont. Ces détritus sédimentent, s'accumulent et leur décomposition entraînent une forte consommation d'oxygène. Ce processus pourrait aboutir à un milieu totalement anoxique.

- Les sels nutritifs

Dans l'ensemble, les sels nutritifs augmentent en période de crue.

Les nitrates varient de 0 à 14 mmol/l. On remarque une accumulation de nitrates et de nitrites au pied du barrage, côté amont, pendant la saison sèche lorsque les vannes sont fermées (Fig. 11, 12). Nous avons vu, précédemment, que dans les mêmes conditions, l'oxygène dissous diminuait: l'oxygène dissous est utilisé lors de la décomposition de la matière organique pour former des nitrites et des nitrates. L'évolution des variations saisonnières des nitrites et des nitrates est inverse à Gandiole de celles observées à Diama-amont.

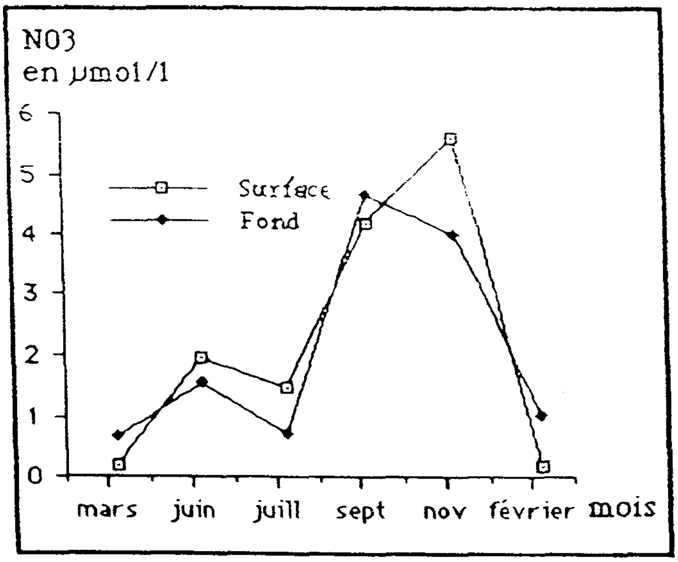


Fig. 11 : Variations saisonnières des nitrates à Gandiole

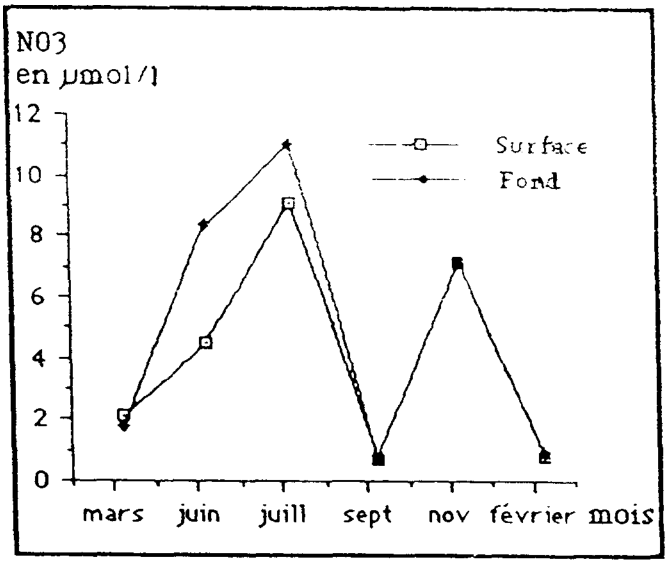


Fig. 12 : Variations saisonnières des nitrates à Diama (amont)

Les concentrations en silicates varient en fonction de la salinité: les eaux douces sont chargées en silice, les eaux marines ont une faible teneur en silicates. Lorsque la salinité est comprise entre 25 et 35 ‰, la teneur en silice est comprise entre 20 et 40 mmol/l. Lorsque les eaux sont douces, la silice est comprise à Gandiole entre 160 et 190 mmol/l à Diama-amont.

- La chlorophylle

Les teneurs sont plus faibles au barrage de Diama, côté amont, qu'à Gandiole et, d'autre part, la crue appauvrit le milieu en chlorophylle.

La faune malacologique

La faune malacologique subit les changements intervenus dans l'estuaire et sa répartition se trouve donc modifiée.

A l'embouchure:

- en 1989, *Donax rugosus* qui traduit une zone de haute énergie est l'espèce dominante, accompagnée par d'autres espèces marines telles que *Chlamys varia, Venus verrucosa, Marginella* sp., *Mesalia* sp., *Turitella bicingulata.*

- en 1991 cette espèce persiste.

A Gandiol:

- en 1989 : la faune malacologique est à dominante polyhaline. On trouve les bivalves tels que *Anomia ephippium* et *Tellina nymphalis* et les gastéropodes *Cylichna grimaldii*.

- en 1991 la faune malacologique ne change pas mais nous notons toutefois que la microfaune de foraminifères a tendance à prendre un caractère marin plus affirmé.

A Diama aval:

- en 1989, *Tympanotonus fuscatus,* espèce polyhaline est abondante dans la mangrove de ce site. L'existence de bivalves *Corbula trigona,* à affinité mésohaline, traduit des eaux douces en provenance de la retenue.

- en 1991, les gastéropodes *Tympanotonus fuscatus* sont tous morts. Cette disparition pourrait être liée aux travaux du barrage ou aux brusques variations hydrologiques en aval du barrage lors des lâchers d'eau.

A Diama amont:

- en 1989, *Corbula trigona* est abondante alors qu'elle était absente de cette zone auparavant.

- en 1991, la persistance de *Corbula trigona* traduit une salinité non négligeable (pénétration d'eau salée en amont).

Vers Maka-Diama, *Corbula trigona* a disparu en 1991 alors qu'elle était encore abondante en 1989. Au-delà, les formes polyhalines et mésohalines sont progressivement remplacées par des formes oligohalines notamment *Melanoides tuberculata* jusqu'àlors absente de cette zone (Monteillet *et al,* 1990; Monteillet *et al,* 1992).

Bilan des modifications dans l'environnement estuarien

Tous ces changements intervenus dans l'environnement estuarien peuvent se résumer ainsi:

- modification de la morphologie du littoral;

- perturbations dans l'hydrodynamique avec des changements brutaux des vitesses de courant, une réduction dans le temps soit du flot du jusant en fonction des ouvertures et fermetures des vannes, une diminution du débit;

- un apport en sédiments dans les zones marginales de l'estuaire lorsque les vannes sont fermées; un lessivage de ces zones avec remise en suspension d'une partie des sédiments dès que l'on ouvre les portes;

- une tendance au colmatage du bief estuarien en amont et en aval du barrage;

- une chute brutale de l'oxygène dissous et du pH au pied du barrage, avec, côté amont, une accumulation des nitrites et des nitrates;

- des quantités très faibles de sels nutritifs dans la partie aval de l'estuaire pendant la saison sèche;

- une biomasse phytoplanctonique peu importante pour une zone estuarienne et qui reflète la pauverté du milieu;

- une modification de la répartition de la faune malacologique;

D'autres observations parallèles ont pu être effectuées sur le terrain. Les plus importantes sont:

- une extension extrêmement rapide de la bilharziose et probablement d'autres maladies liées à la stagnation prolongée des eaux douces, en amont du barrage et plus particulièrement à Richard-Toll;

- une diminution du stock halieutique, les poissons étant arrêtés par le barrage au cours de leur migration (ce qui fait le régal des cormorans, des pélicans, des martins-pêcheurs et autres volatiles abondants dans la région);

- une diminution très nette des activités de pêche et d'élevage (due en partie aux problèmes frontaliers mauritano- sénégalais);

- une quantité importante de nitrates (parfois égale à 100 mg/l) présente dans les nappes phréatiques (Tandia *et al,* 1992).

Conclusions

Le fleuve Sénégal a été, depuis fort longtemps, le cadre d'activités diverses et ceci grâce à des écoulements importants dus à des précipitations abondantes. Depuis maintenant plus de 20 ans, des conditions climatiques particulièrement dures ont entraîné un énorme déficit hydrique dans toute la vallée du fleuve Sénégal et, par conséquent, une dégradation de l'environnement extrêmement préoccupante.

C'est pourquoi, devant un tel état de fait, la construction de deux barrages a été réalisée pour améliorer la gestion de l'eau dans toute la vallée. Or, il est très difficile lorsque l'on construit des infrastructures de satisfaire tous les besoins. Quand il s'agit de barrage en pays sahélien, le problème est encore plus grand puisqu'il faut exploiter au mieux l'eau dans un pays qui en manque cruellement.

Dans le delta du Sénégal, la répartition de l'eau doit se faire en fonction des nécessités telles que: la sauvegarde de l'environnement, l'approvisionnement en eau potable (par le biais du lac de Guiers notamment), l'irrigation des périmètres hydroagricoles, l'amélioration de la pêche et de l'élevage, le développement de la pisciculture.

Tout ceci est vaste et nécessite de nombreuses études avec une concertation approfondie des différents intervenants, ce qui n'est pas toujours le cas. L'environnement, à l'heure actuelle, est une préoccupation à l'échelon mondial, il doit l'être à l'échelon national et c'est grâce à des études multidisciplinaire que nous pourrons mieux comprendre les systèmes dans lesquels nous évoluons.

References

Bâ, M. (1992). Les eaux estuariennes du fleuve Sénégal. Impact des barrages de Diama et Manantali. *Rapport Technique CRDI* n° 89-0074.

Diop, S. & Chevillotte, H. (1992). Etude des modifications intervenues entre le barrage de Diama et l'embouchure du fleuve Sénégal à partir d'images satellitaires. *Rapport CAMPUS.*

Gac, J.Y. (1979). Géochimie du lac Tchad. Bilan de l'altération de l'érosion et de la sédimentation. *Thèse Université Louis Pasteur,* Strasbourg, 249 pp.

Gac, J.Y. (1986). L'invasion marine dans la basse vallée du fleuve Sénégal. *Rev. Hydrobiol. Trop.* 19 (2).

Monteillet, J., Kane, A., Saos, J.L. & Diouf, B. (1990). Environnements sédimentaires du Bas-Sénégal après la mise en eau du barrage de Diama: analyse des particules supérieures à 100 mm. *Rapport Technique* n°4 *"Ateliers conjoints de Recherche sur la "Productivité des Estuaires et Mangroves de l'Afrique de l'Ouest",* COMARAF/UNESCO/PNUD.

Monteillet, J. & Bâ, M. (1992). Evolution de l'environnement sédimentaire du Bas-Sénégal après les barrages de Diama et de Manantali (sédimentologie, macrofaune et microfaune benthiques testacées). *Rapport CAMPUS.*

Pagès, J. (1986). L'environnement d'un estuaire hyperhalin tropical: la Casamance. *Rapport Final EPEEC.* UNESCO, Division des Sciences de la Mer, Dakar: 7-33.

Pritchard, D.W. (1967). What is an estuary: physical viewpoint. In: Estuaries. G.H. Lauff (ef.). *Am. Assoc. Adv. Sci. Publ.* 83: 3-5.

Rüe, O. (1992). Evolution du fleuve Sénégal après la construction du barrage de Diama – Contribution sédimentologique. *Rapport "Atelier de Recherche Conjointe – Estuaire du fleuve Sénégal".* COMARAF "Productivité des Estuaires et Mangroves de l'Afrique de l'Ouest".

Saos, J.L. (1985). Mesures hydrologiques dans le Saloum. *L'estuaire et la mangrove du Sine Saloum, résultats d'un atelier régional Unesco* – Comar, Dakar, du 28 février au 5 mars 1983. UNESCO, Division des Sciences de la Mer. *Rapport sur les Sciences de la Mer* n° 32, Paris: 7-14.

Tandia, A., Sow, M., Bâ, M. (1992). Etude géochimique du système aquifère du delta du fleuve Sénégal. *Rapport Technique "Atelier de Recherche Conjointe- Estuaire du Fleuve Senegal"* COMARAF "Productivite des Estuaires et Mangroves de l'Afrique de l'Ouest".

L'etat actuel des ecosystemes marins cotiers au Cameroun et l'homme

The present state of the marine coastal ecosystem in cameroon and human impact

FOLACK Jean
Centre de Recherches Halieutiques et Océanographiques
PMB 77 Limbe
CAMEROUN

Résumé

Cet exposé est un préliminaire à la connaissance des écosystèmes marines côtiers au Cameroun. Une description de ces écosystèmes est donnée tout en tenant compte des composantes physiques, géologiques, climatologiques, écologiques, biologiques et humaines. Compte tenu de l'impact des activités humaines à partir de l'utilisation des terres littorales et la pollution. Les données sur quelques polluants du milieu marin et chez certains organismes marins sont analysées et montrent que très peu d'études ont été réalisées au Cameroon dans ce domaine. La discussion signale les lacunes sur la connaissance de ces écosystèmes et donne les priorités de recherche à entreprendre tout en souhaitant l'aide internationale et la co-opération régionale.

Abstract

This report is a preliminary on the knowledge of the Marine coastal Ecosystems in Cameroon. A description of these ecosystems is given, taking into consideration the physical, geological, climatological, ecological, and human components. Considering the influence of man on such systems, the report thus analyses the state and impact of human acticities from the utilization of coastal land and pollution. Data on some marine polluants and a few polluants on marine organisms are analysed and show that very little studies have been carried out in Cameroon in this domain. The discussion points out gaps on the understanding of the Cameroon marine coastal ecosystems and gives priority research to be carried out and calls for international support and regional co-operation.

Introduction

Les régions côtières offrent des conditions idéales à toute une gamme d'activités et se prêtent remarquablement à la satisfaction des besoins de l'homme; les plus fortes concentrations humaines se rencontrent dans les agglomérations côtières; plus de 70% des ressources biologiques exploitées proviennent du plateau continental. Ainsi, la mise en valeur et l'aménagement des zones littorales sont partie intégrante du processus de développement d'un très grand nombre de pays.

L'importance de ces zones dans le développement national n'est donc plus à démontrer; en effet, il s'agit des zones soumises à une exploitation intensive et de ce fait assez fragiles vis à vis des aménagements et des exploitations dont ils sont l'object.

Leur gestion a donc des implications multiples vis à vis des activités humaines concernées: échanges commerciaux, pêche et aquaculture, agriculture, industrialisation, navigation et problémes portuaires, urbanisme, santé publique, tourisme et loisir etc... qui sont souvent sources de conflits d'intérêt et de dégradation du milieu naturel.

Les écosystèmes marins côtiers sont très mal connus au Cameroon; il n'y a actuellement au Cameroon que très peu d'études relatives à l'inventaire et à l'exploitation des ressources de la mer, à l'aménagement du littoral et à l'état des environnements côtier et océanique.

Cet article est un préliminaire à la connaissance des caractéristiques des écosystèmes marins côtiers au Cameroun, de leur utilisation par l'homme, dans le but de dégager les priorités pour la recherche scientifique, la co-opération régionale, qui sont des éléments indispensables pour la gesion rationnelle de ces zones côtières.

Caracteristiques

Aspects physiques et géologiques

Le Cameroun est situé au fond du golfe de Guinée, dans la baie de Biafra et s'ouvre sur l'océan Atlantique avec 360 km de côte. Cette côte s'étend depuis la frontière nigérianne (4°40'N) à celle de la Guinée Equatoriale (2°20'N) (Fig.1). De Campo à l'embouchure du Nyong, c'est une côte rocheuse haute avec alternance de baies sableuses et de rochers. Les rivières ont des embouchures banales (Ntem, Nyong), mais deux d'entre elles débouchent sur la mer par des chutes (Lobé, Kienké). Du Nyong à Tiko, il s'agit d'une côte basse marécageuse sans affleurement avec les embouchures des fleuves importants: Sanaga, Wouri, Mungo; dans ces deux portions de la côte, on rencontre deux réserves naturelles: la réserve de Campo et celle de Douala-Edéa.

On retrouve le même type de côte au Nord Ouest à la frontière du Nigeria avec la rivière Akwayafé. Cette configuration favorise la formation d'une végetation de mangrove qui s'étend depuis l'embouchure d'Akwayafé à celle de la Sanage; l'existence de ces nombreux cours d'eau crée plusieurs estuaires.

Climat et hydrologie

Au Cameroun, le climat de la côte est de type équatorial avec une alternance régulière de saisons sèches et de saisons des pluies. La Fig. 2 montre l'évolution annuelle des précipitations des trois principales stations météorologiques côtières: Douala, Tiko et Kribi.

La circulation des eaux est généralement faible, ce qui entraîne un taux de sédimentation élevé; les marées sont de type semi-diurne et atteignent un maximum de 2.70m de hauteur. Du fait de la forte pluviosité et du réseau hydrographique très dense, il existe une couche d'eau superficielle très peu salée ($5 < 25$). Ces eaux typiques de la baie de Biafra ont une température constamment supérieure à 24°C et une épaissur comprise entre 20 et 30m. Ces eaux chaudes reposent sur une couche d'eau profonde froide et salée (Berrit, 1961; Crosnier, 1964). Toutes ces masses d'eau couvrent un plateau continental étroit de 20 miles avec une superficie de 14000 km^2.

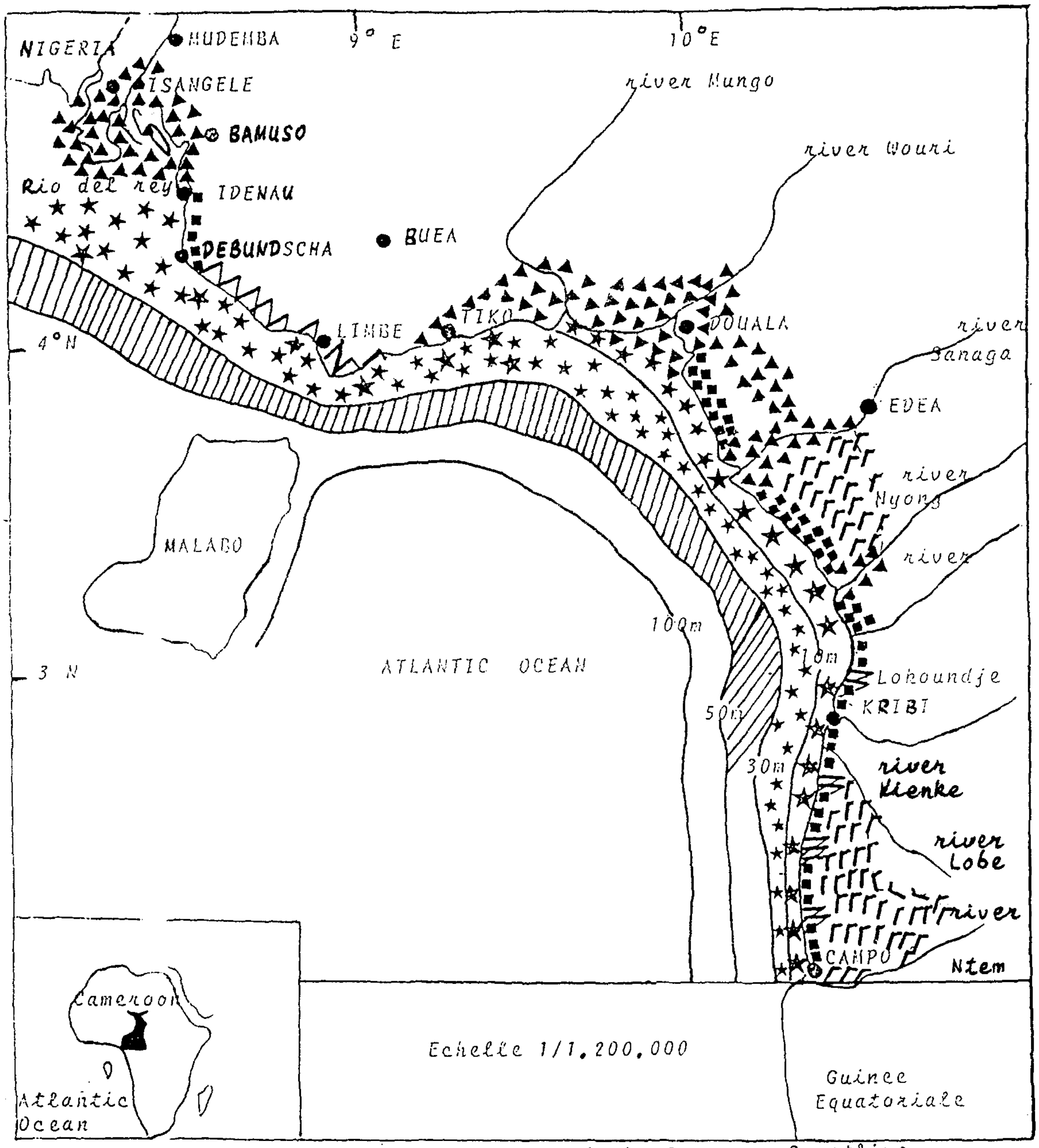


Fig. 1 Characteristies of the Cameroon Coastline.

- Shrimps bottom (Penaeus Duorarum)
- Mangroves
- Natural Reserves
- Sandy Beach
- Rocky Beach
- Fish and shrimps (Parapenaeopsis atlantica)
- Coastal main Town.

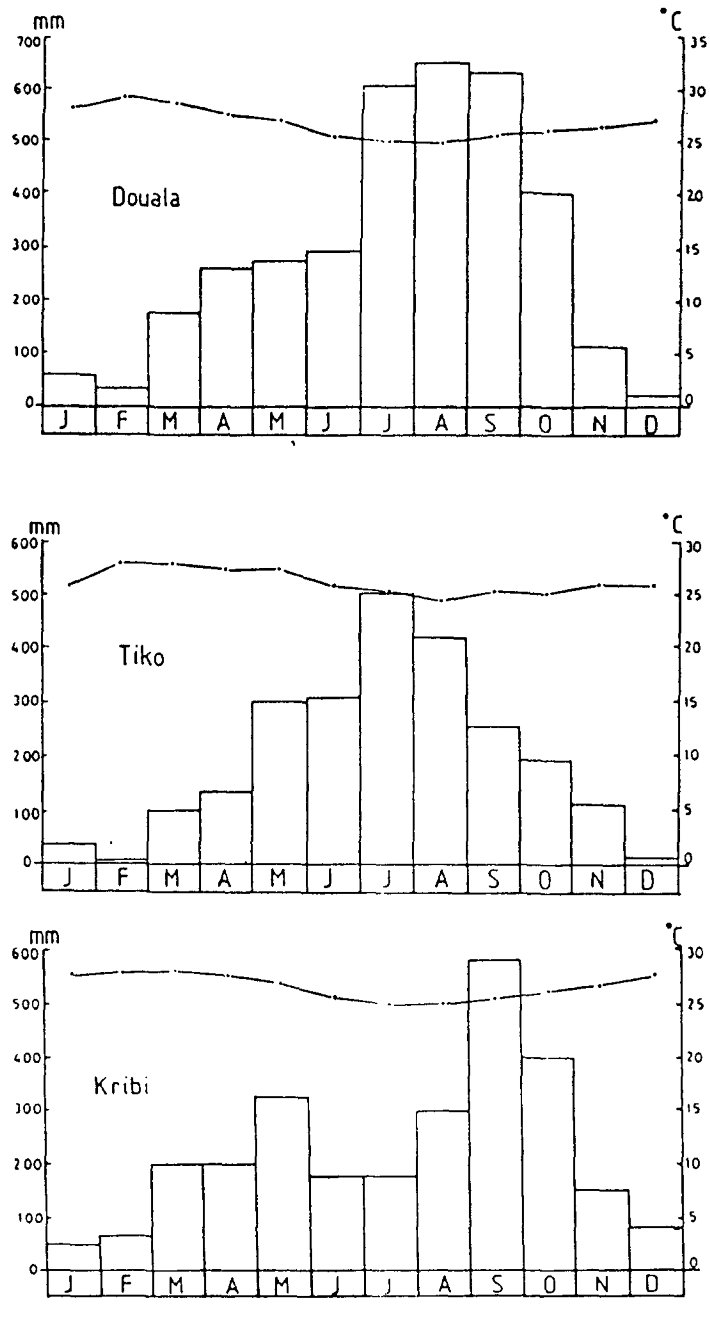


Fig. 2. Annual rainfall (□) and temperature (-.-) of the main coastal stations: Douala, Tiko and Kribi; monthly mean values from 1980 to 1986.

Biologie et écologie

(a) Mangrove

Elle occupe environ 2700 km^2 (Valet, 1987); elle s'étend le long des côtes depuis la frontière avec le Nigéria au Nord Ouest jusqu'à l'embouchure de la Sanaga (Fig.1); la diversité spécifique est faible, comparée aux mangroves asiatiques; dans les trois zones classiques, on observe:

- en zone basse *Rhizophora racemosa* ("red mangrove"), qui est une espèce pionnière et qui peut occuper 95% de la surface; elle atteint ici de grandes tailles.

- en zone intermédiaire inondée, *Rhizophora harrisonii*, *R. mangle* et *Pandanus candelabrum*.

- en zone haute inondée aux marées de vives eaux, *Avicennia* sp. et *Acrosticum aureum*.

La productivité est forte, mais n'a jamais été mesurée, l'exploitation est encore limitée et est très mal connue.

Ces mangroves constituent des zones de reproduction de nombreux poissons tels que *Pomadasys peroteti*, *Tilapia* sp., *Chrysichthys nigrodigitatus*, *Mugil* sp., *Lutjanus* sp., *Ethmalosa fimbrita*, *Cynoglossus* sp. (Youmbi & Djama, 1991).

(b) Algues

Les macroalgues dans l'ensemble ne semblent avoir une biomasse forte que dans les régions froides et tempérées; en zone tropicale, l'abondance décroît pour les températures croissantes; en zone équatoriale, la biomasse est faible. Au Cameroun, les trois étages classiques se retrouvent le long du littoral, malgré une diversité spécifique faible: supralittoral peu fourni; médiolittoral caractérisé par *Cladophora* sp. et *Caulerpa* sp.; infralittoral avec le gentre *Sargassum*.

En ce qui concerne les microalgues, les eaux marines côtières sont très mal connues; Folack (1989) distingue quatre groupes d'algues phytoplanctoniques en fonction de la biomasse (nombre de cellulles), de la diversité spécifique et de la salinité; et constate la dominance des diatomées; les mesures de chlorophylle [a] (Folack, 1988) effectuées respectivement dans la rivière Lobé, dans l'estuaire de la Lobé, dans une lagune côtière de Kribi et dans le milieu marin voisin montrent que la chlorophylle a est deux fois plus élevée dans les eaux continentales comparées aux eaux marines.

(c) Ressources animales

Le Tableau 1 donne la liste des principales ressources animales (espèces de poissons et de crevettes) exploitées au Cameroun actuellement, leur répartition écologique (Crosnier, 1964) est représentée à la Fig 1. Sur une biomasse estimée à 100 milles tonnes, la pêche artisanale maritime est prépondérante et produit entre 30 à 50 milles tonnes par an (Campagne Fridjof Nansen, 1981). Actuellement, la pêche industrielle maritime produit près de 20 milles tonnes par an, chiffre très en baisse, alors que celui de la pêche artisanale maritime est autour de 30 milles tonnes par an. L'exploitation d'autres ressources animales comme les huîtres, les mammifères marins est très mal connue au Cameroun.

Population

Le Cameroun a une superficie de 475000 km^2 et une populatioin d'environ 12 millions d'habitants (chiffre de 1987); la zone côtière qui s'étend sur 360km a une superficie de l'ordre de 7000 km^2 si l'on considère la bande côtière située dans un rayon de 15 à 20 km de la mer; cette partie de la zone côtière compte près de 1.400 millions d'habitants concentrés essentiellement dans certains départements des trois provinces: littoral, sud et sud-Ouest (Tableau 2). La densité moyenne au km^2 est de 200 habitants contre 250 habitants pour l'ensemble du pays; cette baisse de la densité par rapport à la moyenne générale s'explique par le fait que près de 3200 km^2 de la zone littorale sont occupés par la mangrove et les cultures d'exportation.

Table 1. Distribution and ecology of fauna community of Camaroun coastline (fish and shrimps); translated from Crosnier (1964)

FAMILY	SPECIES	Water Characteristics	Nature of the bottom
SCIAENIDES	*Brachydeuterus auritus* *Galeoides decadactylus* *Pseudotolithus typus* *Ilisha africana* *Pteroscion peli*	offshore surface water hot and little salted.	
SCIAENIDES	*P. elongatus* *Arius heudeloti* *Drepane africana* *Pentanemus quinquarius* *Parapenaeopis atlantica* *Palaemon hastatus*	estuary water hot and little salted	light: sandy-mud (6-30m)
SPARIDES	*Dentex angolensis* *D. congolensis* *Paracubiceps le danoisi* *Epinephelus aenus*	under thermocline water, cold and salted	light: muddy sand (40-108m)
LUTJANIDES	*Letrinus atlantica* *Lutjanus dentatus* *Lutjanus goreensis*	base of thermocline	rock: (15-40m)
EURIPATIQUE	*Cynoglossus* spp. *Penaeus duorarum* *Trichiurus lepturus*	thermocline zone	light: muddy and muddy sand (15-100m)

Impact de l'homme

Les industries

La Fig.3 indique la localisation des principales industries dans la zone côtière; nous n'avons tenu compte que de celles dont les rejets sont susceptibles d'atteindre les eaux marines, soit directement ou par l'intermédiaire des cours d'eau. La grande concentration des industries se retrouve à Douala; les autres localités ont à peine une ou deux industries de grande importance; il s'agit de Limbé, Tiko et Edéa.

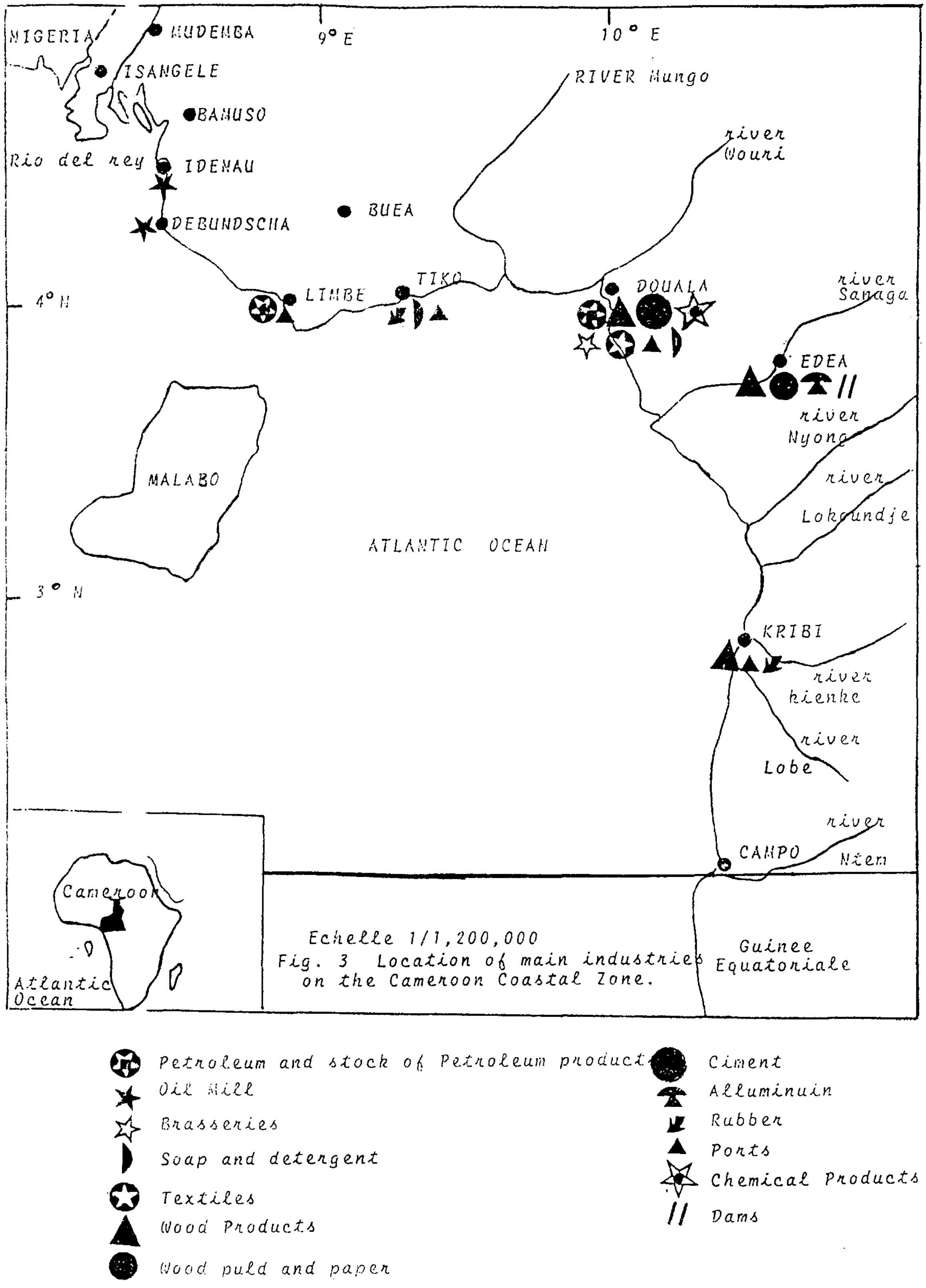


Fig. 3 Location of main industries on the Cameroon Coastal Zone.

La concentration des industries dans une ville a pour conséquence immédiate l'augmentation de sa population, ce qui pose le probléme d'évacuation des déchets provenant des activités humaines en plus de ceux produits par les industries; cet aspect sera développé au paragraphe 3.4.

Dans la catégorie des industries, nous mentionnons le barrage d'Edéa sur la Sanaga et dont le fonctionnement a des effets sur le milieu marin; les activités portuaires (Douala, Limbé, Kribi) apportent des modifications ou perturbations sur la biologie et l'écologie des

Différentes espèces animales et végétales; ceci est bien connu en Europe où les études ont été faites. Au Cameroon, les études font défaut. Actuellement, il y a des projects de création d'un port en eau profonde à Kribi, d'une cimenterie et d'une usine de bitume à Limbé, d'installation d'une zone "franche" industielle sur le littoral.

Table 2. Population of the divisions located at the coastal zone, up to 20km from the sea

PROVINCE	DIVISION	MAIN TOWNS	POPULATION (1987)
Littoral	Wouri	Douala	834.500
	Sanaga Maritime	Edéa	173.000
South	Océan	Kribi Campo	93.000
South West	Fako	Limbe Tiko Buea Idenau Debundsha	248.000
	Ndian	Mudemba Bamusso Ekondo-Titi Isangele Kombo-Abedime	87.500
TOTAL			1.400.000

L'agriculture

Cette zone côtière est dominée par des cultures d'exportation pratiquées par cinq sociétés, qui utilisent plus de 20 milles personnes et une superficie de près de 500 km^2. dont la CDC (Cameroon Development Co-orporation) utilise à elle seule près de 15 milles personnes pour une superficie cultivée de 361, 6 km^2. Le reste se répartit entre la SOCAPALM, PAMOL, HEVECAM et LA FERME SUISSE. Les cultures pratiquées sont: l'hévéa, le palmier à huile et le cocotier, la banane et le thé (Fig.4).

La concentration de ces cultures dans la zone côtière est un indice de la colonisation; en effet, les premiers européens s'installèrent d'abord sur la côte (porte d'entrée au Cameroun); motivés par la fertilité des sols volcaniques des régions du Sud Ouest et du Mungo, ils y ont développé rapidement des cultures que nous voyons aujourd'hui et qui étaient pour eux une source de devise. Cette situation pose aujourd'hui un problème, car avec la poussée démographique et la tendance de créer des industries plus performantes dans les zones côtières, il n'y a plus de terres pour

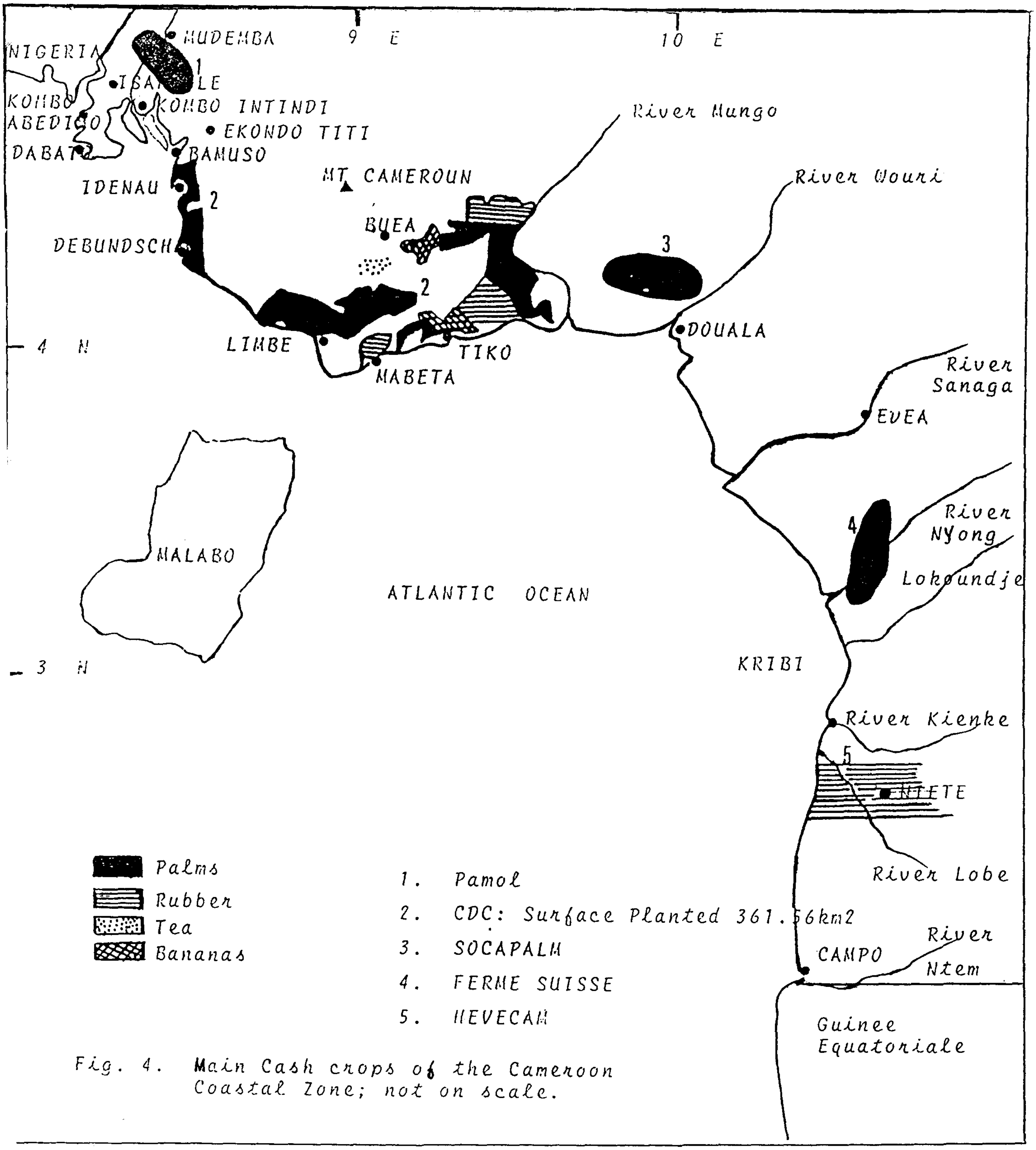


Fig. 4. Main Cash crops of the Cameroon Coastal Zone; not on scale.

construire des habitations, pour pratiquer l'agriculture de subsistence; or ce type d'agriculture joue un rôle important dans les économies traditionnelles en Afrique; la création des industries plus performantes dans ces zones résoudrait en partie le chomage grandissant, d'autant plus que les cultures pratiquées actuellement ont perdu leur valeur sur le marché international; en effet les produits obtenus sont fortement concurrencés par ceux venant d'Asie; cette occupation par les cultures empêche également des aménagements touristiques, source de devise de la plupart des pays côtiers; ceci est surtout très marqué dans le Sud Ouest (Tiko, Limbe, Idenau).

Dans la régionde Kribi, la situation est moins préoccupante, l'introduction de la culture du caoutchouc (hévéa) dans la région de Niete près de Kribi est très récente; le tourisme est assez développé dans cette région.

La pêche et l'aquaculture

Il s'agit essentiellement de la pêche artisanale maritime; c'est la plus grande activité humaine qui se déroule entre la mer et la côte si on exclue les exploitations pétrolières; les acteurs de cette pêche ou pêcheurs vivent dans de petits villages littoraux appelés campements; la pêche se déroule en mer, dans les cricks, les estuaires et les mangroves.

Pour connaître la structure de cette pêche, la côte a été divisée en cinq régions statistiques (Fig.5) qui sont du Nord au Sud: le Ndian, le Fako, le Wouri, la Sanaga maritime et l'océan. Les données statistiques collectées par la station de recherches halieutiques de Limbé sont indiquées au Tableau 3; on compte plus de 18 milles pêcheurs dont 91% sont des étrangers, notamment les Nigérians, les Ghanéens, les Beninois et les Equatoguinéens par ordre d'importance. Cette pêche utilise plus de 6 milles pirogues dont la moitié est motorisée; ces pêcheurs sont des principaux destructeurs de la forêt de mangrove pour la recherche de l'espace pour les habitations, pour le bois de chauffage, de fumage et de construction etc.... Cette destruction est anarchique, non controlée; l'activité de la pêche a donc une influence certaine sur le fonctionnement des écosystèmes marins côtiers.

Quant à l'aquaculture, aucune activité n'est pratiquée dans ce domaine sur le littoral camerounais; pourtant, des potentialités énormes existent dans ce domaine au Cameroun; c'est le cas de la mangrove de Tiko où l'aquaculture en cage peut être pratiquée, et où il y a d'énormes possibilités d'élevage des huîtres de palétuviers; un exemple de l'utilisation de la mangrove pour la crevetticulture est donné au Sénégal (Couteaux, 1986). La région de Kribi est propice à la crevetticulture (Folack, 1988, 1989).

La pollution

(a) Déchets d'origine humaine et industrielle

On peut être en droit de penser qu'il n'y a aucun risque de pollution du milieu marin côtier au Cameroun, car l'activité industrielle y est réduite, la densité de population faible vu l'importance de la longueur de la côte; mais ceci est sans compter que les industries se développent rapidement et se concentrent dans des espaces réduits et surpeuplés; c'est le cas de Douala et Limbe (Victoria) où la pollutioin d'origine humaine et industrielle est signalée par Portmann *et al* (1989).

Ce type de pollution est difficile à étudier et à évaluer car est généralement constitué d'un mélange de polluants; on l'évalue souvent en terme de matière organique oxydable (DBO) et de matière en suspension (MES). Portmann *et al* (1989) estiment en terme de DBO_5 pour les villes de

Douala et Victoria, respectivement 12427 et 794 tonnes par an la pollution déversée dans le milieu marin par la population; en terme de matière en suspension, les chiffres sont respectivement de 17673 et 1129 tonnes par an pour ces dex agglomérations; pour ces mêmes auteurs, la pollution déversée par les industries locales est estimée à 2187 tonnes par an en terme de DBO_5 et de 4800 tonnes par an en termes de MES pour la seule ville de Douala.

Table 3. Structure of marine artisanal fisheries in Cameroon (1) Njock (1985) (2) Scet-International (1980)

REGION	Number of camps (1)	Number of canoes (1)	Number of fishermen (1)	Production in tonnes (2)
Ndian	12	4.256	14.254	26.400
Fako	22	432	1.172	6.600
Wouri	8	888	2.030	12.650
Sanaga	5	233	825	7.150
Maritime Océan	10	202	334	2.200
TOTAL	57	6.011	18.615	55.000

Dans les campements de pêche, les risques de pollution d'origine humaine ne sont pas négligeables; en effet, dans ces campements, les habitations sont dépourvues de toilettes et le niveau d'hygiène y est très peu élevé, puisqu'il est d'usage d'utiliser les plages et les voies d'eau à l'air libre comme toilette, ceci est grave, particulièrement dans les baies fermées, les lagunes et les cricks où la circulation des eaux est généralement faible; les données nous font défaut pour apprécier cet impact sur le milieu marin au Cameroun; mais au Ghana, Biney (comm.pers.) signale que sur 16 lagunes côtières étudiées, 12 sont polluées et deux d'entre elles le sont fortement (lagune de Korle et de Chemu).

(b) Les hydrocarbures

Le Cameroun est producteur de pétrole (forage marin) et possède une raffinerie de pétrole située à Limbé; de plus le golfe de guinée se trouve sur la route des pétroliers qui transportent des gisements de pétrole du Moyen Orient vers l'Europe; ainsi par le jeu des courants et des vents, le pétrole qu'ils déversent en mer lors de déballastage risque d'être rejeté sur nos plages. C'est ainsi que Okonya et Ibe (1985) ont trouvé au Nigeria des concentrations des boules de goudron variant de 11.6 à 96.2 $g.m^{-2}$ sur les plages de Badagary, localié très éloignée de la raffinerie de pétrole, ce qui confirme l'importance jouée par les courants et les vents dans la dispersion des produits pétroliers dans le milieu marin.

Tableau 4 donne la moyenne mensuelle des boules de goudron échantillonnées dans trois sites de la région de Limbé: Bota, Essongo, Débundscha, situés respectivement à 2 km, 20 km et 30 km de la raffinerie de pétrole; les chiffres relevés à Bota sont très voisins de ceux annoncés par Biney (1982) au Ghana (30 $g.m.^{-2}$) et faibles comparés à ceux de Okonya et Ibe (1985); le déballastage des bateaux de pêche, le nettoyage des moteurs de pirogues des pêcheurs sont autant d'élements susceptibles de polluer aussi le millieu marin côtier.

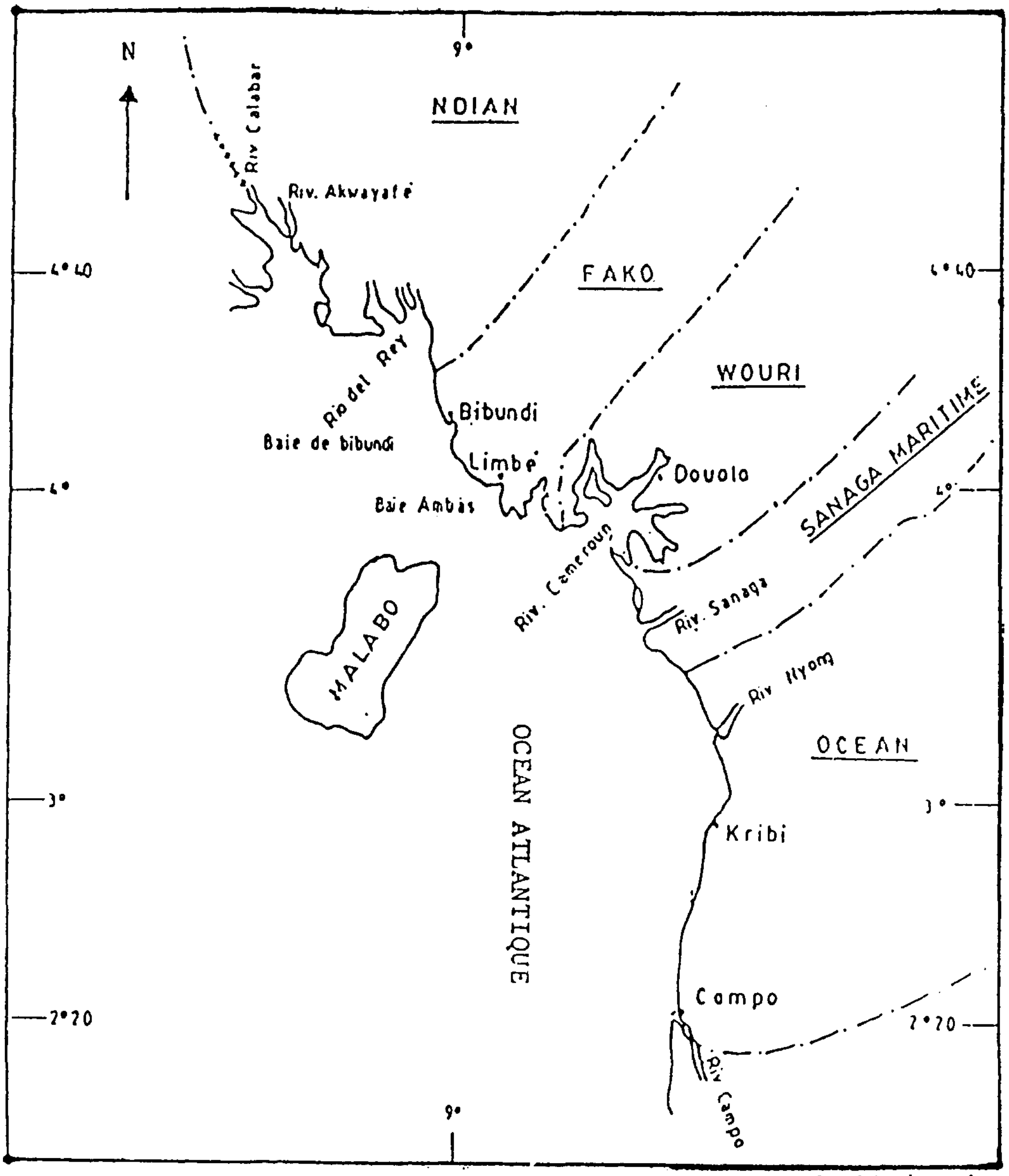


Fig. 5. Survey regions for marine artisanal fisheries in Cameroon.

Table 4. Sampling of tar balls ($g.m^{-2}$); monthly mean values from February 1984 to February 1985; data collected by Ikome (1986).

LOCATION	Seashore Surface	Length of Shorefront	Weight ($g.m^{-2}$)
Bota	rock slabs	75m	42.40
Essongo	fine sand	400m	4.40
Debundsha	coarse sand	175m	3.70

(c) Métaux

Le Tableau 5 indique des concentrations des métaux à l'état de traces relevés dans les diverses espèces d'eaux marines au Cameroun; ainsi Mbome *et al* (1985) trouvent des concentrations de mercure de l'ordre de 0,033 à 0,12 $mg.kg^{-1}$ dans les poissons des eaux côtières de Limbé et de Douala; chez les huîtres et les crevettes récoltées à Mabeta(près de Tiko), ces concentrations sont de l'ordre de 0,061 et 0,057 $mg.kg^{-1}$ respectivement; pour le cadmium, les concentrations sont supérieures à 0,1 $mg.kg^{-1}$ chez les crustacés et sont comprises entre 0,1 et 0,3 $mg.kg^{-1}$ chez les poissons.

Table 5. Levels of metal in some marine organisms ($mg.Kg^{-1}$).
1: Mbome *et al.* (1985); 2: Angwe (1987)

ORGANISMS	Mg	Cd	Zn	Cu	Fe	Mn
Oysters [1]	0.061	0.057	-	-	-	-
Shrimps [1]	0.057	0.100	-	-	-	-
Fish [1]	0.04-0.12	0.1-0.3	-	-	-	-
Scombromus tritor [2]	-	-	0.05	0.03	2.08	0.50
Caranx senegalensis [2]	-	-	0.03	-	8.72	0.16
Pseudotolithus typus [2]	-	-	0.25	2.20	-	-
P. senegalensis [2]	-	-	0.23	0.39	-	-
P. elongatus [2]	-	-	0.28	0.47	-	-
Ethmalosa fimbriata [2]	-	-	0.26	0.42	-	-
Sphyraena piscatorium [2]	-	-	0.45	0.32	-	-

Les concentrations de Zinc et de Cuivre sont analysées par Angwe (1987) chez 7 espèces de poissons les plus consommés au Cameroun (Tableau 5). Cet auteur signale aussi la présence de quelques métaux traces comme le fer, le manganèse; mais ces données restent insuffisantes pour apporter un jugement crédible sur l'état de la pollution des organismes marins au Cameroun; ces résultats indiquent néanmoins que le niveau de pollution au Cameroun est comparable à celui rencontré dans le milieu marin de la région de l'Afrique de l'Ouest et du Centre et ne révèlent pas de contamination grave.

(d) Biocides

Il s'agit essentiellement des pesticides (insecticides, fongicides, nématocides, raticides, etc..) et des herbicides largement utilisés pour lutter contre les vecteurs des maladies des plantes et les mauvaises herbes dans les plantations décrites au paragraphe 3.2. Au Cameroun, les organochlorés sont les plus utilisés: l'aldrine, la dieldrine, le chlordane, et les organophosphosrés: malathion, parathion, fenthion et les carbamates. Tous ces produits atteignent le milieu marin généralement par voie atmosphérique et par ruissellement(eaux de pluie, cours d'eau).

Les études dans ce domaine font défaut; il ne nous a pas été possible d'entrer en possession des quantitées de biocides utilisées actuellement dans la zone côtière; cependant, certains résultats obtenus par Faulkner (1985) dans l'estuaire de la Sierra-Leone montrent que les concentrations des pesticides trouvées dans les poissons ne sont pas élevées et ne posent aucune inquiétude pour la consommation.

Discussion et conclusion

Nous constatons que l'action de l'homme sur les écosystèmes marins côtiers au Cameroun s'exerce à partir des activiés agricoles, industrielle, la pêche et des populations elle-mêmes. Ces activités entraînent une concentration de la population dans des endroits très localisés (villes, campements). Cette utilisation de la zone côtière introduit des grands changements: modification du bébit des cours d'eau par la construction des barrages, intensification du phénomène d'érosion par la destruction de la couverture végétable, création des installatioins portuaires qui augmentent la quantité de matières solides en suspension.

Cependant, l'activité industrielle est encore réduite au Cameroun et les effects sur le milieu marin ne sont pas encore à craindre à court terme; mais si le projet de création d'une zone "franche" industrielle dans la zone littorale se concrétise, le problème serait à prendre au sérieux.

Cet exposé nous a montré qu'il existe de nombreuses lacunes aussi bien dans la connaissance des écosystèmes marins côtiers que de celle des impacts de l'homme sur ces systèmes: c'est ainsi que nous ne connaissons pas les processus écologiques majeurs qui maintiennent ou qui modifient ces systèmes; comment les organismes réagissent entre eux et vis à vis des facteurs du milieu? Quel est l'apport en terme quantitatif et qualitatif des cours d'eau et des forêts littorales (mangroves) au milieu marin? Quel rôle joue la faune terrestre dans ces écosystèmes et ses relations avec la faune marin? Quel est le cycle biologique, la répartition spatio-temporelle des espèces animales et végétales responsables du phénomène de "fouling"? Ceci est fondamentale pour assurer le bon fonctionnement des installatons d'une industrie portuaire. Quelle est la quantité de déchets organiques déversés en mer par jour et par habitant dans la ville de Douala? Ce sont autant de lacunes dont seule la recherche peut nous permettre de combler.

Il s'agira en fait de mener des **recherches prioritaires** notamment:

- l'étude de la mangrove: répartition, identification des espèces, biomasse, cartographie, production, relation sol végétation, échanges avec le milieu marin, utilisation, destruction, conservation.
- l'étude des facteurs physiques et chimiques des eaux, des unités géomorphologiques, de la courantologie, de l'érosion, et des phénomènes d'échange océan-estuaire-continent.
- l'étude de la faune macro et micro: inventaire, répartition et migration, reproduction, croissance recrutement, écologie et potentialités aquacoles, écologie du plancton.
- l'étude des activités économiques et traditionnelles: pêche, agriculture, phénomènes anthropiques: barrages, forages, pression des activités économiques et traditionnelles.

- l'étude de l'environnement: dégradation naturelle et anthropique, aménagement et conservation; pollution domestique: rejets d'égouts à base de matière organique; pollution chimique: hydrocarbures, biocides, métaux lourds, matière organique non domestique; pollution mécanique: aménagements des zones côtières (ports): boues industrielles, déchets solides (remblais).

Le Cameroun offre d'énormes possibilités de co-opération dans le domaine de la recherceche sur les sciences de la mer; le site de Tiko a été visité par les experts de l'UNESCO qui ont souchaité y voir installer un laboratoire régional sur l'étude des mangroves et des estuaires; le Cameroun participe activement au projet Comaraf et a déjà organisé avec succès deux ateliers dans le cadre des activités de ce projet; les écosystemes marins côtiers de la région du golfe de guinée présentent beaucoup de caractéristiques communes: même stock halieutique, existence de nombreux estuaires, de mangrove. Ceci est un indicateur important pour une co-opération régionale entre les pays de la région; il y aura donc des possibilités de standardiser les méthodes et les techniques d'études, d'harmoniser la réglémentation dans le domaine de l'exploitation, d'échange des scientifiques etc... Une telle co-opération ne peut aboutir que si les pays de la régiion et les organismes du système des nations unies apportent leur support aux chercheurs de la région.

Bibliographie

Angwe, C.A. (1987). Level of Zinc and Copper in five species of fish from Ambas bay: a preliminary survey. *Rev sci. et tech. ser. sci. agron.*, 3(2): 167-172.

Angwe, C.A. (1987). Protein composition and some trace metals in *Scomberomus tritor* and *Caranx senegalensis* at Batoke Cameroon. *Rev. sci. et tech., ser. sci. agron.* 3 (2): 161-165

Biney, C.A. (1982). Preliminary survey on the state of pollution of the coastal environment of Ghana. *Oceanol. Acta, 4 supp vol. special*: 39- 43

Berrit, G.R. (1961). Contribution à la connaissance des variations saisonnières dans le Golfe de Guinée. *Cah. Océanogr. Orstom,* 13 (10): 715.715 and 14 (9):633-643

Couteaux, B. (1986). Crevetticulture en Casamance. Acte du séminaire tenu à Ziguinchor du 19 au 24 juin 1986 sur l'estuaire de la Casamance: environnement, pêche, socio-économie CRODT: 257-268.

Crosnier, A 81964). Fonds de pêche le long des côtes de la Republique fédérale du Cameroun. *Cah. Orstom, ser; Océanogr. n° spécial* 132.

Faulkner, D.F (1985). Analysis of pesticides in fish from the Sierra Leone estuary. Rome FAO *WACAF 2 Newsl* 2 (4): 6.

Folack, J. (1988). Estimation et dégradation de la chlorophylle [a] dans une zone crevetticole: Kribi, Cameroun (golfe de guinée). *Cam. J. Biol. Biochem. Sc.* 1 (2): 35-43.

Folack, J. (1989). Etude préliminaire du phytoplancton d'une zone côtière d'exploitation crevetticole (Kribi-Cameroun, Golfe de Guinée, Atlantique Centre Est. *Cam J. Biol. Biochem. SC. 2(1)*: 51-65.

Ikome, E.F. (1985). The levels of pollution due to hydrocarbons on some beaches of the Cameroun West coast: a preliminary survey. *Rev. sci. et tech. ser. zootech. 2(4)*: 81-83.

Mbome, I.L. *et al* (1985). Analyses of heavy metals in fish from the coastal waters of Limbe and Douala (Cameroon). Rome, FAO *WACAF 2 Newsl* 2(4):4.

Njock, J.C. (1985). Repertoire des centres de débarquement de la pêche artisanale maritime camerounaise. Rapp Ann. Station de Recherches Halieutiques de Limbe 1984/1985: 1-55.

Okonya, E.C. & Ibe, A.C. (1985). Tar balls survey on Badagary beach, Nigeria. Rome, FAO *WACAF 2 Newsl* 2 (4): 7.

Portmann, J.E. *et al* (1989). Etat du milieu marin: région de l'Afrique de l'Ouest et deCentre. PNUE, *Rapp. et Etudes de mers régionales* n° 108.

Scet:Internations (1980). Etude régionale sur la pêche maritime dans le golfe de guinée: la pêche maritime au Cameroun, diagnostic et perspective. CEE/FED: 95pp.

Valet, G (1987). Les macrophytes de côtes du Cameroun, *Rapp. tech. n° 1 Comaraf*: 10-11.

Youmbi, T.J. & Djama, T. (1991). Faune ichthyologique de la mangrove de Tiko: composition, écologie et leurs implications sur l'aménagement et l'aquaculture. *Rapp. tech. atelier de recherche sur l'étude pluri-disciplinaire de l'écosystème de Bimbia*. Comaraf, Cameroun, 2-7 décembre 1990: 23-29.

Review on selected marine living resources of Zanzibar: status and issues for conservation

JIDDAWI N.S. & MUHANDO C.A
Institute of Marine Sciences
P.O.Box 668 Zanzibar
TANZANIA

Abstract

The marine environment has always been an area of interest to Zanzibar in view of the significant role it plays in the socio-economic development of the country. However, little attention has been paid in the past to understanding this environment, its role and the interactions that constitute the marine ecosystem. Additionally, the effect of development inland to the coastal environment was not thought to be of great concern to the coastal areas.

The dependence on the ocean and its resources in Zanzibar has increased several fold in recent years as the demand for fish and ocean activities (seaweed farming) is increasing as a result of an expanding human population. Continuous examination of the relationship between man and the marine environment and its resources (human impact) is clearly needed to avoid the risk of depletion and damage. In the past the sea was generally seen as a source of unlimited resources and not likely to be affected in any way. Recent events have raised greater awareness of the delicate nature of the coastal environment and the need for an integrated coastal resources management plan that stresses sustainable development and integrates multi-sectoral planning to enable Zanzibaris to live wisely with the sea.

This presentation attempts to review some of the important problems facing both the exploited marine living resources and their environment. It will recommend actions to be taken so that viable production, management and conservation strategies can be set and implemented.

Introduction

Marine living resources are of vital importance to man, but with present day technological advancement and the increasing human population, exploitation of these resources is increasing at an alarming rate. In order to enhance and protect these valuable resources there is a need to establish a framework for effective management and utilisation of these resources on a sustainable basis.

Zanzibar (Fig.1) possesses a variety of marine living resources which are of great potential for its socio-economic development. The ocean is an important source of income. More than 20,000 people depend directly on fisheries as their main activity and 6,000 people offer supporting services such as boat builders and basket trap makers. Currently with the tourist boom and the increase in seaweed farming activities, more people are involved with the ocean as tour guides to coral reefs and sport fishing areas, seaweed farmers etc. Although at present the percentage contribution of the marine resources to the economy of the country is small (4-10% of the total GDP), the fisheries component provides the main source of protein for the island; the per capita consumption of fish per annum is between 20-30kg. Owing to the increasing reliance on the sea therefore, there is a need to continuously examine the relationship between humans and the

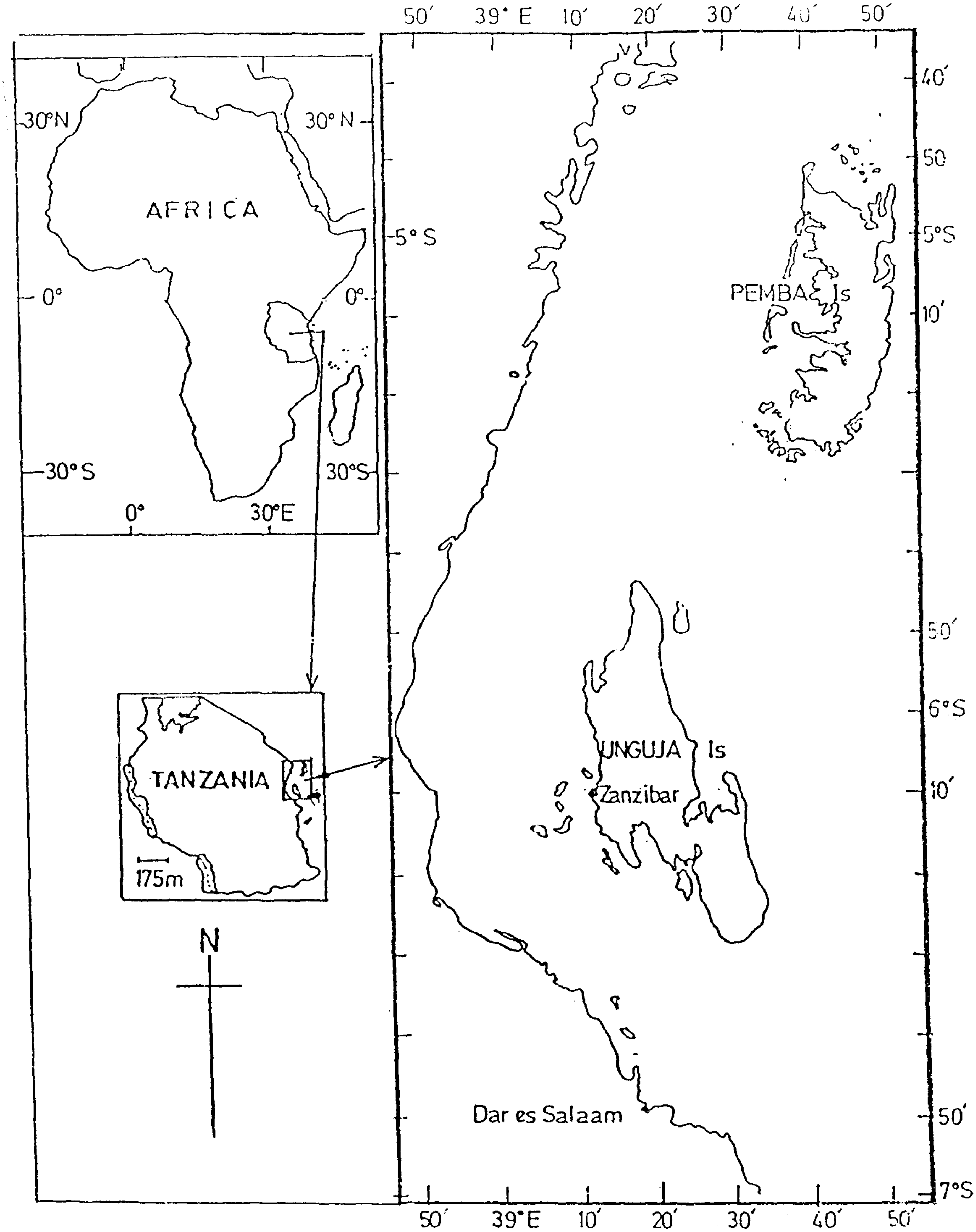


Fig.1. Position of Zanzibar (Unguja & Pemba)

marine environment. Experience on land has shown that man is capable of systematically destroying an environment on which he depend by directly exploiting the natural resources to the point of extinction.

This report is an attempt to present the dangers confronted by marine living resources through resource exploitation by human and recommendations to conserve and utilise them in a sustainable way are suggested.

General problems facing the resources:

1. The resources are a common property. Due to increasing demand, there is overcrowding in localised areas where harvesting is done without control which can lead to over exploitation.
2. Some of the harvesting methods used are destructive.
3. The resource abundance in our waters is not known. This presents a specific problem in fishery planning since there is no scientific information on which to base plans.
4. There is very little knowledge on the biology of marine species to base their conservation.
5. Lack of trained personnel, equipment and funds to carry out the necessary studies on the resources.
6. Unwillingness by some local fishermen to change and try new, better and efficient fishing gears and technology due to ignorance or avoiding expenses.
7. Unawareness of the fishermen of what they are doing (lack of education).
8. Lack of enforcement of the existing laws, most of which are not known to the public.
9. Until early 1990 there had been no specific national policy and clear institutional responsibility for the conservation of marine species. The Commission for Lands and Environment was established in 1988 and the environmental policies were formulated in 1991.

Information on resources and corresponding problems

Fin fish.

The marine fish catches of Zanzibar and Pemba are in the order of between 7000-20000 tons per year, 90% of which is from artisanal fishermen who fish mainly in inshore waters. There is no reliable quantitative estimate of the resources in the artisanal fishing grounds. It is believed that this area is more productive than the offshore areas. The only resource surveys carried out in the area were by the research vessels RV "Dr Fridtjof Nansen" and "Prof. Mesyatsev" in the eighties which did not fully cover the artisanal fishing areas. Statistics from the Fisheries Department and interviews with fishermen indicate that this catch has been decreasing over the past few years (Fig.2 & 3) (Jiddawi *et al*,1989). The fisheries of Zanzibar was described by Tarbit (1984) as already approaching the upper limit of exploitation while Boerema (1981) reported that demersal fish were heavily exploited. Also Horrill (1992a,b) has observed a decline in reef fishes by the small Islands and reefs near Fumba and the west coast of Zanzibar. Probably lack of advancement in the fishermens traditional fishing vessels and gears has caused over exploitation of the inshore resources. The most common fishing vessel in use is the Outrigger canoe (Ngalawa) using oars or sail for propulsion. The deep sea resources are yet to be discovered and utilized accordingly.

The policy of the Zanzibar Government on fisheries is to develop this sector by increasing fisheries production, raising the income of the people and increasing export earnings. In doing sc it has introduced incentives such as tax free importation of engines and gears as well as soft loans to people (Zanzibar Fisheries Policy, 1985). This has created overcrowding of fishermen in the fishing areas and the catches have not increased as was anticipated. For example in the small pelagic fishery for sardines and mackerel in Zanzibar, the increase in the number of vessels operating on the same fishing grounds is thought to have caused a reduction in catches. The Zanzibar Fisheries Co-operation (ZAFICO) fishing in the same areas have been experiencing reduced catches in the past three years (Table 1).

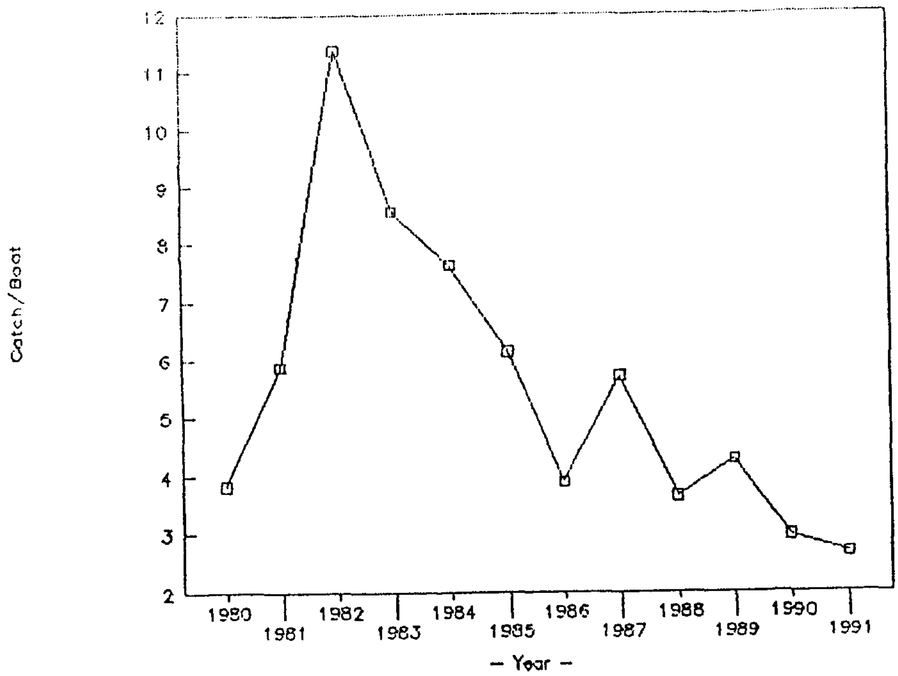


Fig. 2. Catch per boat – Zanibar Fishery 1980 – 1991.

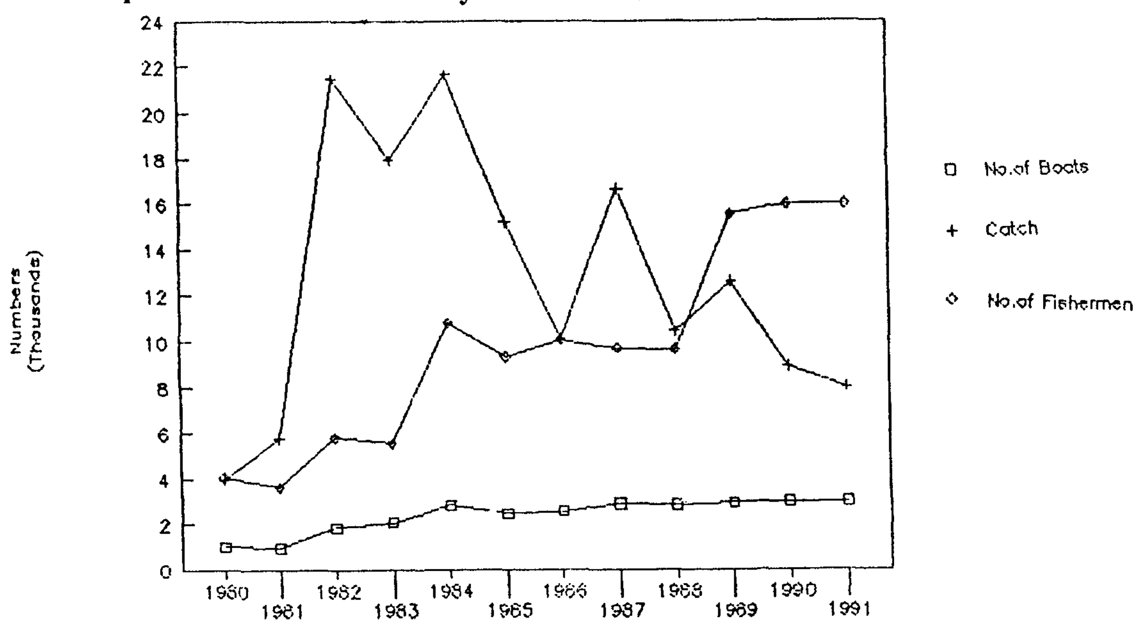


Fig. 3. Catch (ton), No. of boats, No. of Fishermen for Zanzibar Fishery 1980 – 1991.

Table 1. Annual landings and Value ZAFICO 1981-1991

YEAR	Catch (mt)	Value (T.Sh.)
1981	256.5	1.25
1982	242.6	1.56
1983	147.7	1.39
1984	89.5	1.37
1985	287.8	2.63
1986	458.8	8.16
1987	627.0	12.51
1988	567.8	13.56
1989	360.8	13.23
1990	254.9	12.62
1991	236.0	11.97

Some details on destructive fishing methods

The demand for fisheries resources has been increasing over time but not much effort has been made in either modifying fishing gears or discovering alternative fishing grounds. The introduction of destructive fishing methods probably emanates from the need by the fishermen to increase their total catch in as short time as possible in the already overpopulated /overexploited fishing grounds. Theïr is a lack of convenient fishing gears in the markets and poor economic conditions. There is also ignorance of the environmental damage caused by the use of these gears and the laws or regulations governing the fishery in Zanzibar. Also the difficulty of exploiting coral reef resources.

The use of such destructive fishing techniques often leads to indiscriminate destruction of the breeding and nursery grounds of fish thus reducing recruitment potential of fish to the fishery. The following are some of the destructive methods used in Zanzibar.

(a) Dynamite fishing

This kind of fishing method is banned in Zanzibar. However some evidence on coral reef damage by dynamite has been observed north west of Pemba (IUCN/RSRP,1989), and Horrill (1992c) has observed similar type of damage in Pungume and in the Islands south of Fumba. Ecological damage by dynamiting has resulted in reduced fish production in mainland Tanzania, thus adversely affecting fishery and other marine living organisms and the coral reef structure (Bryceson, 1990; Shunula *et al*, 1989).

(b) Juya la Kojani

The coral reefs are crushed and escaping fish are led by divers to the already set surrounding net. This method of fishing is called "Juya la Kojani" and the name stems from the fishermen who originate from Kojani, a small Island in Pemba. The fishing technique is very destructive to coral habitat and therefore directly or indirectly causes adverse conditions to coral resources. There is some evidence in the islands south of Fumba which indicate that the area has been adversely affected by this method of fishery resulting in reduction of fish catches (Horrill, 1992 b)

(c) Spear and harpoon (wounding gear) fishery

Spears and harpoons have been used in catching octopus, lobsters and coral fishes for quite a long time. This type of fishery ranks number three in importance in Zanzibar (Fig. 4) (Hoekstra *et al*, 1990) and number one in the East coast of Zanzibar. Some fishing villages have already noted the reduction of these resources and are trying to enforce closed season/area regulations eg Jambiani and Makunduchi villages. The use of spears and harpoons are banned in mainland fresh-water fisheries due to its destructive nature. Spear-fishing has also been banned in most countries of the south west Indian Ocean (Bryceson *et al*, 1990). Alternative fishing gears (e.g lobster pots currently used in Japan) need to be introduced.

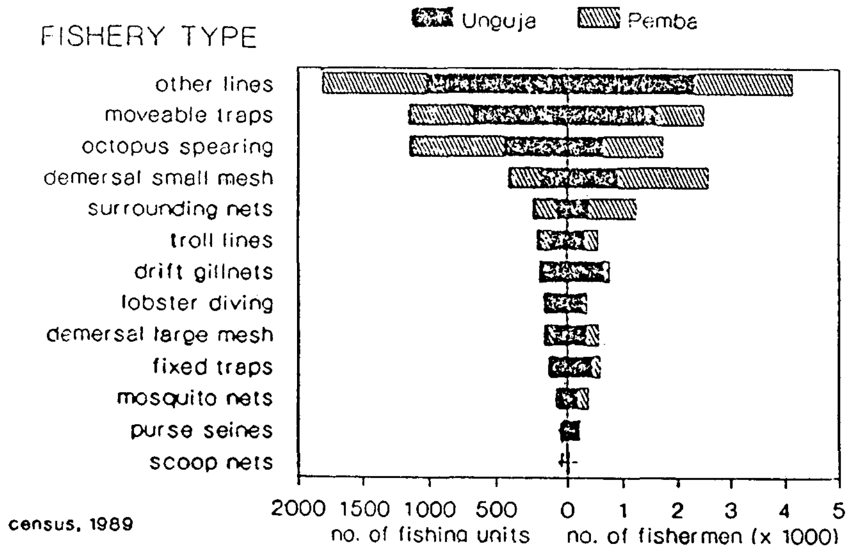


Fig. 4. Number of fishing units and fishermen on Unguja and Pemba by fishery type.

(d) Use of poison

There are some reports that poison fishing is taking place in some parts of Zanzibar. Locally it is referred to as "Utupa". In Kisakasaka village, south of Unguja Island the poison believed to be used there is called "Ngwira". These traditional poisons are mainly of plant origin. The most commonly applied method is the dumping of the crushed plant material in coral crevices and pools of water to kill the fish. This method was also used in Matemwe but the villagers have banned it now after noting its adverse effects.

(e) Beach seine

Beach seining is known to damage reefs (IUCN/RSRP, 1989) because it is principally used too close to the shore and makes use of small mesh size nets. Research on catches from a beach seine along the intertidal area in front of IMS has been undertaken and this has indicated the presence of 47 juvenile commercial species. *Gerres* sp. and *Siganus* sp. were the most abundant juvenile fish observed. In Zanzibar beach seining is prohibited on the habitable islands, but is allowed on the unhabitable islands and banks (Ngoile, 1982). However beach seining is still observed to be practiced in many areas of Zanzibar including the town beaches.

(f) Mosquito net fishery

Mosquito-net fishing ranks number eleven among the fishery types practiced in Zanzibar in terms of number of people engaged in this fishery (Fig.4), (Hoekstra *et al*, 1990). This is a fishing technique mostly carried out by women. The fishery normally takes place in the intertidal areas during low tides. These are important breeding and nursery grounds of fish. The type of net used is normally a big piece of cloth, about 6-15m in length and 2-3m in height. The mesh size of this net, normally is very small or almost absent. The catch always comprises a majority of small fish. In a two months research at IMS in Nungwi village, North of Zanzibar about 17 genera of fish were observed mostly comprising juvenile fish.

Crustaceans, Holothurians and Mollusc Fishery.

Crustacea fishery in Zanzibar is on a small scale level. Spiny lobster are the only crustacea commercially exploited in Zanzibar island. The catch finds its way to tourist hotels and some exported abroad. With the tourist boom the demand of these resources has increased tremendously. A plate of lobster or prawns in a hotel can now cost up to $10. There is no data on population levels of this resource and the fishery needs to be closely monitored to ensure sustainable yields.

All types of mollusc are a delicacy among the coastal people of Zanzibar. They have been used since ages past for different purposes. Although no statistics are available the harvest is undoubtedly significant. The most popular edible gastropods and bivalves on the Islands are the *Strombus* species (Chuale) and *Pinctada* species (Chaza) respectively. Octopus is also very popular.

With the tourist boom a lot of ornamental shells such as tiger cowries, helmet shells, lambis, cones and spider shells are collected from the coral reefs for sale. Some rare shells e.g the green snail (Mba mwezi) can fetch up to $8 per piece. A lot of small curio shops have sprung up on the East coast, which is a zone earmarked for the development of tourism. Some rock shells such as *Checoreus gramosus* are exploited for their operculum which fetches high prices in the middle East (up to $50 per kg). Uncontrolled harvesting could lead to a reduction in species e.g In Kenya large colorful species of gastropods are now scarce on the more accessible parts of the coral reefs (Evans *et al*, 1977) and a similar situation occurred in the Seychelles (Salm, 1978). Halsted *et al*, (1982) reported the existence of 51 species of cowries in the islands. No new studies have been done since then.

Zanzibar waters are fairly rich with sea cucumbers. Ten commercially valuable species are known to exist in the coast of Tanzania (SWIOP Doc, 1985). These are collected by hand on the reef flats at low tide, and by diving with home made masks in water up to 10 meters deep. Operations have increased with the introduction of the SCUBA diving techniques. All the harvest is processed for export to the Oriental market (mostly Hong Kong). Prices paid depend very much on preferences for certain species. Some statistics are kept of the export of the dried product (Table 2), but there are no details as to which species are exported, the origin of the catch, or the time interval involved, so it is very difficult to interpret these statistics in a useful biological perspective. There are no regulations on the harvesting of sea cucumbers, and the harvest appears to be regulated primarily by demand from exporters, local tide and weather conditions, and local customs such as festivals when harvesting is suspended.

The sea cucumber fishery has seldom been subjected to scientific study, or formal management anywhere in the world, and so it is a poorly-understood resource in tropical countries. In Zanzibar it is of concern for two reasons. It represents a significant source of monetary income for many local people, and the exploitation of this resource will almost certainly have some impacts on the overall intertidal and subtitle coastal marine community. Without any regulations governing the operation of this fishery, and in the absence of any data to judge the status of the fishery, it can only move towards increasing over-exploitation, and eventual collapse.

Finally, a unique feature of the holothurians is that some individual sea cucumbers of some species have a remarkable type of fish, known as pearl fish, living as symbionts inside their body cavities. it is simple to monitor the occurrence of these symbiotic pearl fish in harvested and non-harvested sea cucumbers, and to use this as an index of the impact of the holothurian harvest on coral reef biodiversity. Increasing exploitation of the holothurians will selectively eliminate the symbiotic pearl fishes. Two species of pearl fish have been observed in some of the species of holothuria during a one month survey carried out in June by IMS in collaboration with the University of Guelph, Canada in 1992. These are yet to be identified.

Table 2. Export tonnage of commercial resources in Zanzibar for 1990 – 1992.

	1990	1991	1992
Lobster	6.30	3.80	11.67
Holothurians	24.85	37.28	35.67
Gastropods	61.36	41.40	21.60
Octopus/Squid	1.06	1.72	0.50
Operculum	1.42	3.80	1.40
Crabs	0.02	0.40	-
Seaweeds	215.90	1782.80	2400.0*

Turtles and marine mammals

Five species of sea turtles exist in the coastal waters of Tanzania (Frazier, 1976). In Zanzibar however four species of sea turtles have been reported so far. The green turtle *Chelonia mydas* (Kasa or Nduvi), and *Eretmochelys imbricata* (Ngamba), the hawksbill are the most common, followed by the *Caretta carretta* (the logger head) (Mtumbwi, Ranga) and *Dermochelys coriacea* (the leather back). Recent surveys carried out by Clark (1993) here in Zanzibar indicated the absence of the olive ridley *Lepidochelys oliveacea.*

The turtles are hunted (by gillnets and spears) for their meat, eggs and shells which are sold to tourists at high prices. There are reports on the existence of nesting sites for turtles on the beaches between Jambiani and Makunduchi, at Dongwe, Kiwengwa, Mnemba Island and at the small islet "Mwanamwana" north of Tumbatu Island. However, fishermen reported seeing smaller numbers of turtles coming to nest nowadays. This could be due to human disturbance as a result of a lot of hotels being built mostly on sandy beach areas on the East coast (about 22 hotels have been built in this area in the last 3 to 4 years and more are being constructed). Despite the hoteliers being required to build their hotels at least 10m from the high water line most of them don't comply to this rule. *Chelonia* sp. is very site fixed in its nesting and so such disturbances are bound to have a great impacts upon it (Thiagarajan, 1990). Gillnets commonly used in the north and southern parts of the islands mostly trap turtles. The use of this net and spears has increased lately (Hoekstra *et al*, 1990). The rate of depletion therefore is alarming. In most villages fishermen talk of catching an average of between 4-6 turtles per day. This figure seems rather high but it does indicate that turtles are regularly caught.

Currently there is no legislative or conservation effort concerning turtles. The need for steps to conserve these animals is urgent, because turtles are threatened world wide and they have been listed in the IUCN Red Data book as being a vulnerable and endangered species (UNEP/IUCN, 1984; UNEP/IUCN, 1985). In the Philippines and Indonesia green turtle has been hunted to extinction (UNEP/IUCN, 1985). Conservation of turtles is difficult due to its migratory nature, however, turtles with tags bearing addresses from as far as Madagascar, Seychelles and La Reunion have been caught in Zanzibar. The best way is to enforce regional conservation measures.

Not much information exists on marine mammals in Zanzibar. However dolphins are quite commonly seen around the coast. Dead whales have been washed ashore in Zanzibar several times, especially on the beaches east of the Island. Only last year a juvenile Baleen whale measuring about 15m landed at Kizimkazi on the southern tip of the island. Dugongs have been sited, though very rarely, along the Pemba-Zanzibar Channel (Howell, 1989; IUCN, 1988). No live dugong have been sited in recent years

Seaweed and mangroves

The only species which is successfully commercially exploited in Zanzibar is *Eucheuma spinosum* which was introduced from the Philippines. The other common species *E. cottoni* does not do well here as it often becomes heavily epiphytized and has a very low growth rate.

The spread and growth of seaweed farming in Zanzibar is taking place at a very fast rate. At present it is actively taking place in the following villages, 80% of which are situated on the east coast: Jambiani, Paje, Bwejuu, Pingwe, Michamvi, Mungoni, Pongwe, Chwaka, Marumbi, Uroa, Kiwingwa, Pwani, Mchangani, Matemmwe all of which are coral rag areas. Others are Tumbatu Island, Bumwini Mangapwani, Uzi, Ng'ambwa, Unguja Ukuu. In Pemba it takes place in few places such as Kiuyu maziwa ngombe, Tumbe, Shumbe, Kisiwa Panza, Fundo and Chaleni.

By early 1990, a total of over 50 ha. were cultivated in the southern region at Bwejuu, Paje and Jambiani. Each hectare is capable of growing 4 000 *Eucheuma* plants and can yield about 15-25 tons of dry seaweed per year. Seaweed farming is presently conducted by several private and local firms. The companies involved are the Zanzibar East Africa company (ZANEA) and Agro Seaweed Company (AGROSCO) which both began mariculture in 1989.

The fishery catch statistics of 1990 and 1991 from two villages (Paje, Jambiani) with many seaweed farms have indicated a reduction in the annual catches (Table 3). This is as a result of reduced fishing activities by the fishermen who now are engaged in sea weed farming.

Table 3. Fish catches (kg) from three villages with highest *Eucheuma* farming, 1989 – 1990. From Mtolera *et al* (1992)

Year	Jambiani	Paje	Bwejuu	Notes
1989	1580	1931	2456	Farming started in Jambiani
1990	1294	1950	2509	Farming started in others
1991	866	1389	2211	(-)

Some of the ecological implications of seaweed farming have been documented by Mtolera *et al* (1992) which includes the cutting of mangroves for making stakes for farming, and unselective farm clearance affecting the benthic organisms. Also, this species being an alien species, its environmental consequences are not known.

The Zanzibar government is attaching great importance to seaweed culture because of its potential for foreign exchange earnings. Thus, the economic sustainability, the impact to social conditions, the environmental impacts to the intertidal areas, need to be assessed, the last thing the local community will expect is the collapse of the seaweed culture. IMS is currently undertaking a survey to address these concerns in order to assist Zanzibar in managing a sustainable seaweed industry.

There are about 6000 ha of mangroves in Zanzibar and 12,000 ha in Pemba (Griffith, 1949). This area is a nursery and breeding ground for many commercial fish in Zanzibar (Ngoile & Shunula, 1992). The survey carried out by Shunula (1989) indicated that the condition of mangroves in Pemba appears to be in better growth form and less influenced by human activities than that of many places in Zanzibar. Mangrove cutting has been unsystematic resulting in over exploitation especially in Zanzibar town where it is used as fuel wood, building poles and tanning and boat building. For example in Chwaka (Finnida, 1983) due to the increasing demand for construction poles the cutting cycles have been getting shorter and many areas are revisited frequently, resulting in young trees not having enough time to grow to reasonable pole size. The serious damage which may result from this is that the forest may result in having large seed trees, which cannot be used for poles, and seedlings and very small trees that will not yield poles for several years. The Maruhubi mangrove, situated very close to Zanzibar Town, is likely to be the first to suffer heavily.

Recommendations

Education and public awareness

Conservation of marine systems should be geared towards benefits to the community and people should be educated to appreciate the role of conservation. This should involve a variety of groups, e.g. fishermen/women, school children, teachers, curriculum developers, tourist operators, government officials etc. aiming at habitat preservation, species conservation, and sustainable resource utilization.

IMS, in collaboration with the Memorial University of Newfoundland, has already started a new section known as Marine Education Extension and Development (MEED), whereby video tapes and films are made based on local marine environmental problems to be shown to the general public in order to make them aware of the possible long-term benefits of coastal management activities.

Research and Monitoring

A comprehensive research programme on marine resources is required to determine the distribution, abundance, biology and value of resources, threats and conservation needs. Frequent stock assessment as well as environmental surveys are needed to be conducted on the traditional fishing grounds.

Monitoring of certain existing problems such as the use of destructive fishing gears and over exploitation of certain resources is required to determine changes with time.

Development of sound management strategies

Resource users (village level) should be involved in making management plans because they have a better knowledge of the resources, and also to avoid unnecessary interferences with their social and economic activities. Fishery development planners should incorporate research information and conservation needs in their plans.

Institutional and regional co-operation

In order to conserve marine resources a multivariate approach to problems, combined and integrated efforts of various relevant government and private institutions, is essential.

International or regional co-operation is also needed for migratory species such as tuna and turtles. According to Mwaiseje (1983) it is fruitless to conserve migratory species in one place while they are killed elsewhere in places where they are found in large numbers.

Increase in manpower resource

In order to be able to carry out research activities and to expand public awareness and help in solving all the relevant problems related to conservation, sufficient numbers ofeducated people are required in the different fields. Hence training opportunities are a prerequisite.

Enforcement of the laws

Existing laws should be advertised to the public and enforced. A stronger surveillance system should be established. At present the Zanzibar Navy (KMKM) is doing surveillance alone but it is not sufficient due to having few patrol boats and no training for the job. Where possible local fishery patrol groups should be introduced

None of the above mentioned recommendations will succeed if the government lacks the will or ability to ensure that regulations are properly and strictly applied and if the fishing communities and coastal population in general does not perceive any advantage.

Designation of protected areas.

There is a need to establish marine parks in Zanzibar. At present there are no specially managed marine areas to protect the extensive marine biological diversity in our waters. The parks can serve as areas for conservation and gene pools. They can also be used for education, scientific and recreational purposes. Pearson (IUCN/RSRP, 1989) has recommended the coral reefs west of Zanzibar as good sites to start these parks in the Islands. There are plans to make the Chumbe Island reefs into a reserve area for the purpose of conservation and education. Misali Island has also been recommended due to its unique diverse and relatively pristine condition with over 40 genera comprising of 244 species of fish (Horrill, 1992c).

References

Boerema, L.K. (1981). Development of the fishery in Zanzibar. Fishing statistics in Zanzibar. *URT/75/090 Technical report.* FAO Rome, 13pp.

Bryceson,I., De Sousa,T.F., Jehangeer,I & Wynter,P. (1990). State of the marineenvironment in the Eastern African region. *UNEP regional Seas reports and studies.* No 113, 46 pp.

Clark, F. & Khatib, A. (1993). Research on Sea Turtles in Zanzibar. Lecture presented to *International School of Earache* at IMS, March 1993

Jiddawi, N.S & Muhando, C. (1989). Summary of marine resources in Zanzibar. *EES-1 COLE,* Zanzibar. 30 pp.

Shunula, J.P. (1989). The distribution and status of mangroves in Zanzibar: A survey. *EES-2 COLE* Zanzibar. 34 pp.

Evans, S.M., Knowles, G., Pye-Smith, C. & Scott, R. (1977). Conserving shells in Kenya. *Oryx,* 13 (5): 480-485.

Finnida, (1983). Finnida forest inventory. Zanzibar

Frazier, J. (1976). Sea turtles in Tanzania. *Tanzania notes and records* 77 & 78: 11-20.

Griffith, A.L. (1949). Reconnaissance report on the forest problems.

Halsted, J.P. & Halsted, D.C. (1982). The Cowries of Zanzibar. Tanzania *notes and records* 88 & 89: 105-107.

Horrill, C. (1992a). Ecological monitoring of coral reefs around Mnemba, Chapwani, Changuu, and Bawe Islands. EES 11. *COLE* Zanzibar, 13pp.

Horrill, C. (1992b). Status and issues affecting marine resources around the Fumba Peninsula. EES 12. *COLE* Zanzibar, 10pp.

Horrill, C. (1992c). Status of the coral reefs of Misali Island. EES 13. *COLE* Zanzibar, 13pp.

Howell, K.M. (1989). Conservation of marine mammals and turtles in Tanzania. In Mainoya J.R. (Ed.) *Proceedings of workshop on the ecology and bioproductivity of the marine coastal waters of eastern Africa.* Dar es Salaam, Tanzania, 18 – 20 January 1988. Faculty of Science, University of Dar es Salaam: 162-173.

UNEP-RSRP, (1989). coastal and marine environmental problems of the United Republic of Tanzania. By M.Pearson. *UNEP regional Seas Reports and Studies* No. 106, 30 pp + annexes of 114pp.

IUCN, (1988). The coastal resources of Tanga region, Tanzania. *Report of a preliminary study of the status and utilization of Tanga's coastal natural resources, with management recommendations.* October 1987, IUCN, Nairobi. 52 pp.

IUCN/UNEP, (1985). Management and conservation of renewable marine resources in the Indian Ocean region:Overview. *UNEP regional Seas Reports and Studies* No. 60.

IUCN/UNEP, (1984). Marine and coastal conservation in the East African region. *UNEP regional Seas Reports and Studies* No. 39.

Mtolera, M.S.P., Ngoile, M.A.K, Semesi, A.K. (1992). Ecological Consideration in Sustainable Euchuma farming in Tanzania. In Mshigeni *et al.*(Eds) *The First International workshop on Sustainable Seaweed Development in Sub-Saharan*, March 1992, Windhoek Namibia.

Mwaiseje, B. (1983). Some views on marine conservation in Tanzania. In Mainoya, J.R., Bwathondi, P.O.J. & Pratap, H.B.(Eds). *Status and Problems of Marine ResourcesDevelopment in Tanzania*: 41-44.

Ngoile, M.A.K. & Shunula, J.P. (1982). A survey of fishing units in Zanzibar and Pemba. Tanzania Notes and Records. No.88 & 89: 89-96.

Ngoile, M.A.K. & Shunula, J.P. (1992). Status and exploitation of human activities on the marine environment of Zanzibar. In Jaccarini & Martens (Eds) The Ecology of Mangrove and Related Ecosystems. *Hydrobiologia* 247: 229-234.

Salm, R.V. (1978). Conservation of marine resources in Seychelles. *IUCN Report to the government of Seychelles.* Morges Switzerland.

SWIOP Document, (1985). Report on the National Workshop on Bèche de mer processing. July 29-Aug. 2nd 1985. *SWIOP Doc.* OISO RAF/79 065. 15 pp.

Tarbit, J. (1984). Inshore fisheries of the Tanzanian coast. *The Proceedings of the NORAD-Tanzania Seminar to Review the Marine Fish Stocks and Fisheries in Tanzania*; Mbegani, Tanzania, 6-8 March, 1984: 186 pp.

Thiagaran, T. (1990). Status of Sea turtles in Zanzibar. *COLE* Zanzibar, 12pp.

Zanzibar Fisheries Policy, (1985). Sera ya Taifa ya uvuvi nchini. Ministry of Agriculture. 45 pp.

The nature and extent of human impacts on the estuaries and bays of Sierra Leone

JOHNSON Raymond and Reynold
Institute of Marine Biology and Oceanography
Geography Department
Fourah Bay College, University of Sierra Leone,
Freetown,
SIERRA LEONE

Abstract

A detailed discussion on the changes to the major coastal water bodies of Sierra Leone is presented. The nature and extent of impacts on the estuaries and bays of Sierra Leone due to human activities are diverse and in many ways turn out to be negative.

The nature of human impacts in this case is determined by a number of factors including, harbour construction and extension (Sierra Leone River Estuary), clearing of coastal strips for rice cultivation (especially mangrove swamps); building of boat landing sites and other shoreline facilities, tourist resort construction (Tokeh); and Mining activities (Estuaries of the Sherbro and Scarcies River).

The extent of the impact of such activities (land use patterns, industrial and domestic wastes disposal) on marine life, adjoining ecosystems (tidal mudflats, mangrove swamps etc.), and on tourism and residential development are of immense importance.

Introduction

The landforms of the Sierra Leone coastline is a result of geomorphic processes which accompanied the separation of Africa from South America some 180,000,000 years ago. These landforms are modifications of the original coastline by aerial, subaerial and marine influences. The estuaries and bays which are the prominent coastal features show evidence of submergence and play an important role in the economic and social welfare of the country.

The present nature of the unique coastal ecosystems as represented by the estuaries and bays of Sierra Leone is determined by different processes acting in concert amongst which are the semi-diurnal tides, post glacial sea level rise, and waves. The post glacial sea level rise manifests itself in the drowned river valleys, mudflats and mangrove swamps which are indicators of submerged coastlines (Johnson, 1919). The semi-diurnal tides serve to exercabate retrogradation of the coastline, especially in areas where the coastal vegetation (mangroves) have been cleared. The waves continue to erode some areas and at the same time enhance accretion in others through their generation of longshore current. The coast of Sierra Leone is basically a swell coast (Johnson, 1988). These swells can transform to various breaker types on the coast depending on bottom topography.

Attendant problems of these coastal ecosystems (bays and estuaries) are associated with anthropogenic activities due to an increase in population and therefore increased exploitation of the coastal resources. The most obvious of these activities is that of land use patterns in the coastal zone, transportation and disposal of domestic and industrial waste, tourism, fishing and construction of shoreline facilities.

This paper seeks to present the nature and extent of human impacts on the unique coastal ecosystems of Sierra Leone which are comprised of estuaries and bays.

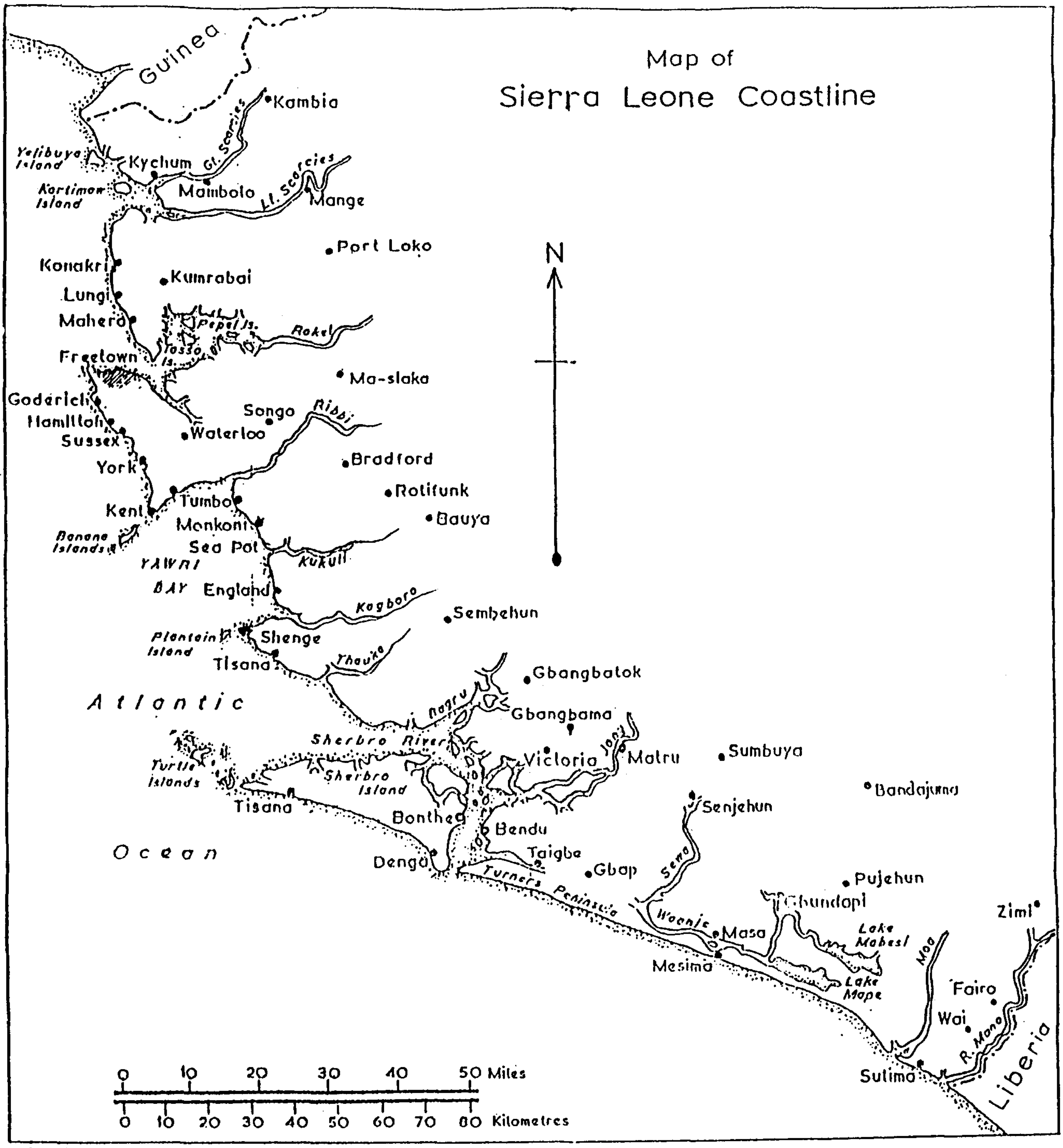
Geography

Sierra Leone has an area of 72,325 km^2 extending between latitudes 6°55' and 10°00'N and between longitudes 10°14' and 13°17'W. The configuration of the coastline and international boundaries of Sierra Leone enclose a very compact country. Sierra Leone is bordered on the north and northeast by the Republic of Guinea, south and southeast by the Republic of Liberia and on the west on by the North Atlantic Ocean.

The geography of Sierra Leone comprises strongly folded igneous and metamorphic rocks belonging to various formations, some known locally as "series" of the Precambrian period. The period of geological history ended nearly 600 million years ago, but nearly all the precambrian rocks in Sierra Leone are very much older than this, with the oldest so far dated over 2,800 million years old (Anderson, 1966). The coastal area consists of nearly horizontal marine and estuarine sediments, gravel, sand and clay some 40.25 km (25 miles) wide, extending from Liberia to Guinea and is known as the Bullom series.

The water resources includes a series of rivers which rise on the dorsal (Guinean Dorsale Hills), the Kolenten or Great Scarcies, the Little Scarcies, Rokel, Jong, Sewa, Moa and Mano Rivers. Other streams in the low lands include the Ribbi, Kukute, Gbangbaia and Waanje Rivers. Nearly all the rivers flow parallel to one another right across the country from the high interior plateau in the east of the country towards the lowland coastal areas before debouching into the Atlantic Ocean.

Sierra Leone's coastline measures approximately 500 km and its Maritime area (from the lowest low tide mark to 200m depth) total 26,400 km^2, while its exclusive economic zone is 155,700 km^2 (World Resources, 1990).The coastline of Sierra Leone can be divided roughly into two sections. The section to the north of Bonthe **(Fig. 1)** is characterized by a series of indentations representing estuaries, bays and creeks of varying sizes, and the section south of Bonthe which has about 200 km of nearly unbroken steep sandy coast, backed with coastal swamps (Johnson & Johnson, 1991). The coastline shows abundant evidence of drowning. The scarcies, shebro, and Sierra Leone River estuaries all seem to continue as submerged channels out across the continental shelf, whilst the complex patterns of tidal creeks is the result of the drowning of a river system developed in relation to a lower sea-level. Creeks being rapidly colonized by mangrove and completely silted-up on their headward region, are typical of the Sierra Leone coastline. In places a parallel series of beach ridges often separated by silting lagoons, forms the actual coast. One such ridge stretches from the mouth of the Moa River to the tip of Turner's peninsula, a distance of 112.70 kms (70 miles). The origin of these ridges has not been investigated, although the way in which the Waanje and Sewa are deflected before they enter the sea suggests a longshore drift from the south east.



S J A Nelson

Fig. 1. Map of Sierra Leone coastline

The Bullom Peninsula is a distinctive sub-region, comprising both swamp and sand ridge areas, but dominated by a low, laterite-capped plateau which terminates seaward in cliffs. It is possible that this is an uplifted deltaic deposit, although it lies at approximately the same level as the main raised beach of the Freetown Peninsula, and may be of similar origin.

West of Cameroon, the Freetown Peninsula is the only place in West Africa where mountains are found on the coast. The remnant of a larger intrusive structure, the Peninsula Mountains rise in abrupt tree-clad slopes. Around their base the main raised beach sloping gradually from a back at 53 m (160ft) has provided suitable sites for settlement (including Freetown). Other beach remnants are known at lower levels and the coast is formed of sand ridges joining rocky headlands with silting lagoons behind them.

Origin of the Sierra Leone coastline

This coastline is believed to have been the result of the dismemberment of the Gondwana land mass, as was put forward by L.C. King in his view of the origin of Africa. This continent, in which the country Sierra Leone is situated, was born in the early cretaceous period with the final breaking of the land mass and subsequent continental drift. The coastline of Africa is said to be the result of the break wherein a coastline not dissimilar to the present day one was created. Subsequent modifications to the outline of the continent south of the Sahara mainly involves the addition of new areas of land by deposition which is being experienced in the area.

The coastal swamp and bar beach region is largely underlain by the Bullom series of sedimentary rocks which rest on the down warped continuation of the main erosion surface. The peninsula land mass at Lungi is a relatively flat land with an average height of 16.3 m (50ft) above sea level.

As already mentioned, the coastline of Sierra Leone is highly indented, with inlets of various shapes and sizes representing former valleys which became submerged as a result of the general post-glacial rise of the sealevel. The natural cause of coastline erosion can perhaps be ascribed to the marine climate and without outside intervention the coastline would always be in equilibrium with the marine forces. Along the coast of Sierra Leone the southwest monsoonal climate prevails. There is the onset of an almost uninterrupted wet season which generally lasts from May to November, interspersed with squally periodsin August-September and May-June. During this period long waves from the southern ocean are reinforced by local winds which give the waves greater force as they pound against the coastline.

Oceanology

The periodic and non-periodic movement of the waters of the Sierra Leone continental Shelf play a very important role in the erosion, transport and redistribution of the sedimentary material in the coastal area.

The surface waves and the long waves, among these mainly the tidal waves, belong to the periodic water motions. The non-periodic water motions include wind-generated currents, gradient and density currents as well as the currents of the surf zone, especially long-shore currents.

On the shores of Sierra Leone waves are generated by the local monsoon especially during the squally period of May-June and August-September and the swell generated by storms during the dry season in the southern part of the North Atlantic (Johnson, R.G. Unpublished dissertation, 1988). The swells reaching the coast have periods varying between 8 to 13 seconds with an average of 10 to 12 seconds. Wave heights in deep water average 0.25 – 1 m. However, heights of 2 to 3 meters or more occur with directions between south and southwest especially during stormy months.

Table 1. Summary of the wave climate in the coastal area. Source: Johnson R.G. 1988

Month	Dominant Wave Direction	Frequqncy (Sec.)	Height (m)
July	S.SE	9	1 – 0.5
August	S.SW	8	1 – 0.5
September	S.SW	8	1 – 0.5
October	S.SE	8	1 – 0.5
November	NE.W	13	0.5 – 0.25
December	NE	14	0.5 – 0.25
January	NE	12	0.5 – 0.25
February	NE.N	12	0.5 – 0.25

The eroding effects of the surface waves in the region seldom reach deeper than to a water depth of 10 m, which means it is effective only in the shallow offshore zone. The area influenced by breakers is restricted to the still smaller strip of the surf zone, but here it is extremely effective and acts together with the long-shore current that carries the sediment which has been put in suspension by the breakers. Locally, the horizontal component of the tidal waves, the tidal current is also capable of eroding the varying off the eroded material into the deep water even by weak residual currents. The region is dominated by the semi-diurnal tide with an appreciable daily inequality (0.04 to 0.34 meters) and an average range of about one meter.

Currents are driven by the south-west monsoon and flow generally from northwest to southeast. Local variations in the strength and even temporary reversal of the current near the coast are caused by corresponding variations in wind force and direction. The meeting of the fresh river water and the saline sea water gives rise to density currents which can be effective in transporting sediments to great depths.

Coastal currents, and mostly the Guinea current here, are responsible for the redistribution of the sedimentary material brought down to the ocean by the rivers and the large amounts of mainly terrigenous material also made available through intensive erosion by constantly breaking waves of high destructive force. Surface current velocities are between 0.3 m/s to 0.55 m/s with a predominant north easterly direction. Near-bottom current velocities were between 0.05 m/s and 0.15 m/s with a north-westward flow. The influence of the tidal current is greater in the coastal areas and needs to be given more attention.

The effects of sea level rise is clearly manifested in the south along Turner's Peninsula where the church at Ma-Bap which was some 100m inland about 20 years ago is now almost in the sea. A rough estimate indicates that sea level has been rising at a rate of between 0.2 – 0.5 cm/yr.

Sedimentation

Sierra Leone is situated on part of the African platform, which experienced submergence during the Miocene. Evidence of submergence can be seen in the strong indentations of the coastline, where bays and estuaries represent drowned valleys fringed by a series of islands.

The continent has a prevalent subequatorial climate (high temperatures, high humidity and high precipitation), which enhances chemical weathering. The weathered materials are carried to the ocean through surface runoffs by a series of rivers **(Fig. 1)**. The sediment, which is transported in large quantities by these rivers, is mainly of terrigenous origin. The coastline derives sediments from terrestrial, aerial and marine sources. The sediments consist of terrigenous quarts, sand grains, clay and gravel, which represent weathered material of the earth's crust of continental origin. The carbonate content of shell remains is fairly high.

Shelf deposits indicate that the main area of the shelf is filled with medium sized grains whilst the depressions (valleys) of the internal sectors of the shelf consist mainly of coarse grains of different sizes with a good mixture of clay, sand and gravel (up to 50%). The whole area is laden with small and broken shells. The outer zone of the shelf is often laden with stones. On the upper reaches of the continental shelf, at a depth of about 150 m, medium sized grains gradually give way to small size grains. Within the limits of the whole shelf zone muddy deposits are nearly absent. A boundary region of sandy particles with silt lies at a depth of about 500 m. Mud occupies a depth from 1500 – 2000 m. However the important source of marine sediments is from depths to which waves and tides are effective up to about 10 m depths. The longshore drift is also important in the redistribution of coastal sediments within a narrow strip of the coastline.

Composition of the marine coastal ecological systems

The coastal system of Sierra Leone consists of two distinct parts viz: (i) the shore, which faces the ocean and is directly under the influence of the forces of the sea especially the waves. It includes the sub-aerial portion of the shore as well as the dynamically active inshore sea bed, and (ii) the coastal plain, consisting of mangrove swamps and mud flats associated with estuaries and sheltered embayments, pocket beaches alternating with rocky headlands, low cliffs of poorly consolidated clays, sands, silts, and gravels, sand beach ridges which form extensive plains and fringed by generally steep, microtidal beaches in the south and are hydraulically influenced by the sea.

The productivity of the estuaries and bays of Sierra Leone

The estuaries and bays support diverse ecosystems from which the inhabitants of coastal areas and beyond derive their livelihood. These habitats include the mangrove ecosystem, inter-tidal mud flats and swamps. Because of their location near terrestrial sources of sediments, the estuaries and bays contain large amounts of nutrients. The combination of this nutrient supply with generally shallow water gives rise to a diverse and large flora and fauna. The substrate in these areas serve as spawning and nursery grounds for most coastal/marine organisms.

The pelagic community of the estuaries, bays and mangrove related ecosystems, are made up of a fairly large number of animals: species living at the surface, part of whose body project through the air e.g. pleuston, the hydrozoans and the chondrophones; the planktonic organisms which include *Biddulphia*, *Coscinodiscus*, *Rhizosolenia*, *Tricodesmuim* and *Thalazsiosira* become very abundant especially during the period from December to February.

The prominent members of the pelagic community however are the nektons, perhaps because of their direct impact on the welfare of the local population. Amongst this rather broad group of organisms, the main pelagic fishes, shrimps and oyster which are of commercial importance tend to be dominant.

The pelagic fish species **(Table 2)** live in the surface waters and they belong mainly to the members of the clupeid family namely *Ethmalosa fimbriata, Sardinella* spp. and *Ilasha africana.*

Table 2. List of fishes observed and approximate abundance

Fish species encountered	Approximate abundance
Ethmalosa fimbriata	XXXX
Sardinella maderensis	XXXX
Gerres melanopterus	XX
Liza dumerili	XX
Mugil sp.	XX
Pseudotolithus brachyura	XX
Ilisha africana	XX
Pseudolithus brachygnathus	X
Plectorhycus macrohyus	X
Chloroscombrus chrysurus	X
Liza grandisquamis	X
Caranx senegallusa	X
Scomberomorus tritor	X
Hemiamthus brasiliensis	X
Polydactylus quadrifilis	X
Brachydeuterus auritus	X
Galeonides decadactylus	X
Sepia officinalis	X
Trichurus lepturus	X
Dasyatis margarita	X
Carax sp.	X
Penaeus notialis	X

Key: XXXX = Highly abundant sp., XX = Fairly abundant sp., X = Species present.
Source: COMARAF TECHNICAL REPORT, 1989.

The estuaries and bays also support a fairly rich fauna. In the estuary of the Sierra Leone river, the Venus community occurs near the north of the deep channel on shelly-sand and fine laterite gravel. The dominant members of the community include small crustaceans, periferans, nemerteans, lamellibranchs and ascidians.

The mid-estuarine regions are occupied mainly by the Amphioplus sub-community on sandy muds with the dominant members being the gephyreans, polychaetes and ophiuroids.

Further upstream a Venus/Amphioplus transition occurs but becomes progressively less common in the upstream direction.

The Pachymelania community found on coarse sand in the upper estuarine region is dominated by the filter-feeding gastropods *Pachymelania aurita.*

The estuarine gravel community occurs on laterite gravel in the deep channel of the Sierra Leone River with fauna consisting mainly of *Astrangia* spp., *Thelapus* spp. and *Arca imbricata*. The fauna in other regions are poorly studied but has identical distributional patterns.

The mangroves associated with the estuaries and bays of Sierra Leone **(Table 3)** which are the typical vegetation on the swamps, resulted from the deposition of silt and clay along the major river channels and yields tons of organic matter per hectare annually through litter fall and wood production. These yield a substantial amount of dissolved organic carbon. A proportion of this organic matter is cycled within the mangrove system while some are exported to support the nearshore fishery. The environmental role of this natural resource includes coastal barriers in storm protection, flood and erosion control and habitat nursery for fish, shrimps and other marine fauna.

Table 3. Distribution of mangroves (Source: Johnson & Johnson, 1991)

Location	Area (ha)	Percentage
Scarcies River	13007	7.6
Sierra Leone River	34234	19.9
Yawry Bay	24505	14.3
Sherbro River	99854	58.2
TOTAL	171600	100

Human habitation and traditional usage of the coastal area

The National Population Census of 1985 put the population of the country at 3.52 million with an annual growth rate of about 2.5% per year.

Over half of this population lives in more than 100 coastal villages scattered along the whole length of the coastline (see map). The main preoccupation of the inhabitants of these villages is fishing, which is carried out mainly by traditional methods. These coastal villages have been named artisanal fishing villages. The activities of coastal dwellers in the estuaries and bays of Sierra Leone vary over a very wide range, from various adjacent land use practices and transportation, to fish harvesting.

These activities affect the processes taking place along the coastline and coastal areas. The estuaries and bays support the luxuriant growth of mangroves which serve basically as a fuelwood source and industrial products (building materials) for the people and as a source of livelihood. As their main preoccupation is fishing, the coastal populace rely mainly on the mangrove resources of the coastal area for a fish-smoking area also used for house building, poles for fishing and as a fuelwood source. The mangrove areas are cleared for paddy rice cultivation and for salt making.

Most of the artisanal fish landing sites are also located on the beaches close to the villages. In some areas, e.g. along some parts of the Goderich and other beaches, the local inhabitants indulge in removing sand from the beaches for house and other construction purposes and other facilities.

Along other parts of the Sierra Leone coastline, tourist resorts and other facilities have been built and a good number of factories and industries can also be found e.g. along the Freetown Peninsula and along the southern banks of the Sierra Leone River Estuary.

The coastal areas are more or less the "**sinks**" for land based pollutants. Most of the domestically and industrially derived wastes find their way into the nearby streams, rivers and estuaries. Along parts of the coastline can be found several large pits where rubbish is dumped for burning as the main method of disposal.

The most heavily exploited water body in Sierra Leone is the Sierra Leone River Estuary which debouches into the Atlantic Ocean north of the Freetown Peninsula. This estuary is not only the largest in the country but also hosts one of the best natural harbours in the world. This estuary also acts as a receptacle for waste materials derived from most of the industries located in Freetown close to the lower reaches of the estuary.

The revolutionary trend and shipping involving containers has necessitated not only the modernisation of port facilities but extensions to accommodate more cargo and shipping facilities. This necessitated the extension of the port of Sierra Leone which was undertaken in 1968. However indiscriminate destruction of the mangroves is associated with problems such as erosion, destruction of fish nursery grounds and increased salt water intrusion into denuded mudflats.

Impact of human intervention

The delicate equilibrium of the coastline of Sierra Leone is constantly endangered by direct or indirect intervention by the people as a result of their activities. This intervention has been accelerated by the growing poverty of the people, having a GNP of US$220 – one of the lowest in the world.

The lack of adequate supply of electrical and other environmentally friendly sources of energy has led to a dramatic increase in fuelwood consumption including the mangroves. Fuelwood supplies 80% – 87% of household requirements. Increased farming and mining activities along the banks of rivers and streams have caused extensive siltation of their channels. Most of these water bodies either dry up or contain very little water during the dry season. The impact of such activities on the coastline is quite evident. Deforestation of the mangroves leads to the silting up of our estuaries and bays as the sediments which were once trapped by them are now fully exposed to the marine forces, such as waves and tides. Sediment supply to the coastal area by some of the rivers is drastically reduced due to the drying up of the streams that feed them. The sediment load of rivers affected by mining activities are equally reduced as they too become silted up. The low river flow especially during the dry season does not possess enough power to dislodge the sediments, with the result that the channels become clogged up. The coastline is therefore deprived of sediments and this in turn increases the risk of erosion. This impact on the coastline is identical to the result produced by damming of some of the major rivers e.g. the Rokel River.

Pollution of the estuaries and bays is perhaps the most serious threat that can be posed to these vulnerable coastal systems. A number of industries including the refinery and the country's main port are found along the southern bank of the Sierra Leone river estuary. Although investigations show a relatively low level of pollution in general, quantitative estimates for polluting substances are inadequate. When aquatic ecosystems are acidified there is a rapid decline of organisms. Large organisms may not be harmed, but the egg, sperm and developing young of aquatic organisms are severely stressed if the pH shifts as little as one unit from the optimum. A pH of 4.5 or lower upsets the balance of an ecosystem. As reproductive rates drop, fewer food organisms are available to consumers which are higher on the food chain.

A fairly large number of tourist resorts and other facilities have been built and a good number of factories and industries can also be found e.g along the Freetown Peninsula and along the southern banks of the Sierra Leone River Estuary. Industrial wastes may include compounds of heavy metals such as Lead, Chromium, Zinc, Copper and Mercury. Because of the fragile nature of marine ecosystems and their importance to marine food chains, the sensitivity of plankton populations to industrial wastes is a problem of great concern. Exposure to industrial waste may result in reduced populations or a bioaccumulation of toxic substances. In either case, there may be changes or imbalances in the ecosystem. Pesticides used to minimize food losses can enter the aquatic ecosystem where they bioaccumulate in the food chain. In Table 4 the BOD and COD concentration of the estuarine water at selected sites are given.

The BOD values for the sites investigated lie below the acceptance limit set by the WHO for international water quality standards (15.9 – 37.5 mg/1) with warning limits from 18.9 – 34.9 mg/1.

Coastline erosion is perhaps the most evidenced impact of human intervention along the coast of Sierra Leone. It poses a considerable threat to tourists and other facilities along parts of the coastline of the Freetown Peninsula. Adjacent to the Aberdeen Creek on the eastern side of the village, right down to Coffee Wharf where the settlers were settled after the abolition of the slave trade, erosion has been significant although rates have not been measured.

According to the results of interviews with the local people the high water tide mark is now about 180 m further inland than it was about 60 years ago. This can give rates of 3 meters/year. In the northern parts of the Sierra Leone coastline no less threat is being posed by erosion. Between Mahela and Sasiyek Creeks, a new 1,500 m long peninsula has been formed. Erosion is also prominent at Konakridee and in the south long Bonthe Island and at Turner's Peninsula (Bap-Mabay). According to estimates derived from aerial infra-red photographs taken in 1976, for the 46 years period from 1930-1976, Yeliboya Island which is situated in the north of the country (see map) has shifted some 1,000 meters from the southeast as a result of erosion **(Fig.2).**

Table 4. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) for the Sierra Leone River estuary

Location	Mean COD		Mean BOD	
	(mg/1)	Std	(mg/1)	Std
Whiteman's Bay	44.10	10.53	11.02	1.83
Kroo Bay	43.20	12.96	17.55	3.82
King Jimmy	42.60	11.54	12.01	3.47
Susans Bay	51.30	10.58	15.16	3.30
Cline Bay	36.70	06.08	09.37	1.77

BOD : Biochemical Oxygen Demand Source: Sankoh, 1992.
COD : Chemical Oxygen Demand
Std : Standard deviation

Sierra Leone has three functional ports – Freetown, Pepel and Point Sam and two ports which are Moribund-Bonthe and Sulima all of which are located in sheltered estuaries. The decline of the last two ports is partly due to heavy siltation which has never been dredged. The Freetown port however is frequently dredged. The increased rate of siltation in the approaching channels and port anchorages can be attributed to the extensive removal of the mangrove swamps to make place for rice cultivation without the construction of any shoreline structures.

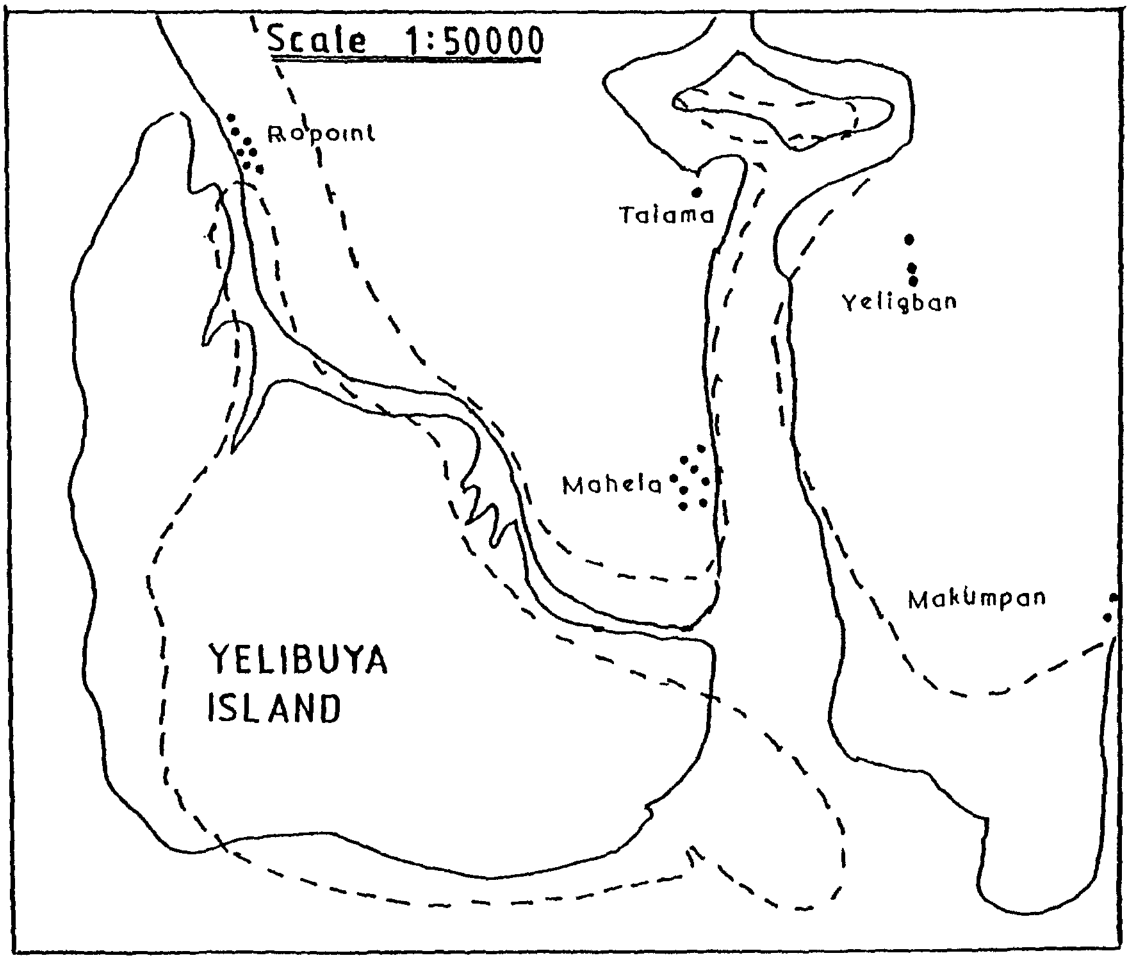


Fig. 2. Map of Yelibuya Island – Change of coastal contours (1930 – 1976).
Original coastal contour ______________
Present coastal contour - - - - - - - - - - - - - -

Coastline protection is only being initiated at the Lumley Beach area where breakwaters are being constructed. The open shoreline itself has undergone changes but they are not as noticeable as those of the sheltered estuaries and there are no ports on this open shoreline. The overall picture seem to point towards accretion in the sheltered embayment and estuaries and erosion on the coastline.

Conclusions

The bays and estuaries of Sierra Leone and their associated coastal ecosystems (inter-tidal area, mangrove forest etc.) support a diverse and large flora and fauna.

They serve as spawning and nursery grounds for many open-ocean organisms and are clearly being abused.

The consequences of coastal area development and the utilization of its resources are both positive and negative.

In the light of the foregoing conclusions, it is recommended that:

(a) access to these resources be carefully regulated;

(b) coastal dwellers be encouraged to involve in such activities as mariculture, and where the clearing of mangroves are concerned, replanting exercises should be undertaken;

(c) the local community participate more fully in the management of the resources;

(d) industries and factories maintain environmental safety standards;

(e) environmental impact assessment be carried out before any touristic or industrial project be undertaken;

(f) public awareness be created through continuous educational programmes;

(g) research facilities be improved through international co-operation.

References

Anthony, E.J. (1988). Artificial structures and Shorelines Sierra Leone. 4pp.

Bird, E.C.C. (1981). World-wide trends in sandy shoreline changes during the past century. *Geographie Physique et Quaternaire 35*: 241-244.

Bryant, E. (1981a). coastal erosion and accretion, Stanwell Park Beach, N.S.W, 1890-1980. *Australian Geographer 15*: 832-390.

Healy, T.R. (1980). Conservation and Management of coastal resources: the earth science basis. In Anderson, A.J. (Ed.), The Land Our Future: *Essays on Land Use and Conservation in New Zealand.* Longman Paul Ltd, Auckland: 139-260.

Johnson, R.G. & Johnson, R.G. (1991). State of Mangrove Resources and coastal Environment in Sierra Leone. *Paper presented at National Seminar on Fishery Development*, Freetown.

Johnson, R.G. & Johnson, R.G. (1992). The Mangrove of Sierra Leone (West Africa). Paper presented and *ISME/ITTO/COMARAF-Workshop on conservation and utilisation of mangrove forests in the Latin America and Africa regions.* Dakar – UNESCO/BREDA, 20-22 January 1993.

COMARAF PROGRAM, (1990). Productivity of estuaries and mangroves of West Africa. *Technical report, Joint Research Workshop. Multidisciplinary study of the Bunce River*, Sierra Leone.

Management of coastal ecosystems and development needs: an alternative option

KIFLEMARIAM Melake
Department of Biology, Addis Ababa University
P.O. Box 1176 Addis Ababa
ETHIOPIA

Abstract

Coastal ecosystems, subsystems and resource units are under the direct influence of two different but naturally interlinked environments, i.e. terrestrial and aquatic. They are exceptionally fragile although their potential could be of utmost importance for various development purposes. Africa's coastal zones are comparatively smooth and with lower concentration of continental shelves. A lot of African maritime countries are facing the adverse consequences of natural and artificial factors despite the fact that various marine resources of coastal ecosystems could contribute to their nutritional, industrial, educational and recreational needs. A modest attempt was made to assess the roles that these coastal systems have in development and the problems of coastal zones management with particular reference to the Red Sea coastal systems. Schematic models depicting human ecology, the coastal system, an ideal system of development and relative coastal health were used. Emphasis rests upon the incorporation of ecological and conservation principles so that development could be sustained based on multipurpose objectives and moves.

Introduction

Coastal environments are valuable national assets for the poor maritime states of Africa because they are treasure-troves of natural resources. Hence, they could be of utmost importance for various purposes, which possibly embrace economic, social, cultural, scientific, educational, recreational and/or ecological interest. Interests may emanate from appreciating their biological, physical, chemical and geological resource potential. Unfortunately, it is no longer simply idle talk that human life in poor maritime states is under serious ecological stress.

The economy and ecology of any given ecosystem is dictated by the content of its information and energy. Energy and information content partly controls the persistence and metabolism of its biota. Some of it is also related to its physical environment. coastal zone problems may be identified when and where their information and energy content is degraded. The situation may be reflected, at least in principle, by greatly altered physical, chemical and biological parameters (variables).

Ecological problems of coastal zones may not be new. We have accumulated ample information through time, albeit biased. A number of activities were also going on in the last two decades since 1972. They culminated in the Rio Conference and Agenda 21. However, we are far from having relatively ideal conditions. There remains a domineering concern when the real magnitude of our ecological problems is seriously taken into account.

At present, we have reached a time in which none of us can sigh resignedly and which neither mere hypnotizing political jargons nor cosmetic reforms are valid. Apparently J. Swift (1975) reminded us "*...that whoever could make two ears of corn or two blades of grass to grow upon a spot of ground where only one grew before, would deserve better of mankind and do more essential service to his country than the whole race of politicians put together*". Each of us carries a heavy burden of responsibility on his back. This gathering, in my belief, will partly enable us to share our burdens.

We may face no difficulty in answering the WHAT? of coastal zone deterioration. Moreover, it may be rather easy to respond to questions of WHERE? and WHEN? because they merely deal with space and time, respectively. All of them are inherently qualitative and descriptive.

It is true that answering these questions will not suffice to meet the vital demands of "biological dimensionality". Nagging issues arise when we pose and ponder HOW? we can dispose of coastal zone problems. In addition, it may be enigmatic WHY? we *a fortiori* encounter such adverse ecological cases.

The above mentioned fundamental questions of HOW? and WHY? impel us to scrutinize our defects of "KNOW-HOW" and "KNOW-WHY". Both do not only demand a clearly defined view, but also entail urgent verification of our scientific, technical development and the problems of coastal zone management with particular reference to the Red Sea coastal systems. This attempt was supported by schematic models depicting human ecology, an ideal-system of development, the coastal zone and its relative health. Alternative options, integrating ecological and conservation principles, are proposed for development to be sustained. The proposed options integrate development and ecological management. They by and large fulfil the demands of multipurpose objectives and moves.

The study area and some of its ecological problems

Homo sapiens will reach the beginning of the 21st Century embracing disastrous ecological problems of a complex nature. Man's ecologic enigma reflects none other than the intricacy of "biological dimensionality" (the four dimensional continuum of life). Hence, the concern fort the welfare of coastal zones, as part and parcel of our general concern, emanates from serious interest in fostering the dimensional continuum of all forms of life, but special emphasis rests upon human life.

Coastal zones result from the interaction of two different, but tightly interlinked media – the terrestrial and aquatic media. coastal zones are priceless human ecological systems. We find some major world metropolitan cities located (founded) along coastal zones. This could serve as an example in stressing the significance of coastal systems as highly favoured human ecosystems. Nevertheless, coastal ecosystems are exceptionally fragile. African coastal systems which are found along the Red Sea coast are no exception.

African countries that border the western coast of the Red Sea proper are three, while on the eastern side are two. The continental coastline, west of the Red Sea, is comparatively smooth. The smoothness of this coastline is not unique to the three African maritime states only, it is also a common feature of the African continent as a whole. This phenomenon explains the comparative problem of port development in Africa.

Some coastal parameters of African countries bordering the eastern side of the Red Sea are presented in **Table 1**. It is believed that this information will provide basic background to partially cover the regions overall ecological perspective.

Table 1. Some coastal parameters of African countries bordering the western part of the Red Sea

Parameters	Egypt	Sudan	Ethiopia (ERT)
1. C*.Lenght (%)	50.4	19.0	30.6
2. S. Area (%)	22.6	13.4	64.0
3. P/L Ratio	0.28	0.35	0.37
4. Phy. Chara.	Fringed Reef	?	Patched/Elong.
5. Fishing G.	Productive	Fairly Prod.	Highly Prod.

C* = coast, S = Shelf, P = Population, L = Length

Fishing ground productivity is graded by evaluating relatively the Suez Canal, Sudanese coastal zone and the Southern Part.

According to the data in Table 1, the southern part has comparatively the highest shelf area and is the second in coastline length. Having the largest shelf area (which is relatively productive) opens up ideal conditions for taking advantage of this region and to utilize the natural resources for various developmental purposes. Unfortunately, complex political and socio-economic problems in the last three to four decades has affected these possible moves. Apparently, the problem is still far from finding a permanent solution.

This ratio of population to coastal length (demographic data was based on a mid-80's census) reveals a trend that generally increases as one proceeds from the north towards the south. The validity of this parameter may be questioned because it assumes that the whole coastal zone is utilizable. It is also true that this assumption deviates from reality. However, we could appropriate a general index that may indicate the density of human population which theoretically and/or indirectly may share coastal resources either for nutritional or other purposes. The index may not, however, lack validity in indicating the density which could otherwise be supported by alternative coastal resources.

Based on this basic, albeit crude information, we may possibly deduce that the southern coastal zone of the Red Sea, has relatively favourable environmental parameters.

In addition, this zone has numerous strange and anomalous ecological features which differentiate it from other tropical and temperate seas. Some of them include:

- Its coastal terrestrial environments are desert systems and are desiccated with salt.
- It is the warmest of all tropical seas in the world. Due to this, its coast is stripped by the scorching sun.

- The west coast of the Red Sea is bare. It has no natural port, except Massawa. Massawa is a very small sandy island. Its surrounding shallow coastal habitats arise from three small islands which are connected to each other by causeways.
- Geologically, the sea is young. Its coastal fauna is endemic and remains isolated. According to the British Museum Report (1952), the fauna is believed to originate from the Mediterranean and Arabian Seas.
- The southern coastal zone is uniquely enriched with enchanting coralline islands. Their marvellous sea bottoms provide opulent habitats which contribute to the survival of diversified life.

The above listed ecological features are very informative and partly indicate the distinctive assets of the southern Red Sea coastal zone.

Major principles of ecology and conservation apply equally to all coastal zones. Certain variations may possibly arise due to deviations and through human involvement with varied management and development moves. Differences may also arise due to human social, economic, behavioural and political inclinations and preferred priority measures. For instance the Côte d'Ivoire practices mining of bauxite and iron ore, which Nigeria does for sand and petroleum, whilst rice growing is practised in Madagascar (The Courier, 1988).

Anthropogenic manipulation of coastal ecological systems, either for its economic benefit or for conservational purposes, apparently is not devoid of certain defects. These anthropogenic weaknesses may generally be attributed to human ignorance, arrogance, thoughtlessness and lack of responsibility for future generations. Unequivocally, these same human thoughtlessnesses partly contribute to the deterioration of terrestrial ecosystems and their loss of productivity.

Since two decades ago, it has become a vogue to ascribe the problems of coastal ecological systems solely to human civilization. Human civilization, by and large, is understood in terms of advanced technology, advanced facilities, urbanization, high educational standard, fashionable ways of life, mechanized agriculture, affluence, hygiene, etc. But, can it be the only true notion of civilization? This notion imparts an impression that we may categorize coastal problems into two polarized causes, i.e. affluence and polluting technology (Commoner, 1973) and effluence (Shaw, 1989). This division may partly explain the differences between the north and the south. However, such dichotomy may not appropriately reflect the actual image of least developed countries in time. It may not also be proper to discard the argument outright.

Following this, certain problematic issues have been enumerated, with particular reference to the coastal systems, subsystems and resource units of the southern Red Sea. These were collected from Kiflemariam (1988a and b, 1989a and b, 1990, 1991a and b, in press, unpublished 1 and 2):

Concerning coastal fisheries economics:

Lack of efficiency in coastal fisheries production contrary to the broad objectives of fisheries programmes in underdeveloped countries. The broad objective of Fisheries are meant to:

1. contribute to the national economic development;
2. augment the national nutritional sufficiency in food (protein requirement);
3 open up employment opportunities and to improve living standards;
4. maintain fishery resources on a sustainable basis;

Destructive techniques in resource exploitation of foreign ships and personnel

(The Soviets were controlling the southern Red Sea coast for about 14 years, up to 1989):

1. complete domination of the coastal zone by Soviet Naval ships and their secretive exploitation of coastal resources, but nobody knows its extent to date;
2. deployment of a highly mechanized and modern fishing ship which practically exploited coastal fishery around Dahlak Islands irrespective of reproductibility and biotic resource renewability for at least two years (in particular around Dahlak, Kebir, Nocra, Norah and others). Nobody knows what it was doing and why it was there for about two years, but later certain coastal areas were found to be devoid of fish (pers. obs. in 1988);
3. use of dynamites in fishing (personal communication with naval personnel). The use of dynamites is destructive and indiscriminately destroys aquatic biota and their habitats.

Concerning government policy:

There was no well formulated fisheries policy. Apparently, most activities were taking place with no defined and devised programme. Certain ambitious tendencies to modernize vessels, equipment, and others were attempted by foreign NGOs (e.g. LWF). The LWF was trying tackle technological problems of this fisheries sector which was, however, inappropriate. Eventually, the project was terminated.

Controversy between economic exploitation of coastal resource units

(i.e. beaches, mangrove ecosystems, bays and coral reef) and the sustainability of non-renewable natural resources and environmental health were evident:

1. removal of evergreen bushes from the mangrove ecosystem of Green Island. The aim was hotel construction;
2. utilizing the mangrove ecosystem for military activities which includes fencing the locality with buried grenades;
3. cement production (mostly by dynamiting the local environment) plus the use of the naturally favourable area around Gurgusum as a beach for recreation and tourist attraction. This environment was also mostly under the direct control of the Navy and Army.

Lack of scientific knowledge about ecotone ecosystems:

There is meager or no knowledge of the ecological characteristics of ecotone ecosystems and the potential of their natural resources. (The ecotone is a transition zone with a high number of species (Leopold, 1933). It is also an area of tension from where the most important species of adjacent communities attain their boundaries (Clements, 1905). Apparently, the ecotone ecosystem remained unrecognized by almost all field workers.

Lack of economic, social and political commitment to organize and materialize marine parks and reserves.

This zone is endowed with fascinating coral reefs and possibly the world's most beautiful coral fishes:

1. Marine parks could play a valuable role in attracting tourists. The Dahlak Islands have a great potential for developing one of the most beautiful marine parks in the world (Ray, 1970);
2. Marine parks could help to conserve marine wealth such as fish, various shells and corals. Dr. Christopher Roads, the Deputy Director of London's Imperial War Museum (with his research group) came across Crown of Thorns starfish in 1967, 1968 and 1969 (Anonymous, 1970). No further effort was made to continue studies of this type. It is also true that no one has solid data which could indicate the actual potential, type, composition and diversity of the fauna and flora of the coast;
3. Marine parks could serve as breeding reservoirs which would help to maintain the productivity of neighbouring coastal fisheries. Some human activities threaten every precious marine species – including whale fisheries, incidental catch in fishing nets, environmental disturbance, habitat modification and damping chemical pollutants;
    - 3.1. the southern coastal zone of the Red Sea accommodates six species of dolphin (Evans, 1983). Dolphins are not to be fished, however from 1985-88 not less than six dolphins were caught by local fishermen (pers. obs.);
    - 3.2. Dugong (*Dugong dugong* Erxleben) is the only large aquatic herbivore (mammal) which is distributed along the coast of East Africa, the Red Sea, the coast of southern Asia as far as the Solomon Islands and the northern coasts of Australia (Allsopp, 1960; Bertram & Bertram, 1968a, b; Huges & Oxley-Exland, 1971; Heinsohn, 1972). Two of these rare species were trapped by local fishermen around Hergigo Bay and the Soviet Military personnel around Gugusum Beach in 1987-88 (pers. obs. and comm. with local fishermen).
    - 3.3. sea turtle is one of the most commercially important species around the coastal ecosystems of the Red Sea. It was commercially exploited up to the end of the 60's. It then became scarce and local fishermen were advised not to catch it. In 1988, a turtle was unfortunately found around Hergigo Bay and fishermen caught it for their own consumption (per. obs.).

Lack of respect and unwillingness to appreciate social, cultural, traditional etc. formation and practices of local fishermen communities.

Unwillingness to recognize and satisfy the developmental needs of the fishermen community (especially the islanders).

Government arrogance and dominance in controlling them as sites of strategic military importance and decades of warfare.

These resulted in the destruction of coastal mangrove vegetation and the environment around Hergigo, and some other islands.

By and large, up to September 1990, the coastal ecosystems and resources units were relatively free of chemical pollutants (Kiflemariam, 1991a). Very minor changes were observed during five years of monitoring programmes around the shallow coastal habitats of Massawa.

Minor changes were attributed to municipal wastes, human interference in collecting corals, swimming and medication by burying oneself under coastal sand.

Approach: theoretical and practical considerations

"All things flow", said Heraclitus. Ecclesiastes 1:7 reads: "All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they turn again".

Both statements stress that change is a common phenomenon on earth. Everything on earth changes. If everything changes, then change is the rule and not an exception. Nature is cybernetic in character. Natural ecosystems metabolically respond to changing environmental conditions through their cybernetic potential. That is why undisturbed nature is said to know best (Dubos, 1973). Cybernetic potential is applicable up to a certain level.

In accordance with these arguments, our concern over coastal system deterioration will not be due to change *per se*, rather it will be due to the magnitude, intensity and frequency of changes under human influence in space and time.

Human action, devoid of foresight, led to ecologically unstable and developmentally unsustainable coastal systems. At present, we have reached a time in which we are forced to reassess and reevaluate our perceptual, technical, methodological, practical, financial, and organizational potential. These are paramount to drive us towards a new dimension which could enable us to approach our complex problems and to curb them and those of future generations.

Development is essentially a material and organizational matter (Riddle, 1981). Its needs and moves aim at maximizing human economic benefits, but mostly they focus at uni-purpose objectives. By doing so, they antagonize coastal ecological limitations, i.e., limitations of the quality of social life, coastal profitability, per capitum energy consumption, per capitum output, natural resource's potential, biodiversity, productivity sustainability, stability, complexity, ...etc.

These limitations evoke a need to grasp the neglected, but profoundly true Laws of Environmental Biology. In this context we may state them as: (a) the needs of consistent coastal zone ecological states, (b) the naturally predestined genetic constitution of coastal zone biota.

Development is exploitative in nature. It takes place at an ecosystem level of organization. Exploitation, which rules in reducing ecosystem productivity, will ultimately lead to adverse effects on organisms, species, population, communities, man, and at large, the biosphere. That is why ecological management is advocated nowadays. Nevertheless, development should meet the demands of society, it should start from within and must depend largely on local natural assets. It must be sustained within the framework of the society's culture, tradition, etc.

Ecological management is concerned with planning, selecting, organizing and implementing appropriately substantiated and devised programmes. It presupposes feed-back mechanisms. As with development, ecological management should take place at an ecosystem level of organization. It should involve the public in time and space.

Based on the above briefly entertained conditions both development and ecological management are human in origin. They are functionally linked with human needs and capabilities. Hence our theoretical and practical approaches towards highly fragile coastal zone systems should be anthropocentric. We may possibly devise an anthropocentric ideal-system of coastal development as schematically presented in **Figure 1**.

In this model, development is determined by the subsystems and interactions of skilled human resources, type and level of technology and capital resources. These, in turn, are influenced by human (community) ideals, government policies, exogenic factors, and their overall complex interactions. The dynamics of this complex organization aims at satisfying human welfare, health and economic needs. How can we maintain this complex structural set-up? How can we sustain the dynamics for this complex organization?

Unequivocally, the core of this active system is Man. It is the rational minded man. This implies that an approach that could sustain the anatomy and physiology of this system is human ecological view. Thus, everything starts, focuses and continues with man as the centre of attention.

The human role in our ecological systems was, is and will continue to be dynamic. His activities in time and space are unstable and often contradictory. This cannot and must not continue because at this juncture, biologically and socially, the experience of the father has become almost useless to the son (Dubos, 1971).

The diversity and inertia of change are becoming beyond comprehension. They are going on unapproachably because of our reductionist attitudes, beliefs and stand. We also always forget one of the environmental variables – man himself. Man is part of the whole. His activities change. His needs change. His behaviour changes. Therefore, a holistic approach including man in the ecosystem, should be human ecology.

In our present attempt, human ecology is comprised of two separate but firmly intertwined systems (i.e., in terms of previous human understanding) which are natural ecological and modern economic systems. This holistic approach may be illustrated as given in **Figure 2**.

Figure 2 demonstrates that both systems are open and not closed (isolated). Both systems remain dynamic and not static. They posses structural components with characteristic alignment and design to give rise to a complex organization. The life of the systems is sustained by metabolic interaction so that the accommodation, distribution and utilization (interpretation) of information is efficiently facilitated. Both systems must entail bio-regulation or limitations. Their development must proceed orderly with certain definite purpose.

The structural and functional relationships of this economic and natural ecosystem may further be elaborated using **Figure 3** which illustrates the intertwined relationship of these systems in space. Of the two, modern economic systems are purely human ecosystems. They embrace four sets of structural components: **PHYSICAL COMPONENTS** (including physical environmental variables, environmental conditions); **BIOTIC-COMPONENTS** (human beings, animals, plants, fungi, bacteria, protozoa); **SOCIO-ECONOMIC** (agricultural, technical, industrial, and social organization) and **BEHAVIORAL** (history, culture, tradition, ideals, bio-memory, etc.). Accordingly, human impact may be viewed or delineated in terms of three rather interrelated chains of interactions, i.e., **MAN <------> NATURE INTERACTIONS, MAN <------> HIS PRODUCT INTERACTIONS, AND MAN <------> HIS PRODUCT <---> NATURE INTERACTIONS**.

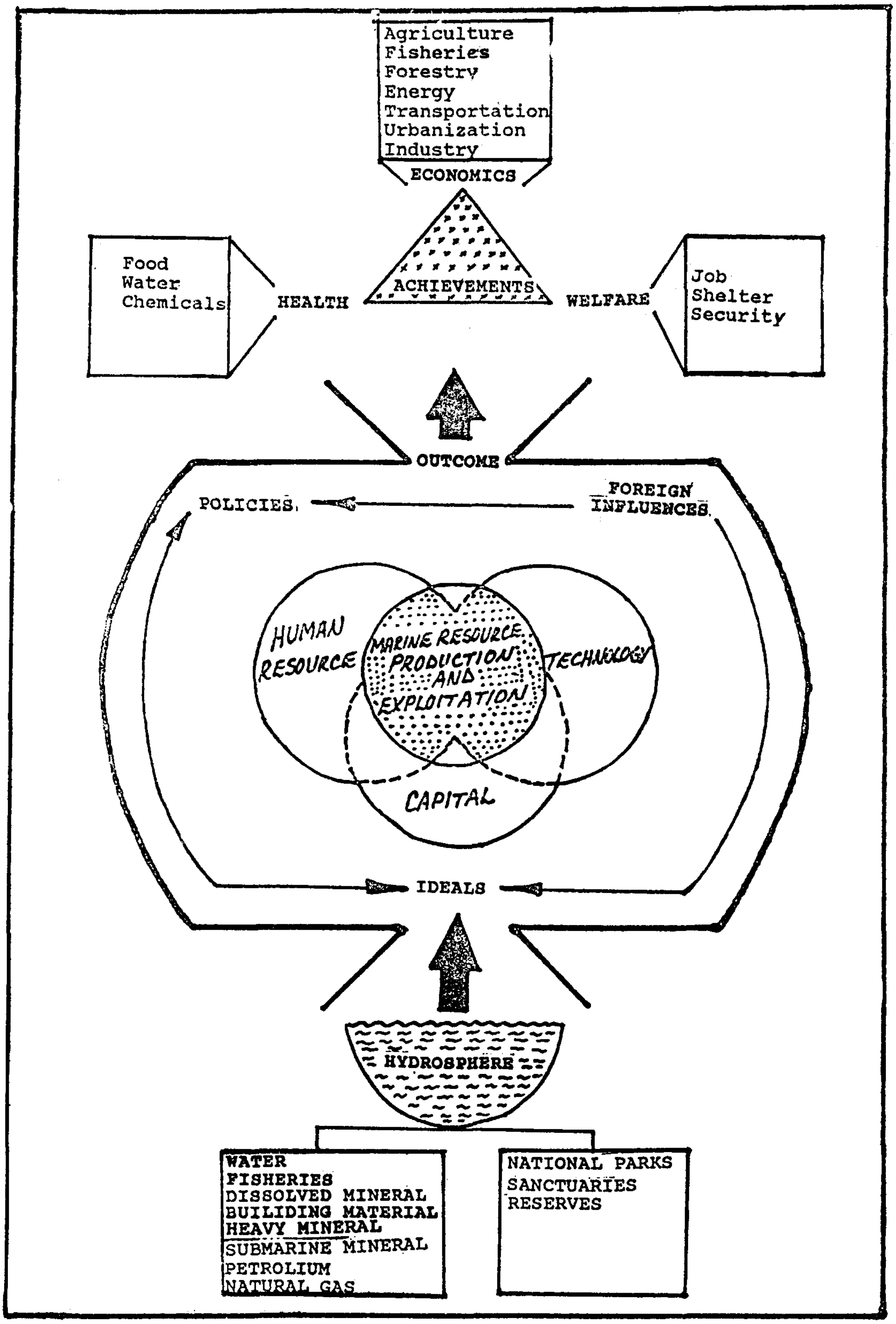
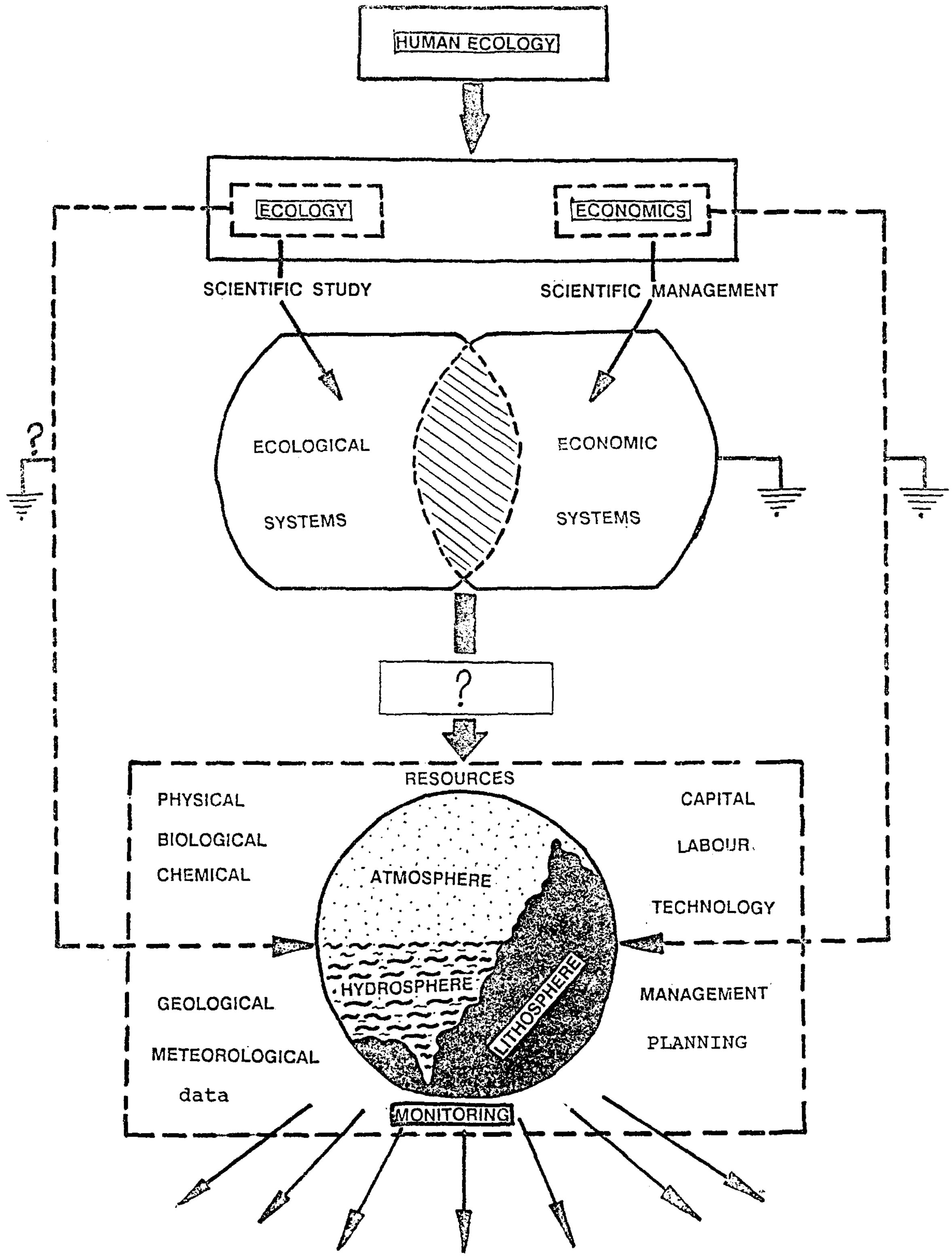


Fig. 1. An ideal system of coastal development (After Kiflemariam, 1989a)



ıg. 2. **A holistic schematic model depicting Human Ecology and its two component systems** (After Kiflemariam, 1990 – with some modifications).

Let us pose a very vital question here. What if the historical development of our economic and natural ecological systems is not harmonious? What does this imply in view of the three chains of interactions?

Such cases manifest unbalanced or non-harmonious ecological states between the two systems. If the two systems are found at two different non-harmonious states, metabolically there will follow unequal exchange of energy and information among them. This case reminds us Margalef's Ecological Principle **"If two systems with different energy and information contents are brought into contact, the better developed one will grow richer and the lesser developed will lose information and energy"** (Castri & Hadley, 1980). This ecological principle implies that unequal states of systems result in increasing the magnitude, intensity or degree of variation. If it is left uncontrolled or unregulated, this variation will proceed to a stage whereby the degraded system will be left devoid of some of its essential component parts. Human impacts widen the differences between the level of ecological states of economic and natural ecological systems. A lot of African coastal environments manifest such trends.

Scientific personnel and legal organizations are responsible for dealing with the study, research and analyses of environmental problems. Refined outcomes could be of use to devise plans and to formulate policies. Well founded and objectively devised plans could be effected for remedial, protective, preservation, conservation and/or exploitative moves.

The first step in any of these moves is data collection and analysis. In analyzing our data of coastal environments we usually deal with techniques of factor analysis. It is true that the concepts of factor analysis techniques are influenced by the concepts of "Limiting Factors". This technique enables us to delineate a certain variable. Nevertheless, it is reductionist and cannot lead to long lasting solutions. A holistic approach presupposes a synthesis in manipulating environmental data.

Validation: an example

Let us consider the developmental problems of the southern Red Sea coastal fisheries. It is characteristically traditional. Kiflemariam (1988a,b; 1989a,b; 1990) attempted to investigate its problematic issues, and the investigation was approached holistically using human ecological views. A model of an integrated Fisheries Development System **(Figure 4)** was devised.

The system (Fig. 4) is composed of social, structural, duties (responsibilities) and technological subsystems. All interact internally and are influenced by exogenics.

This approach integrates fisheries biology, fisheries economics and fisheries ecology as well as other socio-politico-economic domains. This system is an active system where there are inputs, outputs and active interactions, and among them various feedback mechanisms.

This integrated (holistic) approach to studying fisheries problems in developing countries is appropriate because of the complexity of these problems, involving as they do social, economic, biological, psychological and political parameters. They are all equally important in the sense that none can be ignored.

Approaching the problems in this integrated form is vital in the assessment and critical evaluation of the situation so that the best solution will be available to augment fisheries development and management based on the objective conditions of a given environment.

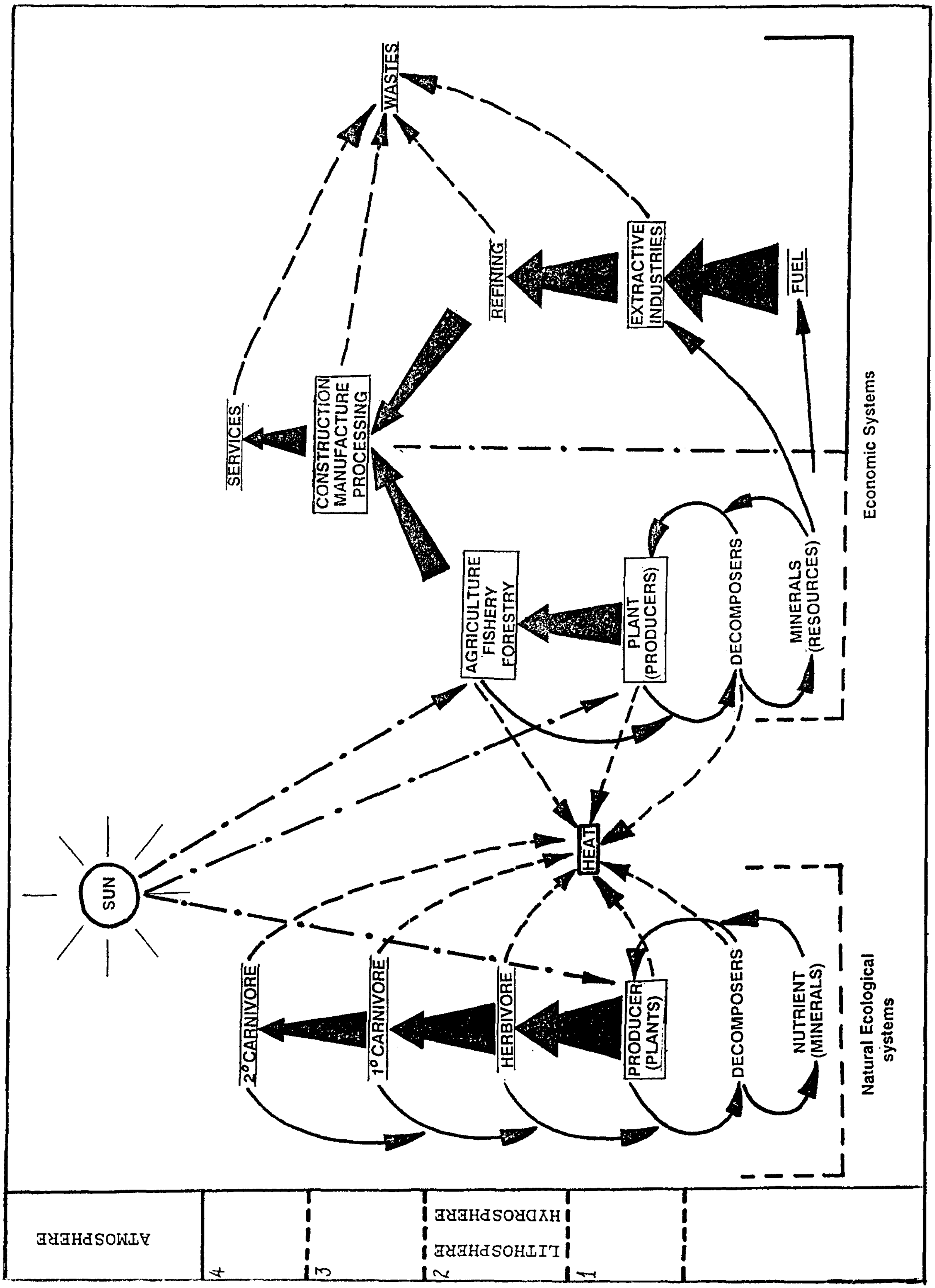


Fig. 3. Model of structural and functional relationships of natural ecological systems and economic systems (After Kiflemariam, 1991b)

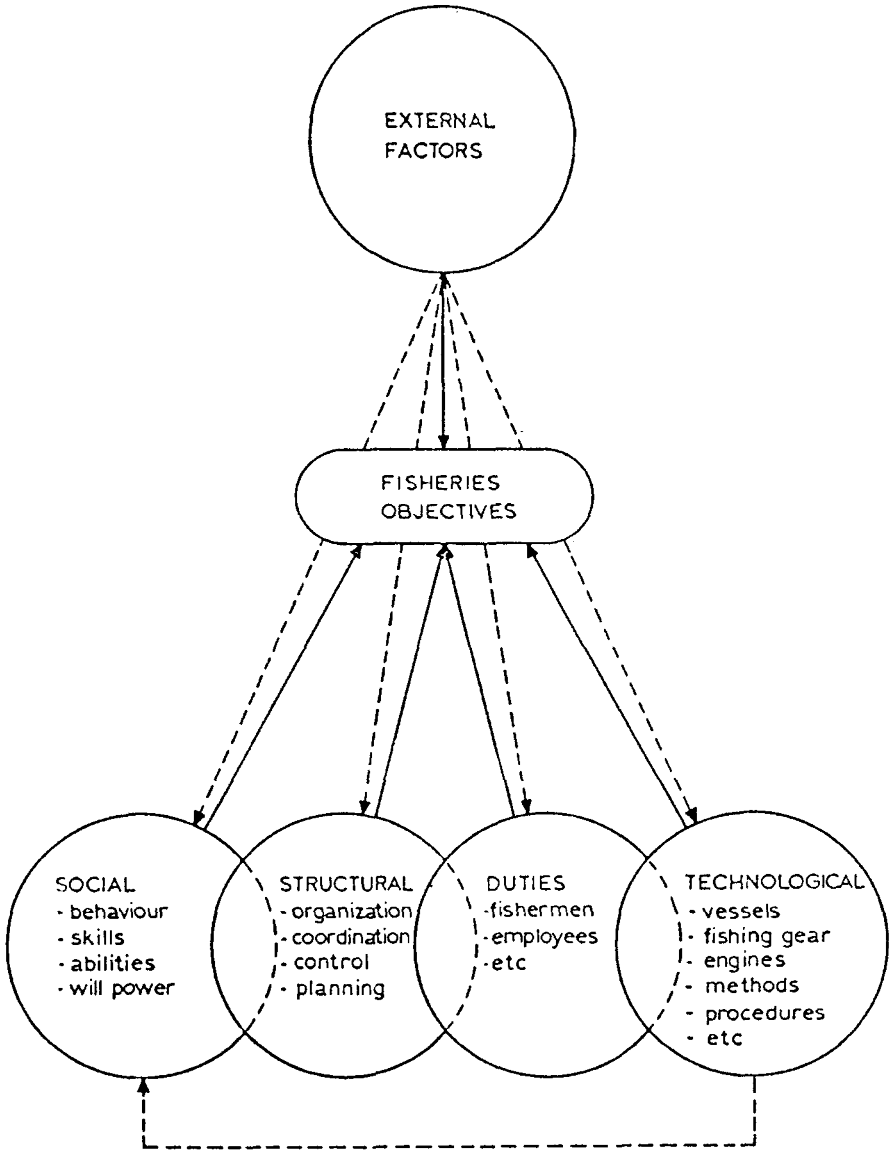


Fig. 4. Fisheries development systems – an integrated approach
(After Kiflemariam, 1989b)

Evaluation assessment

Generally, it is evident that human influence has led to disastrous ecological consequences in coastal environments. These problems are witnessed within human ecosystems and their danger is felt bounded by the potential of human perception. The nature and extent of these consequences imposes upon greater scientific knowledge and wider views. A holistic approach is, therefore, proposed here in order to handle these adversely affected fragile systems in their ecological and evolutionary perspective.

We have to do so in order to enhance "caring and sharing". We have to do so, so that we can change not only human "living standards" but also to evaluate the "quality of life". The question of sustainability is crucial to effect these changes.

The trend since the 70's was to propose the "wise use of natural resources" whenever the question of exploitation of natural resources is raised. It is true that wisdom is vital. It is also true that wisdom is necessary. However, wisdom *per se* is not sufficient. The dimension of sustainability extends far more than it.

Sustainability by nature is human. It implies that man interacts with open systems. It also implies that man is inherently linked with his environments, but that he, always and everywhere, remains a complement of the whole system. Sustainability again implies that man should emphatically recognize his needs and biotic limitations. By and large, all these domains are embraced within the proposed holistic approach.

Our current moves, needs and status strongly urge us to follow holism. Holism, in turn, compels us to grasp the dimensionality of life. Life is inter-disciplinary. It is true whether it is aerial, terrestrial, coastal or aquatic. Life is an ecological and an evolutionary phenomenon; re-evaluate most of our natural sciences which remained theoretically, methodologically and technically as sciences of things by neglecting the human element; mould and remould our potential cognition and to reconsider the dominant concept of "environmental determinism". This concept generally influenced and determined our activities for the last 40 – 50 years; reassess intellectual bias towards applied and technical professions. We should reconsider and appreciate the roles of "mission oriented" or "problem approach" research and field activities; reassess the validity and continuity of project oriented scientific activities. We have to reassess the impact of projects that are exogenically controlled and that exclude members of the local community and reevaluate our attitudes towards artificially created contradiction between ecology and economics.

Our protective, preventive, remedial or conservation practices mostly depend on monitoring programmes (to systematically accumulate data and to analyse them). Hundreds of computer or mathematical models are used in different places by various different authorities. Of the models we may point to some such as Environmental Information Systems, Geographical Information systems, etc. Most of them are narrow in approach and uni-purpose in objectives. And still we are far from possessing holistic models to human perpetrated but holistic problems.

Conclusive remarks

A holistic approach presupposes all our scientific activities to be devised with a multidisciplinary set-up. It rejects sectorial compartmentalization of sciences, professions, methods, techniques, offices and responsibilities. It rejects so, because "the truth is the whole".

Our current activities, in assessing human impacts upon coastal zones, may probably enable us to determine how far changes have progressed in time and space. Although, at this juncture we have no other alternative, yet we have to recognize that our findings will still remain largely informative and slightly conclusive. Therefore, we cannot claim to have endeavoured sufficiently and efficiently to tackle the intricately related causes and effects.

In our attempts, we are trying to move a step further, but we remain far from solving the enigma. It is true, because we could not answer the question HOW? and WHY?

Most of our assessments are project oriented. They are dictated by finance and a limited time duration. Our assessments may merely focus on the natural, economic or social environment and may leave out or neglect other sectors.

Qualitatively, most of our field practices are surveys and not environmental assessments. Our surveys or assessments involve only trained or skilled human resources, but exclude the local community. By doing this, we exclude the traditional (culturally) trained human factors which are tightly linked with the affected environment.

Our practice, which is enforced from without, will remain partial in outcome and questionable unless it is otherwise supported from without. No sustainability is envisaged without fulfilling these preconditions.

The experience from the Red Sea coastal zones implies that human impacts may be neutralized if we work co-operatively and co-ordinately irrespective of the various artificially created boundaries. Human impacts may be neutralized if we develop a readiness and good will to approach the tough question of WHY?

References

Allsopp, W.H.L. (1960). The Manatee: Ecology and use for weed control, *Nature,* 188: 762. Anonymous. (1970). Tourist Increment, *Il Bolletino*, Asmara 15 Gennaio, 1970.

British Museum. (1952). The "MANIHINE" Expedition to the Gulf of Aqaba, *The British Museum (Natural History) Zoology,* 1(8): 153-252.

Bertram, G.C.L. & Bertram, C.K.R. (1986a). Bionomics of Dugongs and Manatees, *Nature*, 218: 423-426.

Bertram, G.C.L. & Bertram, C.K.R. (1986b). The Sirenia as aquatic Meat-producing Herbivore. *Symposium of Zoological Society, London,* 21: 385 – 391.

Castri, F. di & Hadley, H. (1980). Research and Training for Ecologically sound Development: Problems, Challenges and Strategies. *Tropical Ecology and Development* 2: 1229-1252.

Clements, F.E. (1905). *Research Method in Ecology*, University Publishing Company, Lincoln, Nebraska.

Commoner, B. (1973). *The Closing Circle*. Jonathan Cape Ltd., London.

Dubos, R. (1971). Man and his Environment: Scope, Impact and Nature. In: T.R. Detwyler (Ed.), *Man's Impact on Environment* MacGraw-Hill Book Company, New York, 684- 694.

Dubos, R. (1973). Humanizing the Earth: *Science*, 179: 769-772.

Evans, P.G.H. (1983). Cetaceans of the Red Sea: Edward Grey Institute, Zoology Department, Oxford, 13 pp (Mimeograph).

Heinsohn, G.E. (1972). A study of Dugongs *(Dugong dugong)* in Northern Queensland, Australia: *Biological Conservation*, 4: 205-213.

Huges, G.R. & Oxley-Oxland, R. (1971). A Survey of Dugongs *(Dugong dugong)* in and around Antonio Eres, Northern Mozambique: *Biological Conservation*, 3: 299-301.

Kiflemariam, M. (1988a). Case history study of the Ethiopian Red Sea coast Fisheries. A paper presented in the 3rd Workshop of Natural Science Faculty, Asmara University, May 4-5 1988, Asmara.

Kiflemariam, M. (1988b). Bio-Economic persperctives of the Ethiopian Red Sea coast Fisheries. *Ethiopian Journal of African Studies*, 5: 21-31.

Kiflemariam, M. (1989a). Role Marine Resources for Development. A paper presented in the regional Symposium of Marine and other natural products, Asmara University and The Chemical Society of Ethiopia, 25 February, 1989, Asmara.

Kiflemariam, M. (1989b). Problems of Marine Fisheries Development. The Ethiopian Case, *Ocean and Shoreline Management*, 12: 347-361.

Kiflemariam, M. (1990). Some Ethiopian Red Sea Pelagie and their significance. *Proceedings of the First National Conference of Ethiopian studies. Addis Ababa, April 11-12, 1990.* Institute of Ethiopian Studies, Addis Ababa University, Addis Ababa: 177-188.

Kiflemariam, M. (1991a). Community structure of Macrobenthos around coastal habitats of Mitsiwa (Massawa), Ethiopian Red Sea, *COMARAF Serie Documentaire No. 8*. UNDP-COMAR-UNESCO, 35pp.

Kiflemariam, M. (1991b). Human Ecology: Africa's Alternative to Environment and Development. A paper presented to the African Academy of Science Conference on Environment and Development, 11-12 November, 1991, Mbabane, Swaziland.

Kiflemariam, M. (in press). Ecology of Macrobenthos in the shallow coastal areas of Tewalit (Massawa), Ethiopia, *Journal of Marine Systems.* Elsevier Science Publishers.

Kiflemariam, M. (unpublished, 1). Multi-purpose Interest over the Ethiopian Red Sea coast. A plenary lecture delivered in the 6th Annual Congress of the Chemical Society of Ethiopia, 11- 12 August 1989, Science Faculty, Addis Ababa University, Addis Ababa.

Kiflemariam, M. (unpublished, 2). Ecological View: An approach to Explore and Exploit the Ethiopian Red Sea, Department of Biology, Asmara University, Asmara.

Leopold, A. (1933). *Game Management,* Charles Scribner's and Sons, New York.

Ray, C. (1970). Feasibility study for Marine Parks at Dahlak, *Il Bollettino*, Asmara, 30 Gennaio, 1970.

Riddel, R. (1981). *Ecodevelopment*, Gower Publishing Company Ltd., Hampshire.

Shaw, P.R. (1989). Rapid population Growth and Environmental Degradation: Ultimate versus Proximate Factors. *Environmental Conservation*, 16: 199-208.

Simon, D. (1989). Sustainable Development: Theoretical Construct or Attainable Goal? *Environmental Conservation*, 16: 41-48.

Swift, J. (1975). In: *New Scientist*, 67: 79.

The Courier, (1988). Fragile but fruitful. *The Courier* No. 109: 15-18.

Environmental impact assessment for sustainable development of coastal and marine resources.

MWEU Nguta C.
Kenya Marine and Fisheries Research Institute
P.O.Box 81651 Mombasa
KENYA

Abstract

Sustainable development arises from the premise that environment and development are interdependent. Environment impact assessment studies the effects of a proposed action on both the natural and human environment. The ability to predict changes resulting from specific development proposals can be applied only when there is adequate knowledge on the proposal and the functioning of the aquatic ecosystem features. Therefore, no universal guidelines for assessing ecological impacts, would be applicable to all situations. In this paper a systematic approach for assessing such ecological impacts with particular reference to some existing and proposed developments on the Kenyan coastal zone is presented.

Introduction

There has been a growing environmental awareness among society increasingly focussing attention upon the interactions between development actions and their environmental consequences. This has led to the public demanding that environmental factors should be explicitly considered in the decision making processs (OECD, 1979).

Early attempts at environmental assessment were inadequate and often based upon Cost Benefit Analysis (CBA) which highlighted economic aspects at the expense of environmental issues.

Such shortcomings and flaws in the CBA approach became apparent and led to the new approach towards evaluation which came to be known as Environmental Impact Assessment (EIA). This can be described as a comprehensive approach to project evaluation, in which environmental considerations, and not only economic and technical considerations as was often previously the case, are given their proper weight in the decision-making process.

For a start it should be understood that sustainable development is the recognition that environment and development are interdependent. EIA can, therefore be considered as an important tool in the sound assessment and evaluation of development proposals. This paper examines the aims, objectives and broad principles of EIA as they relate to the application at the project level.

There is no general and universally accepted definition of EIA. Several definitions provide a broad indication of the aims and objectives and illustrate differing concepts of EIA. (Ahmed & Sammy, 1985; Canter, 1979; UNEP/UNESCO, 1987)). Basically EIA is a study of the effects of a proposed action on the environment. This may therefore include the evaluation and ultimate reconciling of social and economic aspects of a development with their ecological and environmental effects. In general therefore, EIA tries to identify, predict and to describe in appropriate terms the penalties and benefits of a proposed development project. The assessment needs to be communicated in terms understandable by the community and decision-makers and the advantages and disadvantages should be identified on the basis of criteria relevant to the particular area of the country affected.

Thus the main objectives of EIA are to provide decision makers with an account of the implications of proposed courses of action before a decision is made. The results of the assessment are assembled into a document called an Environmental Impact Statement (EIS) which contains a discussion of beneficial and adverse impacts considered to be relevant to the project, plan or policy. This completed EIA document is one component of the information upon which the decision maker ultimately makes a choice. Other factors such as unemployment and national policies energy requirements may influence the outcome of the decision at this stage.

The EIA document which is the key output of the EIA process should included the following:

(i) a description of the project proposal and the activities it is likely to generate;

(ii) description of the location where the proposed project is to be sited, including the environmental and socio-economic parameters that may be affected;

(iii) reasons to support the selection of proposal site and the technology to be applied in the proposal. A description of practical alternatives which have been considered should be included;

(iv) identification and assessment of anticipated negative and positive impacts on environmental quality and health as a result of implementing the project proposal;

(v) description of ways proposed for eliminating, minimizing or mitigating the anticipated adverse impacts, and

(vi) proposed monitoring programme of the environmental impact of the project. Procedure for the preparation of the EIA document will differ from country to country depending upon national legislative requirements (Jain *et al*, 1977), but the three options that exist for the preparation of the EIA document are by:

   a) the company or individual proposing the project;

   b) the government department authorizing the project; or

   c) an independent party.

Environmental impact assessment methods

Many guidelines, models and methods have been developed to aid identification, prediction and assessment of impacts. The implementation of EIA may be subdivided into the following separate tasks and activities:

(i) impact identification – this refers to the need to determine those impacts requiring investigation;

(ii) impact measurement – this usually refers to a quantitative estimation of the magnitude aspects of impacts;

(iii) impact interpretation – refers to the need to determine the importance of an impact;

(iv) impact communication to information users – refers to the presentation of information to help decision-makers and the interested public to come to some conclusions on the merits and disadvantages of a proposed project.

Some EIA methods can aid only a few of these activities while some can be used for nearly all. In this introduction of methods only simple checklists and interaction matrices will be discussed.

Checklists

Checklist methods are among the first EIA methods to be developed. The simple checklist lists environmental factors present in the locality of the proposed development which should be addressed. The list can contain flora, fauna, hydrological regimes, surface waterbodies and other categories of factors. No information is provided on specific data needs, measurement, impact prediction and assessment methods. Simple checklists provide a systematic approach to an environmental impact study.

Descriptive checklists refer to methodologies that include lists of environmental factors along with information on measurements and impact prediction and assessment. These checklists are more widely used in environmental impact studies (Canter & Hill, 1979).

Another major group of checklists are known as scaling or ranking checklists. In this method algebraic- or letter-scales are assigned to the impact of each alternative being evaluated on each identified environmental factor. Ranking checklists refer to approaches in which alternatives are ranked from best to worst in terms of their potential impacts on identified environmental factors. These checklists are useful for comparative evaluations and hence selection of the preferred alternative.

Checklists of the "questionnaire" type are also common. This checklist presents a series of questions related to the impacts of a project. The checklist is used to provide answers to specific questions relating to the project being assessed followed by additional questions to investigate the nature of particular impacts in detail (Clark *et al*, 1981).

The usefulness of checklists is limited because impacts cannot be identified in a comprehensive way unless detailed knowledge of the characteristics and actions associated with the project are related in a systematic manner to components of the environment. Consequently, checklists of development actions and checklists of environmental components have been brought together in a two-dimensional matrix to aid systematic identification of impacts.

Matrices

The most famous of these methods is probably the matrix developed by Leopold and his colleagues (Leopold *et al*, 1971). A list of development actions is displayed horizontally, while a list of environmental components is displayed vertically. When a given action is anticipated to cause a change in an environmental factor, this is noted at the intersection point in the matrix and further described in terms of magnitude and importance considerations. Assigning scores for magnitude and importance depends on the subjective views of those assessing a proposal. Owing to their subjective nature the scores cannot be manipulated arithmetically. Thus although such matrices may contain a considerable amount of information on impacts, the subjective nature of the information should be kept in mind. Despite these and other shortcomings the continued popularity of the matrices method attests to its utility in EIA.

Selection of a methodology

Selection of a methodology should focus on methodologies developed for project types similar to the potential project being evaluated. The selected process will be governed by consideration of the following desirable characteristics:

An environmental impact methodology should be as comprehensive as possible. Both significant beneficial as well as detrimental impacts should be highlighted. Methodologies should be within the legislative policy of the governmental ministry responsible for the impact study.

Methodologies should be dynamic and adaptable to changes occurring in the study area. The importance of environmental factors from one geographic area to another should be considered, and flexibility provided to adapt the methodology to differing environmental settings.

Also, another desirable characteristic is that the methodology be more oriented towards a quantitative rather than a subjective approach.

Finally, the selected environmental impact methodology should be implementable with respect to manpower, funding, data and time requirements.

EIA for sustainable development of coastal and marine resources

In order to deal effectively with the problem of identifying and predicting impacts of an aquatic environment, an understanding of the basic nature of the life process and how it functions in water must be gained. This leads to the need for aquatic baseline studies as an integral part of the EIA process. Such monitoring can ensure that adverse effects are detected at an early stage so that remedial action can be taken before expensive mitigation actions are required.

EIA is also a mechanism which aids the efficient use of natural and human resources valuable to those promoting developments and those responsible for their authorization. EIA may reduce the cost and time taken to reach a decision by minimizing subjectivity and duplication of effort, as well as identifying and attempting to quantify and primary and secondary consequences which may incur the use of expensive pollution control equipment, compensation or other costs at a later date.

To be effective EIA should be implemented at an early stage of project planning and design. It must be an integral part in the design of projects, rather than something utilized after the design phase is complete. EIAs can be implemented to test alternative project designs at an early stage in order to emphasize benefits and minimize harmful effects of the choice design. Hence EIA can be used not only to investigate and avoid harmful impacts but also to increase likely benefits.

The emergence of an optimum alternative in terms of the objectives or goals relevant to a proposed project means that EIAs may have significant long-term financial advantages. If a potential problem is identified early in project planning it may allow considerable financial savings to be achieved. In extreme cases the abandonment of a project may be required if all alternative designs or locations are considered unsuitable in terms of likely detrimental effects. It is more likely, however, that design modifications may obviate the need for expensive ameliorating action once a project becomes operational.

The incorporation of EIA into decision making may create a number of benefits. First, if a forecast of the likely impacts of development are available allowances can be made and infrastructure provided in a manner whereby negative impacts are minimized. Second, where uncertainty exists as to future development, EIA can identify areas most susceptible to adverse impacts and so guide site selection. EIA can only be used when the alternative sites are few in number, otherwise EIA can be time consuming and very expensive. EIA can, nevertheless, aid the identification of the most suitable site in terms of benefit maximization and reduction in harmful effects. Should no site be considered suitable, then the results of EIA aid the determination of broad environmental, social or heath criteria to be used when a large number of sites are screened for their suitability.

Most coastal cities in Kenya are major tourist centres with most industries being concentrated in Mombasa. Human impacts on the marine coastal areas are therefore evident in many forms, including pollution. Practically all of the human development activities have not been subjected to EIA studies, resulting in a deterioration of the coastal environment.

Among the most important sources of land-based pollution is the sediment transported by the various rivers. Poor agricultural methods, overgrazing and the indiscriminate destruction of forest cover are major causes of the rapid loss of top soil transported to the sea.

The deposit of sediment although beneficial to marine fisheries in some cases (UNEP, 1982) has resulted in the destruction of the coral reefs around Malindi.

Major industries such cement and limestone quarrying, chemical and textile plants have the potential to cause polllution.

The rapid population growth of the coastal town and an increase in industrial and commercial activities has resulted in inadequate sewage treatment and disposal facilities and the sea has provided an easy disposal solution. Although the situation may not be very serious there is a need for EIA studies especially to monitor the situation which is still a problem requiring constant attention (Nat.Rep.Kenya, 1971) .

Possible cases of thermal pollution are associated with a number of industries that use seawater for co-oling purposes. The temperature of the discharged co-olant water may be high enough to have adverse effects on the marine environment. In particular the thermal generating stations situated at Mbaraki Creek and Kipevu in Mombasa and that situated at Malindi could result in adverse impacts on the marine environment. These are old plants that were installed with little environmental considerations. It is gratifying to note that EIA studies are being conducted for a proposed power plant and the Export Processing Zone at Kipevu sponsored by the World Bank.

Coastal tourism development through the rapid expansion of hotel establishments along with the infrastructure that goes with it has taken place in total disregard of environmental issues. This development, often based solely upon economic factors, has resulted in the destruction of critical marine habitats. This state of affairs has been encouraged partly because of the lack of legislation regarding the various aspects of tourism development and the impact these might have on the coastal and marine environment.

Some reasons for the non-use of EIA

Apart from lack of proper legislation relating to environmental management, other problems that hinder the use of EIA's in Kenya are identified as:-

1. Lack of trained personnel in many fields leading to inadequate preparation of EIA reports.

2. Lack of baseline data on environmental and social systems.
3. Lack of financial resources which is closely related to lack of trained manpower.
4. Lack of co-ordination between relevant ministries. This inhibits co-operative work when consultation and information exchange is important.
5. Limited public knowledge and participation in EIA.
6. Low status in governmental hierarchy of environmental ministries compared to development and economic growth ministries.

Conclusion

EIA should be an essential part of any developmental project, however small. A sound approach would be a shared responsibility between the authorizing agency and the developer. One to lay down the terms of reference and guidelines for EIA and the other to bear the costs and carry out the actual assessment. An independent reviewing body to supervise and control those activities would be useful. The role of public participation in the whole exercise should not be overlooked. This may increase the acceptability of the project and minimise the chances of conflict and delay. Finally, EIA has been in use for sometime now in a number of developed countries. Its promotion world-wide should be intensified. International organizations and governments need to make their stand on EIA clear. A mandatory requirement for the inclusion of EIA in all major international and national development projects should be instituted.

References

OECD, (1979). Environmental impact Assessment Analysis of Environmental consequences of significant Public and Private Projects. *Organization for Co-operation and Development*, Paris.

Ahmed, Y.J., & Sammy, G.K. (1985). Guidelines to Environmental impact Assessment in Developing Countries. Holder and Stonghton, London.

Canter, L.W. (1979). Environmental Impact Assessment. McGrow Hill: London.

UNEP/UNESCO, (1987). Methodological guidelines for the integrated environmental evaluation of water resources development. *UNESCO*, Paris.

Jain,R.K., Urban, L.V., & Stacey, G.S. (1977) Environmental Impact Analysis: A new dimension in decision making. *Van Nostrand Reinhold Environmental Engineering Series*, London.

Canter, L.W. & Hill, L.G. (1979) Handbook of variables for Environmental Impact Assessment. Ann Arbor, Michigan: Ann Arbor Science Publishers.

Clark, B.D., K. Chapman, Wathern, P. & Bisset, R. (1981). A Manual for the Assessment of major Development Proposals. *London: HMSO.*

Leopold, L.B. *et. al.* (1971). A procedure for Evaluating Environmental Impact, *U.S. Geological Survey Circular 645*. Washington D.C., U.S. Geological Survey.

UNEP, (1982). Marine and coastal Area Development in the East African region, UNEP. *region Seas Reports and Studies* No. 6, p. 13.

National Report on the human environment in Kenya. (1971). Prepared by the working committee of the *United Nations Conference on the Human Environment,* Nairobi, p.69.

Impacts of onshore developments and tourism on the kenya coastal fisheries: the artisanal spiny lobster fishery

OKECHI J.K.
Kenya Marine and Fisheries Research Institute
Mombasa Laboratory
P.O. Box 81651 Mombasa
KENYA

Abstract

Data on the spiny lobster fishery landings from the Kenya coast from the period 1972-1991 indicate a stable fishery of 70 mt annually. The Lamu district contributes over 53% of the landings. The species Panulirus ornatus contributes over 90% of the lobster catch. Spiny lobsters are Kenya's most valuable seafood resource on a price per weight basis.

The growth in the tourist industry on the Kenya coast has led to the construction of many beach hotels. As a result of the popularity of the lobsters, the increase in the number of tourists into the hotels has led to the rise in their cost. On the other hand, the hotels discharge their wastes, particularly raw sewage, into the sea. This, together with other wastes from the urban centres, is a threat to the habitats of the spiny lobsters, namely: the mangrove swamps, seagrass and seaweed beds and the coral reefs. These habitats are further threatened with the increasing pressure on them by tourists, boats and fishermen, who go around collecting sea shells for aesthetic purposes, throwing wastes into the sea, for example tin cans, wrappers and plastics, and destroying the coral reef. These, together with increased shore developments such as urbanization and industrialization and the pollution originating from them, threatens the water quality and the lobster fishery.

Observations conducted on the Kenya coast show that juvenile spiny lobsters frequent mangrove forests and that the adults are found in the coral reefs and rocky bottoms. This paper presents further material on the growth of mortality and exploitation rate of the spiny lobsters. It presents management regulations on the lobster fishery

Introduction

In 1991, 8,004.566 mts of fish were landed on the Kenya coast where the spiny lobster comprised 59.735 mt. (Table 1. Fisheries Department Kenya (FDK), 1991). However, it is likely that actual landings from the fishery are considerably higher than 8,004.566 mt. A number of remote landing beaches and markets may not be reached by FDK personnel who record daily landings. Most of the fishes inhabit the diverse marine habitats along the Kenya coast.

With the current developments along the coast and in the watershed, the fisheries yields are threatened. The developments in question include the destruction of mangroves by deforestation for (i) construction, (ii) firewood, and, to a limited extent, (iii) making of fishing gear. Other equally important developments include aquaculture, mariculture, salt manufacture, waste disposal (dumping), domestic sewage, oil spillage and siltation. These interfere with the feeding and breeding grounds (habitats) of the fishes along the coast. Mangroves are important breeding and

Table 1. Reported marine fish catch (mt) from the Kenya coast for 1991
(Data from Fisheries Department, Government of Kenya)

	A	B	C	D	E	F	G
1	Year: 1991						
2	District	Lamu	Tana River	Kilifi	Mombasa	Kwale	Totals
3	Species	Kilograms	Kilograms	Kilograms	Kilograms	Kilograms	Kilograms
4	Rabbitfish	236389	32	101081	283172	87381	708055
5	Scavengers	283794	0	79017	215696	87182	665689
6	Snappers	61799	4573	9718	104133	60857	241080
7	Parrotfish	37707	0	34573	157844	82702	312826
8	Surgeonfish	3860	0	10345	26628	13800	54633
9	Unicorn	1646	0	2898	3730	7958	16232
10	Grunter	43845	0	7817	25878	17768	95308
11	Pouter	36202	0	1950	30101	34808	103061
12	BlackSkin	26518	0	18802	16244	46729	108293
13	Goatfish	13753	0	1472	1548	21065	37838
14	Streaker	861	93	6896	166258	6881	31356
15	Rockcod	34510	40	23390	44227	23763	125930
16	Catfish	8237	2615	9208	8305	11166	39531
17	Mixed	170315	1832	67788	236209	46760	522904
18	Not Accounted	143915	378	56243	175504	82323	459363
19	Jacks	24021	325	14349	113719	22654	175068
20	Mullets	54104	1078	22785	54223	23684	155874
21	Little Mack	5040	0	12717	55178	36938	109873
22	Barracuda	22790	33	13814	47287	15457	99381
23	Milkfish	2791	0	5249	7520	8863	24423
24	Kingfish	2389	36	43341	27070	10809	83645
25	Queenfish	73	766	20858	13564	11088	46349
26	Sailfish	717	0	74128	4097	6375	85317
27	Tunny	5390	515	35715	1751	13131	56502
28	Dolphin	0	0	11265	1308	2069	14642
29	Mixed Pelagic	2160	1090	25851	79384	39758	148243
30	Not Accounted	17921	576	42011	60765	28624	149897
31	Total	137396	4419	322083	465866	219450	1149214
32	Sharks/Rays	32166	1554	66392	129183	32271	261566
33	Sardines	230	87	74807	223556	48574	337254
34	Mixed Fish	31327	3065	57565	740149	15146	847252
35	Lobsters	31211	1523	14320	7039	5642	59735
36	Prawns	8978	1578	24981	482692	5122	523351
37	Crabs	28663	350	19048	21452	7474	76987
38	Not Accounted	10328	518	8752	76679	2736	99013
39	Beche-de-Mer	5117	0	68	67170	6308	78657
40	Octopus	225	0	18167	54338	46687	119417
41	Squids	379	0	7848	28235	19626	56088
42	Total	6272	0	28104	209567	72621	316564
43	Grand Total	1489015	406622	1077065	3854462	1054578	8004566

feeding habitats for prawns, crabs, lobsters and certain types of fishes (Fig.1). Also seagrasses and seaweed beds and corals are important feeding grounds of most of the marine fishes.

This paper addresses itself to the biology of spiny lobsters along the Kenya coast and the effects of coastal developments on their fishery.

Materials and methods

Observations were made on the Kenyan coast of the Indian Ocean on the nature of the artisanal fishery in relation to other developments. These included identifying the habitats of spiny lobsters, the landing beaches, the marketing, and the relationship between the lobster resources in their habitats and coastal urban and rural developments.

Further, some biological data relevant to the estimation of the parameters, which will be used in modelling with the major aim of managing and conserving the lobster fishery resource was collected. These were estimated using the Wetherall, modified Wetherall and Ford-Walford plots (Wetherall *et al.*, 1987; Pauly, 1984). This included weights and lengths of individual lobsters, breeding seasons and species diversity.

The parameters developed included asymptotic lengths, growth constants, growth performance and mortalities. Some management and positive developments on the lobster fishery are discussed.

Results and discussion

Species diversity and biotopes

The artisanal lobster fishery along the Kenya coast exploits several species (Genus: *Panulirus*). These include *Panulirus ornatus, Panulirus penicillatus, Panulirus versicolor, Panulirus longipes longipes, Panulirus homarus* and *Panulirus polyphagus* These species are exploited in a number of biotopes which include the coral reefs, mangroves, seagrass meadows, seaweed beds, estuarine, environments and rocky bottoms (FAO, 1971; Mutagyera, 1978; Okechi & Polovina, in press).

Synopsis of the lobster fishery

Spiny lobsters have supported an artisanal fishery along the Kenya coast since at least 1954 (Mutagyera, 1978). The fishing is mainly undertaken by divers who use snorkeling gear. The introduction of these diving accessories has enabled the fishermen to dive deeper (to about 10 metres) and to access lobsters in habitats which they have not been able to exploit before. Other methods used, though to a lesser extent, include traps and trammel nets. Landing of spiny lobsters from the Kenya coast since 1972 to 1991, collected by the FDK, have been stable at about 70 mt except for 1987 and 1988 (Fig.2). Higher landings reported in 1987 and 1988 are due to very high landings from Mombasa. It is possible that imports from Tanzania are included in Mombasa landings in those years. It is likely that actual landings from the artisanal fishery are considerably higher than the 70 mt level indicated by the data reported by FDK. Major landing is done at Kiunga, Lamu, Kizingitini and Kipini. Other landings occur in Malindi, Kilifi, Mombasa, Shimoni and Vanga (Fig. 1). No records are available on landings by species, but discussions with fishermen and dealers suggest that *P. ornatus* accounts for over 90% of the landings. The FDK records the landings by district, and over the period 1989-1991, 53% of the landings came from Lamu district. Monthly landings of spiny lobsters pooled over two years (1989 and 1990) indicated the highest landing during the period October-April (Okechi & Polovina, in press). The months of the lowest catch are May-July, during the South East Monsoon when strong winds produce unfavourable fishing conditions (McClanahan, 1988).

Spiny lobsters are Kenya's most valuable seafood resource on a price per weight basis. In March, 1993 the average price paid to fishermen for a whole live spiny lobster was approximately US \$ 8 Kg^{-1}. Most of the catch is marketed live or fresh within the country. The major tourist towns where lobsters are consumed are Mombasa, Lamu, Malindi at the coast and Nairobi in Central Kenya.

Effects of onshore developments and tourism

An important observation made on the Kenya coast is the close association of the landing beaches with mangrove forests and estuarine environments. Juvenile lobsters were found in the mangrove habitat, but the fishing is done mainly at the coral reef and rocky bottoms. This therefore requires that these habitats are protected from the deleterious effects of pollution and overfishing. Overfishing of lobsters is evidenced by the preponderance of juveniles in the landings. Figs. 3 and 4 show the population structure and growth curves of the most important lobster landed on the Kenya coast, *P. ornatus* which constitutes over 90% of the total landings. It can be deduced that the majority of the lobsters are harvested before they attain sexual maturity. Our analysis on data collected (Table 2) shows that the lobster attains a symptotic (maximum) length (L_{00}) ranging between 18.5 to 20.3 cm carapace length. It has a growth constant of $0.21y^{-1}$, total mortality of $1.20y^{-1}$, a natural mortality of $0.14y^{-1}$ and a fishing mortality of $1.06y^{-1}$

From these results the calculated exploitation rate is very high at 88.3% showing that fishing intensity is very high. The high prices offered to fishermen have lead to increased fishing pressure on lobsters. Due to this, fishermen have been encouraged to overfish in the inshore waters. Further, the common man cannot afford this valuable protein resource. This development therefore has far reaching effects on the economy and protein nutrition of the coastal communities.

There are no regulations specifically governing the lobster fishery. Ecosystem overfishing is evident. The fishermen are encouraged to harvest females carrying eggs as the eggs are used to make a special sauce which is served with co-oked lobsters or other gourmets in tourist hotels and restaurants. This encourages recruitment overfishing.

Retention of female lobsters with eggs should be prohibited and those accidentally caught should be released into the sea. This does little harm to the welfare of the fishermen, as the lobsters can be caught later after the eggs have hatched. FAO (1971) set the minimum carapace length for *P. ornatus* at 8.0 cm. Mutagyera (1983), placed it between 8.5 – 9.0 cm carapace length and in the nearby Island of Zanzibar, Mutagyera (1978), reported berried *P. ornatus* of 8.5 cm carapace length. So as to enable all female lobsters to spawn at least once, harvesting *P. ornatus* less than 9.0 cm carapace length should be discouraged. As a deterent measure to lobster fishermen and dealers, consumers should discourage acceptance of any lobsters that are sublegal and those carrying eggs, although this is not an easy objective to enforce. This will ensure a sustainable harvest that is economically profitable.

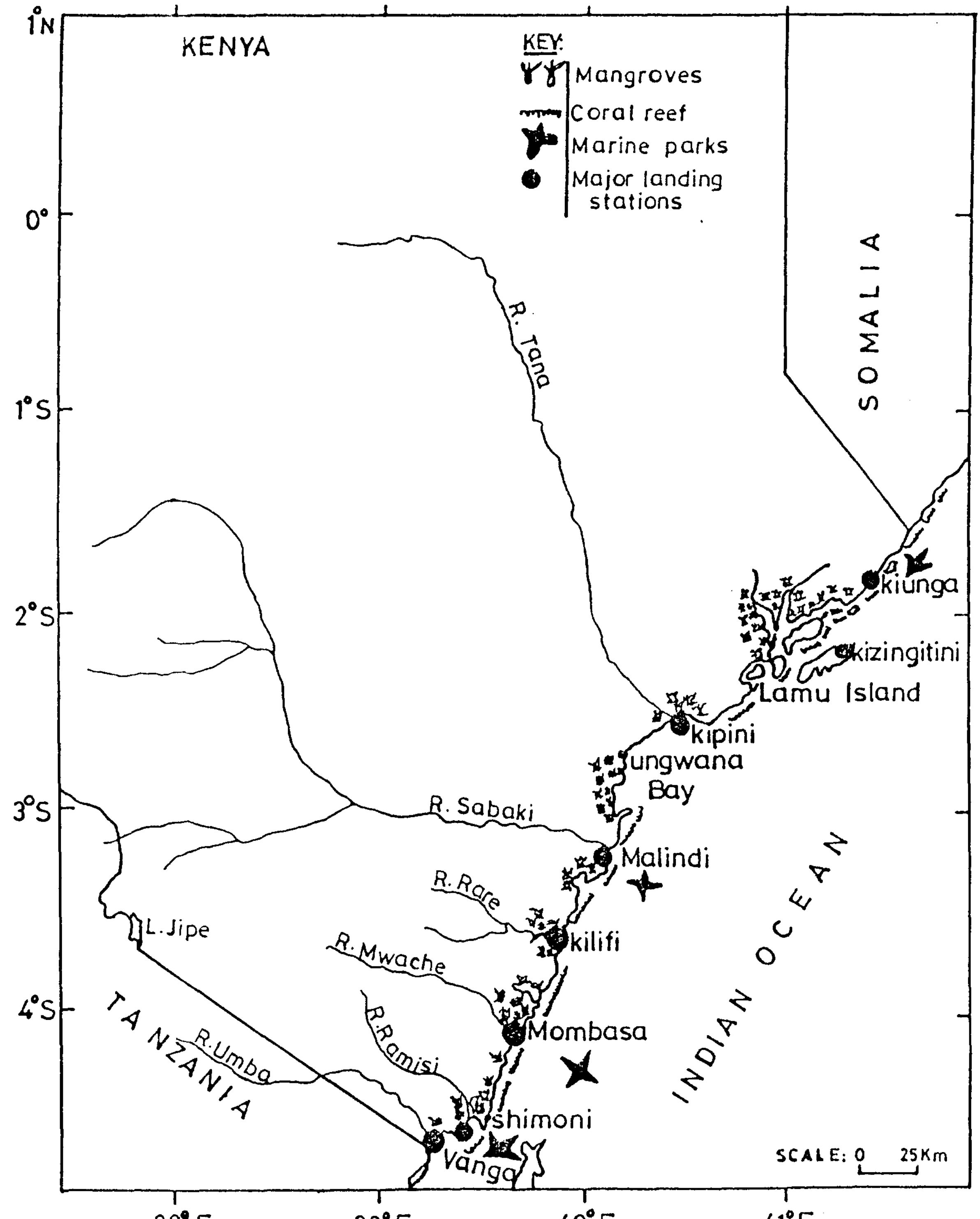


Fig. 1. The major landing stations of spiny lobsters and some of their main coastal habitats (mangrove creeks, estuaries and coral reefs) and marine parks.

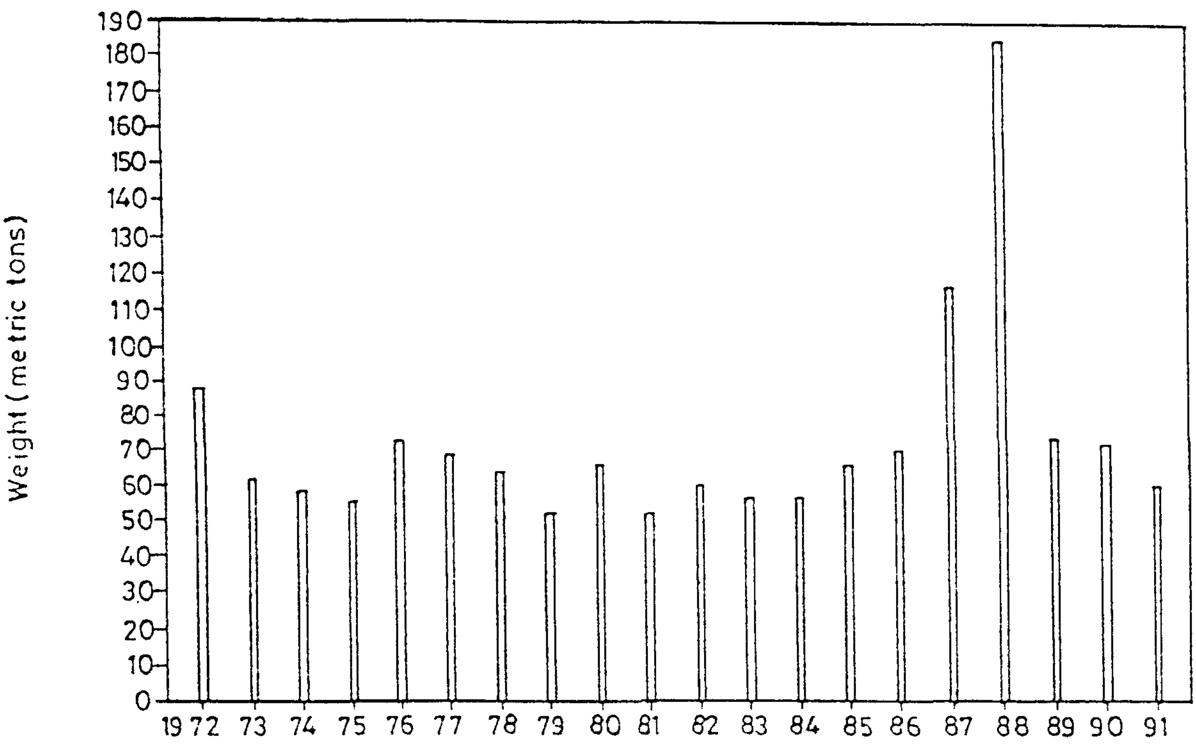


Fig. 2. Annual spiny lobster fishery landings (mt) from the Kenyan coast 1972-91. (Data from Fisheries Department, Government of Kenya)

There are four parks along the Kenyan coast. All fishing, including lobster fishing, is prohibited in the parks. Marine parks act as sanctuary areas or "resource-replenishment" areas. However, given the relatively small areas contained in these parks, it is unlikely that they provide significant protection for the spiny lobsters and other marine fishes.

The tourism industry has led to the construction of many beach hotels on the coast. More than 350,000 tourists visited the coast in 1989. With tourism growing at 11.6% yearly this means that 436,000 visitors visited the coast last year (Min. of Tourism, 1992). The coral reef constitutes the major habitat for the spiny lobsters and other coral reef fishes. The lobster fishery mainly takes place at the coral reefs. Due to increased pressure from tourists and fishermen, some coral reefs at the coast have little marine life left. The reef acts as a sea break and its destruction leads to shore erosion (UNEP/IUCN, 1988). The shell collectors hack at the reef with crowbars and hammers and remove shells beneath the crevices. These as well are the places where the spiny lobsters prefer to stay in the coral reef. In this way, the habitat of the lobsters as well as coral reef fishes is destroyed.

Most urban centres such as Mombasa, Malindi, Kilifi and Lamu discharge their wastes into the sea. The wastes include domestic sewage and industrial wastes, oils and grease from motorised vessels, hotels and ships; and other wastes such as used cans, garbage and wrappers. Similarly agricultural activities in the watershed result in silt and nutrients, mainly phosphates and nitrates, being carried down to the sea leading to eutrophication. These affect the water quality particularly

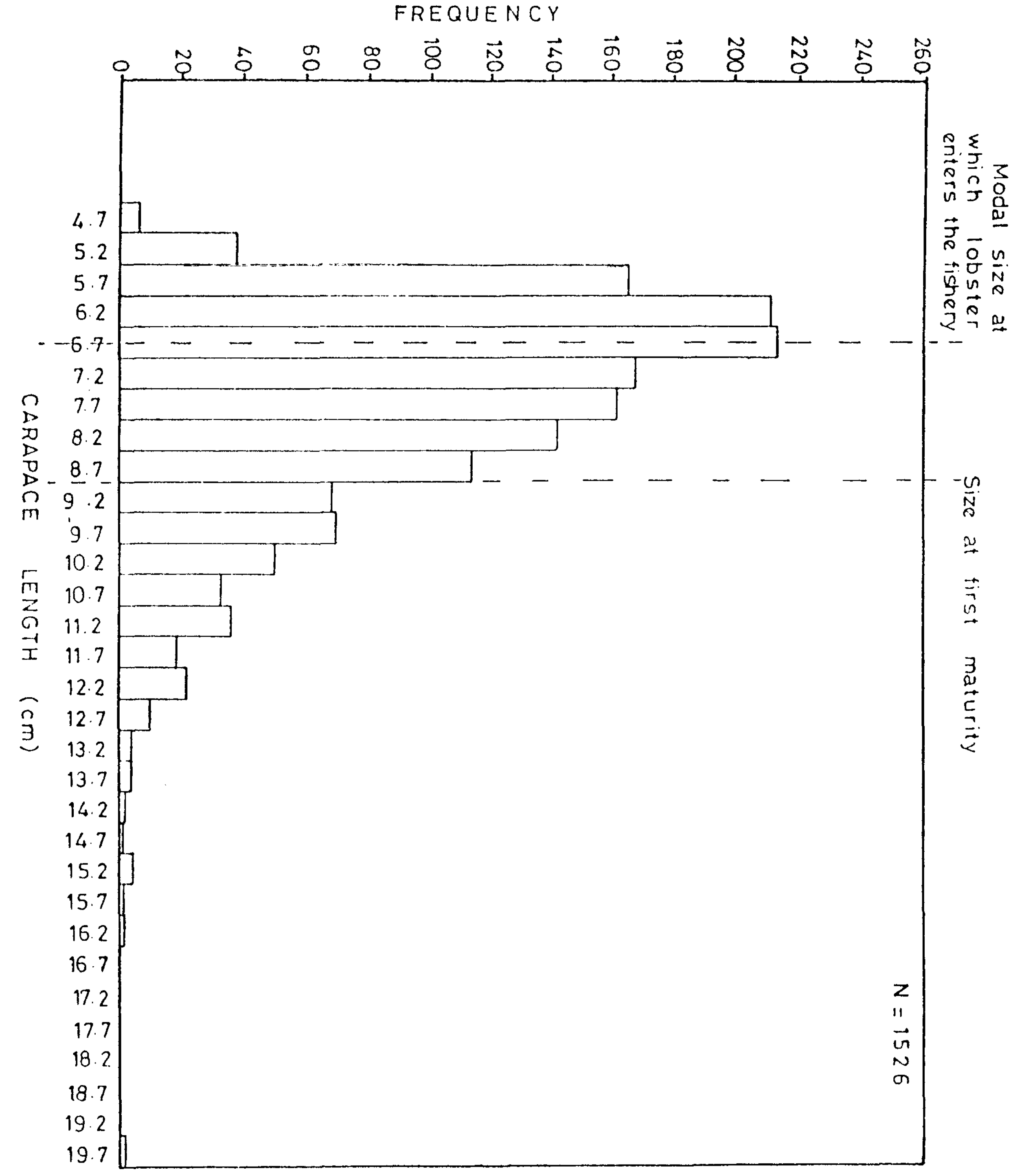


Fig. 3. The population structure of *Panulirus ornatus* from the Kenyan waters of the Indian Ocean for samples taken during the period July 1992 – January 1993.

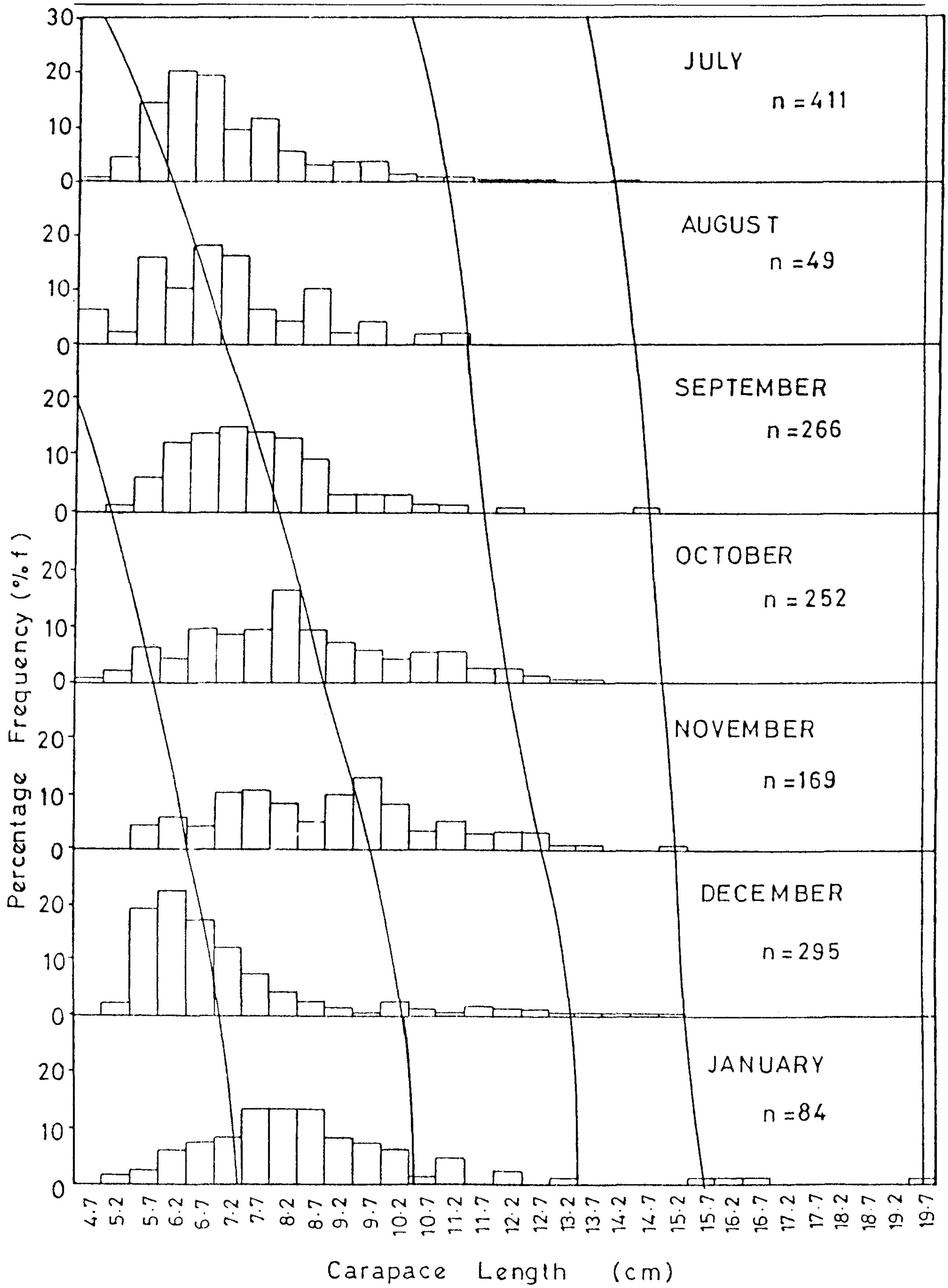


Fig. 4. Growth curve of *Panulirus ornatus* from the Kenyan waters of the Indian Ocean for samples taken during the pariod July 1992 – January 1993.

Table 2. **Length frequency distribution of *Panulirus ornatus* from the Kenyan waters of the Indian Ocean for samples taken during the period July 1992 – January 1993.**

Class	Class mid-point	Frequency							
		Jul	Aug	Sept	Oct	Nov	Dec	Jan	Total
4.5-4.9	4.7	2	3	0	1	0	0	0	6
5.0-5.4	5.2	20	1	2	5	0	8	1	37
5.5-5.9	5.7	59	8	17	17	6	57	2	166
6.0-6.4	6.2	82	5	33	10	10	67	5	212
6.5-6.9	6.7	79	9	38	24	7	51	6	214
7.0-7.4	7.2	37	8	41	21	17	37	7	168
7.5-7.9	7.7	46	3	39	22	18	23	11	162
8.0-8.4	8.2	24	2	35	42	15	13	11	142
8.5-8.9	8.7	12	5	26	24	9	7	11	94
9.0-9.4	9.2	14	1	8	18	17	3	7	68
9.5-9.9	9.7	15	2	9	14	22	1	6	69
10.0-10.4	10.2	6	0	8	10	14	7	5	50
10.5-10.9	10.7	5	1	4	13	6	3	1	33
11.0-11.4	11.2	4	1	3	14	9	2	4	37
11.5-11.9	11.7	3	0	0	6	5	5	0	19
12.0-12.4	12.2	1	0	2	6	6	4	2	21
12.5-12.9	12.7	1	0	0	3	5	2	0	11
13.0-13.4	13.2	0	0	0	1	1	1	1	4
13.5-13.9	13.7	0	0	0	1	1	1	0	3
14.0-14.4	14.2	1	0	0	0	0	1	0	2
14.5-14.9	14.7	0	0	0	0	0	1	0	1
15.0-15.4	15.2	0	0	1	0	1	1	1	4
15.5-15.9	15.7	0	0	0	0	0	0	1	1
16.0-16.4	16.2	0	0	0	0	0	0	1	1
16.5-16.9	16.7	0	0	0	0	0	0	0	0
17.0-17.4	17.2	0	0	0	0	0	0	0	0
17.5-17.9	17.7	0	0	0	0	0	0	0	0
18.0-18.4	18.2	0	0	0	0	0	0	0	0
18.5-18.9	18.7	0	0	0	0	0	0	0	0
19.0-19.4	19.2	0	0	0	0	0	0	0	0
19.5-19.9	19.7	0	0	0	0	0	0	1	1
	Total	411	49	266	252	169	295	84	1526

when discharged to mangrove forests and seaweed areas which are the nursery grounds of spiny lobsters. Siltation hampers the growth of corals. The discharge of raw sewage and other wastes from tourist hotels and agricultural activities result in the growth of algal blooms which block light from penetrating the water surface. The proliferation of algal blooms kills fish and other marine life as oxygen supply is cut off. Swimming at the beaches is also affected. Thus this poses a serious threat not only to the lobster fishery but also to the tourist industry. A standard policy on environmental management for all onshore developments should be formulated. Also an integrated approach to coastal zone management should be considered if these resources are to be sustained.

Acknowledgements

This work was executed and is presented here with the permission of the Director KEMFRI, Dr. E. Okemwa. The work is sponsored by KBP.

References

FAO, (1971). Report to the Government of Kenya on the evaluation of prawn *(Penaeidae)* and spiny lobster *(Palinuridae)* marine resources. Based on the work of H. Brusher, Marine Fisheries Biologist. *Rep. FAO/UNDP (TA) (3006)*: 40pp.

Fisheries Department, (1991). Annual Fisheries Landings. Government of Kenya.

McClanahan, T. R. (1988). Seasonality in East Africa's coastal Waters. *Mar. Ecol. Prog. Ser.* 44: 91-199.

Ministry of Tourism, (1992). Annual Report. Government of Kenya

Mutagyera, W.B. (1978). Some observations on the Kenya lobster fishery. *E. Afric. Agric. For. J.* 43 (4): 401-407.

Mutagyera, W.B; (1983). Palinurid lobster biology and fishery in Kenya Waters. *Kenya Aquatica Bulletin.* No. 1: 26.

Okechi, J.K. & Polovina, J.J. (in press). The spiny lobster fishery of Kenya. Blackwell Scientific Publications Ltd Osyney Mead Oxford, England (UK).

Pauly, D. (1984). Fish Population Dynamics in Tropical Waters: A Manual for use withprogrammable calculators. *ICLARM*, Manita, Philippines. 352pp.

UNEP/IUCN, (1988). Coral Reefs of the World. Volume 2: Indian Ocean, Red Sea and Gulf. *UNEP regional Seas Directories and Bibliographies.* IUCN, Gland, Switzerland and Cambridge, U.K; UNEP, Nairobi, Kenya. 1 + 389pp., 36 maps.

Wetherall, J.A., Polovina, J.J. & Ralston, S. (1987). Estimating growth and mortality in steady fish stocks from length-frequency data. In D. Pauly and G.I. Morgan (Eds) *Theory and application of length-based stock assessment.* ICLARM Conference Proceedings 13: 109-122.

Cetaceans and fisheries in Kenya coastal waters: a preliminary study

OMONDI E.O.
Kenya Marine and Fisheries Research Institute
P.O.Box 81651 Mombasa
KENYA

Abstract

Of all marine resources characteristic of the Kenya coast, marine mammals are least studied singly or in association with other resources. In this paper, available records on cetacean catches by districts between 1978-1991 inclusive were used to assess the status and trend of their fishery, distribution, and interactions with sharks, clupeids and tuna landings. Spartial and temporal variations in takes were evident. The Mombasa district led in total catch (62.2 tons) while the Tana River district ranked last (0 tons). Fluctuations in catch were highest in Mombasa (S_d = 3.8) and lowest in Lamu (S_d = 0.7). The mean annual landings (X) at $p<0.05$ corresponded well with the totals for the districts. The sharks, clupeids and tuna were landed by a range of fishing gears that changed with time. Total fish catch by species fluctuated considerably. Although the lines of 'best-fit' showed some relationship between the landings of sharks, clupeids and tuna on one hand and cetaceans on the other, the linear component on the relationships were not highly significant at $P < 0.05$ (4.84). The possible impacts of other human activities on the cetacean populations are discussed. Priority areas in marine mammal studies and management strategies vital in ensuring a balanced co-existence of the coastal populations and ecosystems are also discussed.

Introduction

Ecological, economic, subsistence and cultural values of marine mammals are well documented (UNEP, 1984, 1985; Holt, 1986; Klinowska, 1991). For centuries, cetaceans (whales, dolphins and porpoises) have continually been killed (Leather wood *et al*, 1989). As they are harpooned, shot, netted and trained to jump through hoops, their populations are seriously threatened. Habitat degradation, food depletion, water pollution and invasion of breeding grounds all pose major threats to the mammals (UNEP, 1988). Killing of large cetaceans is regulated by the International Whaling Commission (IWC). Direct takes of small ones have increased in some less developed parts of the world (Perrin, 1989), and careful and tactful monitoring, together with information on direct and incidental takes, is vital (Klinowska, 1991). The status of most species in the less studied oceans, such as area 51 (Western Indian Ocean) are still unknown.

The distribution of cetaceans in the southern and northern hemisphere is well known (Brown, 1986; & Barstow, 1988). Whereas Heintzelman (1981) reported 27 species as occurring in the Indian ocean, Holt (1988) estimated the number to be about 7 baleen whale species and 33 small cetaceans. Mortality of cetaceans in passive fishing nets and traps havealso been extensively discussed (IWC, 1990). In the Indian Ocean most of the work has been restricted to the extreme south and the coasts of India (Moses, 1947; Rao, 1962; Alagarswami, *et al*, 1973). The only records available in Kenya are those compiled by the Kenya Fisheries Department. Although all cetaceans are considered as 'dolphins', the data provide a basis for future detailed work. In this paper catch statistics are analysed in an attempt to describe the distribution of the cetaceans and to identify any interactions between them and selected fisheries resources.

Environment

The Kenya coast is heterogenous in nature with its 650 km length extending from latitude 1½°S to 4½°S (Fig. 1a) bordering Somalia in the north and Tanzania in the south. It supports fringing reefs and patches of reefs which lie mostly 0.5 -0.2 km offshore.

The coastal climate is dominated by seasonal monsoon winds: the southeast Monsoon (SEM) from April to October and the northeast Monsoon (NEM) from November to March. Currents derive from the South Equatorial Current which splits on reaching the African coast to form the East African coastal current (northerly flow). Along the Kenya coast, this causes a northward water movement for most of the year. Current velocity is high averaging 2-4 knots. The influence of the northeast monsoon in the northern part of the coast reverses the current flow southward. Hove (1981) and Newell (1957) presents further details. The effect of such changes is reflected on productivity and exploitation of the available marine resources which includes fisheries, mangrove forests, marine algae and seagrasses. The fisheries resources exploited mainly by artisanal fishermen and which the government intends to intensify have performed below expectations (Oduor, 1984). Among other species, sharks, clupeids and tuna used in this study are caught. Although the fishing gears are specific in time and space, sharks were mainly landed by gill nets (jerife) polymide ply 2, 24, 36, x 56 MD x 144 m x 152 mm and line fishing. Other mesh sizes; 2", 3" 4" and 4½" are used for smaller species. Tuna were landed by lines whereas modified and/or unmodified beach seines, cast nets and surrounding nets were used in the clupeid fishery (Mbuga, 1984).

Materials and methods

Catch statistics

Fish annual landings collected by the Kenya Fisheries Department (KFD) over a thirteen year period (1978 – 1991) were used. Estimates for 1983 were excluded due to an inconsistency in recordings. Total weights were presented in metric tons to the nearest one decimal place.

Distribution

The statistics were compared graphically and statistically for each of the fishery and all the five coastal districts; Kwale, Mombasa, Kilifi, Tana-River, and Lamu (Fig. 1a). The outcome of these comparisons were used as indicators of distribution.

(a) Mean landings

This was computed as: **X = X/N met.tons**

X = mean landing
X = annual landings in metric tons and
N = total number of years.

To the mean, a 95% confidence limit was attached using the formula:

$$X \pm t.s/N$$

where t was read from the Students' table at a selected probability level, ($P<0.05$) with N-1 degrees of freedom, and being the standard deviation.

(b) Standard deviation

This was used as a measure of fluctuation about the mean using the equation:

$$Sd = X^2 - (x)^2/N$$

X and N are the same as for mean.

Fisheries cetacean interaction

The relationship between landings of cetaceans on the one hand, and sharks, clupeids, and tuna on the other in each of the districts, was studied by regression analysis using the simple regression equation:

$$b = \{xy - (x)(y)/N\}/N$$

b = regression coefficient
x = cetacean catch
y = landing of each of the fishery used alternately.

The significance of the regression was tested at a probability level ($P< 0.05$) in an analysis of variance. The total sum squares of Y, (Y^2) was partitioned into two, each divided by its number of degrees of freedom, to obtain mean squares. F was computed as regression mean squares, divided by residual mean squares.

Results

Distribution

Cetaceans were widely distributed during 1978-91 throughout the Kenya coast with the exception of the Tana-River district. However, sharks, clupeids and tuna were landed in the district. Cetacean landings differed in time and space (Fig.2). The Mombasa district led with a catch total of 62.6 metric tons, followed closely by the Kilifi district, with 62.0 metric tons. Combined statistics for the cetaceans and the four selected fish species indicated that despite this, only 1.1% of Mombasa district's catches comprised the cetaceans. Other percentages were; Kilifi, 3%; Kwale, 2.8%; Lamu, 0.8% and Tana-River, 0%. Table 1(a) and (b) shows the apparent variations. The highest spread from the mean (Sd = 3.8) was recorded in Mombasa.

Table 1a: Total landings and standard deviations of landings by districts (1978-91)

	Total Landings (Met.tons)				Standard Deviations			
District	Cetaceans	Sharks	Clupeids	Tuna	Cetacean	Sharks	Clupeids	Tuna
Kwale	27.9	321.4	542.4	124.4	1.8	5	15.6	5.3
Mombasa	62.6	1417.2	3798.2	204.9	3.8	26.9	46.6	5.7
Kilifi	62	982.7	600.6	422.4	2.9	28.9	20.1	10.5
Tana R.	0	86	1	20.1	0	4	0.2	1.2
Lamu	3.6	348.8	0.5	80.7	0.7	10.1	0.1	4.2
Grand Total	156.1	3156.1	4942.7	849.5	-	-	-	-

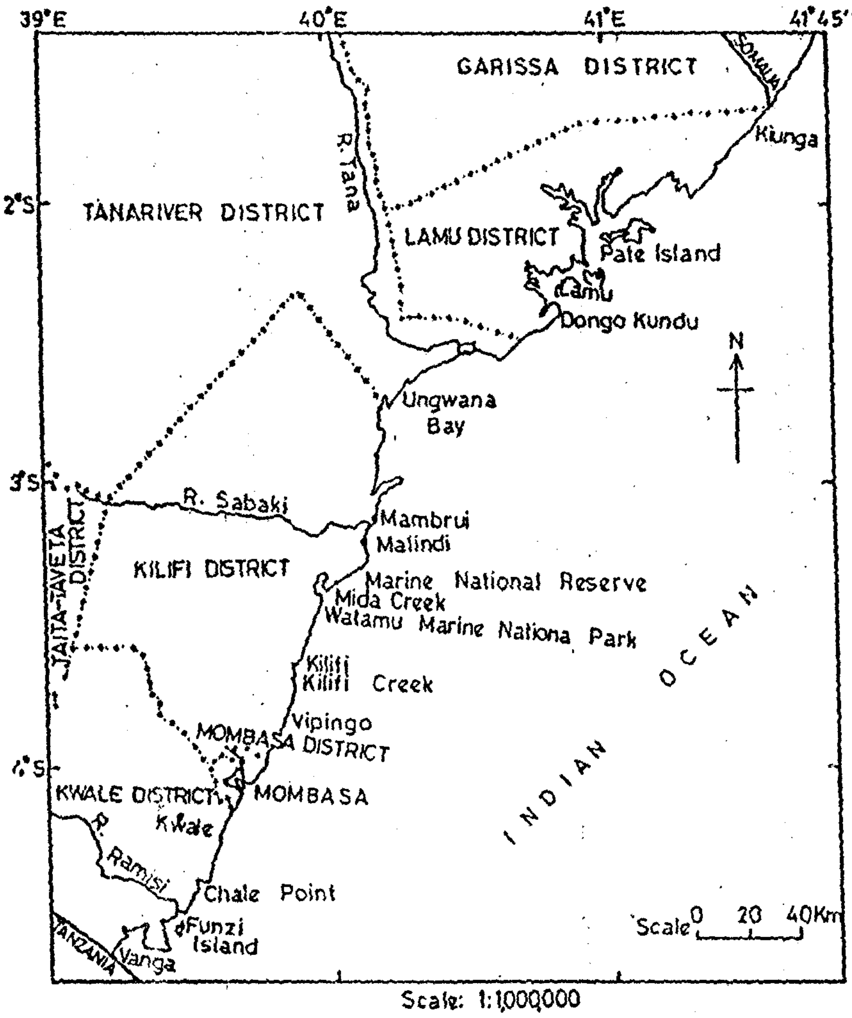


Fig. 1a. Map showing sampled areas by district.

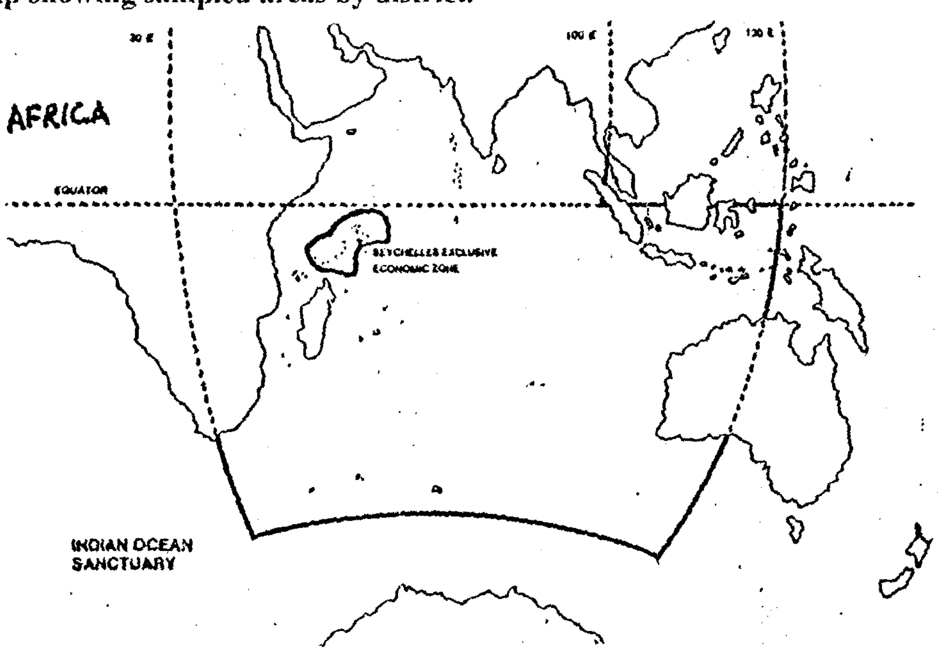


Fig. 1b. The Indian Ocean Whale Sanctuary extends as far south as the 55 degree So thereby excluding the pelagic minke whale grounds in the Arctic.(From Holt, 1986)

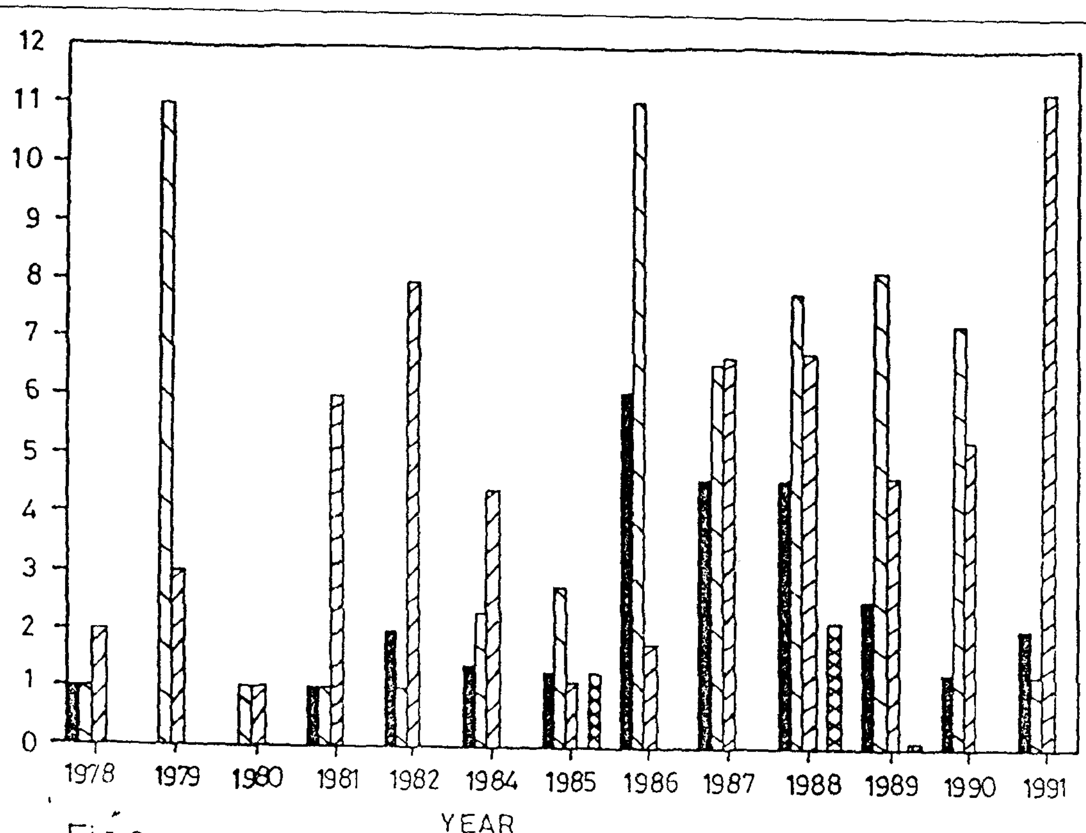

12
11
10
9
8
7
6
5
4
3
2
1
0
1978
1979
1980
1981
1982
1984
1985
1986
1987
1988
1989
1990
1991
YEAR
LANDINGS (Metric tons)

Fig. 2

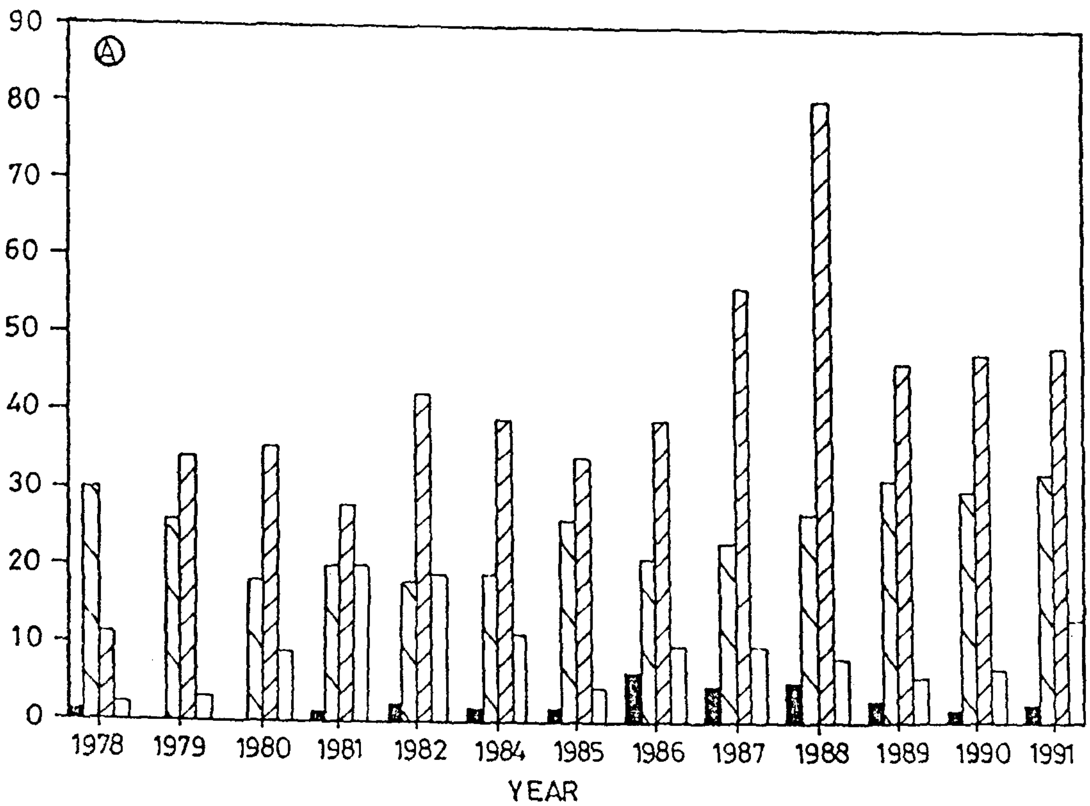

A
90
80
70
60
50
40
30
20
10
0
1978
1979
1980
1981
1982
1984
1985
1986
1987
1988
1989
1990
1991
YEAR

Fig. 3

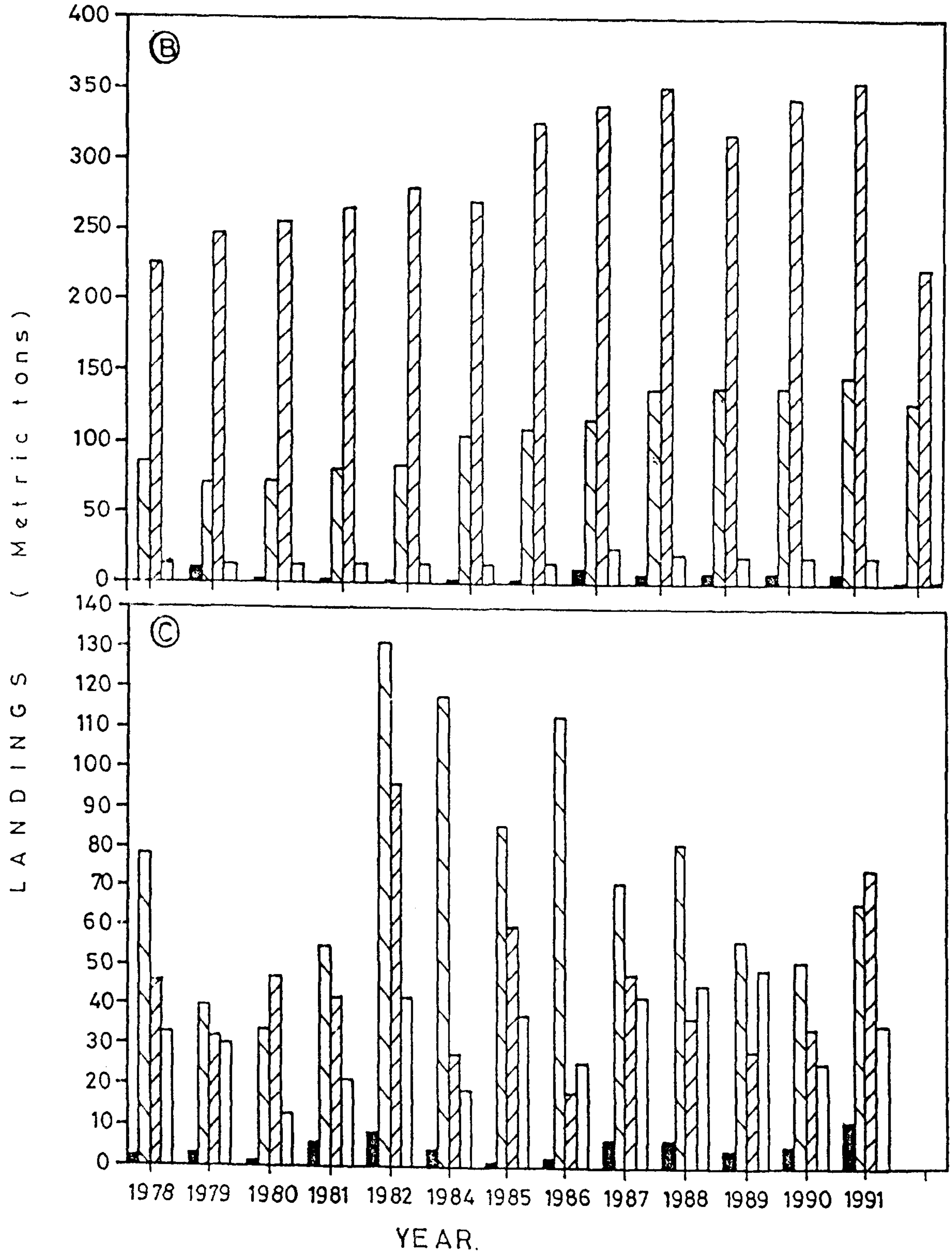

B
C
LANDINGS (Metric tons)
400
350
300
250
200
150
100
50
0
140
130
120
110
100
90
80
70
60
50
40
30
20
10
1978 1979 1980 1981 1982 1984 1985 1986 1987 1988 1989 1990 1991
YEAR.

Fig: 3

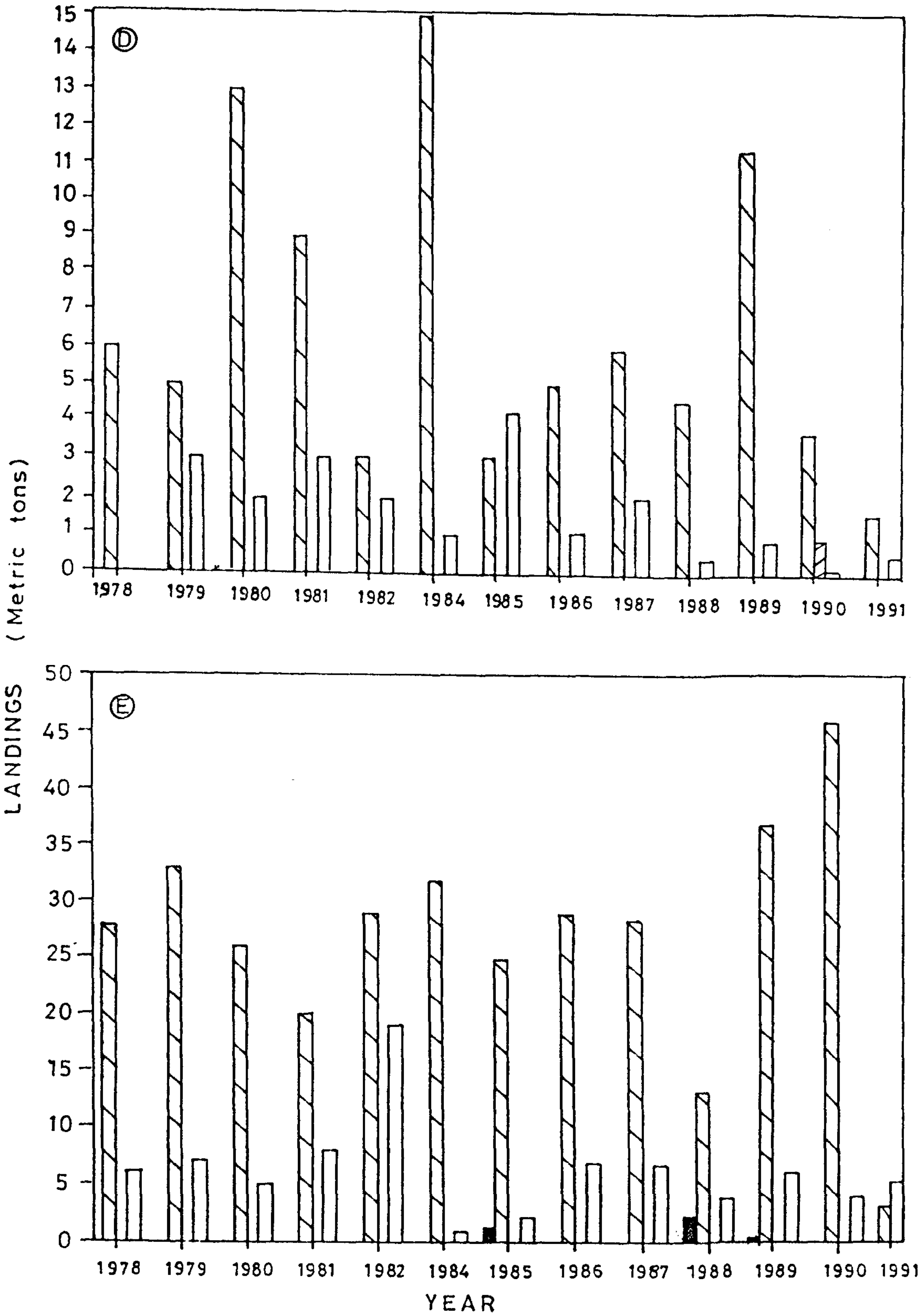

D
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1978 1979 1980 1981 1982 1984 1985 1986 1987 1988 1989 1990 1991
LANDINGS (Metric tons)
E
50
45
40
35
30
25
20
15
10
5
0
1978 1979 1980 1981 1982 1984 1985 1986 1987 1988 1989 1990 1991
YEAR

Fig 3

Table 1b: Mean landings by districts*

Mean Annual Landings (Met.tons) at P<0.05				
District	Cetaceans	Sharks	Clupeids	Tuna
Kwale	2.1 ± 1.9	24.7 ± 3.02	41.7 ± 9.42	9.3 ± 3.8
Mombasa	4.8 ± 2.29	109.0 ± 16.24	292.2 ± 28.01	15.8 ± 3.4
Kilifi	4.8 ± 2.0	75.6 ± 17.40	46.2 ± 12.3	32.5 ± 6.3
Tana River	0	6.6 ± 2.41	0.5 ± 0.12	1.6 ± 0.7
Lamu	0.3 ± 0.42	26.8 ± 6.10	0.04 ± 0.12	1.6 ± 0.7

*Data from Kenya Fisheries Department landing records (1978 -1991)

Except for Tana River, Lamu and Kwale during 1979 and 1980, all the other districts reported catches yearly (Fig.3a-e).

Cetacean catches compared to other species.

For the four districts of Kwale, Mombasa, Kilifi and Tana-River, total cetacean landings were less than that of sharks, clupeids and tuna. Lamu was unique, landing more cetaceans than clupeids.

Trend of cetacean fishery

*** Kwale district**

The district showed a distinct pattern in cetacean fishery. It had slight variations in catch between 1978-85 followed by an increase between 1986-88 and finally, a fall (Fig.3a).

*** Mombasa district**

Apart from 1979, the years between 1978-82 experienced a constant catch of cetaceans averaging 1.0 met tons per annum. Fig 3b showed that catches then increased gradually until 1990. The tuna fishery had a similar trend but with higher fluctuations (Sd = 5.0).

*** Kilifi district**

Cetacean landings fluctuated considerably over the period with a lower spread from the mean than that of Mombasa and the other fisheries in the district (Table 1a). From the bar graphs of Figure 3c, it is difficult to relate cetacean catches to any other fishery.

*** Tana – River**

No cetacean catches were reported. The district was poor in fishery of the fish species compared to other districts. Whereas no tuna was recorded in 1978, sharks dominated the fishery throughout the period.

*** Lamu district**

Although higher than the total catches of clupeids, cetacean landings were very low, averaging 0.3 metric tons per annum. Figure 3e featured an exceptionally low catch in 1989.

Throughout the period, both tuna and sharks were landed with the former taking the lead.

Fisheries – cetacean interaction

From regression graphs, there seems to be some relationship between the landings of the cetaceans and that of sharks, clupeids and tuna (fig. 4-7). Computed values of regression analysis are presented in Table 2. Both at the district and species level, the computed values of F were less than the tabular value for 1/11 (V_1, V_2) degrees of freedom at $p<0.05$ (4.84). This meant however, that the linear component on the relationships were not highly significant.

Table 2. Regression coefficients (r) and variance ratio (f).

Species	Sharks – Cetaceans		Clupeids – Cetaceans		Tuna – Cetaceans	
District	(r)	(f)	(r)	(f)	(r)	(f)
Kwale	0.090	0.845	4.970	1.473	0.280	0.760
Mombasa	2.807	1.050	6.940	1.073	0.979	1.382
Kilifi	1.232	0.972	3.590	1.578	1.455	1.111
Tana R.	-	-	-	-	-	-
Lamu	28.431	0.302	0.040	0	6.745	0.174

Discussion

That cetaceans were caught along the Kenya coast agrees with Barstow (1988) that they occur in all oceans of the world. A lack of reports on catches in the Tana-River districts could be because cetaceans have preferences (Heintzelman, 1981). In this case however, it may be attributed to a low clupeid fishery out-put and/or uncontrolled landings. The former would be true in the case of *Delphinus delphis* (common dolphin) whose diet includes commercial species, especially anchovies and clupeids in the Western Indian Ocean. Neither the difference in the area of districts adjacent to the Ocean nor the inaccuracies in the collection of fisheries statistics (Oduor, 1984) convincingly explains the discrepancy in the Tana-River district. Intense agricultural activities, discharge, dumping and damming along the River Tana may have a profound effect on the cetacean populations, distribution and catch within the area, under its influence. Klinowska (1991) explains this to be true for river dolphins. Compared to other parts of the world the takes in Kenya might be considered low. This must not be taken to justify continued or increased exploitation of the cetaceans unless their populations are understood. Commercial fisheries are reluctant in providing their catch datal (Oduor, 1984). The declaration of the Indian Ocean north of Lat. 55°S as a sanctuary (IOS) in 1979 could explain the low catches (Fig. 1b). The use to which caught cetaceans are put to in Kenya is unknown. Catches and their skeletons disappear completely from the beach, suggesting the catches could be intentional although the statistics do not indicate it. The situation in Kenya might be similar to that of Sri Lanka (Leatherwood *et al*, 1983a) where fishermen, either aware it is illegal to fish dolphins or due to their weights, cut adrift the entangled cetaceans which later die. The records would then be under-estimated. In the tropics, fishermen have long used dolphins especially to locate schools of tuna and other fish (UNEP, 1985) which would then be caught using hook and line or netting techniques. The dolphins are also stranded in the process. The restriction of artisanal fishermen to the inshore waters render their statistics inadequate in clearly establishing the fisheries-cetacean interactions unless supplemented by information from commercial and sports fishermen. This could justify the insignificant linear component observed here.

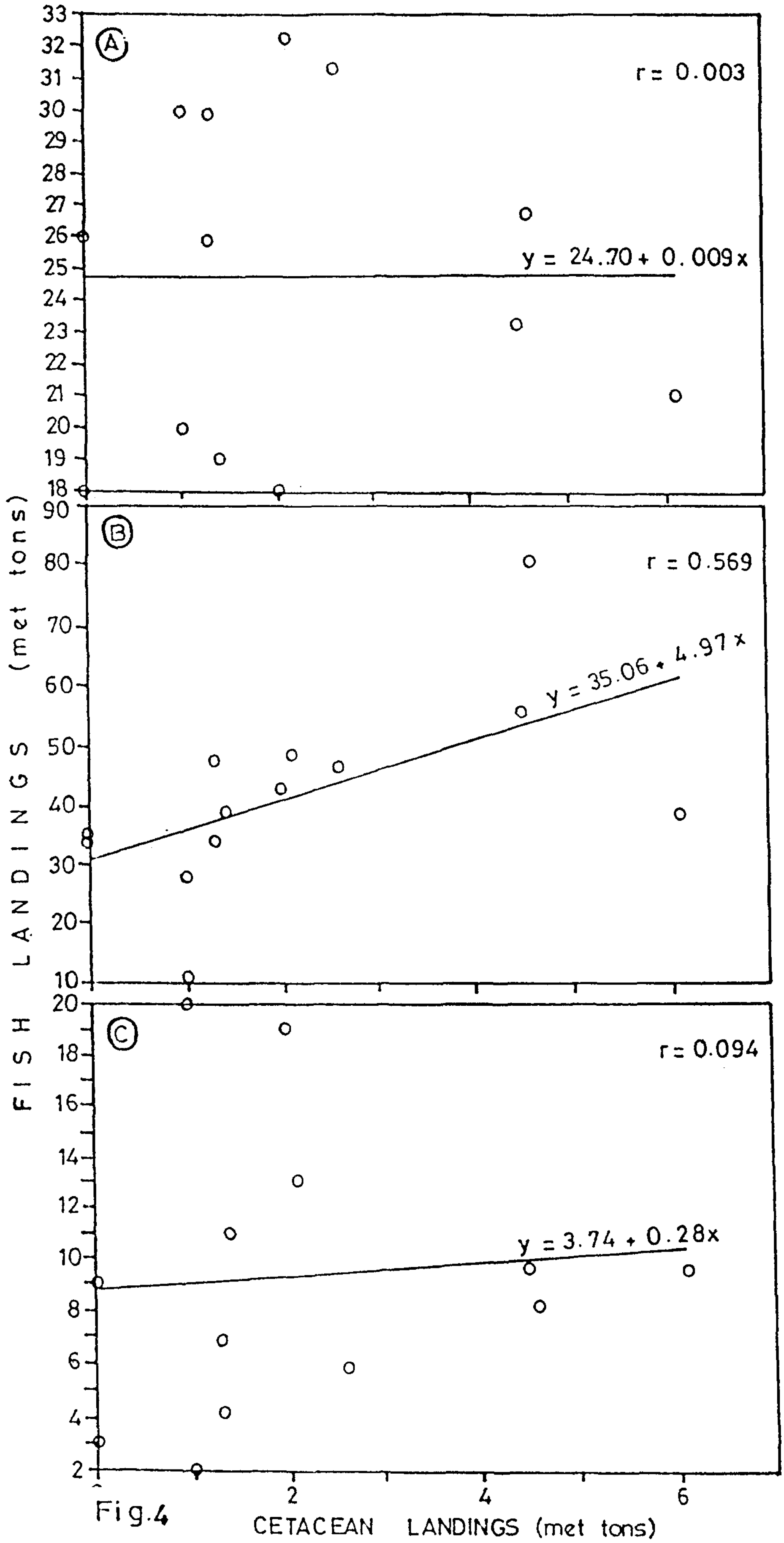

A
r= 0.003
y = 24.70 + 0.009x
B
r = 0.569
y = 35.06 + 4.97x
C
r= 0.094
y = 3.74 + 0.28x
FISH LANDINGS (met tons)
CETACEAN LANDINGS (met tons)

Fig.4

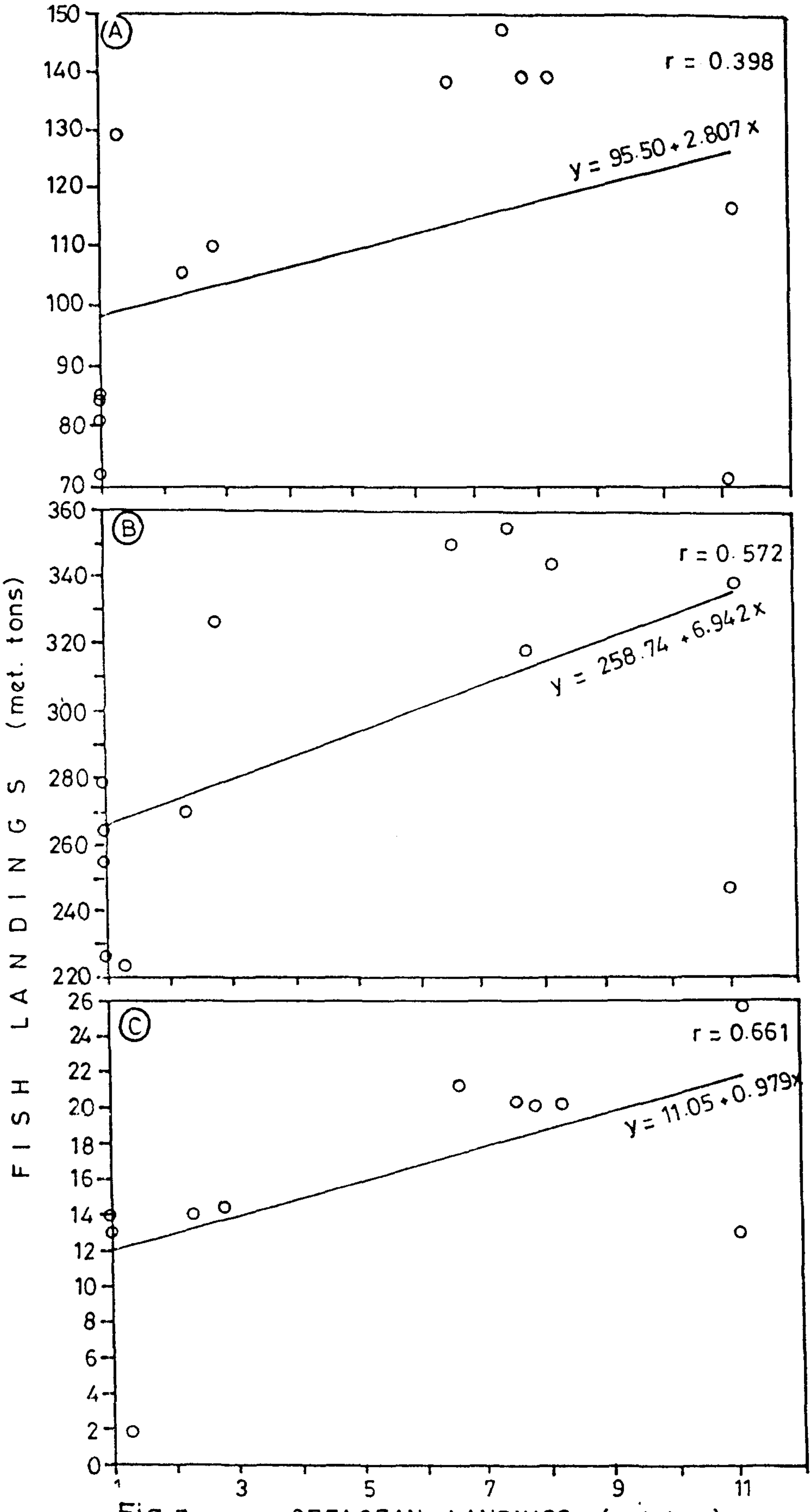

A
r = 0.398
y = 95.50 + 2.807 x
B
r = 0.572
y = 258.74 + 6.942 x
C
r = 0.661
y = 11.05 + 0.979x
FISH LANDINGS (met. tons)
CETACEAN LANDINGS (met tons)

Fig. 5

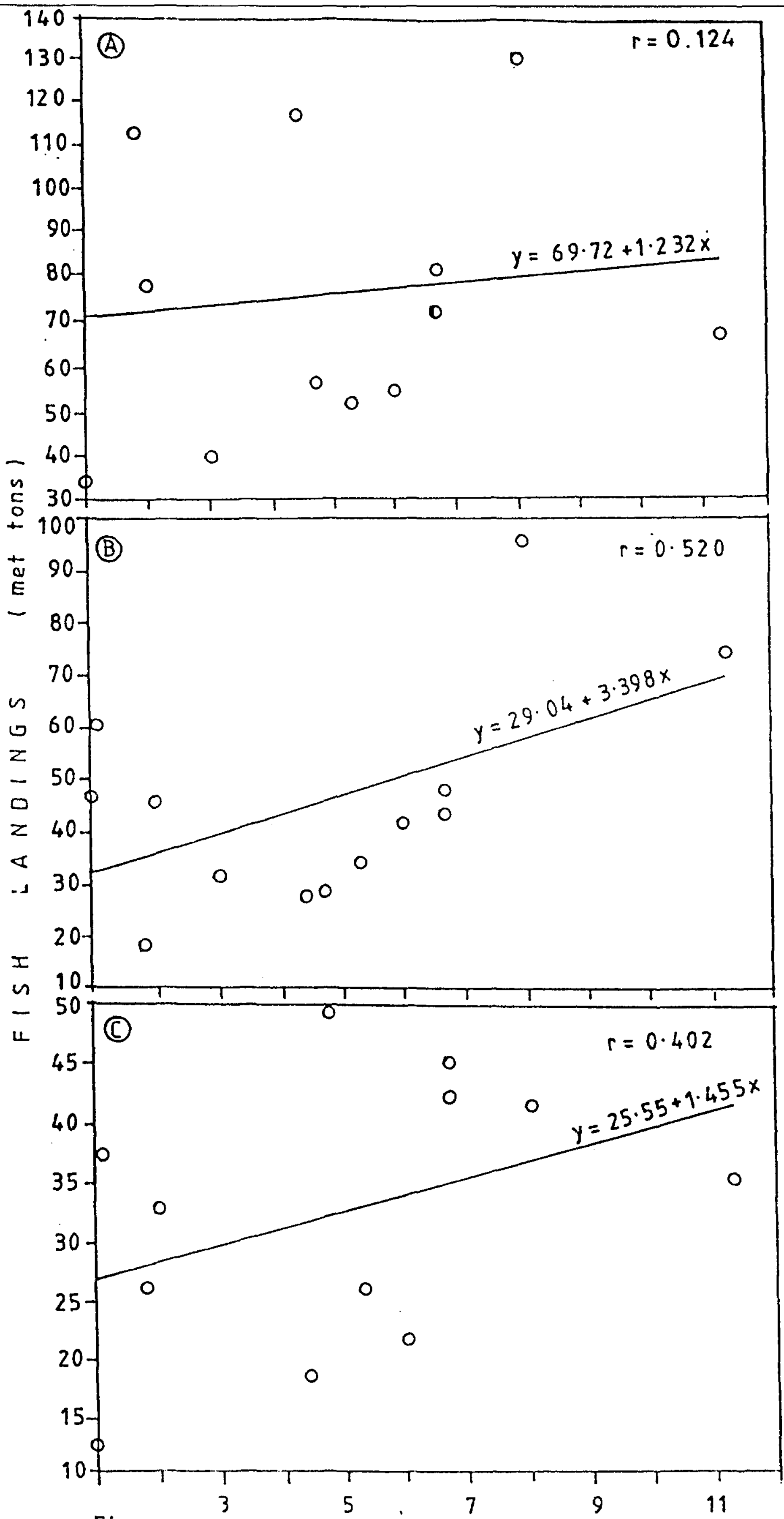

Ⓐ
r = 0.124
y = 69·72 +1·232x
Ⓑ
r = 0·520
y = 29·04 + 3·398x
Ⓒ
r = 0·402
y = 25·55+1·455x
FISH LANDINGS (met tons)
3
5
7
9
11
CETACEAN LANDINGS (met tons)

Fig 6

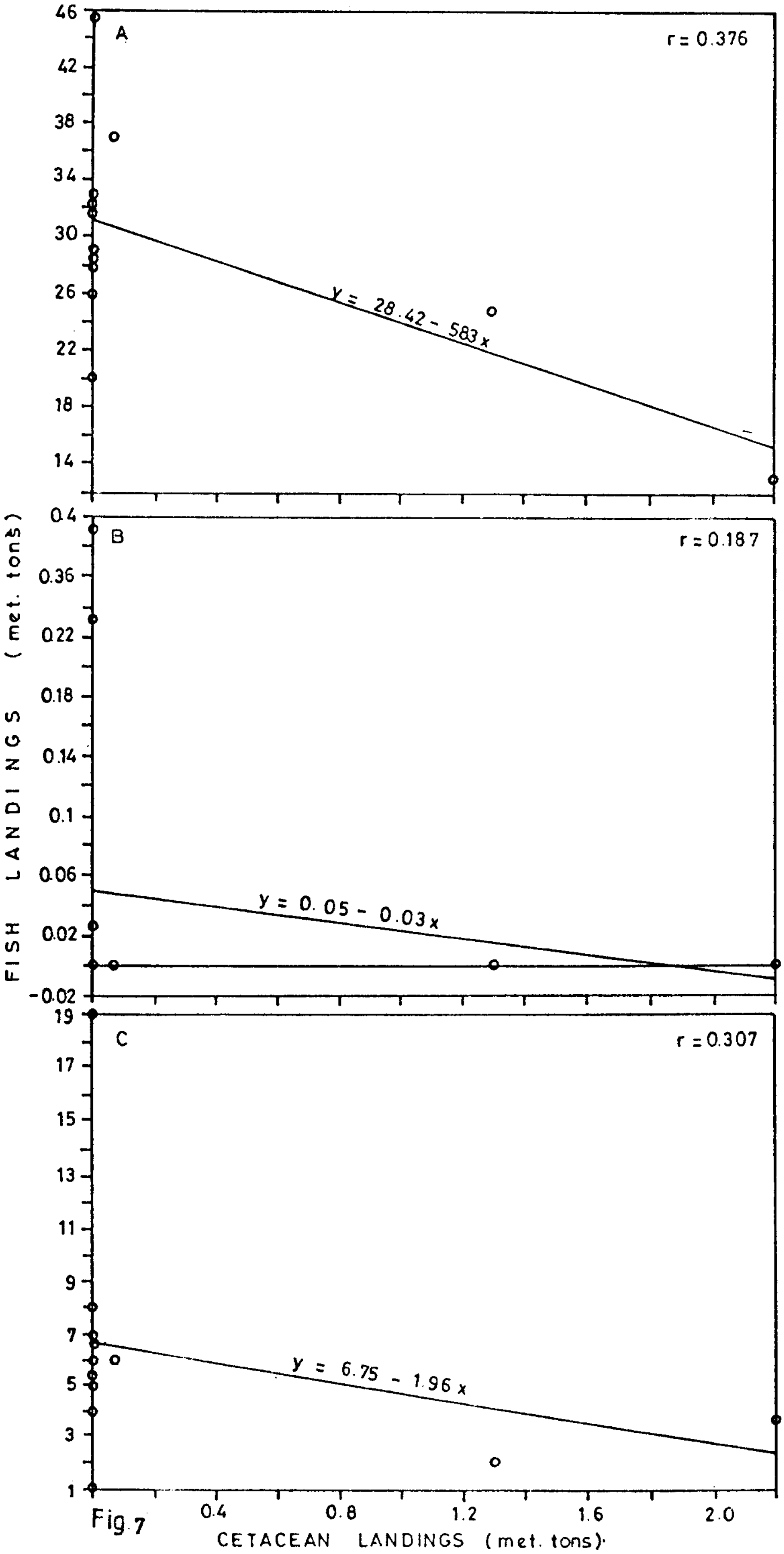

A
r = 0.376
y = 28.42 - 583 x
B
r = 0.187
y = 0.05 - 0.03 x
C
r = 0.307
y = 6.75 - 1.96 x
FISH LANDINGS (met. tons)
CETACEAN LANDINGS (met. tons)
0.4
0.8
1.2
1.6
2.0

Fig. 7

Conclusion

Cetaceans are widespread along the Kenya coast where they are landed together with fish each year. Catches fluctuate in time and space. No fishery is apparently specifically responsible for the cetacean takes. Other fisheries (apart from those considered in this paper) require examination. It is the intention of the Kenya Government to utilize all the available exploitable marine fisheries resources to provide food for the growing population, to the rural and coastal population and to earn foreign exchange from export. Her target landing of 20,000 metric tons per annum by the year 1988 has not been realised as only 10,000 metric tons were landed in 1991 (Fisheries Dept. 1992, unpublished). Any attempts to intensify fishing could be extremely detrimental to the cetaceans of the Kenya coast unless the effects of the fishing gears on the mammals are firmly established. It is imperative that urgent back-up studies on cetacean taxonomy, distribution and incidental entanglement be conducted and used as a basis for future development in both the sector of marine fisheries and cetacean conservation in Kenya.

Acknowledgements

I am extremely grateful to the Kenya Fisheries Department (Marine Sector) for their invaluable help in collecting data in the field. I am also indebted to Dr. Ezekiel Okemwa, Director Kenya Marine and Fisheries Research Institute who helped in one way or the other. The patience of my wife Susan during the course of this work is heartily acknowledged. Finally I sincerely thank Mrs. Grace Kondi who typed this work.

References

Alagarswami, K., Bensam, P., Rajapandian M.E.& and Fernando, B.A.(1973). Mass stranding of pilot whales in the Gulf of Mannar. *Indian J. Fish.*, (2): 269-279.

Barstow, R. (1988). *Meet the Great Ones.* An Introduction to whales and other cetaceans. Pub. cetacean society Int. Wethersfield connecticut, USA.

Brown, S.G. (1986). Research on Large and Small cetaceans: Conservation and Management *AMBIO. XV (3):* 168-172.

Fisheries Dept. Kenya (1992). Fish Landings in Kenya. (Unpublished document)

Heintzelman, D.S. (1981). *A World Guide to Whales, Dolphins and Porpoises.* Winchester Press. Tulsa, Oklahama.

Holt, S. (1986). Mammals in the Sea. *AMBIO XV, (3):* 126-133.

Hove, A.R.T. (1981). Some aspects of currents, sedimentation, depositional environments and submarine geomorphology of Kenya's submerged continental margins. In: Management of coastal and offshore resources in East Africa. Institute for Development Studies, University of Nairobi *Occasional Pap. 28:* 127-144.

IWC, (1990). Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, October 20-21, 1990. 56pp.

Klinowska, M. (1991). Dolphins, Porpoises and Whales of the World. *The IUCN Red Data Book.* Pub. IUCN, Gland Switzerland and Combridge UK. 420pp

Leatherwood, S. & Clarke, J. T. (1983a). Cetaceans in the straits of Malacca, Andaman Sea and Bay of Bengal, April 1982, with a preliminary review of marine mammals records from the use regions. Document NARA/SMMIO/SP 5, presented to the Symposium of Marine Mammals of the Indian Ocean. Colombo Sri Lanka 22-25 February 1983. National Aquatic Agency 33pp (Unpublished).

Leatherwood, S. and Reeves, R.P. (1989). Marine Mammals Research and Conservation in Sri Lanka 1985-86 *Marine Mammal Tech. Rep. No. 1.*, UNEP, Nairobi, Kenya. 138pp.

Mbuga, J.S. (1984). Fishing Gears of the Kenya Marine Waters. The Proceedings of the NORAD KENYA Seminar to Review the Marine Fish Stocks and Fisheries in Kenya, Mombasa, Kenya 13-15 March 1984. 210pp.

Mitchel, E (1975). Porpoise, Dolphin and Small whales fisheries of the world. IUCN Monograph No. 3, IUCN and Natural Resources, Morges 129pp.

Moses, S.T. (1947). Stranding of Whales on the coast of India. *J. Bombay Nat. Hist. Soc,* 47:377-378.

Newell, B.S. (1957). A preliminary survey of the hydrography of the British East African coastal Waters. *Fish Publi. Land.* 8: 1-21.

Oduor, B. W. (1984). Status of fish catches and landings in Kenya. *The proceedings of the NORAD-KENYA Seminar to Review the Marine Fish Stocks and fisheries in Kenya.* Mombasa, Kenya, 13-15 March 1984. 210pp.

Perrin, W.F. (1989). Dolphines, Porpoises and Whales. *An Action Plan for Conservation of Biological Diversity 1988-92.*

IUCN/SSC Cetacean specialist Group and US National Marine Fisheries Service. IUCN,Gland, Switzerland 28pp.

Rao, K.L. (1962). On the capture of a Baleen Whale at Kakinada on The East coast of India. *J. Mar Biol. Ass. India,* 3:273

UNEP, (1984). Marine and coastal Conservation In East African region. *UNEP regional Seas Reports and Studies No. 3g,* 293pp.

UNEP, (1985). Marine Mammals. Global Plan of Action. *UNEP regional Seas Reports and Studies* No. 55, 115pp

UNEP/IUCN (1988). *Coral Reefs of the World. Volume 2: Indian Ocean, Red Sea and Gulf. UNEP regional Seas Directories_and Bibliographies* IUCN,Gland, Switzerland and Cambridge, UK/UNEP, Nairobi, Kenya 1+38gpp., 36 maps.

Distribution ecology and the impact of human activities on some *gracilaria* species of the kenya coast

OYIEKE Helida A.
Kenya Marine & Fisheries Research Institute
P.O. Box 81651 Mombasa
KENYA

Abstract

The genus Gracilaria belongs to the group of seaweeds that are of commercial value and are being harvested worldwide for their active ingredient agar. A pre-requisite for the harvesting of these plants, which has often been ignored, is a study on their ecological requirements within an ecosystem which leads to better understanding of the plants and hence good management practices and conservation in cases where wild stocks are harvested. With this aim in mind a study on the distribution ecology of 8 different Gracilaria species; G. corticata, G. crassa, G. edulis, G. fergusonii, G. millardetii, G. salicornia, G. verrucosa and Gracilaria sp. was carried out along the Kenyan coast extending from the North-coast to the South-coast border. In the study rocky platforms with their reef edges exposed to the open sea had a wider variety of species than either rocky platforms in sheltered waters or sandy beaches (the mean number of species per site being 3.6 ± 0.8, 1.4 ± 0.5, 2.0 ± 0.7 respectively). With regard to the frequency of occurrence in all the 23 stations studied the most common species was G. salicornia followed by G. corticata and G. crassa. G. verrucosa, G. edulis and Gracilaria sp. were less common while G. millardetii and G. fergusonii were rare. The plants were observed to grow in varied types of habitats and microhabitats in the eulittoral zone which included rocky coral platforms with their associated lagoons, pools and fringing reefs, sandy beaches and mangrove swamps. G. salicornia tended to show no specific ecological niche as it was observed in all the habitats and microhabitats studied while the rest of the species were more specific in their niche requirements. The threat that human activities impose upon these plants is discussed.

Introduction

Seaweeds play an important ecological role such as primary production, nutrient storage and cycling, sediment formation and the provision of habitats which support enhanced secondary production (Lapointe, 1989). In Kenyan coastal waters there is a rich flora of over 300 species (Moorjani, 1977). Most of the Kenyan seaweed records are species lists and taxonom in studies with very little ecological work (Coppejans and Gallin, 1989; Isaac, 1967; 1968; 1971; Isaac and Isaac, 1968; Lawson 1969; Moorjani, 1977; 1980; Oyieke and Ruwa, 1987).

Apart from their ecological role seaweeds have also been known to serve as raw materials for several commercial products (Michanek, 1979). *Gracilaria* is one of the most important seaweeds for the commercial production of agar (Santos, 1980). Species of *Gracilaria* are common along the Kenyan coast and could provide a major source of agar. Hence there is need to manage and conserve wild stocks of *Gracilaria* species in order to maintain and enhance their productivity. The study reported herein, on the distribution of *Gracilaria* species of the Kenyan coast, was carried out in order to provide information relevant for future sustainable commercial exploitation of these plants, and to elucidate facts on the impact of human activities on their survival.

Materials and methods

Twenty three stations were chosen along the Kenya coast for study (Fig. 1). At each sampling station a straight 4m wide transect was laid out from the beach to the edge of the reef covering the whole length of the reef platform. All the pools and lagoons that the transects cut through were sampled for species of *Gracilaria* during low tide. Snorkeling was done wherever necessary. At the reef snorkeling was carried out along the edge of the outer reef, 50m on each side of the transect. A record of all the habitats and microhabitats was taken. In order to give a fair representation of each station, 3 such transects were studied 100m apart thus giving a continuous 300m section of the outer reef covered at each station. This study was carried out during the peak seaweed growing season (unpublished data) between the months of August and December. In order to find out the impact of development programmes along the coastal zone on these plants, the species diversity of study sites at Mckenzie station were compared for the years 1986, 1990 and 1993.

An attempt also was made to study the zonation pattern of the species and for this Hartnoll's (1976) and Lewis's (1964) universal zonation schemes were adapted. The height above datum of each beach sampled was determined during calm waters around neap tide days, using tidal predictions for 1990.

Results

The distribution of the various *Gracilaria* species along the Kenya coast is shown in Table 1, whilst profiles of some of the representative stations studied showing details of different habitats are shown in Figure 2 (a-c). The beaches studied can be divided into 3 cartegories based on their substrates. There were sandy beaches either with or without mangrove ecosystems, rocky platforms without a reef edge mainly found where there was sheltered waters, and rocky platforms with a reef edge exposed to the open sea.

The most common of all the *Gracilaria* species studied was *G. salicornia*. It was recorded virtually at all sampling stations and in every habitat and microhabitat. The species was mainly eulittoral though a small percentage was recorded from the sublittoral. Individuals of this species ranged from those which were completely exposed to desiccation during low tide to those which were permanently covered by water in pools. On the basis of their substrates four ecotypes were recorded; one type was observed growing in shallow intertidal pools of up to about 10 cm deep while the other type grew directly on rocky surfaces as cushions and these were completely exposed during low water. The third type was observed in intertidal rocky-muddy substrates where the algae grew in big bundles up to 15 cm in diameter, while the fourth type was recorded in the sublittoral with erect long thalli.

G. corticata and *G. crassa* were the next most common species. The former had two ecotypes; the first one grew as an epiphyte on seagrasses either in the sublittoral or in eulittoral pools while the second type grew directly on rocky surfaces at the edge of the reef. *G. crassa* on the other hand grew in rocky pools at the reef edge where they were hidden in crevices. The pools were either sublittoral or in the lower eulittoral zones.

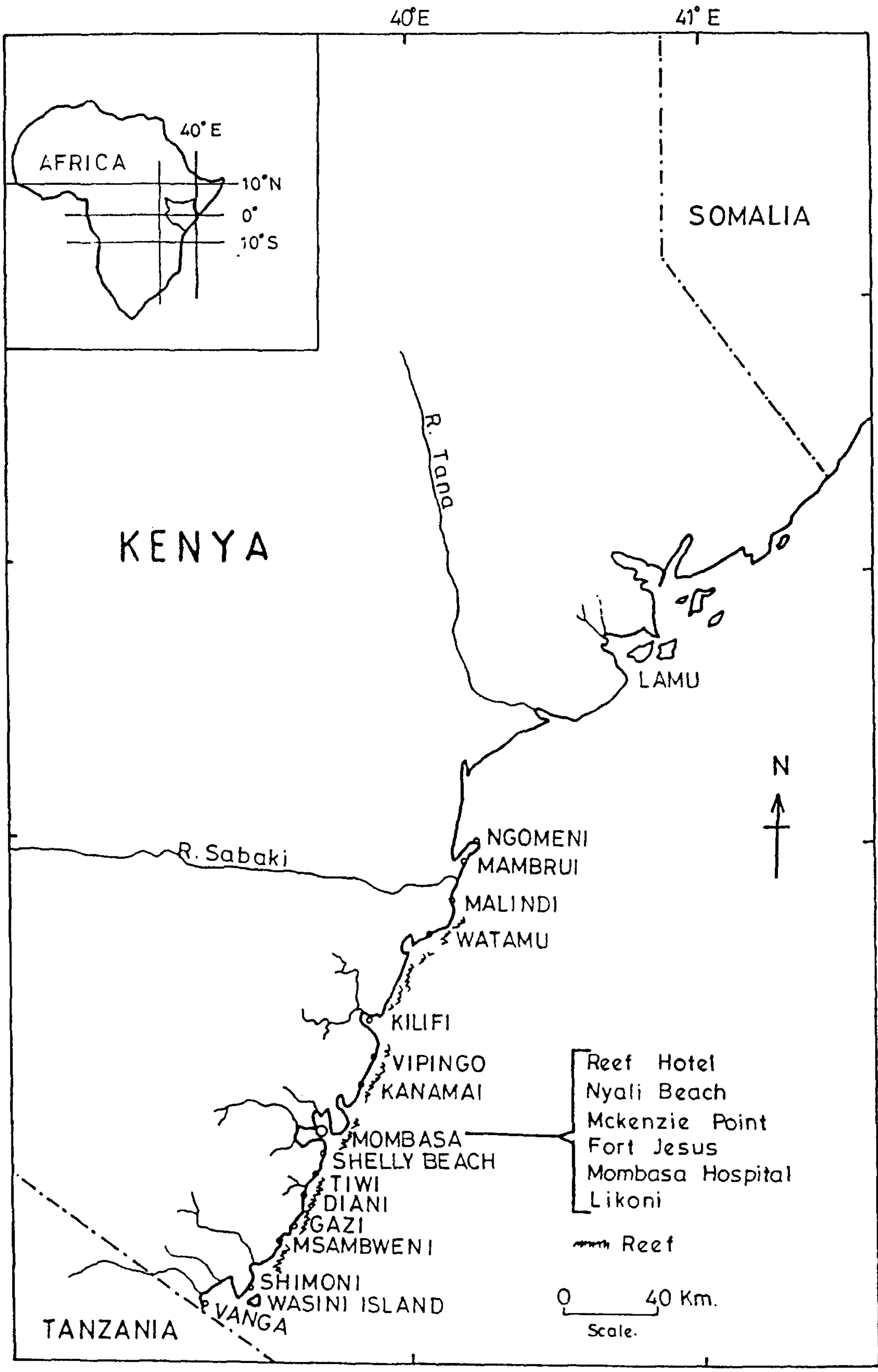


Fig. 1. Kenya coast showing stations of study. Inset: regional location.

Table 1. The distribution of *Gracilaria* species along the Kenya coast.

SPECIES	STATIONS																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
G. Corticata J. Agardh	x		x	x	x	x		x	x		x		x		x			x			x		x
G. Crassa Harvey			x	x				x		x	x		x		x	x	x				x		
G. edulis (J. Ag;) Silva								x			x										x		
G. fergusonii J. Agardh										x												x	
G. millardetti J. Agardh												x											
G.salicornia (J. Ag;) Dawsoon	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
G. verrucosa (Huds.) Papenfus				x														x					x
Gracilaria sp			x								x		x										
Total No. of spp.	2	1	4	4	2	2	1	4	2	3	5	2	4	1	3	2	2	3	1	1	4	2	3
Substrate	S	S	RR	RR	S	S	S	RR	R	RR	RR	RR	RR	R	RR	S	S	S	R	R	RR	R	S

Key: **RR** rocky platform with reef edge, **R** rocky platform without reef edge, **S** sandy beaches

G. verrucosa, G. edulis and Gracilaria sp. were less commonly observed, each species being found at only 3 of the 23 stations. *G. verrucosa* was recorded in sandy channels where it grew directly from the sand with part of its based parts being partly buried in the soft sediments in the sublittoral.

G. edulis was basically eulittoral growing in shallow sandy or rocky pools either in association with seagrass or in isolation. *Gracilaria* sp. on the other hand was observed basically in the eulittoral with a small percentage in the sublittoral zone. These eulittoral plants grow in small rocky pools on the reef platforms.

They are cartilagenous, flat, 3-6 cm high with a blade diameter of 2.4 mm broad. The branching pattern is dichotomous with a distinguishable main axis. Blade margins are smooth with bi-lobed rounded tips. Fresh specimens are brownish yellow and when pressed they turn pinkish red. Thallus has rhizoidal structures for attaching onto the rocks.

Judging from this study, *G. millardetii* and *G. fergusonii* would be classified as rare in their distribution along the Kenya coast. The former was recorded only in shallow rocky eulittoral pools at one site, while the latter was recorded in the sublittoral among hard substrates such as dead coral rocks at two widely separated sites.

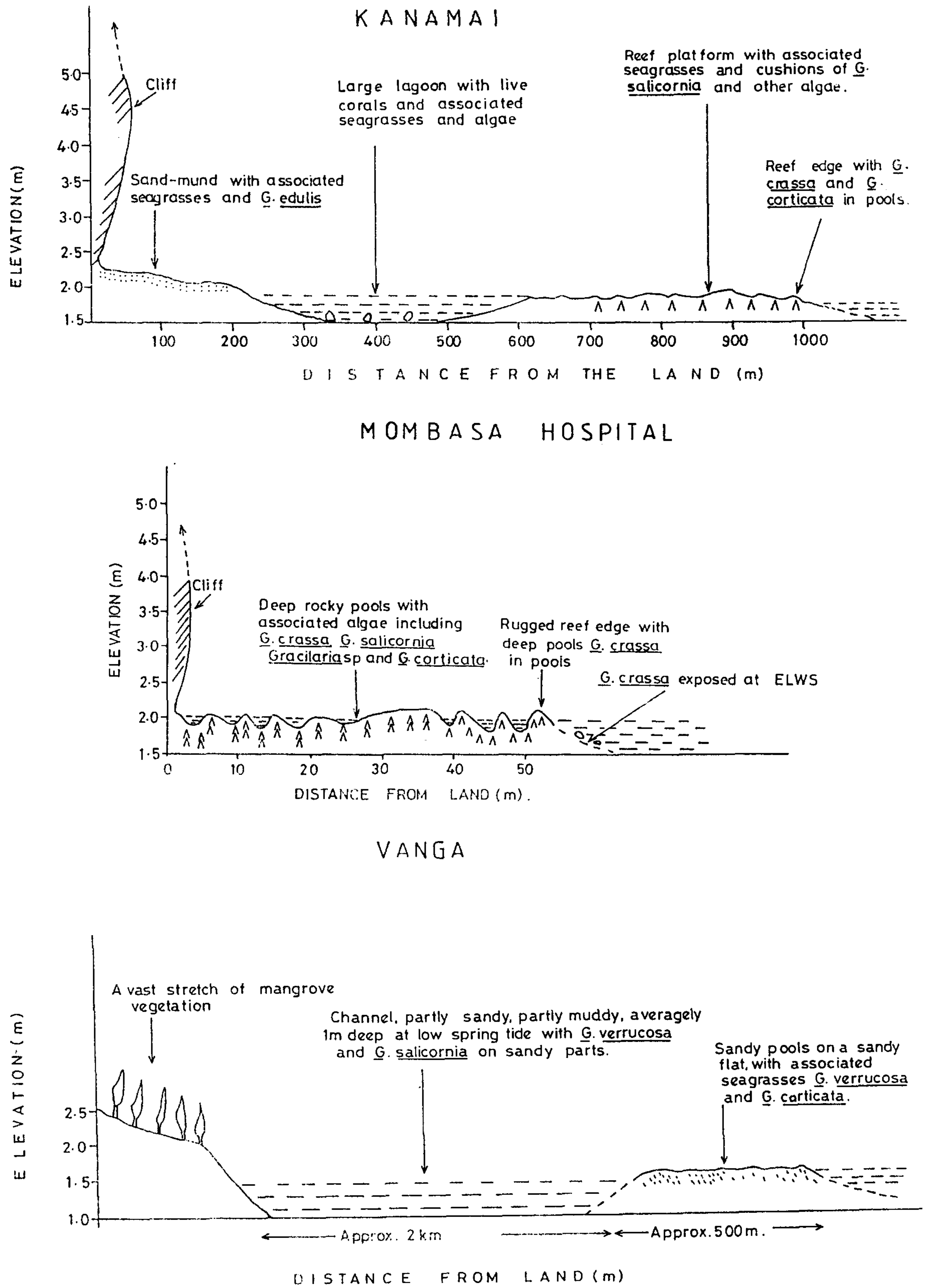


Fig. 2 (a-c). **Profiles of some representative stations studied indicating details of habitats and microhabitats.**

Discussion

The north-south distribution of the *Gracilaria* species along the Kenya coast did not show any specific trend. However, stations with rocky platforms having their reef edges exposed to the open sea had a wider variety of species than rocky platforms in sheltered waters or sandy beaches (mean number of species per site were 3.6 ± 0.8, 1.4 ± 0.5, 2.0 ± 0.7 respectively). Though no quantitative studies were carried out on standing crops of the different species, it is apparent from field surveys that *G. salicornia* is the most abundant followed by *G. corticata* in terms of biomass. The survey has shown a lack of large expanses of *Gracilaria* beds as reported from the temperate zones. Most of the populations grow in discrete patches. This observation could be attributed to the high temperatures experienced in the tropics which could possibly limit the maximum growth and productivity of the plants as well as the grazing activities of animals (Chapman & Chapman, 1973; McLachlan & Bird, 1986).

According to the Hartnoll (1976) shore zonation scheme adapted for the study it is apparent that *G. millardetii,* and *G. edulis* are the only species that are found only in the eulittoral whereas *G. verrucosa* is the only species that is found only in the sublittoral. The remaining species grow partly in the eulittoral zone and partly in the sublittoral (Fig. 3). It therefore follows that a larger percentage of the species grow in the eulittoral zone and particularly so in the lower eulittoral zone.

G. salicornia has been observed to grow in all types of microhabitats including those that subject it to complete desiccation stress at low tide. Those ecotypes which are characterized by cushion forms of growth appear to be better suited for survival in the harsh physiological conditions (Taylor & Hay, 1984). Upright elongated growth forms of this species are found where there is constant water cover, either in the form of pools, lagoons, wave splash or when in the sublittoral.

Of the coastal ecosystems the eulittoral zone, reported in this study as the main zone for the growth of *Gracilaria* species, experiences a great deal of disturbances from human activities through the hotel and other industries. The construction of hotels in some cases extend to this zone thus literally destroying the habitat. For instance, a transect at Mckenzie station in 1986 had 4 species of *Gracilaria* while the same transect in (1993) had relics of only one species *G. salicornia* which has been observed to be able to withstand very harsh conditions. Along this transect a hotel jetty has been constructed thus altering the environment by creating extra shade while the pillars of the jetty alter the flow of water in the area. Another transect in the same station was observed to cover one of the largest *G. corticata* beds during this study in 1990. The same area is currently being reclaimed for the purpose of jetty construction for a fish processing factory. The whole *G. corticata* bed has been totally wiped out. The eulittoral zone as a habitat is further affected by pollution effects which result from human activities. Apart from untreated seawage and factory effluents which are discharged directly onto this part of the coastal zone, waves and currents concentrate other pollutants such as hydrocarbons from the high seas and urban areas, in this zone.

The above cited interferences apply to all other eulittoral zone organisms and hence it is a threat to the whole ecosystem within this zone. There is, therefore, a serious need for policy-makers and coastal zone planners and managers to work in a more co-ordinated manner so as to come up with plans that would conserve the survival of organisms within the eulittoral zone. Otherwise, the present un co-ordinated development programmes along the coastal zone would lead to the extinction of some rare species sooner than expected.

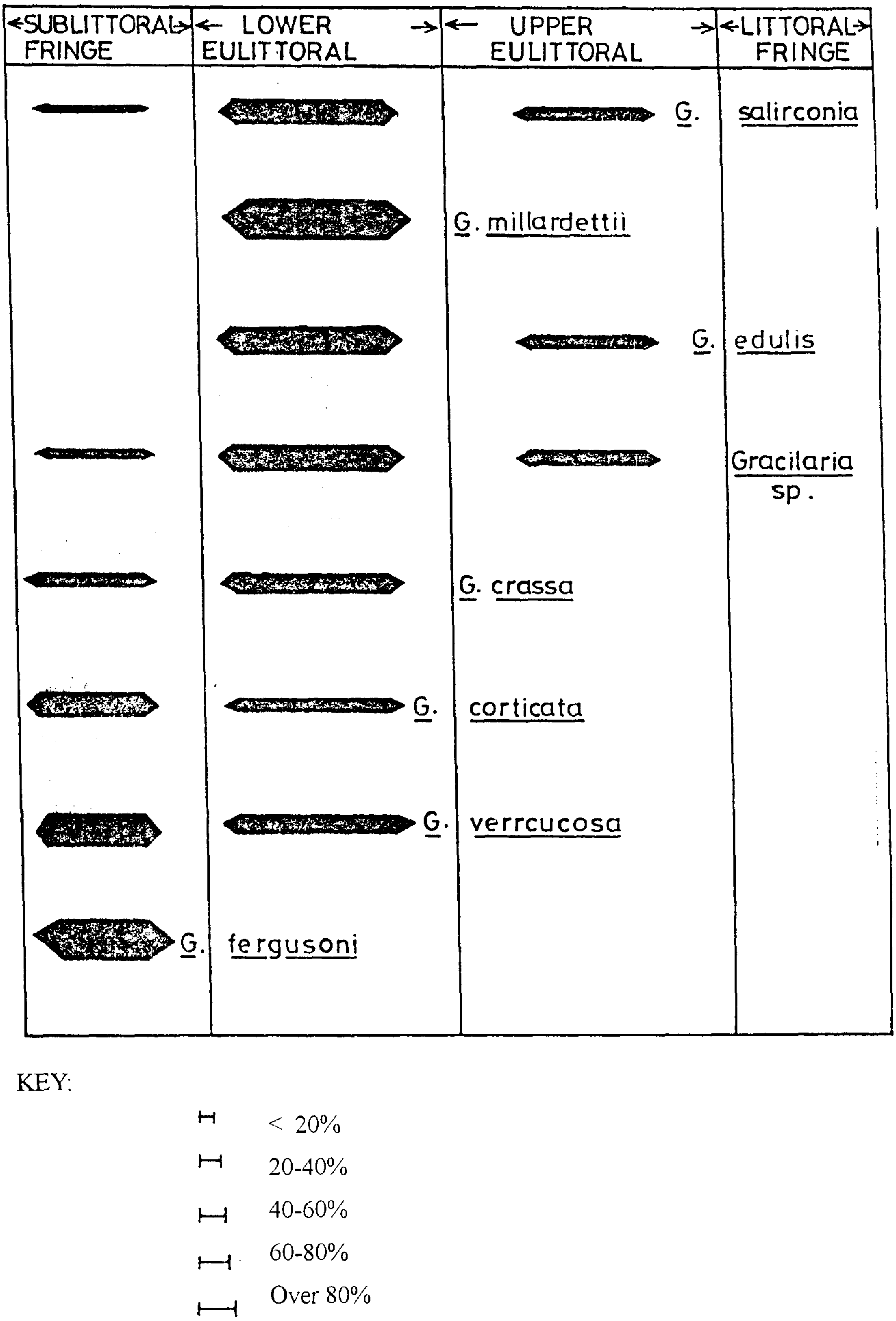


Fig.3. Relative zonation of different *Gracilaria* species showing percentage of number of times each species is found at each zone.

Acknowledgement

I am grateful to the Director of the Kenya Marine & Fisheries Research Institute, Dr. Ezekiel Okemwa and the Director of the Kenya-Belgium Project, Prof. Phillip Polk for their support. My thanks also go to Mr. Ndiege for his technical assistance. I am indebted to the German Academic Exchange Programme and the National Council For Science & Technology for their financial support which enabled me to do this work.

References

Chapman, V.J. & Chapman, D.J. (1973). The Algae. 2nd Ed. Macmillan Press Ltd. London. 497 p.

Coppejans, E. & Gallin, E. (1989). Macroalgae Associated with The mangrove vegetation of Gazi Bay (KENYA). *Bull. Soc Roy. Bot. Belg.* 122: 47 – 60.

Hartnoll, R.G. (1976). The ecology of some rocky shores in tropical East Africa. *Estuarine and coastal Marine Sciences* 4: 1 – 21.

Isaac, W.E. (1967). Marine Botany of the Kenya coast. 1. A first list of Kenya Marine Algae. *J. E. Afr. Nat. Hist. Soc.*26 (2): 75 – 83.

Isaac, W.E. (1968). Marine Botany of the Kenya coast. 2. A second list of Kenya Marine Algae. *J. E. Afr. Nat. Hist. Soc.* 27 (116): 1 -6.

Isaac, W.E., (1971). Marine Botany of the Kenya coast. 5. A third list of Kenya Marine Algae. *J. E. Afr. Nat. Hist. Soc.*28 (122): 1 – 23.

Isaac, W.E. & Isaac, F.M. (1968). Marine Botany of Kenya coast. 3. General account of environment flora and vegetation. *J.E. Afr. Nat. Hist. Soc.* 27 (116): 7 – 28.

Lapointe, B.E. (1989). Macroalgae production and nutrient relations in oligotrophic areas of Florida Bay. *Bull. Mar. Sci.* 44 (1): 312 – 323.

Lawson, G.W. (1969). Some observations on the littoral ecology of rocky shores in East Africa (Kenya and Tanzania). *Trans. R. Soc. S. Africa* 38: 329 – 340.

Lewis, J.R. (1964). The ecology of rocky shores. English University Press, London, 232 pp.

McLachlan, J. & Bird, C.J. (1986). *Gracilaria* (Gigartinales, Rhodophyta) and Productivity. *Aquat. Bot* 26 (1-2): 27 – 49.

Michanek, G. (1979). Seaweed resources for pharmaceutical use. In: *Marine Algae in Pharmaceutical scienc* , de Gruyter, Berlin: 203 – 235.

Moorjani, S.A. (1977). The ecology of Marine Algae of the Kenya coast. A Ph.D. Thesis, University of Nairobi, pp 285.

Moorjani, S.A. (1980). Rocky shore zonation in Kenya. Horizontal and vertical distribution patterns in marine flora. Paper presented at the *UNESCO/ALESCO Symposium, on the coastal and marine Environment of the Red Sea, Gulf of Aden and tropical western Indian Ocean,* Khartoum, Sudan. 5th – 11th January, 1980.

Oyieke, H.A. & Ruwa, R.K. (1987). Non-encrusting macroalgal zonation on rocky cliffs around Mombasa, Kenya. *Kenya J. Sci.* B. 8 (1-2): 77 – 96.

Santos, G.A. (1980). Quality of carrageanan and agar. In: *Pacific seaweed aquaculture,* Abott, I.A., Foster, M. and Eklund, L. (Eds). California Sea Grant Program, UCSD, 123 -129.

Taylor, P.R. & Hay, M. E. (1984). Functional morphology of intertidal seaweeds: adaptive significance of aggregate vs. solitary forms. *Mar. Ecolog. Prog. Ser.* 18: 295- 302.

Formation végétale des berges de la Lagune Ebrie (Côte d'Ivoire): évolution entre 1933 et 1992

Formation of the littoral vegetation of the Ebrie Lagoon (Côte d'Ivoire): evolution between 1933 and 1992

SANKARE Yacouba.
Centre de Recherches Océanologiques
B.P.V 18 Abidjan
COTE D'IVOIRE

Résumé

Cet article présente les résultats d'étude comparative des végétaux des berges de la lagune Ebrié depuis 1933 à ce jour. Les caractéristiques de ces végétaux, nombre d'espèces et aire d'occupation ont permis de mettre en évidence de très profondes modifications. La végétation très diversifiée, luxuriante était dominée numériquement par les grands arbres comme les palétuviers Rhizophora racemosa dans les année 30. Actuellement elle est peu diversifiée, composée d'arbustes et dominée par les végétaux flottants Pistia stratiotes, Salvinia molesta et Eichhornia crassipes. Ces derniers présentent des risques écologiques et socio-économiques. Ces modifications de la végétation des berges de la lagune Ebrié sont essentiellement dues aux activités humaines.

Abstract

This article presents the results of a comparative study on the littoral vegetation of the Ebrie lagoon since 1933 up to now. The characteristics of these plants, the number of species, the land of occupation showed some important changes. The vegetation was very diverse, rich and dominated by high trees of Rhizophora racemosa in the thirties. It is less diverse presently and composed mainly of small trees and dominated by floating plants Pistia stratiotes, Salvinia molesta and Eichhornia crassipes. These floating plants present some ecological and socio-economical threat for the water and the population. Observed modifications of the vegetation of the littoral of the Ebrié lagoon are mainly due to human activities.

INTRODUCTION

La lagune Ebrié constitue un modèle intéressant d'étude d'évolution des végétaux des berges par sa position centrale entre les lagunes Aby et Grand-Lahou (qui présentent encore une végétation luxuriante) et la présence d'une activité humaine très importante.

La faune ichthyologique, zooplanctonique et benthique sont l'objet de travaux importants mais les peuplements végétaux sont beaucoup moins étudiés. Nous devons citer essentiellement les travaux de Hedin (1933), Porter (1950-1951), Nicole *et al* (1987), Amon *et al* (1992), Guiral et

Etien (1992) et Sankaré *et al* (1992). Sur ces rives, nous ne nous sommes intéressés qu'aux secteurs lagunaires compris entre la région de Grand-Bassam à Dabou.

Cet article rend compte de l'évolution des végétations des bords de la lagune Ebrié; c'est pourquoi après avoir décrit les variations des peuplements végétaux, nous nous attacherons à présenter les principales causes de ces modifications.

Formation vegetales actuelles

Les formations végétales actuelles ont été divisées en trois grands ensembles : Les forêts marécageuses, les mangroves et les macrophytes flottants (Tableau 1, liste de l'ensemble des espèces).

* *Les forêts marécageuses*

Ces forêts sont localisées aux environs de la lagune Adjien, Ono et dans la région de Dabou autour de la rivière Agneby et sur la rive sud opposée (Figure 1). Les sols de ces milieux sont plats, mal drainés et très riches en matière organique. Ces forêts sont directement influencées par les eaux douces et sont dominées par les espèces comme :

Mitragyna ciliata Aubrev. et Pellegr. (Rubiacées)
Symphonia globulifera Linn. (Guttiferacée)
Raphia hookeri Man et Wendl. (Arecacées)
Cyrtosperma senegalense (Schott) (Aracées)
Anthocleista vogelii planch. (Loganiacées)
Bambusa vulgaris schrad ex Wendel (Poacées)
Dalbergia ecastophyllum Linn. (Papilionacées)

* *Les mangroves*

Les mangroves sont localisées dans les régions lagunaires d'Aghien, de Grand-Bassam, de part et d'autre de la lagune Ebrié entre Vitré et Bingerville et tout autour de l'Ile Boulay dans la région d'Abidjan.

Ces forêts se développent sur des sols hydromorphes salés résultant de l'influence des eaux marines. Elles comprennent essentiellement des arbustes de palétuvier blanc *Rhizophora racemosa* G. F.W. Meyer (*Rhizophoracées*) de palétuvier rouge *Avicennia germinans* Linn. (*Avicenniacées*) et le palétuvier gris *Conocarpus erectus* L. (*Combretacées*).

Ces espèces présentent une distribution zonale qui s'observe depuis le fond de l'eau jusqu'à la terre ferme. Cette disposition est liée à la capacité des végétaux à tolérer la salinité. *Rhizophora racemosa* se rencontre généralement à l'interface eau-sédiment dans les zones à faible teneur de sel sur les substrats vaseux et *Avicennia germinens* en arrière plan sur les sols vaso-sableux.

Ces végétaux sont remplacés par endroits par *Acrostichum aureum* Linn. (*Adiantacées*) et *Drepanocarpus lunatus* G. F. W. Rey (*Papilionacées*).

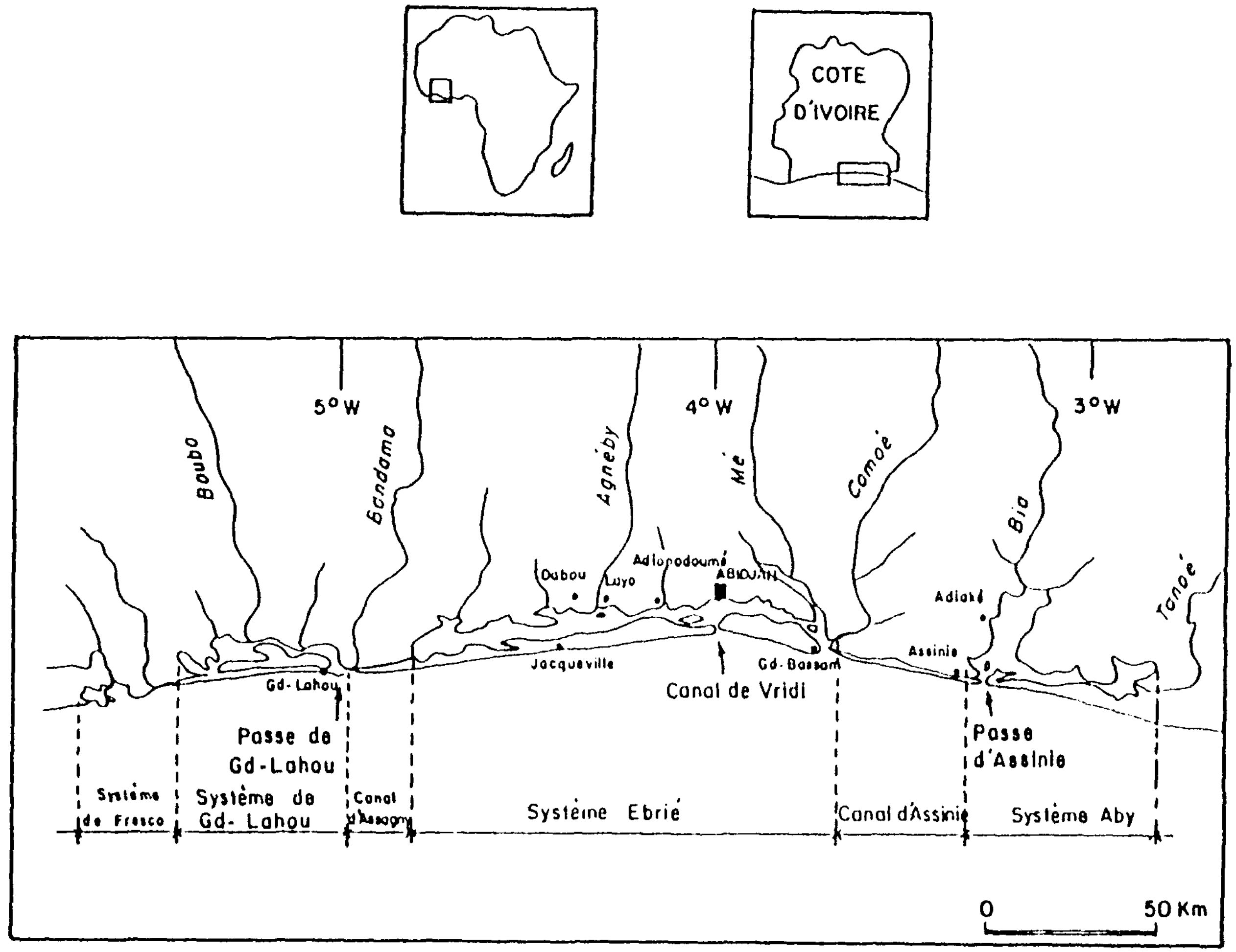


Figure 1. Le réseau lagunaire ivoirien

Tableau 1. Liste alphabétique des principales plantes rencontrées dans la région d'étude (1933).

Pistia stratiotes
Nymphaea lotus
Utricularia sp.
Cyperus polystachys
Fuirena umbellata
C. haspan
C. denudatus
Stylis pitosa
Cyrtosperma senegalensis
Lisochilus sp.
Crinum natans
Mitragyne macrophylla
Anthocleista nobilis
Crudia senegalensis
Ficus goliath
Cathormium altissimun
Chrysobalanus Icaco
Crudia senegalensis
Drepanocarpus lunatus
Ecastophyllum Brownei
Ficus Leprienri
F. mucuso
Haplormosia monophylla
Herminiera elaphroxylon
Lonchocarpus sericeus
Martretia quadricornis
Memecylon spathandra
Ormocarpum verrucosum
Parkia agboensis
Parinarium tenuifolium
P. excelsum
Pterocarpus esculentus
Sygidium guineense
Symphonia gabonensis
Var macrantha
Uapaca guineensis
Tetracera leiocarpa
Loranthus pubiflorus
L. incanus
Kalanchoe crenata
Xylopia aethiopica
Afzelia microcarpa
Coelocaryum oxycarpum
Dialium Dinkklagei
Erythrophlaeum ivorense
Gardenia viridissima
Monodora myristica
Pachystela cinerea
Rerodendron scandens
C. Schifferi
Combretum dolichopetalum
Merrimia angustifolia
Mucuna flabellipes
Vigna vexillata
Pterocarpus esculentus
Crudia senegalensis
Memecylon spathamdra
Mitragyne macrophylla
Anthocleista nobilis
Uapa guineensis
Drepano-carpus lunatus
Eriocaulon angustifolia
Cyperus haspan
Fimbrostylis africana
Paspalum scrobiculatum
Abrus canescens
Antiaris toxicaria
Canarium occidentale
Detarium Chevalieri
Erythrina senegalensis
Glycine hedysaroïdes
Mammea african
Pentachlethra macrophylla
Pipladenia africana
Pynertia occidentalis
Saccoglottis gabonensis
Acalypha paniculata
Alternanthera sessilis
Amaranthus spinosus
Aneilema beninense
Baphia polygalacea
B. nitida
Cardiospernum halicacabum
Cleome ciliata
Conopharyngia crassa
Culcasia scandens
Cyperus caracasanus
Diodia scandens
Nicoliana tabacum
Hibiscus surallensis
Indigofera hirsuta
Manihot Teissonieri
Palisota thysifolia
Phyllantus amarus
P. niruroïdes
Rauwolfia vomitoria
Strophanthus Preussii
S. sarmentosus
Talinum triangulare
Tristemma hirtum
Acanthospermum hispidum

**** Les macrophytes flottants***

- Les macrophytes flottants fixés émergés

Ce peuplement végétal est dominé par *Echinochloa pyramidalis* (Lam) Hitch et Anse. (*Poacées*) et se rencontre dans les secteurs lagunaires influencés directement par les eaux douces c'est à dire sur les rives lagunaires de la région de Bassam jusqu'à Bingerville et de la région lagunaire de Djemin à Dabou.

- Les macrophytes flottants libres

Ce groupe comprend les espèces : *Eichhornia crassipes* Solms-laub. (*Pontéderiacées*) *Salvinia molesta Mitch.* (*Salviniacées*), *Pistia stratiotes* Linn. (*Aracées*). Ces plantes couvrent presqu'en permanence les bas cours du fleuves Comoé et de la rivière Agneby. Elles s'observent périodiquement sur la lagune Ebrié (secteur oriental) après les post-crues des cours d'eau précédents.

Formations vegetales en 1933

Antérieurement à l'ouverture du canal de Vridi en 1951, les peuplements végétaux comprenaient entre Grand-Bassam et Dabou d'après Hedin (1933) et Porter (1950 et 1951) plusieurs types de groupements (Tableau 2, liste de l'ensemble des espèces).

On notait des eaux libres à la terre exondée plusieurs types de ceinture hydrophytique aux embouchures du fleuve Comoé et des rivières Agneby et la Mé.

Les hydrophytes flottants fixés et submergés comprenaient *Nymphaea lotus* en voie de disparition, les hydrophytes flottants libres *Pistia stradiotes*. En arrière plan de cette ceinture, succèdait une prairie très développée de *Echinochloa pyramidalis* à laquelle se substituait *cyperus articulatus*.

Les forêts marécageuses étaient présentes dans les zones de bas-fond mal drainées et périodiquement inondées par des eaux douces. Ce groupement particulièrement bien développé dans l'embouchure de l'Agneby, la Mé, dans les régions d'Abidjan et de Bingerville comprenait de nombreuses espèces végétales comme *Mitragyna ciliata*, *symphonia globulifera* et *Raphia hookeri*, *Afzelia microcarpa*, *Dialum Dinklagei*.

Les régions de Grand-Bassam (Aghien et Potou, autour de l'île Vitré et la région de Bassam), Bingerville, Abidjan, Ile Boulay et Djemin étaient caractérisées avant l'ouverture du canal de Vridi par leurs immenses massifs forestiers composés spécifiquement de *Rhizophora racemosa*. Ces arbres atteignaient facilement 20 m de hauteur.

De ces observations, il ressort que :

Les forêts marécageuses couvrent une faible superficie et sont désormais dominées numériquement par le genre *Raphia*, correspondant à des plantes de lumière, indiquant une ouverture de celles-ci par l'homme.

Tableau 2. Liste alphabétique des principales plantes recontrées dans la région d'étude (1992).

Acrostichum aureum
Aframomum elliotii
Agelaea obliqua
Alchornea cordifolia
Alternanthera maritima
Anthocleista nobilis
Avicennia germinans
Berlinia confus
Borassus aethiopum Mart.
Calamus deerratus
Calophyllum inophyllum
Cassia alataa
Cathormion altissium
Chrysobalanus icaco
Clerodendrum thyroideum
Cludia klainei
Conocarpus erectus
Cuviera macroula
Cyperus articulatus
Cyrtosperma senegalense
Dalbergia ecastaphyllum
Dichapetalum pallidum
Drepanocarpus lunatus
Echinochloa pyramidalis
Eichhornia crassipes
Eleocharis variegata
Ethulia conyzoides
Ficus congensis
Ficus ovata Vahl
Flagellaria guineensis
Heteropteris leona
Hibiscus tiliaceus
Hypolytrum purpurascens
Ipomea stolonifera
Ipomea pes-caprae
Ixora laxiflora
Lonchocarpus sericeus
Macaranga heudelotii
Mariscus ligularis
Mitragyna ciliata
Morelia senegalensis
Nauclea latifolia
Nephrolepis biserrata
Ocimum gratissimum
Ormocarpum verrucosum
Ostryocarpus riparius
Pandanus candelabrum
Panicum repens
Paspalum vaginatum
Paspalum conjugatum
Paullinia pinnata
Phoenix reclinita
Phyllanthus reticulatus
Pistia stratiotes
Pterocarpus santalionoides
Pycreus polystachyos
Raphia hookeri
Rhizophora racemosa
Salvinia nymphellula
Salvinia molesta
ecurinega virosa
Sporobolus virginicus
Strophanthus gratus
Symphonia globulifera
Tabernaemontana crassa
Tapinanthus bangwensis
Uapaca heudelotii
Uncaria africana

Les mangroves régressent. En effet, les mangroves comprises entre Grand-Bassam et Abidjan ne sont plus représentées que par des arbustes de *Rhizophora racemosa*, par endroits elles sont remplacées par *Acrostichum aureum*. Cette forêt est inexistante dans la région d'Abidjan et en voie de disparition dans la zone de l'île Boulay et Djemin.

De nouvelles espèces végétales sont apparues. Ce sont *Salinia molesta* et *Eichhornia crassipes* etc. Les Tableaux 1 et 2 présentent la liste des végétaux rencontrés avant et après l'ouverture du canal de Vridi. Cette liste n'est pas exhaustive mais indicative.

Les causes principales de ces modifications sont de plusieurs ordres, mais dans ce rapport nous nous limiterons volontairement aux principales actions humaines:

* *Agriculture*

Les végétaux des berges lagunaires sont détruits et remplacés par de vastes plantations de cocotiers *Cocos nucifera* L. (Arecacées). Cette espèce, en raison de l'hydrochorie de ses fruits et de sa résistance au sel se développe très bien dans les zones de mangroves et sur les berges lagunaires. Les berges lagunaires autour d'Abidjan sont souvent utilisées pour des cultures maraîchères, de fleurs et pour l'élevage de porcs.

* *Foresterie*

Les bois de palétuviers sont fréquemment utilisés dans la construction d'habitats, de ponts, de supports des filets fixes, de bois de chauffe et de fumage.

* *Teintures*

Les populations riveraines (Ebrié et Ahizi) extraient des écorces des palétuviers des matières tannantes ou colorantes. Ces produits sont utilisés pour teindre les tissus et les filets dans le but de les protéger contre les insectes et les produits chimiques de l'eau.

* *Travaux d'aménagement*

La plupart des quartiers de la capitale Abidjan sont contruits sur les sites des anciennes forêts marécageuses ou de palétuviers (quartier de treichville et koumassi). Cela a pu se réaliser grâce à la destruction des forêts et à la stabilisation des sols par du sable extrait du fond de la lagune Ebrié.

L'extraction de sable, le détournement des eaux par la construction des barrages hydroélectriques et des ponts contribuent à de profondes modifications du substrat et de l'hydrodynamisme des eaux. Les végétaux des berges lagunaires comme les palétuviers pour qui les besoins en eaux douce et en sédiment fins riches en éléments nutritifs sont permanentes, se dégradent et disparaissent (Nicole *et al*, 1987).

Cette situation est aggravée par le rejet en lagune de nombreux polluants (déchets domestiques, agricoles et industriels).

Les ouvertures fréquentes dans les forêts marécageuses et les mangroves ont favorisé le développement des plantes comme *Raphia* sp, et *Acrostichum aureum*.

Outre cela, le développement des cultures en arrière plan des rives a créé des espaces et des conditions propices au développement des herbiers des berges lagunaires.

Porter (1950, 1951) montre que les prairies à *Echinochloa pyramidalis* se développent en arrière plan des zones d'agriculture et attribue cela à la déforestation, qui tout en favorisant l'érosion alimente les berges lagunaires et les baies en sédiment riche en éléments nutritifs. Par ailleurs, l'emploi d'engrais fertilisant constitue une source importante d'éléments nutritifs à cette plante. Cette herbe couvre actuellement presque la quasi totalité des berges de la lagune Ebrié de Grand-Bassam à Dabou.

* *Introduction d'espèces exotiques*

Les plantes flottantes *Salivinia molesta* et *Eichhornia crassipes* sont apparues respectivement en 1983 et en 1985 en lagune Ebrié.

Guiral et Etien (1992) signalent que ces plantes flottantes libres ont été introduites volontairement comme plantes ornementales par les Horticulteurs, puis accidentellement elles ont envahie les eaux ivoiriennes.

Les Tableaux 3 et 4 présentent l'historique d'invasion de certains plans d'eau dans le monde et singulièrement en Afrique. Il apparaît que le Ghana, pays limitrophe et partageant avec la Côte d'Ivoire certains cours d'eau a été envahi par les plantes flottantes *Salvinia molesta* et *Eichhornia crassipes* un ou deux ans plutôt que la Côte d'Ivoire. Aussi, l'hypothèse que les plantes ont pu être introduites involontairement dans le pays (grâce à l'hydrodynamise ou par les bateaux Ghanéens) n'est à écarter. En effet, le fleuve Tanoé (qui prend sa source au Ghana se jette dans la lagune Aby) et diverses passes permettent la communication et la navigation entre les deux territoires.

Par ailleurs, il y existe un important trafic de marchandises et de personnes.

Enfin, de nombreuses passes relie toutes les lagunes de Côte d'ivoire. La combinaison de tous ces facteurs ont certainement favorisé l'introduction en Côte d'Ivoire des plantes flottantes.

La prolifération et l'explosion de ces plantes ont été favorisées par la présence de milieux répondant aux conditions optimales de leur développement. En effet la présence de nombreux barrages et ponts, tout en répondant aux besoins de développement du pays ont transformé les milieux lotiques en écosystème aquatique lentique, riches en éléments nutritifs. Ces lacs de barrage et les lacs hydro-agricoles constituent les lieux privilégiés pour la croissance des macrophytes flottants. Ce sont les cas des lacs de barrage d'Ayamé, de Taabo et de Koossou qui sont presque recouverts par ces végétaux.

Dans tous les cas les végétaux des berges lagunaires sont considérés comme n'ayant pas de valeur. Ces agissements sont dus à la méconnaissance de ces peuplements et de leur importance pour la survie des écosystèmes aquatiques.

Ces dernières années, suite aux envahissements périodiques de la lagune Ebrié, ces peuplements végétaux et plus particulièrement les macrophytes flottants ont eu un regain d'intérêt compte tenu de l'importance de leurs impacts écologiques et socio-économiques. En effet, leur prolifération interdit toute exploitation et utilisation du plan d'eau. En effet la pêche (source de revenu et de nourriture pour les populations riveraines) et la navigation se trouvent directement affectées. Outre cela, ces plantes favorisent la prolifération de maladies endémiques comme la bilharziose et le paludisme.

En conclusion, cette étude comparative des variations des peuplements de végétaux des régions de Bassam à Dabou de 1933 à nos jours permet de faire quelques remarques:

- avant l'ouverture du canal de Vridi en 1951 ils comprenaient de nombreuses espèces dont les plus importantes (taille et aire d'occupation) étaient les palétuviers.
- après l'ouverture du Canal vers les années 90 ces peuplements ont été profondément modifié en grande partie par les activités humaines. Ils présentent moins d'espèces, des mangroves en voie de disparition et des plantes exotiques. Ces dernières constituent un réel danger écologique et socio-économique.

Tableau 3. Apparition de *Salvinia molesta* dans quelques pays africains.

PAYS	ANNEES	AUTEURS
ZIMBABWE	1959	Mitchell, 1972
KENYA	1976	Gaudet, 1976
CONGO	1965	Little, 1965
GHANA	1980	Okera, Com. Pers
COTE D'IVOIRE	1983	Guiral & Etien, 1992

Tableau 4. Apparition de *Eichhornia crassipes* dans quelques pays africains.

PAYS	ANNEES	AUTEURS
EGYPT	1950	Tackholm & Drar, 1950
ZAIRE	1955	Dubois, 1955
MOZAMBIQUE	1958	Mendonca, 1958
ANGOLA	1958	Mendonca, 1958
SOUDAN	1958	Gay, 1958
SENEGAL	1965	Little, 1965
AFRIQUE DU SUD	1979	Scott *et al.*, 1979
BENIN	1984	Oso, 1988
NIGERIA	1985	Oso, 1988
GHANA	1985	Okera, Com. Pers.
COTE D'IVOIRE	1985	Guiral & Etien, 1992

Face à ces profondes modifications nous recommandons:

- l'éducation et la sensibilisation des populations (riveraines et urbaines) sur l'importance de ces végétaux,
- la réabilitation et la surveillance de ces biotopes,
- le contrôle rigoureux des entrées et des sorties du patrimoine génétique végétal et animal,
- la conduite de recherche pluridisciplinaire afin de mieux comprendre le fonctionnement et de mieux préciser le rôle des végétaux des berges lagunaires sous les tropiques.

Bibliographie

Amon Kothias, J.B., Guiral, D., Sankaré, Y., Kaba, N. & Etien, N. (1992). Suivi cartographique de l'expansion des macrophytes envahissant le système lagunaire Ebrié (Côte d'Ivoire). *J. Ivoir. Océanol. Limnol. abidjan,* Vol 1 (2): 11-24.

Dubois, L. (1955). La jacinthe d'eau au congo Belge. *Bulletin Agricole du Congo Belge*, 46: 893-900.

Gaudet, J.J. (1976). *Salvinia* infestation on lake Naivasha in East Africa (Kenya). pp. 193-209. In Varshney C.K. et Rzoska J. (Eds) Aquatic weed in South East Asia.

Gay, P.A. (1958). *Eichhornia crassipes* in the Nile of the Sudan. *Nature*, London, 182: 538-539.

Guiral, D. & Etien, N. (1992). Les macrophytes aquatiques des berges lagunaires. *J. Ivoir. Océanol. Limnol. Abidjan*, Vol. 1(2): 25-40.

Hedin, L. (1933).Observations sur la végétation des bords lagunaires dans la région de Grand-Bassam et de Bingerville (Côte d'Ivoire). La terre et la Vie, 3 (10) : 596-609.

Little, E.C.S. (1965). Occurence of *Salvinia auriculata* Aublet on the Congo river. *Nature*, London, 208: 1111-1112.

Mendonca, A. (1958). Etat actuel du problème de l'*Eichhornia crassipes* au Mozambique et en Angola. *Bull. Agric. Congo Belge,* 7: 1268-1362.

Nicole, M., Egnankou, W., & Schmidt M. (1987). Les zones humides côtières de Côte d'Iv... Rapport ORSTOM, Université Nationale Côtez d'Ivoire, C.I. *Nature* (eds), 73p.

Mitchell, D.S. (1972). The Kariba weed: Salvinia molesta. Brit. Fern Gaz., 10(5): 251-252.

Oso, B.A. (1988). Invasion des eaux nigérianes par la jacinthe d'eau: observations sur le terrain. Proceedings of International Meeting on *Eichhornia crassipes*. Lagos, 1988.

Porter, R. (1950). Compétition au sein de groupements végétaux aquatiques dans les lagunes de Côte d'IVoire. *Bull. Soc. Bot. France*, 4, 6 :109-112.

Porter, R. (1951). Les variations des ceintures hydrophytiques et gramino-helophytiques des eaux vives du système lagunaire de la Côte d'IVoire. *Bull. Inst. de l'AFN.* 13(4): 1011-1028.

Sankare, Y., Amon Kothias, J.B. & Konan, A.A. (1992). Les effets de la réouverture de l'embouchure du fleuve Comoé sur la végétation littorale lagunaire (lagune Ebrié – Côte d'Ivoire). *J. Ivoir. Océanol. Limnol. Abidjan Vol.1* (2) :71-79.

Scott, W.E., Ahston, P.J. & Steyn D.J. (1979). Chemical control of the water hyacinth on Harbeesport Dam. Water research Commission, Pretoria, 84 pp.

Tackholm, V. & Drar, M. (1950). Flora of Egypt. Vol. 11. Fouad I University Press, Cairo.

La peche par empoisonnement dans les lagunes Ivoiriennes: effets sur l'environnement

Fishing with poisons in the lagoons of the Ivory Coast: effects on the environment

SANKARE Yacouba, KABA Nasséré et Etien N'DAH
Centre de Recherches Océanologiques
B.P.V 18 Abidjan
COTE D'IVOIRE

Résumé

Les produits toxiques utilisés pour la pêche comprennent des substances naturelles (plantes) et des substances chimiques (pesticides).

Les substances naturelles proviennent de plantes appartement aux espèces Chrysanthemum cinerariafolum, Chrysanthemum roseum, Chrysanthemum marshali, Barringtonia sp., Derris elliptica, Lonchocarpus sp., Owenia vernicosa, Raphia sp. et Tephrosia sp.. Les produits chimiques utilisés sont nombreux et les plus communs en Côte d'Ivoire sont l'endosulfan et le lindane. Les poissons concernés par cette pêche sont généralement Tilapia guineensis, Tilapia mariae, Sarotherodon melanotherodon, Tylochromis jintinki et Hemichromis fasciatus.

Malheureusement ces produits naturels et chimiques ont des effets néfastes sur l'environnement aquatique et sur la santé humaine.

Abstract

Toxic products used to fish are composed of natural (plants) and chemical (pesticides) substances.

Among the plants used we have the species of Chrysanthemum cinerariafolum, Chrysanthemum roseum, Chrysanthemum marshali, Barringtonia sp., Derris elliptica, Lonchocarpus sp., Owenia vernicosa, Raphia sp. et Tephrosia sp.. Many chemical products are used but the most common in Côte d'Ivoire are endosulfan and lindane. Target fishes of this activity are Tilapia guineensis, Tilapia mariae, Sarotherodon melanotherodon, Tylochromis jintinki and Hemichromis fasciatus.

Unfortunately, those natural and artificial products have many negative effects on aquatic environment and human health.

Introduction

Le système lagunaire ivoirien forme un ensemble de plans d'eau s'étendant parallèlement au littoral sur environ 270 km (Figure 1). Il comprend quatre grands ensembles qui sont, d'Ouest en

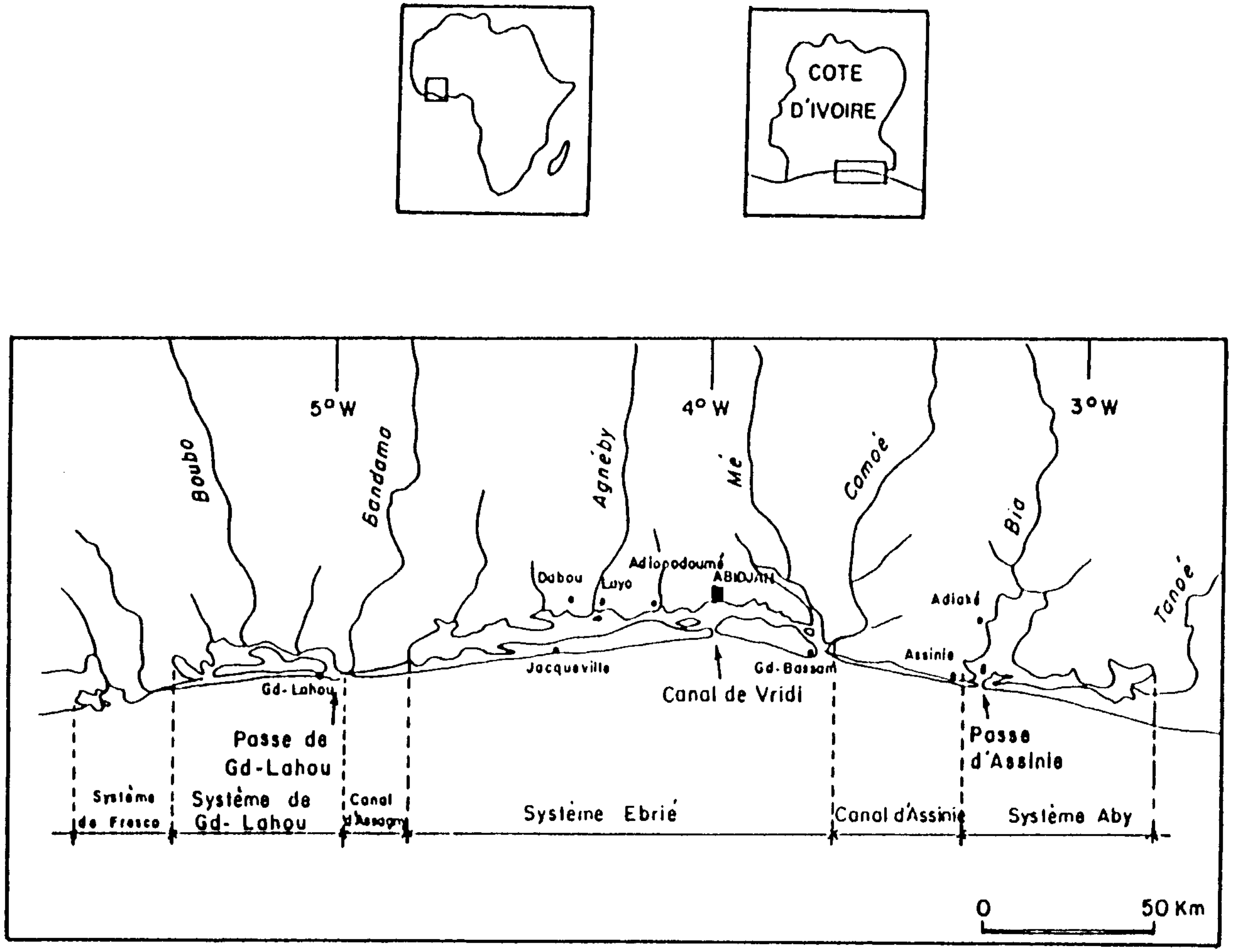


Figure 1. Le réseau lagunaire ivoirien

Est la lagune de Fresco, la lagune de Grand-Lahou, la lagune Ebrié et la lagune Aby (Tastet, 1974; Varlet, 1978).

Ce système lagunaire est le support de plusieurs activités aussi bien économiques que récréatives comme la pêche et le transport. La pêche constitue l'activité principale de nombreuses populations ivoiriennes. Cependant, le système lagunaire ivoirien et plus particulièrement sa faune aquatique est menacée par les différentes techniques de pêche (Garcia, 1978) et surtout par la pêche aux produits toxiques.

La pêche par empoisonnement des poissons est une technique utilisée de plus en plus par certains pêcheurs. Malheureusement, les impacts de cette pratique de pêche sur le milieu, la faune et la flore sont encore très mal connus.

Dans le travail présenté ici, notre propos est d'une part, de décrire à partir de la littérature les effets des produits (naturels et artificiels) utilisés en Côte d'Ivoire pour la pêche par empoisonnement et d'autre part de formuler des recommandations.

Considerations generales

La pêche par empoisonnement bien que' interdite par les autorités gouvernementales et coutumières se pratique clandestinement par des pêcheurs dans toutes les lagunes ivoiriennes. Les lieux privilégiés pour cette technique de pêches sont les baies et les forêts de palétuviers.

En Côte d'Ivoire, les lagunes sont essentiellement rassemblées le long de la moitié orientale de la façade littorale. Elles communiquent avec l'océan et entre elles grâce à des canaux.

La lagune de Fresco, localisée à l'extrême Ouest est la plus petite et la moins profonde. Elle est bordée par les forêts de palétuviers les plus luxuriantes de la Côte d'Ivoire et se raccorde à la lagune de Grand-Lahou par le canal de Niouniourou.

La lagune de Grand-lahou, orientée Est-Ouest couvre une superficie de 450 km² et les eaux sont peu profondes (la moyenne est de 3 m). Elle communique avec la lagune Ebrié par le Canal d'Assagny. Elle présente très peu de baies mais presque totalement entourée par des palétuviers *Rhizophora racemosa* détruits par endroits par les populations riveraines.

La lagune Ebrié est, elle aussi étirée d'Est en Ouest et couvre une surface de 566 km². la profondeur moyenne est de 4 m. Les baies, situées surtout sur la rive nord représente près de 20 % de la surface totale. Les forêts de palétuviers dominées par *Rhizophora racemosa* bordant cette lagune ont été détruites par les activités humaines (travaux d'aménagement et usages domestiques), seules persistes des reliques dans les régions de Bassam et de l'île Boulay.

Enfin, la lagune Aby localisée plus à l'Est couvre une superficie de 424 km². Les baies rencontrées représentent moins de 5% de la surface totale. Elle est bordée dans la région Sud de forêt de palétuviers composée essentiellement d'arbustes tels que *Rhizophora racemosa*.

Les baies et les mangroves concernées sont peu fréquentées compte tenu de leur éloignement et de leur accès difficile dû à la forêt luxuriante.

Outre cela, elles se rencontrent dans des secteurs lagunaires soumis aux influences continentales, à une salinité très variable avec la saison: dominance marine en saison sèche (15 ‰), continentale en saison des pluies (inférieure à 2 ‰), sauf dans la région lagunaire de l'île Boulay où la salinité des eaux est élevée (supérieure à 20 ‰) à cause de l'influence directe et permanente des eaux marines transitant par le canal de Vridi.

Quoique les écarts de températures soient faibles (amplitude thermique annuelle : 5°c), les eaux de ces milieux sont plus tièdes en saison sèche qu'en saison des pluies (Tastet, 1974; Varlet, 1978).

Les sédiments des baies comprennent des sables, des vases, des sables vaseux et du gravier mélangé aux débris végétaux.

Les sédiments rencontrés dans les mangroves sont de deux types :

- La vase molle gluante et noire dans les zones de mangrove où la marée est moins sensible (lagune de Potou et Aghien)
- Formation de feutrage et de racine dans les zones où le marnage est prononcé (Zabi & Sankaré, 1986).

Les travaux de Albaret (1988) et Albaret & Ecoutin (1992) montrent que les principales espèces de poissons pêchés en lagune sont rencontrées dans les baies et les mangroves. Ces auteurs signalent huit catégories de peuplement de poissons rencontrés dans les eaux lagunaires ivoiriennes. Dans ce rapport nous insisterons sur les poissons économiquement et écologiquement importants rencontrés dans les mangroves et les baies. Ces poissons comprennent :

* **les formes exclusivement estuariennes** (poissons présents uniquement en milieu lagunaire où se déroule la totalité du cycle biologique) *Tylochromis jentinki*, *Sarotherodon melanotherodon*, *Tilapia* sp. et *Gerres nigri*;
* **les formes estuariennes d'origine marine** (espèces marines adaptées aux conditions lagunaires) *Pomadasys jubelini*, *Ethmalosa fimbriata*, *Trachinotus teraia*;
* **les formes estuariennes d'origine continentale** (espèces d'origine continentale adaptées au milieu lagunaire) *Chrysichtys sp.*, *Claria ebriensis* et *Hemichromis fasciatus*;
* **et les formes marines – estuariennes** (se différencie de la forme précédente par le fait qu'elles ne se reproduisent pas en lagune) *Trachinotus ovatus*, *Mugil curema*, *Elops lacerta* etc.

Zabi et Sankare (1986) signalent plusieurs espèces d'organismes benthiques dans les mangroves et les baies de nos lagunes et plus particulièrement en lagune Ebrié. Les groupes souvent rencontrés sont les oligochètes, les polychètes, les mollusques (gastéropodes et pélécypodes), les crustacés (crabes, crevettes et squilles) et les insectes aquatiques. Sur un total de 122 espèces récoltées en lagune 74 espèces se trouvent dans ces biotopes.

Les espèces abondantes par classe sont les gastéropodes: *Littorina angulifera*, *Pachymelania fusca*, *Tympanotonus fuscatus*, *Thais forbesi* et *Pugilina morio*; alors que les pélécypodes sont dominés par les huîtres *Crassostrea gasar*, *Corbula trigona* et *Arca senilis*. Les crustacés sont représentés par le crabe nageur *Callinectes amnicola*, la crevette rose *Penaeus notialis*, La crevette de mangrove *Alpheus pontederiae*, les crabes amphibies *Cardiosoma armatum*, *Uca tangeri*, *Goniopsis pelii*, et *Sesarma huzardi*.

Tous ces organismes qui passent tout ou en partie leur vie larvaire, juvénile ou adulte dans ces biotopes présentent des caractéristiques physiologiques et écologiques qui nécessitent les milieux précités pour la pérennité de l'espèce. Aussi, ces biotopes sont considérés comme des nurseries.

Peche par empoisonnement

La pêche par empoisonnement dans les eaux lagunaires ivoiriennes porte sur les Cichlidae à savoir *Tylochromis jintinki*, *Sarotherodon melanotherodon*, *Tilapia giuneensis* et *Hemichromis fasciatus*. Ces poissons sont recherchés pour la simple raison qu'ils sont prisés par les populations.

Cette pêche revêt deux formes: la pêche "traditionnelle" qui utilise des plantes et la pêche "moderne" qui utilise des produits chimiques et plus précisément des pesticides.

Pêche traditionnelle (plantes utilisées et methodes)

Plusieurs espèces de plantes sont utilisées par les pêcheurs pour assommer et tuer les poissons. Les plus communément signalées par de nombreux auteurs tels que Bishop *et al* (1982), Heizer (1953) sont: *Chrysanthemum cinerariafolum*, *Chrysanthemum roseum*, *Chrysanthemum marshali*, *Barringtonia* sp., *Derris elliptica*, *Lonchocarpus* sp., *Owenia vernicosa*, *Raphia* sp., *Tephrosia* sp. (cultivée parfois en plante de couverture dans les caféiers). Toutes ces plantes se rencontrent en Afrique et en Côte d'Ivoire les plus utilisées pour la pêche par empoisonnement sont les genres *Raphia* et Tephrosia

Heizer (1953) décrit quatre techniques traditionnelles de pêche par empoissonnement. La première technique consiste à plonger les plantes broyées dans l'eau. La seconde est une amélioration de la précédente et consiste à laisser séjourner le broyat des plantes dans un récipient contenant de l'eau. Cette dernière après un à deux jours est ensuite recueillie et déversée dans le milieu. La troisième technique consiste à faire un appât en combinant les plantes avec des aliments diverses (généralement des féculents). Enfin la quatrième est la pêche traditionnelle par fumage. Les trois premières techniques se rencontrent en Côte d'Ivoire et sont même pratiquées dans les eaux continentales.

Pêche "moderne" (pesticides utilisés et methode)

Il existe de nombreux produits chimiques qui sont utilisés pour la pêche par empoisonnement. Ces produits, à l'origine sont destinés à lutter contre les "pestes" c'est à dire les insectes, les champignons, les mauvaises herbes aussi bien en agriculture qu'en protection humaine et animale. Ce sont essentiellement des dérivés chlorés et les plus fréquemment utilisés sont le DDT (dichloro-diphényle trichloroéthane), le lindane, le dieldrine, le cyanide de sodium, la roténone, la quinaldine, l'antimycine (fintrol-5). Les plus couramment utilisés par les pêcheurs en Côte d'Ivoire sont l'endosulfan et le lindane (Eldredge, 1987; Kaba, 1989).

Outre cela, il existe des produits naturels commercialisés tels que le *Chrysanthemum* sp. communément appelé le pyrèthre et cultivé pour ses fleurs qui contiennent un produit insecticide: la pyréthrine. Ce produit se trouve dans le commerce sous plusieurs formes (poudres et extraits de pyréthrine).

Dans tous les cas, les pêcheurs localisent dans une première phase, et cela pendant la journée, la zone à prospecter, puis très tôt le matin ils s'y rendent et y déversent les produits chimiques.

Effets des poisons

* *Mode d'action et effets des plantes*

Les principaux composés actifs signalés dans les plantes utilisées pour la pêche par empoisonnement sont la roténone (Roark, 1932), la saponine et la tephrosine (Bishop et al., 1982).

La roténone ($C_{23}H_{22}O_6$) et des composés voisins sont des poisons d'absorption, sans aucune nocivité pour l'homme et les animaux à sang chaud. En revanche, ils sont très efficaces contre certains animaux aquatiques. Ce sont des enzymes d'inhibition de la respiration qui tuent les poissons en bloquant le processus d'échange d'oxygène. Cependant, il semble sans effet immédiat sur de nombreux invertébrés aquatiques (Eldredge, 1987).

La saponine, matière active obtenue de *Barringtonia* sp., est un composé soluble dans l'eau qui, au contact des branchies des poissons, les paralysent.

La téphrosine (oxydéguéline) agit aussi sur la respiration des poissons.

* *Modes d'action et effets des produits chimiques*

Les pesticides utilisés pour la pêche par empoisonnement présentent un large spectre d'impacts.

(a) impacts sur l'environnement aquatique

Les pesticides se retrouvent dans la colonne d'eau et dans le sédiment et compte tenu du fait que leur dégradation est très lente (4 à 5 ans de demi-vie pour le DDT) et que leur bioaccumulation est croissante d'un niveau trophique à un autre, ces produits peuvent contaminer toute la chaîne alimentaire aquatique. Cette contamination se fait soit par filtration de l'eau contaminée, soit par ingestion des particules en suspension ou sédimentées.

Les effets des pesticides sur la faune et la flore aquatiques sont extrêmement variés et dépendent de l'organisme, de son état de maturité, de la nature, de la dose du produit et du temps d'exposition. Aussi, ces produits ont des effets sur le phytoplancton, le zooplancton, les poissons et les organismes benthiques.

Rajendran et Venugopalan (1983) montre que les pesticides tels que le DDT et le lindane provoquent une diminution de la production phytoplanctonique.

Balk et Koeman (1984) analysant l'effet des pesticides sur les invertébrés concluent que ces derniers agissent sur le système nerveux soit par action directe sur les nerfs ou par interférence avec la transmission des impulsions nerveuses. En effet, des crabes du genre *Uca* exposé pendant trois jours à 0,08 ppm de DDT acquièrent une hyperactivité avec une profonde modification du rythme d'activité, Fingerman et Van Meter (1979). Martin *et al* (1976) montrent dans une étude comparant quelques organismes estuariens que les crevettes sont les plus sensibles aux polluants.

Il est bien connu que les poissons sont les organismes qui sont immédiatement affectés par les pesticides. Des tests des effets des organochlorés sur les poissons indiquent que ceux-ci répriment la sécrétion de gonadotropine dont la conséquence est une baisse de l'activité gonadotropine durant la phase du cycle de reproduction (Singh & Singh, 1983).

Quelle que soit la méthode, l'utilisation de poisons pour la pêche des poissons aura les mêmes résultats c'est-à-dire la dégradation des biotopes et la destruction de la faune et de la flore aquatique non cibles.

Par ailleurs, des études in vitro effectuées par Etien et Dadié (1992) ont mis en évidence les critères anatomo-pathologiques des pesticides gramoxone (herbicide), gammaline (insecticide) et thiodan(insecticide) sur l'oeil, les branchies, la bouche, les nageoires, les organes internes, la coloration de la peau des poissons appartenant aux espèces *Chrysichtys nigrodigitatus* et *Tilapia aurea*. Les expériences montrent une inco-ordination motrice caractérisée par une nage désordonnée et des mouvements convulsifs. Les poissons intoxiqués présentent aussi des difficultés respiratoires (bouche ouverte à la mort). Le Tableau 1 montre les effets lésionnels observés chez les poissons sous l'action de chacun des pesticides. L'on peut remarquer l'abrasion des lamelles branchiales qui fera que la fixation de l'oxygène au niveau des branchies ne pourra plus se faire. Par ailleurs, du fait de leur nature lipophile, les produits tels que le thiodan et la gammaline vont se fixer dans le foie et dans le cerveau.

Le fumage des poissons selon la méthode traditionnelle (à chaud) ne permet pas de distinguer un produit sain d'un produit intoxiqué.

Les poissons intoxiqués conservés sous glace présentent encore une certaine qualité commerciale, après trois jours. Toutefois, quelques caractères tels que les nageoires hérissées, la peau décolorée et la cornée opaque fait suspecter une intoxication.

Enfin, le dosage des résidus de lindane dans certaines parties des poissons a montré que ce dernier se concentre plus dans les branchies que le cerveau et la chair. Il faut noter que l'endosulfan se dégradant rapidement, le dosage doit être effectué rapidement au risque de ne pouvoir détecter les résidus.

(b) impact socio-économique

L'usage des produits toxiques pour la pêche constitue aussi un problème socio-économique, interdisant toute utilisation du plan d'eau contaminée et favorisant des troubles de santé.

De la modification de la qualité de l'eau, il résulte:

- l'abandon de la zone contaminée par les animaux aquatiques donc par les pêcheurs;
- la destruction de la faune et de la flore aquatiques non cibles et plus particulièrement des juvéniles de nombreux poissons et crustacés, et par conséquent sur leurs futurs stocks et par voie de fait sur les revenus des pêcheurs;
- les poissons ainsi capturés se conservent difficilement et par conséquent ont une faible valeur marchande.

Tableau 1 - Lésions observées après intoxication des mâchoirons (Chrysicthys nigrodigitatus) et des Tilapias (Tilapias aurea) par le thiodan, la gammaline et le grammoxone (Etien et Daddié, 1992).

		TILAPIA SAIN	TILAPIA INTOXIQUE	MACHOIRON SAIN	MACHOIRON INTOXIQUE
THIODAN	Nageoires	non hérisées	hérissées	non hérisées	hérissées
	Bouches	fermée	ouverte	fermée	ouverte
	Coloration	gris métallique	blanchâtre	gris métal	gris métal mucus
	Branchies	rouge vif	pâles	rouge vif	rouge sombre violacée
	Oeil	Abs.voile blanc	voile blanc	gris	gris
	Organes	non lysés	putréfaction rapide	non lysés	putréfaction rapide
GAMMALINE	Nageoires	non hérisées	hérisées	non hérisées	hérissées
	Bouches	fermée	ouverte	fermée	ouverte
	Coloration	gris métal	blanchâtre	gris métal	gris métal mucus
	Branchies	rouge vif	légèrement colorées	rouge vif	rouge sombre
	Oeil	Abs.voile blanc	voile blanc	gris	gris
	Organes	non lysés	putréfaction rapide	non lysés	putréfaction rapide
GRAMOXONE	Nageoires	non hérisées	hérissées	non hérissées	hérissées
	Bouches	fermée	ouverte	fermée	ouverte
	Coloration	gris métal	verdâtre	gris métal	reflets verdâtres
	Branchies	rouge vif	rouge sombre	rouge vif	rouge sombre
	Organes	non lysés	putréfaction rapide	nonlysés	putréfaction rapide

Outre cela, les poissons pêchés par empoisonnement présentent de nombreux risques d'intoxication pour le consommateur.

Olishifski (1979) note que les hydrocarbones chlorés ont des effets sur le foie, les reins, le système nerveux de l'homme. Par ailleurs, ils sont carcinogènes et peuvent plonger l'homme dans un coma et le conduire à la mort.

Conclusion

Il ressort de cette étude que des produits toxiques sont utilisés par certains pêcheurs pour capturer des poissons de la famille des Cichlidae.

Ces produits sont utilisés dans des secteurs lagunaires, à savoir les baies et les forêts de palétuviers difficilement accessibles par voie terrestre et riches en animaux aquatiques.

Ces produit utilisés ont de nombreux impacts sur l'environnement aquatique. Malheureusement, les travaux de recherche concernant ces effets sont éparses.

Recommandations

Nous recommandons donc :

- d'éduquer et de sensibiliser les populations riveraines sur les impacts de cette pratique sur l'écosystème aquatique et les risques sanitaires et économiques pour la population,
- de responsabiliser les autorités villageoises, c'est à dire leur permettre de mener des contrôles sur le terrain et les marchés dans les villages et de sanctionner les fautifs,
- de mener des recherches sur les effets de ces produits sur nos écosystèmes lagunaires.
- et d'instaurer des contrôles rigoureux et systématiques de salubrité les produits de pêche.

Bibliographie

Albaret, J.J. (1988). Les Poissons: biologie et peuplement In: *Environnement et Ressources aquatiques de Côte d'Ivoire.* 2. Les milieux saumâtres: l'exemple de la lagune Ebrié. Dufour,P., Durand, J.R. & Zabi, G.S. (Eds). 35p à paraître.

Albaret, J.J. & Ecoutin, J.M. (1992). Communication mer-lagune: impact d'une réouverture sur l'ichtyofaune de la lagune Ebrié (Côte d'Ivoire). *J. Ivoir. Océanol. Limnol. Abidjan. Vol I N°2*: 99-109.

Bishop, K.A., Baker, L.M. & Noller, B.N. (1982). Naturally-occuring icthyocides and a report on *Owenia vernicosa* F. Muell.(Family Meliaceae), from the Magela Creek system, Northern territory. Search, 13(5-6): 150-153.

Eldredge, L.G. (1987). La pêche par empoisonnement dans les récifs coralliens. In "*Impacts des activités humaines sur les récifs coralliens: connaissances et recommandations*" B. Salvat (Ed.) Antenne Muséum E.P.H.E., Polynésie française: 63-66.

Etien, N. & Dadié, P. (1992). Definition de critères anatomo-pathologiques de certains pesticides sur les poissons.(sous presse).

Fingerman, S.W. & Van meter, C. (1979). Increased spontaneous locomotor activity in the fiddler crab (*Uca* sp.) after exposure to a subletal concentration of DDT. Bull. Envron. Contam. and Toxico.,21(1-2): 11-16.

Garcia, S. (1978). Bilan des recherches sur la crevette rose *Penaeus notialis* de Côte d'Ivoire et conséquences en matière d'aménagement. Doc; Scient. Cent. Rech. Océangr. Abidjan, VolIX,N°1: 1-41.

Kaba, N. (1989). Etude synthétique de la pollution par les pesticides et PCB dans les environnements marins et lagunaires: cas de la Côte d'Ivoire. *Cent. Rech. Océanogr. Abidjan.* NDR. 02/87 40p.

Heizer, R.F. (1953). Aboriginal fish poisons. *Bull. Bur. American Ethnol.*, 151:225-283.

Martin, J.M., Meybeck, M., Salvadori, F. & Thomas, A. (1976)-Chap III – Pollution par les pesticides et les chlorodiphényles(PCB). In: *pollution chimique des estuaires: Etat actuel des connaissances.* Centre National pour l'Exploitation des Océans(CNEXO). Série: Rapport Scientifiques et Techniques N°22.

Olinshifski, B.J. (1979). Fundamentals of industrial hygiene, 2nd edition, National Safety Council, Chicago, Illinois, pp. 1023-1117.

Raejendran, N. & Venugopalan, V.K. (1983). Effects of pesticides on phytoplankton production. Mahasagar, Vol.16 N°2: 193-197.

Roark, R.C. (1932). A digest of the litterature of *Derris* (Deguelia) species used as insecticides, 1747-1931. *U.S. Dept. Agricult. Miscell. Publ.*, 120: 1-86.

Singh, H. & Singh, T.B. (1983). Effect of pesticides on fish reproduction. *Acta Biol. Iugosl (Ichthyol)*, 15(1) :71-81.

Taste, J.P. (1974). L'environnement physique du système lagunaire Ebrié: I et II. *Ann. Univ. Abidjan, Sér. Doc., N°11*, 28p., 58 Figs.

Varlet, F. (1978). Le régime de la lagune Ebrié, Côte d'Ivoire. Traits Physiques essentiels. Trav. et Doc. ORSTOM, N°83, 162p, 110 Figs.

Zabi, S.G. & Sankare, Y. (1986). Note préliminaire sur les espèces de la macrofaune benthique des mangroves de la lagune Ebrié (Côte d'Ivoire). UNESCO-MAB-CRDI 1-6 Décembre, Dakar (Sénégal): 115-123.

Human impact on mangrove forests: a case study of Zanzibar

J.P. SHUNULA
University of Dar-es-Salaam
Institute of Marine Science
P.O. Box 668 Zanzibar
TANZANIA

Abstract

Investigations have been conducted on the areas of three mangrove forests (Chwaka, Michamvi, and Maruhubi) in Zanzibar, using aerial photographs taken over a span of 40 years. The findings revealed darastic reduction in coverage for two of the areas investigated, Michamvi and Maruhubi, from 800 to 43 ha and 1040 to 76 ha respectively between 1949 and 1989. The third area, Chwaka, appeared to have expanded slightly over the same period of time from 2520 to 3065 ha.

The current volume of house construction wood harvested from one of the mangrove forests studies (Chwaka) was also studied and quantified (in terms of scores) for the period 1990 to 1992. An increase in the volume of wood harvested was depicted. The volume increased from 126,315 scores in 1990 to 431,075 and 514,889 scores in 1991 and 1992 respectively.

The implications of the observed area reductions and the rising demand for mangrove forest products on coastal erosion and near shore siltation are discussed, together with possible solutions proposaled for mangrove replanting schemes in order to meet future demand, alleviate coastal deforestation and erosion as well as promote biodiversity. It is suggested that areas of Zanzibar Island which show a potential for mangrove growth, such as most parts of the western coast, should be planted with suitable species. This would not only be an economic venture but will also contribute towards coastal protection and increased fish production through the creation of habitats.

Introduction

Studies on the effects of human activities on the mangrove forestry resources of Zanzibar, either do not exist, or at best are scanty. Shunula (1989) reports on the general status and harvesting of mangroves, while Shunula & Ngoile (1989) report on the effects of sewage and industrial wastes on these communities.

The mangroves of Zanzibar cover about 6% of the total land surface which is about 265,000 Ha. This proportionately small area is of major importance to the fishery of these Islands (Ngoile & Shunula, 1992). The importance of mangroves to local fisheries was also reported in Indonesia by Martosubroto & Naamin (1977).

Of late, it has been realized that human activities, such as the cutting of firewood, timber, charcoal and the conversion of mangrove land to agriculture or aquaculture, may lead to adverse changes in this coastal vegetation. In Madagascar, for example, mangrove ecosystems were untouched until the introduction of rice cultivation as a major food crop in the nineteenth century. Similar situations have occurred in Sierra Leone and Guinea. Mangrove forests in these countries have experienced various degrees of damage. In Asia the decline in mangrove forest cover has also been reported to be concomitant with the progressive expansion in rice cultivation. It is reported for instance that half of the deltaic Mangrove area on the River Ganges has been reclaimed for rice cultivation (Banergee, 1964). In other locations, e.g. Trinidad, Martinique Island, Fiji and Puerto Rico, considerable areas of mangrove land have been reclaimed for sugar cane production while in Cambodia, Vietnam and the Gulf of Papua, coconut plantations have replaced mangrove areas.

Fortunately in Zanzibar the conversion of mangrove land to agriculture has not occurred to any notable extent. However, it is feared that the increasing demand for high grade marine foods such as prawns may, in the near future lead to the utilization of mangrove land for aquaculture. The current major source of disturbance to the mangrove vegetation in Zanzibar is the harvesting of wood products such as timber, firewood and charcoal. In the face of increasing demands for these products major changes to the forest structure can easily occur.

In order to assess the impact of human activities on these forests in Zanzibar the current study was undertaken as a follow up to an earlier communication (Shunula, 1989) which reported widespread clearance cutting of mangroves especially in Unguja Island. It was considered that the study would provide an insight on the trend of mangrove forest land, together with the levels of exploitation, as well as further suggest possibilities for replanting schemes in appropriate locations.

Materials and methods

Aerial photographs of the costal forests of Zanzibar taken between 1949 and 1989 were obtained from the Mapping Division of the Department of Lands and Surveys, Zanzibar, and were studied. For each of the selected sites, Chwaka and Maruhubi, the area covered by mangrove vegetation in 1949 and 1989 as indicated on the aerial photographs was calculated using the relevant scale indicated on the photos. Prior to this the photos were traced using transparent tracing paper. Calculations of the areas were made using graph papers. The areas so estimated were then compared to find out whether or not reduction or expansion had occurred between the years 1949 and 1989.

The volume of mangrove wood passing through the Chwaka village wood selling centre was estimated using reports on the numbers of scores of poles landed, and the records of permits issued to mangrove wood cutters. These were obtained from the Department of Forestry. This information was compiled for the years 1990 – 1992 as records for earlier years were not available.

Studies were also conducted on the vegetation maps of the western shoreline of Unguja Island (Zanzibar) in order to record all the areas, including the smallest one, having some mangrove trees. This was coupled by site visits to the various places in order to verify the information recorded on the maps, and to assess possibilities for a mangrove plantation scheme.

Results and discussion

Hectarage: The areas in hectares of the study sites are depicted in Table 1. As seen from the table, the mangrove stand at Maruhubi has undergone a very serious reduction in size between 1949 and 1989. Nevertheless the Chwaka stand appears to have been simply oscillating, but is a little more extensive than it was in 1949.

Table 1. Areas in Hectares for Chwaka and Maruhubi between 1949 and 1989.

Year	Chwaka (Area in Hectares)	Maruhubi
1949	2520	1040
1952	3112.2	--
1977	2693.5	--
1989	2064.9	76.5

The mangrove stand at Maruhubi has suffered heavy damage and reduction in extent due in part to its proximity and easy accessibility from the Zanzibar Town population which has expanded from less than 50,000 in 1949 to about 400,000 in 1989. It is within easy reach of exploiters searching for fuel wood, poles, boat building material, materials for making fish traps, and barks for the extraction of tannin. Some of these activities are continuing to the present day. There is, for example, a boat yard within the mangrove area which obtains some of its repair wood from the forest. Tubs for leather tanning is also in existence within the area, although the mangrove species *Rhizophora mucronata*, whose bark is the most common source of tannin, is almost absent from this area (less than ten stunted trees). A number of seedlings are present suggesting thatthe species is capable of recolonizing the area. In recent years this stand may have been affected by chemical effluent from a currently closed shoe factory, as well as possible oil spills, both from Zanzibar harbour and the oil depot at Mtoni, and dumping of domestic refuse.

As is seen in Table 2, the volume of wood required for house construction purposes has increased tenfold within the last three years. This has coincided with a trade liberalization policy of the Government of Tanzania, which has brought about a considerable rise in housing requirements by investors, and the development of hotels, most of which rely heavily on local construction materials including mangrove wood. During this period there was also a rise in the pole trade from the Tanzanian mainland, from where, in 1991, ca 125,000 poles were imported into Zanzibar; this increased in 1992 to 185,000 poles (Zanzibar harbour records, 1992). Earlier records (Griffith, 1947) show that the total number of poles used in Zanzibar was about 2 million, whereas today the number from Chwaka alone exceeds 10 million.

The period between these years, (1990-1992) has also seen the successful introduction of seaweed farming, especially on the east coast of Zanzibar. This type of farming has in the main been utilizing mangrove wood stakes. Such stakes are reported to last longer in sea water compared to stakes of other tree species. This utilization has definitely taken its toll, but the amount used remains to be quantified. The activity is indeed likely to increase given that the world market for seaweed products such as carrageenan is still increasing.

Table 2. Number of poles (in thousands) of various mangrove wood categories harvested from Chwaka mangrove forest during the years 1990-1992.

Wood Category (category by use)	YEARS 1990	1991	1992
Roof support (Boriti)	4.4	11.1	8.6
Pillars (Nguzo)	18.8	133.7	91.9
Reepers (Mapau)	20.9	146.8	108.0
Straps (Fito)	2,526.3	8,329.7	10,069.1
Total No. of Poles	2,526.3	8,621.3	10,277.6

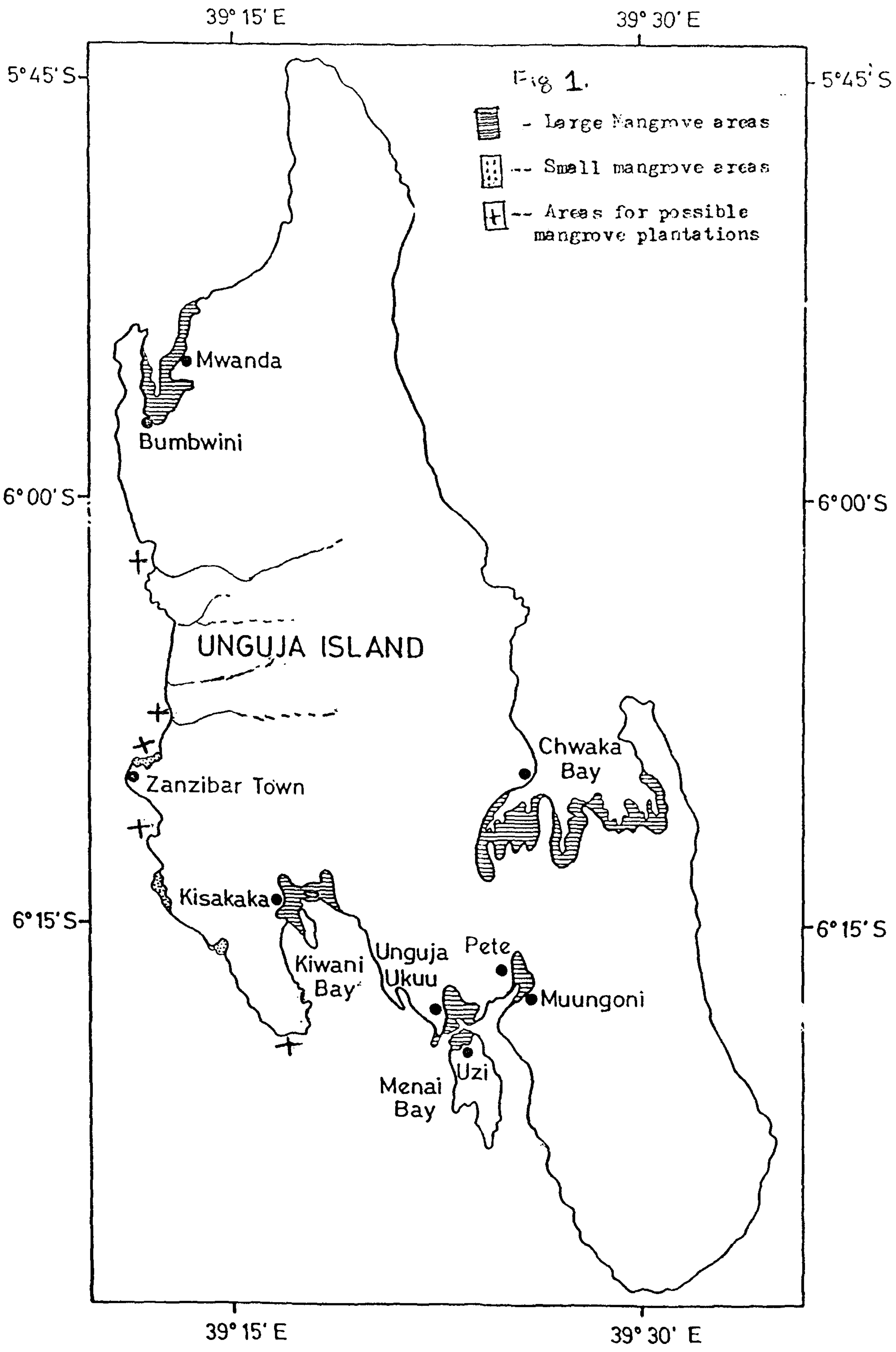
Apart from the use of mangrove wood in the house construction industry, mangroves also supply firewood for the towns and for lime burning, as well as tan bark for the local domestic shoe factories and timber for boat building. Although no quantitative figures are available on these activities, it is likely that they have increased considerably in response to the demands of an increasing human population.

The loss of disturbance of coastal vegetation, including mangroves, may lead to serious erosion problems, in addition to the loss of fish habitats. Already, there has been an outcry at Mwanda village, on Makoba Bay north of Zanzibar town regarding the loss of land to the sea. This village is fringed on the sea side by a highly disturbed mangrove forest. It is believed that this has partly contributed towards the erosion problem being presently experienced.

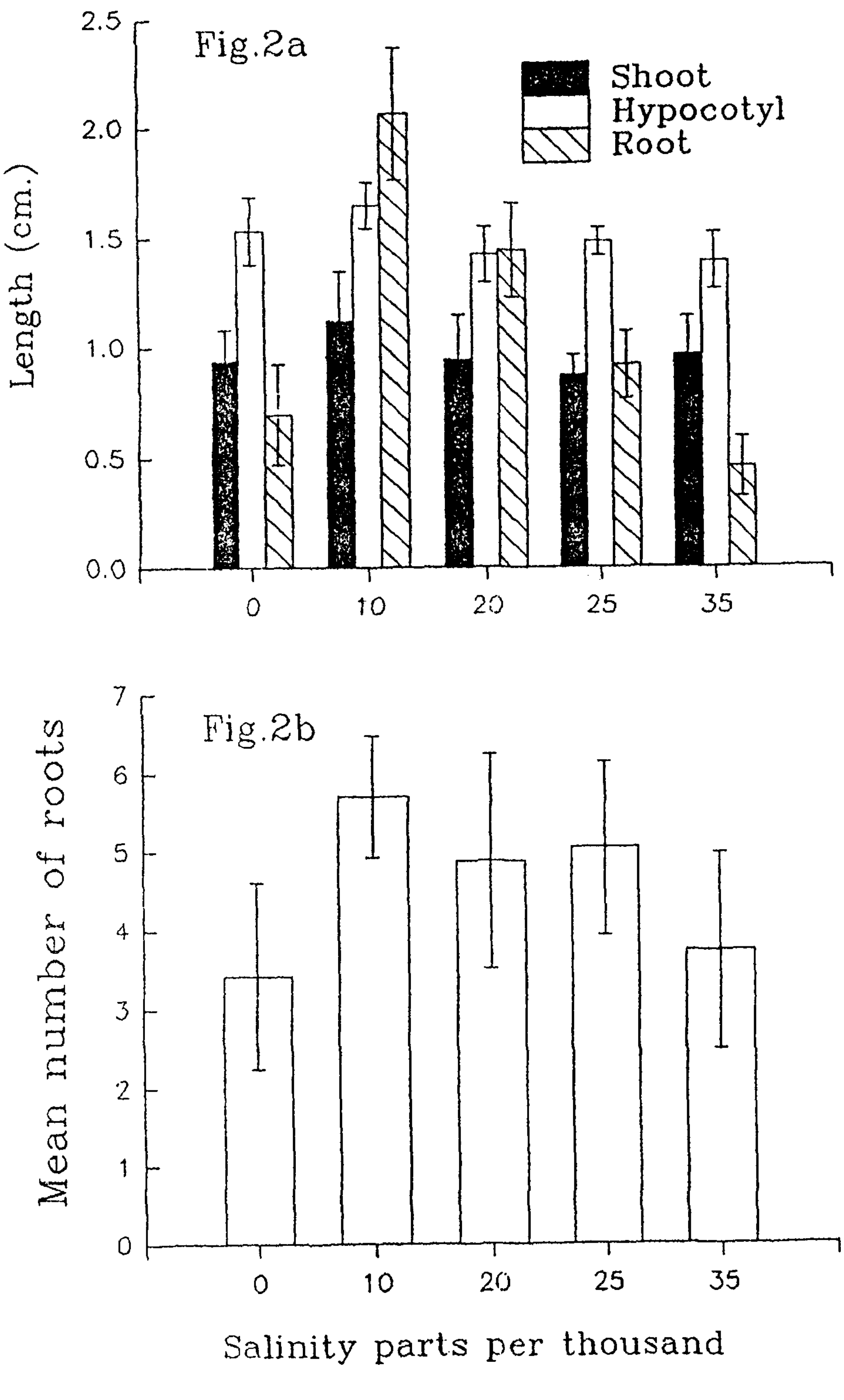
An increase in the amount of suspended particles in the water column in certain areas in Zanzibar has also been reported (Mwaipopo, pers. comm.) and although there is no direct evidence these results can perhaps be correlated with the decrease in mangrove forests and a general lack of silt trapping vegetation along the shores.

Recent reports of sporadic death and bleaching of coral reefs, in a number of places in the inshore waters of Zanzibar could be due to a variety of reasons, among them dynamite fishing, eutrophication, increased water temperature and siltation. Partial solutions to such problems could include replanting of mangroves in order to retain silt and to remove excess nutrients from the land water run off. Suitable areas for replanting are shown in **Figure 1**.

It will perhaps be necessary to establish nursery farms for mangrove seedlings, which can then be transplanted into areas of recolonization. In order for such nurseries to be successful it is important that we know the optimum conditions for seed germination and seedling growth. An example of such a study is presented here.



39° 15' E
39° 30' E
5°45' S
6°00' S
6°15' S
Fig 1.
- Large Mangrove areas
-- Small mangrove areas
-- Areas for possible mangrove plantations
Mwanda
Bumbwini
UNGUJA ISLAND
Zanzibar Town
Chwaka Bay
Kisakaka
Kiwani Bay
Unguja Ukuu
Pete
Muungoni
Uzi
Menai Bay



Germination experiments were conducted on *Avicennia marina*, one of the most abundant species in Zanzibar and one which shows the widest salinity tolerance (Shunula, unpublished). The aim was to establish the best optimum salinity conditions for germination and early growth of this species. Seeds of *A. marina* were germinated under the salinities 0 ppt, 10 ppt, 20 ppt, 25 ppt, and 35 ppt. Un-germinated, mature seeds of the same age and size were picked from the parent trees and used in the experiments.

Experiments were placed in containers with 400 ml seawater diluted appropriately to obtain the desired salinity as measured with a refractometer. After 14 days the seedlings were examined, the numbers of roots per seedling were counted and the length of the roots, shoots and hypocotyl measured. The data was analysed by ANOVA using the MINITAB statistical package. The data is presented in **Figure 2** as the appropriate means with error bars showing 95% confidence limits.

Figure 2a shows the results of this experiment. Root length is significantly greater at 10 ppt; salinities between 10 and 25 ppt appear to favour root growth, whereas hypocotyls and shoots appear to grow equally well at all salinities tested.

Figure 2b shows the mean number of roots per seedling vs salinity. Seeds produced significantly more roots at 10 ppt than at 0 ppt, but whilst a trend to fewer roots was observed with increase in salinity no significant differences were seen. Perhaps larger sample sizes would give clearer differences. While these results are preliminary it is perhaps significant that root number and root growth rate are most affected by salinity as it is this plant organ which is in most intimate contact with the saline soils and is the most important in anchorage as well as obtaining water and nutrients for the developing seedling.

References

Benergee, A.M. (1964). West Bengal Forests, In *Forest of Sunderbans Centenary Commemoration Volume*. Calcutta: DFO Planning Statistical Cell. As quoted in: Chapter 13. Agriculture. In Hamilton L.S. and S.C. Snedaker (Eds) 1984, *Handbook for mangrove area management*. Original document not seen by author.

Griffith, A.L. (1949). Reconnaissance Report on the Forest problems of the Zanzibarprotectorate. MSS. Report. Govt. Printer, Zanzibar.

Martosubroto, P. & Naamin, N. (1977). Relationship between tidal forests (mangroves) and commercial shrimp production in Indonesia. *Marine research in Indonesia* 18: 81- 86.

Ngoile, M.A.K. & Shunula, J.P. (1992). Status and exploitation of mangrove and associated resources in Zanzibar. In Jaccarini, V. & Martens, E. (Eds) The Ecology of Mangrove and Related Ecosystems. *Hydrobiolgia* 247: 229 – 234.

Shunula, J.P. (1989). A survey on the distribution and status of mangrove forests in Zanzibar Nov. – Dec. 1989. MSS. Report published by the Commission for Lands and Environment, Zanzibar.

Shunula, J.P. & Ngoile, M.A.K. (1989). Consequences of human activities on the marine environment of Zanzibar. In: Khan, M.R. & H.J. Gijzen (Eds) *Environmental Pollution and its management in Eastern Africa.* Proceedings of a symposium organized by the University of Dar-es-Salaam, Sept. 11 – 14 1989.

The potential human-induced impacts on the Kenya seagrasses

Joseph G. WAKIBYA
Kenya Marine and Fisheries Research Institute
P.O. Box 81651 Mombasa
KENYA

Abstract

The seagrass beds constitute one of the most conspicuous and common ecosystem types along the Kenya coast. The distribution of seagrasses in Kenya is presented. Because of their shallow sublittoral and to some extent intertidal existence, seagrass systems are subjected to stress, imposed by man's ever-growing use of the coastal zone. Observations on our coast have shown that seagrasses are under human threats. These are discussed and include: mechanical disturbance from human activity; e.g., dredging and filling operations; agricultural practises; logging; fishing and the release of sewage and/or chemicals. The introduction of the alien seagrass species Zostera capensis Setchell is postulated. The appropriate seagrass conservation and strategies are also recommended.

Introduction

Kenya's shallow coastal regions of estuaries, bays and reefs represent important areas in coastal zone productivity. Their importance lies in the fact that these shallow zones are colonised by vast expanses of marine angiosperms, commonly referred to as seagrasses. Seagrasses serve multiple functional roles in coastal ecosystems (Wood *et al*, 1989; UNEP, 1985; Mc Roy & Mc Millan, 1977). They superimpose a structural component on an otherwise bare sand or mud bottom. This structure serves as a habitat for many small invertebrates and fish. As a nursery, breeding and feeding ground, the habitat contributes to the fisheries productivity of the Kenya coastal waters; particularly for Lethrinids, Lutjanids, Siganids, Scarids and Spiny Lobsters (UNEP, 1985). In addition to the habitat function, seagrasses function as a refuge for the mobile species, by providing a source of protection from predators. The blades of seagrasses support a diverse and epiphytic growth which is a source of food for herbivores and this contributes to the overall high productivity of the system. The combined primary productivity of the plant and associated algal components rivals that of many of the world's cultivated crops (Mc Roy & Mc Millan, 1977). In addition to these intricate ecological functions, seagrasses have been used by man as food and source of income. The leaves of *Enhalus acoroides* are used for weaving mats and hats and the rhizome is eaten as mtimbi by the Lamu people.

Because of their shallow sublittoral and intertidal existence, the Kenya seagrasses are subjected to stress imposed by man's ever-growing use of the coastal zone. The continued multiplicity of demands upon the estuarine and coastal environment as producers of food, avenues of transportation, receptacles of waste, living space and sources of recreational or aesthetic pleasure, calls for the assessment of the human effects on the seagrass beds. There are various reports on the Kenya seagrass (Isaac, 1969; Isaac & Isaac, 1968; De Wit, 1988; Moorjani, 1978). These are based on their distribution and ecology or floral biology. There is virtually little information on human impacts on these important habitats along the Kenya coast. The emphasis of human impacts is long documented on the coral reef (Mc Clanahan & Muthiga, 1988; McClanahan and Shafir, 1990) and mangroves (UNEP, 1985). The main aim of this study was therefore to collect as much information as possible on the various potential human impacts on seagrasses in Kenya which is a neglected resource.

Materials and methods

Visits were made on various sites along the Kenya coast where any human disturbance on seagrasses was visible. The following stations were visited to represent the general human activities: Mambrui, Malindi, Vipingo, Mombasa and Diani (Fig. 1).

The various stations were visited from 1990-1992. At each station any human activities that were destructive to the seagrass growth and development were observed and photographs taken. The intertidal seagrasses and associated macro-algae were also surveyed where a potential impact was observed. Representative samples were collected by snorkeling and wading for qualititative and quantitative analysis. The samples were placed in numbered polythene bags and taken to a laboratory for analysis. The samples were sorted out into species composition using the Philip *et al*, (1988) and Jaasund (1976) nomenclature. Representative samples are deposited at KMFRI Herbarium. The seagrass beds were also carefully inspected to determine their health and state of development. Both the seagrasses and their damages were photographed at low tide. The fishermen were also interviewed on their fishing methods.

Results and discussions

Distribution of Seagrasses

A total of 12 species of seagrasses have been collected in the Kenya coastal waters, belonging to two families, Hydrocharitaceae and Potamogetonaceae (Table I).

Table 1. The Kenya Seagrasses

Family: Potamogetonaceae

Cymodocea rotundata Ehrenb & Hempr. ex Aschers
Cymodocea serrulata (R. Br.) Achers & Magnus.
Halodule uninervis (Forsk.) Aschers.
Halodule wrightii Aschers.
Syringodium isoetifoliuom (Aschers.) Dandy
Thalassodendron ciliatum (Forsk.) den Hartog
Zostera capensis Setchell.

Family: Hydrocharitaceae

Enhalus acoroides (L.f.) Royle
Thalassia hemprichii (Ehrenb.) Aschers
Halophila ovalis (R.Br.) Hook. f
Halophila minor (Zoll.) den Hartog
Halophila stipulacea (Forsk.) Aschers

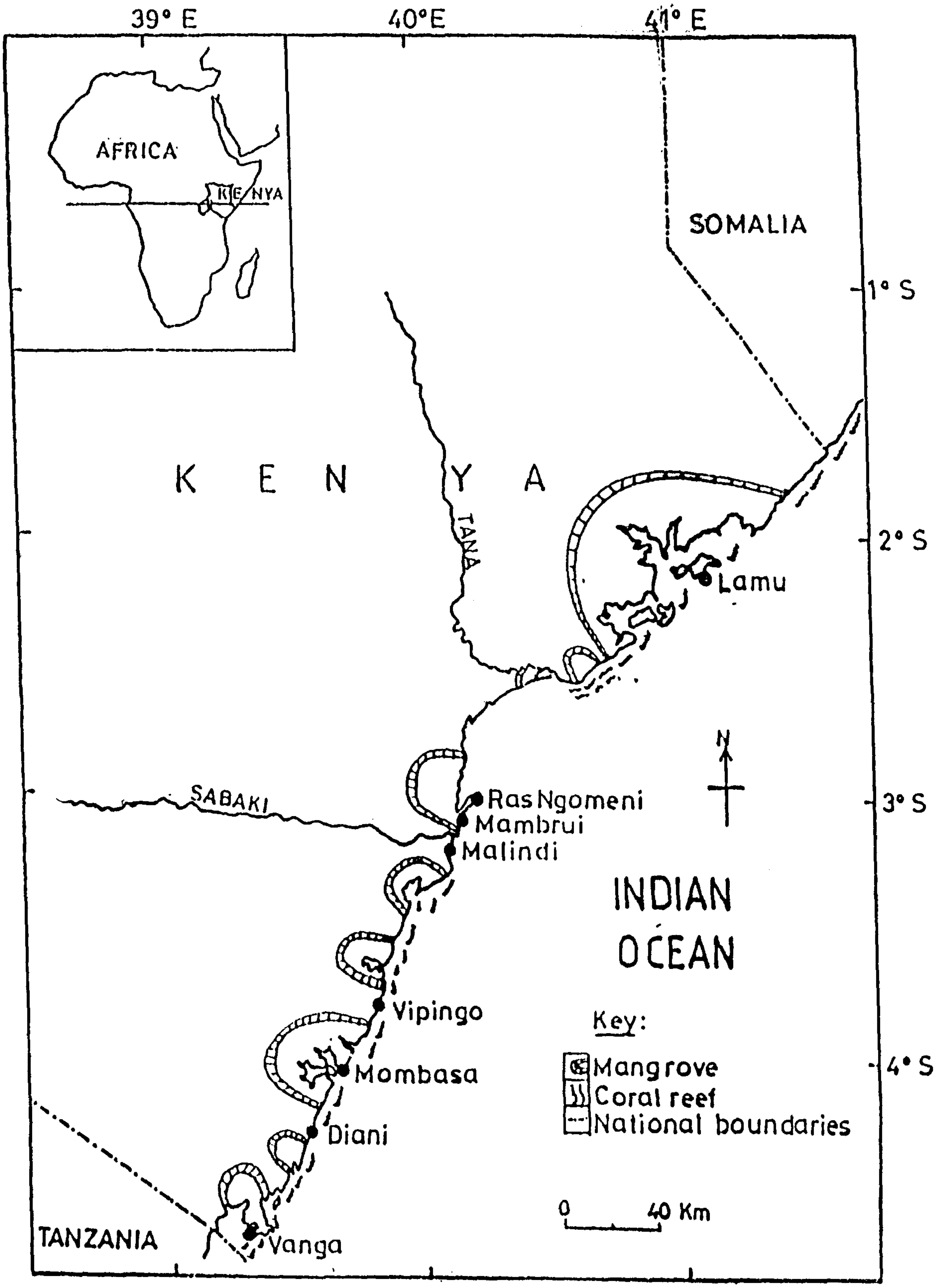


Fig. 1. Kenya coast showing places where collections were done, mangrove and coral reefs.

Table 2. Distribution of seagrasses along the Kenya coast.

Seagrass species	Stations							
	Lamu	Ras Ngomeni	Mambrui	Vipingo	Mombasa	Diani	Gazi	Vanga
Cymodocea rotundata Ehrenb & Hempr. ex Ashers	+	+	–	+	+	+	+	+
Cymodocea serrulata (R.Br.) Aschers & magnus	+	+	–	+	+	+	+	+
Halodule uninervis (Forsk.) Aschers.	+	+	–	+	+	+	+	+
Halodule wrightii Aschers.	+	+	–	+	+	+	+	+
Syringodium isoetifolium (Aschers.) Dandy	+	+	+	+	+	+	+	+
Thalassodendron ciliatum (Forsk.) den Hartog	+	+	+	+	+	+	+	+
Zostera capensis Setchell	+	–	–	–	+	–	+	+
Enhalus acoroides (L.f.) Royle	+	+	–	–	+	–	+	+
Thalassia hemprichii (Ehrenb.) Aschers.	+	+	+	+	+	+	+	+
Halophila ovalis (R.Br.) Hook. f	+	+	–	–	+	+	+	+
Halophila minor (Zoll.) den Hartog	+	+	–	–	+	+	+	+
Halophila stipulacea (Forsk.) Aschers	–	–	–	–	+	+	+	+

\+ Present – Absent

Nine of the seagrass species were widely distributed along the coast where substrates were suitable while *Enhalus acoroides, Zostera capensis* and *Halophila stipulacea* were observed to show a restricted distribution. During the study, Gazi, Mombasa and Vanga stations were found to have all the 12 species while at Mambrui only 2 species were observed to be growing (Table 2). Seagrasses were found growing on the reef platforms lagoons, creeks, bays and channels.

Human influences on seagrasses

While seagrass beds generally have experienced less direct damage than the mangroves and coral reefs, seagrasses have not been totally spared from human activities. In general, Mombasa was observed to have more human activities destructive to seagrasses followed by Malindi. However, Mambrui has only one source of human activity that is more detrimental towards seagrass growth and development. Motor boat propellers, anchors and aesthetic activities were observed in stations where there was a high density of hotels. These activities include:

Dredging and filling operations disturbances

Dredging and filling operations affect a larger part of the coastline than the other activities which are localised. These operations were observed to involve land fill for the construction of jetties, bridges and roads. It also involves the deepening of channels for ship traffic e.g. Kilindini harbour. These operations are also manifested in water front construction of hotels or residential facilities. They destroy seagrasses directly either by uprooting or burying them. In Mombasa, a fishing company is building a jetty by burying several seagrass species namely: *Halophia ovalis, H. stipulacea, Halodule uninerris, Cymodocea rotundata* and *Syringodium isoetifolium.*

The area covered by sediment is about 200 m^2. In addition to the direct burial, a secondary effect from turbidity affects the productivity of the seagrass beds and its associated communities.

Silt discharge disturbances

Large-scale rural activities in areas outside the coastal zone have affected seagrasses. These activities include deforestation, over grazing and poor farming techniques. This has resulted in a tremendous increase in silt carried by major rivers to the coastal zone and affecting seagrass beds. This is mostly illustrated by the silt load of the Sabaki river discharged at its mouth which has affected the occurrence and growth of seagrasses at Mambrui, 5 kilometers south of the river. The seaweed and seagrass composition and distribution at Mambrui is different from other stations visited. Only 2 seagrasses were collected at Mambrui in 1992. These were *Thalassia hemprichii* and *Thalassodendron ciliatum*. The situation was different in 1972 when Moorjani (1978) collected 4 species of seagrasses and the author collected 3 species in 1989. The 2 species collected recently are only scattered patches of 3m x 3m coverage at the most. This is unlike other reef platforms where both species cover several hundred meters of seagrass. The difference can be attributed to shore pollution from the River Sabaki whose outflow is carried north along the shore by the flow of the East African coastal Current (EAAC). The high silt load and the large volume of fresh water from the river does not create a suitable seagrass habitat. The substrate covering the reef platform has a higher silt and lower sand percentage. This results in an unstable environment for the seagrass growth and colonization. The silt load also creates turbidity of water and reduced penetration of light, thus impairing photosynthesis. It is presumably the dimmer light which discourages the growth of seagrasses. Dimmer light intensity is evident by the dominance of Rhodophyceae (red algae) in the infralittoral fringe instead of the Phaeophyceae (brown algae).

Chemicals like herbicides which are washed down from farming lands by the river might also be detrimental to seagrass growth. These chemicals might be include Atrazine which is used to kill Kikuyu and couch grasses in uplands.

Oil and sewage pollution disturbances

With Kenya's continued energy demands, the transport of petroleum threatens the coastal zone. Oil pollution is perhaps the biggest threat to seagrass beds in Kenya. This can be through the spillage of crude oil from the ship traffic at the Kilindini harbor or in the deep sea. Considering the vast amount of shipping traffic carrying oil from the Middle East to other parts of the World (Fig. 2), it is somewhat surprising that there have been no major oil spillages in Kenya. Over 200 tankers may pass through the Kenya coastal region on any one day, along which is the busiest route in the world.

Reports of oil spillage are shown in Table 3.

Table 3. Some records of oil spillage affecting seagrass bed.

Year	Location	Tonnage
1962	Puerto Rico	10,000
1973	Puerto Rico	37,000
1978	Amoco Cadiz	-
1988	Mombasa	5,000
1989	Alaska	40,000
1991	Kuwaitover	100,000
1992	La Coruna	20,000
1993	Shetland	85,000

Seagrasses are not the most susceptible portion of the community to oil pollution but the associated fauna which are often severely affected. Nevertheless, oil soothes leaves thus affecting photosynthesis by reducing rate of carbon uptake, Mc Roy and William (1977). This results in the plant drying and then dying. At Mombasa, in 1988 a fuel tank was accidently pierced by a crane and almost 5000 tonnes of heavy thick fuel destroyed a large area of mangrove and associated biotopes. Several seagrasses associated with mangroves were also destroyed and have not yet reappeared at the site. These were *Halophila stipulacea* and *Halodule wrightii*. Oil spillage is quite frightening because the potential for damage is higher in Kenya as most of its seagrass resources are located in creeks, bays and reef platforms which are barely subtidal.

Although seagrass communities are sensitive to additions of nutrients from sewage outfalls and industrial wastes, sewage is not a widespread problem in Kenya. However, with the increasing population in Mombasa and Malindi, the volume of domestic solid and liquid wastes along the sea is becoming locally significant. Sewage reduces water quality so that seagrasses cannot grow well. It also stimulates excess epiphytic production which may adversely affect the seagrasses by persistent light reduction. At Mombasa near the point where the Municipal sewage is discharged

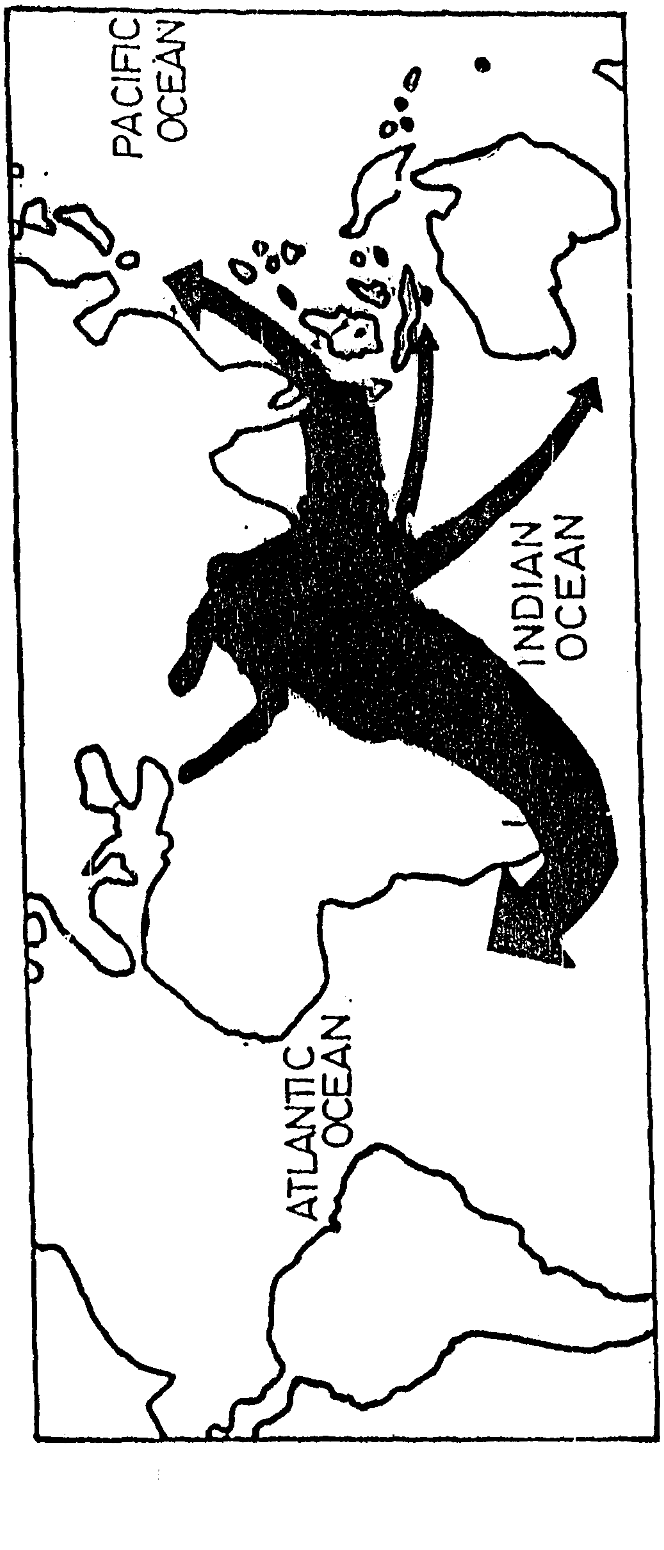


Fig. 2. Oil routes in the East African region.

into the sea, the excessive growth of *Enteromorpha* and *Ulva* was observed. *Enteromorpha* has a shading effects on the seagrass *Thalassia hemprichii*. Some significant growth of *Enteromorpha* was observed at points where hotels discharge their wastes directly into the sea.

Fishing activities and their disturbance

Various fishing activities destructive to seagrass beds include fishermen's foot and canoe pathways. These activities involve the continuous pathways fishermen use from the beach to the deep sea. These appear as a bare sand footpath ranging from 300 metres – 500 metres long and 0.5 – 1 metre wide. Therefore an area ranging from 300 meters square to 500 meters square is devoid of seagrasses. In some stations e.g., Tiwi, Shelly Beach and Vipingo as many as three to five pathways were observed. The pathways pass through the intertidal flats where *Thalassia hemprichii* and *Thalassodenron ciliatum* were growing luxuriantly. Because of the continuous usage of the pathway, recolonization of the seagrasses have not been possible. The construction of canoe pathways was also observed at various stations. Fishermen dig out intertidal flats separating two separate navigatable channels to allow their canoes to pass from one channel to another. This involves digging out areas ranging from 5 meters – 10 meters long and 1 – 2 meters wide. All the seagrass in the area is uprooted. This practice was common at Shelly Beach, Diani and Msambweni. Both activities involves the uprooting and removal of the whole seagrass plant.

It also causes bottom sediment to be stirred up, promoting oxidation of the sediment so that recolonization of seagrasses is slowed. Other seagrasses affected by these activities are *Halophila stipulacea* and *Halodule uninervis.*

Motor boat propeller and anchor disturbance

This is a common form of disturbance to seagrasses at Diani, Mombasa and Malindi. This human activity was observed to involve the cutting of leaves and shoots of seagrasses found in shallow waters where the density of motor boats was high. Boat traffic pathways were observed because of bare sand patches with no vegetation. The anchor uproots rhizomes leaving some holes in the seagrass bed. This was not a serious problem but with a high density of motor boat, can be destructive if unchecked.

Aesthetic disturbances

This activity involved water-oriented recreation with the exception of recreational fishing. Swimming beaches are made less attractive by the presence of a high tide drift of decaying seagrasses.

Several observations were noted where the hoteliers cleared seagrasses from large areas as it was deemed a nuisance to swimmers. This was so especially at newly-created beach hotels. In one hotel, at Bamburi, an area of 100 by 100 metres square was observed to having been cleared of seagrasses. If all the hotels along the beach destroyed seagrasses for swimmers, almost half of the intertidal seagrass beds would be destroyed. Clearing of seagrasses involves cutting all the shoots and the rhizome, especially those of shallow-rooted seagrasses like ***Halodule*** spp. and *Halophila* spp. Much of this activity was observed at Mombasa, Malindi and Diani where there are chains of tourist hotels.

Introduction of alien seagrass species

Indiscriminate human activity has allowed the introduction of alien or adventive seagrass species into other areas. *Zostera japonica* was introduced to the Pacific coast of North America as was *Sargrassum muticum,* when Japanese oysters were brought to Willapa Bay, Washington in 1925. *Halophila stipulacea,* a species of the Indo-Pacific, escaped into the Mediterranean with the opening of the Suez canal in 1869 (Lipkin, 1972). In Kenya, *Zostera capensis*, which is a temperate species, has a restricted distribution (Fig. 3). It has been collected in stations which used to be harbours or calling ports by early traders. It is observed to be growing without a companion in all stations visited and occurs as sparse patches of less than 4 meters square. *Zostera capensis*, grows luxuriantly in the cool waters of the South African region. Their species might have been introduced from South Africa by ships calling at the Kenya ports and harbours.

Consequences of seagrass destruction

The ecological consequences of seagrass destruction have been extensively documented during and since the sudden and drastic decline of *Zostera marina* on both sides of the Atlantic ocean during the 1930s (den Hartog, 1987; Kemp *et al*, 1983; Milne *et al*, 1954). Along most areas of the U.S. coast, 99-100% of the seagrass were destroyed in one year. The disturbance was a characteristic "wasting disease" (den Hartog, 1987), but its direct cause is still subject to question. Many changes accompanied this disturbance and could occur on the Kenya coast if human disturbances are not controlled. These changes include **(1)** study beaches were eroded and were replaced with rocky rubble because the protective effects of the seagrasses were removed **(2)** the fisheries changed. It took 30 – 40 years for full recovery of the vegetation and its associated fauna and flora.

Human activities along the Kenya coast have had various impacts on seagrass and its associated biota. Silt discharge and dredging and filling operations have resulted in loss of seagrass species. At Mambrui, only two seagrasses are growing because the environment is not suitable for the growth of other seagrass species.

Seagrass beds serve as a buffer between coral reefs and terrestrial runoff, by accumulating and retarding silt and nutrients. However, this buffering capacity of seagrass beds might be exceeded and result in a decrease of seagrass growth. This has already been observed at Mambrui. The subsequent result will be disastrous for the coral community which will then be directly exposed to this material. The result will be a decrease in the diversity of the coral reefs. This will affect the tourism industry by reducing foreign exchange and job opportunities.

The loss of seagrass from intertidal environments will also increase the velocity of water currents, thus coastal erosion will be accelerated. This will mean losing beach land where hotels and residential facilities are positioned. Man's destruction of seagrasses in Kenya will also reduce the fisheries resources. This is because seagrass beds provide nursery, feeding and breeding grounds for invertebrates and fish, especially those of commercial values e.g. prawns, lobsters and fish. Herbivores like marine turtles and sea cows might become extinct species since they use seagrasses as their main food.

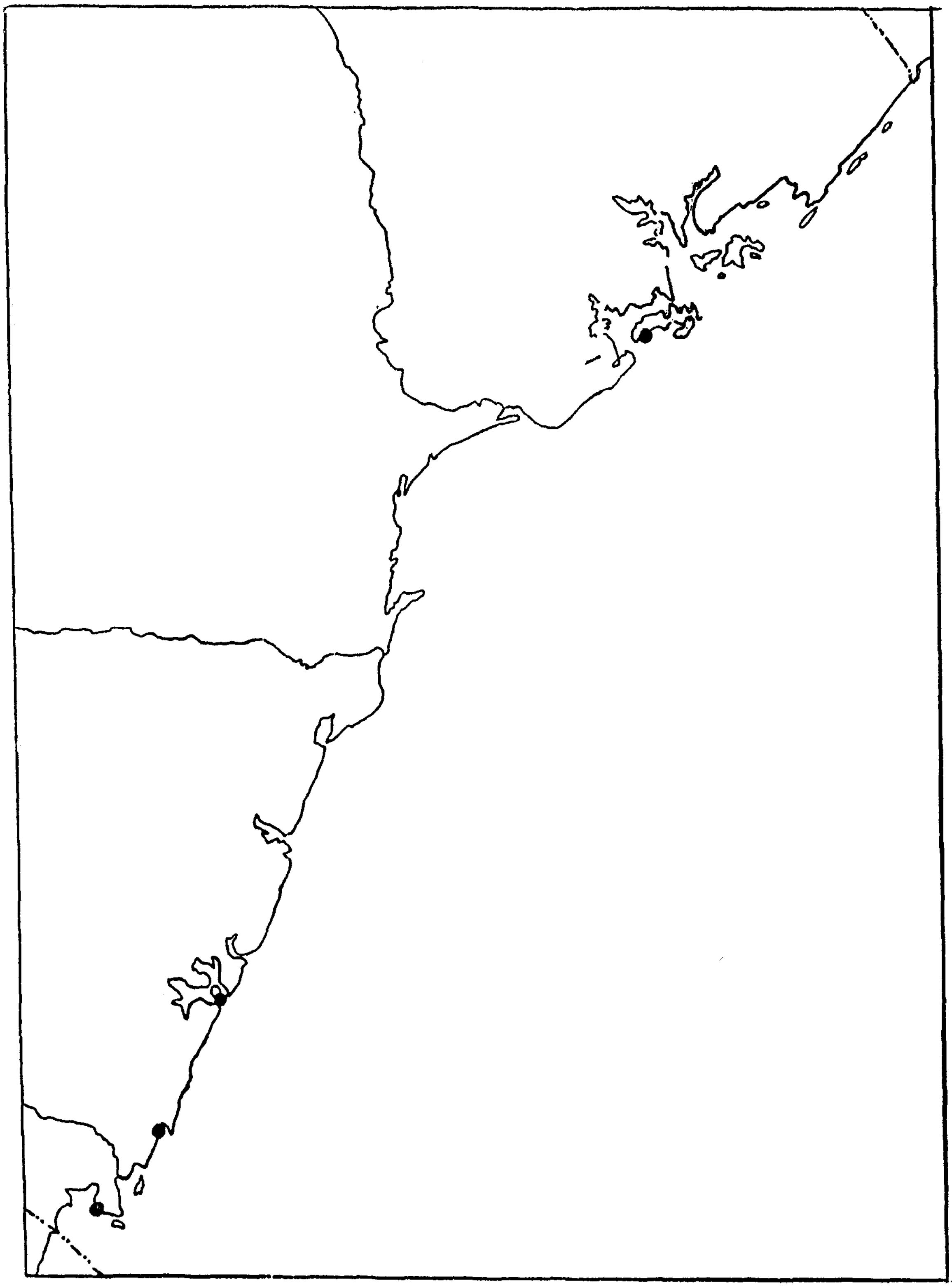


Fig. 3. Distribution of *Zostera capensis* along the Kenya coast.

Seagrass conservation strategies

Although nobody would advocate complete absence of human activity in or adjacent to seagrass beds, the following strategies are necessary for proper management.

(1) Mapping of seagrasses. Management of the seagrass resources must not only recognize their importance but also where the resource is located and its abundance. This resource can be mapped where signs of their destruction are eminent e.g. Mombasa, Malindi – Watamu and the rivers; Tana, Sabaki and Hamisi coastal zone. Identification and initiation of studies in representative natural seagrass beds should be encouraged so that this information may act as baseline data.

(2) Transplanting the seagrasses techniques should be developed which can be used to restore any lost seagrass.

(3) The problem of silt discharge by rivers must be solved in areas of deforestation and poor farming techniques by educating farmers on the dangers of soil erosion. Afforestation programmes should be encouraged along river basins and in hilly areas.

(4) Creation of exclusions zones around sensitive coastal habitats e.g. mangroves, coral reefs and seagrass beds, such as those adopted by the United States in the aftermath of the Exxon Valdez disaster; some extending to 100 miles from shore. Sewage should also be treated before being discharged into the sea. It can be dried and used as fertilizers by farmers.

(5) Rapid renewal of the world's ageing tanker fleet so that safety features will be maintained. Improvement of building standards to cut the risk of accidental oil spillages.

(6) Feasibility studies should be undertaken before any dredging filling operations are allowed to commence along the Kenya coastal zone. This is to determine the impact on the coastal ecosystems.

Acknowledgement

This research was supported by financial assistance from KBP and KMFRI. I wish to thank the Director KMFRI for his co-operation, Yvette for assistance in organizing the field surveys, Ambani, Ndirangu and Kilonzo for assistance during the field work and Miss Eunice Onyango for kindly typing this manuscript.

References

Den Hartog, C. (1987). *Aquat. Bot. 27:* 3-14

De Wit, M. (1988). Vegetatie – ecologische studie van de zee-grasgemeenchap in Gazi Bay (Kenya). Msc. Thesis Vol 1, 166pp.

Isaac, F.M. (1969). *J.E. Afr. Nat. Hist. Soc – Vol XXVII No. 1 (116)*: 29-47.

Isaac, W.E. & Isaac, F.M. (1968). *J.E. Afr. Nat. Hist. Soc. Vol. XXVII No.1 (116)*: 7-27.

IUCN/UNEP (1985). Management and conservation of renewable marine resources in the Eastern African region UNEP regional seas Reports and Studies No. 66 UNEP.

Kemp, W.M. Boynton, W.R., Twilley, R.R. (1983). *Mar Technol.* 17(2): 78-89.

McClanahan, T.R., & Muthiga, N.A. (1988). *Hydrobiologia* 166: 269-276.

McClanahan, T.R., & Shafir, S.H. (1990). *Decologia* 83: 862-870.

McRoy, C.P. & McMillan, C. (1977). In: McRoy, C.P. & Helfferich, C. (Eds) Seagrass Ecosystem: A scientific perspective. Marcel Deller Inc. New York, pp. 53-88.

Milne, I.J. & Milne, M.J. (1954). *Sci. Amer.* 184(1): 52-55.

Moorjani, S.A. (1978). The ecology of marine algae of the Kenya coast. Ph.D. Thesis, University of Nairobi, 285pp.

Philip, R.C. & Ernani, G.M. (1988): Seagrasses. *Smithsonian contribution of marine sciences* 34.

Annex I

Recommendations

The Seminar,

Recognizing the important role that marine coastal ecosystems (e.g. mangrove, estuaries and deltas, seagrass beds, coral reef, etc...) play in the marine productivity and stability of the coastal zone,

Noting the increasing adverse impacts of human activities in these ecosystems,

Noting further the transboundary nature of many of these human impacts,

Recommends that:

1. Each country should establish a base line data bank on natural resources of its coastal zone and their current status and location/mapping, where possible; hence the urgent need for national capacity building in marine sciences.
2. Environmental Impact Assessment (EIA) should always precede any coastal development project, and this should be closely followed by monitoring schemes on the project operations.
3. There is a need for public awareness programmes on all environmental issues affecting the coastal zone, and to involve local communities in development and management programmes thereof.
4. There should be cross-sectoral and inter-institutional co-ordination as well as regional and international co-operation in all activities relevant to the coastal zone.
5. There is a need for clear and appropriate national legislations on environmental issues affecting the coastal zone and their enforcement, as well as for building up the necessary capacity for doing so.
6. There is a need to reconsider all previous relevant recommendations and examine their implementation in order to reveal their success or failure.
7. Where possible, countries should take steps to rehabilitate those ecosystems that have already been degraded, and to prevent further degradation.
8. In order for countries to be able to implement the above-mentioned recommendations, international organizations, especially those of the United Nations system, are urged to provided the necessary support, particularly at the level of capacity building.

Annex II

Opening speech

By Dr. Paul B. Vitta, Director/ROSTA

Invited participants, fellow colleagues, ladies and gentlemen.

On behalf of the Director-General of UNESCO, Mr. Federico Mayor, and on my own behalf, I have much pleasure in welcoming you to the UNESCO regional Office for Science and Technology in Africa (ROSTA), and to this regional Seminar on Human Impacts on coastal Ecosystems which will be going on until Thursday of this week.

As you probably know, UNESCO attaches much importance to the development and promotion of marine science research and related training and their application to the conservation and management of marine and coastal ecosystems and their resources. As early as 1960, the General Conference of UNESCO, at its 11th Session, established the Intergovernmental Oceanographic Commission (IOC) for the purpose of promoting, mainly through international co-operation, marine scientific investigations and related ocean services, systematic observation, training, education and mutual assistance with a view to learning more about the nature and resources of the oceans. With time, it became increasingly clear that a major challenge facing many countries was the need to exploit their marine resources without damaging the environment, especially in the coastal regions where there exists a fragile equilibrium of the complex natural systems, and that the rational management of these regions would depend on a scientific understanding of these natural systems and the resources which they contain. In an attempt to address this need, the General Conference, at its 23rd Session (Paris, 1986), formally adopted the "UNESCO Major Interregional Project on Research and Training leading to the Integrated Management of coastal Systems", which is familiar to most of you as COMAR.

While implementing our own activities under COMAR and its operational arm, the UNESCO/UNDP regional Project (RAF/87/038) for Research and Training on coastal Marine Systems in Africa (COMARAF), we have noted with much encouragement that the number of scientists actively engaged in marine coastal ecosystems research in Africa has been steadily increasing, partly as a result of these activities, and partly as a result of complementary activities of relevant UNESCO programmes such as the IOC under its regional Committees for the Central Western Indian Ocean (IOCINCWIO), and for the Central Eastern Atlantic (IOCEA); of the Man and Biosphere (MAB) e.g. under its Project 7 – Ecology and rational use of island ecosystems; as well as of sister U.N. organizations such as UNEP under its Action Plans for the protection and development of the marine environment and coastal areas of the West and Central African region (WACAF), and of the East African region (EAF). Furthermore, of late relevant discussions at the highest level have been going on within the framework of the recently concluded United Nations Conference on the Environment and Development (UNCED, Brazil, 1 -12 June 1992) which addressed development issues in relation to the environment.

It was therefore felt that sufficient data have been collected under the programmes referred to above to warrant a seminar of this kind at this particular time, and it is hoped that coming within one year of UNCED's adjournment, this seminar will also provide an appropriate forum for you to acquaint yourselves with UNCED's conclusions and to enhance their follow up.

The following are, in brief, some of the issues relevant to the marine environment that were highlighted during UNCED (see Chapter 17 of Agenda 21):

(i) The population pressure on the costal area is increasing, especially in tropical and sub-tropical zones where the poorest countries are also found.

In the tropical coastal zones exist some of the most productive ecosystems: coral reefs, estuaries, mangroves, seagrass beds, lagoons, etc. These systems are of central importance for the marine productivity in those areas. At the same time the ecosystems are subject to accelerating degradation and depletion, putting the production and protein sources for the population at risk.

A rational use and development of coastal areas requires the ability to determine the present state of these ecosystems and to forecast future conditions and effects of human action.

(ii) Marine pollution and effects of land-based activities on coastal zone conditions are major problems in most regions of the world. These threaten the natural resources in the coastal zone. The contamination posing the largest threats are at present: sewage, overload of nutrients, synthetic organic compounds, overload of land-derived sediments, litter and plastics.

(iii) The effects of climate variability and change are potentially very important for the coastal area, through changes of sea level, meteorology,

seasonality, precipitation levels, events like storm surges, cyclones; shifts in marine living resources; coastal erosion and general degradation.

(iv) The role of the oceans in the climate system and the possibility of forecasting climate changes and variability from adequate ocean observations and modelling can, in combination with modelling of economies, help remedy impacts of changes and define economically valid counter measures and useful response strategies.

(v) Changes in the radiation budget, and especially ultraviolent radiation can influence the productivity of the marine ecosystems and their composition. This cannot as yet be quantified.

(vi) Maintenance of marine living resources in coastal and shelf seas and open ocean, i.e. management of fisheries.

(vii) Maintaining the biological diversity and ecosystem integrity in heaving exploited and stressed near-shore and coastal ecosystems, e.g. lagoons, wetlands, estuaries, mangroves, seagrass beds, coral reefs, and certain fish species in areas of over fishing, as well as certain marine mammals.

(viii) The ocean and marine environment uses are intersectoral and normally there is no single national authority dealing with marine affairs. Many different sectors of society have an interest in this part of the environment. This implies that ownership is difficult to establish, and the view is often that oceans and the marine and coastal environment are common heritage. This in turn implies open access, and an associated lack of responsibility on the part of many users.

In other words, the overall goal of protection and development of oceans and coastal areas is to ensure their sustainable use and management without jeopardizing their ecological integrity.

In order to achieve this the issues referred to above must be addressed. A guiding principle in achieving this should be capacity building so as to help ensure self-sufficiency in dealing with the issues and the associated problems.

Chapter 17 part E of Agenda 21 specifies as overall objectives (para 17.100) in abbreviated form:

(i) promotion of scientific research and systematic observations;

(ii) promotion of exchange of data and information;

(iii) co-operation with a view to the development of standard inter-calibrated procedures, measuring techniques, data storage and management capabilities for scientific research on, and systematic observation of the marine environment.

In conclusion, I sincerely hope that by the end of this seminar you will have identified measures aimed at mitigating adverse human impacts on coastal ecosystems in order to improve balanced co-existence of man and these ecosystems. On our part, ROSTA will continue to promote marine science and management of the coastal zones in the region, for instance by publication and dissemination of the results of this seminar, as well as to promote the implementation of relevant recommendations of UNCED.

I wish you a successful and fruitful seminar.

Annex III

List of participants

1. Dr. Jacques ABE
Chief, Laboratory of Physics and Marine Geology
Centre de Recherches Océanographiques
B.P. V18
ABIDJAN
COTE D'IVOIRE
Tel: (225) 35.50.14 / 43.09.24
Fax: (225) 35.11.55
Telex: 214235F Attn Mix CROA

2. Dr. (Mrs) Mariline BA
Département de Géologie
Faculté de Sciences
Université Cheikh Anta Diop
B.P. 15063,
DAKAR-FAN
SENEGAL
Tel: (221) 25.74.05
Fax: c/o Salif Diop UNESCO SG
(221) 23.83.93

3. Mr. P. GWADA
Research Officer
Kenya Marine and Fisheries Institute
P.O. Box 81651,
MOMBASA
KENYA
Tel: (254-11) 472456/70
Fax: (254-11) 472215

4. Dr. Jean FOLACK
Research Officer
Fisheries Research Station
P.M.B. 77,
LIMBE
CAMEROON
Telex: 5952 KN
Fax: (237) 33 24 16

5. Ms. N.S. JIDDAWI
Research Fellow
Institute of Marine Sciences
University of Dar-es-Salaam
P.O. Box 668
ZANZIBAR
TANZANIA
Tel: (255-54) 32128 / 30741
Fax: (255-54) 33050

6. Dr. Raymond JOHNSON
Lecturer/Research Fellow
IMBO/Geography Department Fourah Bay College
University of Sierra Leone
FREETOWN
SIERRA LEONE
Cable: c/o UNESCO MINEDUC FREETOWN
Telex: 3210 BOOTH SL
Fax: (232-22) 224439

7. Dr. Els E. MARTENS
Senior Lecturer
Department of Zoology
University of Nairobi
P.O. 30197
NAIROBI
KENYA
Telex: 2295 VARSITY KE
Tel: (254-2) 442316 (off.), 566447 (res.)
Fax: (254-2) 566447

8. Dr. Kifflemariam MELAKE
Assistant Professor
Department of Biology
Addis Ababa University
P.O. Box 1176,
ADDIS ABABA
ETHIOPIA
Tel: 11.08.44
Telex: 21205
FAX: (251-1) 551244
ERITREA

9. Thomas M. MUNYAO
Research Officer
Kenya Marine and Fisheries Institute
P.O. Box 81651,
MOMBASA
KENYA
Tel: (254-11) 472266/70
Fax: (254-11) 472215

10. Ms. N. MUTHIGA
Senior Research Officer
Kenya Marine and Fisheries Institute
P.O. Box 81651,
MOMBASA
KENYA
Tel: (254-11) 472266/70
Fax: (254-11) 472215

11. Dr. C. Mweu NGUTA
Research Officer
Kenya Marine and Fisheries Institute
P.O. Box 81651,
MOMBASA
KENYA
Tel: (254-11) 472266/70
Fax: (254-11) 472215

12. Dr. Eric O. ODADA
Senior Lecturer
Department of Geology
University of Nairobi
P.O. Box 30197
NAIROBI
KENYA
Tel: (254-2) 449233
Fax: (254-2) 443816

13. Mr. J.K. OKECHI
Research Officer
Kenya Marine and Fisheries Institute
P.O. Box 81651,
MOMBASA
KENYA
Tel: (254-11) 472266/70
Fax: (254-11) 472215

14. Mr. E.O. OMONDI
Research Officer
Kenya Marine and Fisheries Institute
P.O. Box 81651,
<u>MOMBASA</u>
KENYA
Tel: (254-11) 472266/70
Fax: (254-11) 472215

15. Mr. Martin OPUBA
Assistant Science Secretary
National Council for Science and Technology
P.O. Box 30623
<u>NAIROBI</u>
KENYA
Tel: 336173

16. Mr. Otula OWUOR
Science Writer
Nation Newspapers Ltd
P.O. Box 49010
<u>NAIROBI</u>
KENYA
Tel: 221222; 337710; 337691
Fax: 214047
Telex: 22239

17. Mrs. H.A. OYIEKE
Senior Research Officer
Kenya Marine and Fisheries Institute
P.O. Box 81651,
<u>MOMBASA</u>
KENYA
Tel: (254-11) 472266/70
Fax: (254-11) 472215

18. Dr. M. PORCHER
CETE Méditerranée
B.P.37000
<u>13791 AIX-EN-PROVENCE Cédex 3</u>
FRANCE

19. Ms. V. L. RUBY SAHA
Planner
Planning Division
Ministry of Housing, Lands and Town & Country Planning
Edith Cavell Street
PORT LOUIS
MAURITIUS
Tel: (230) 212.72.98 (Office)
454.16.74 (House)
Fax: (230) 212.42.40

20. Mr. J. P. SHUNULA
Senior Research Fellow
Institute of Marine Sciences
University of Dar-es-Salaam
P.O. Box 668
ZANZIBAR
TANZANIA
Tel: (255-54) 32128 / 30741
Fax: (255-54) 33050

21. Mr. J.G. WAKIBYA
Research Officer
Kenya Marine and Fisheries Institute
P.O. Box 81651,
MOMBASA
KENYA
Tel: (254-11) 472266/70
Fax: (254-11) 472215

UNESCO-ROSTA Secretariat

Dr. Paul B. VITTA
Director
UNESCO regional Office for Science
and Technology in Africa
P.O. Box 30592
NAIROBI
Kenya
Tel: (254-2) 230 800 or 520 600
Fax: (254-2) 215 991
Telex: 22275
Cable: UNESCO NAIROBI

Dr. H. DRIESSLE
Programme Specialist in Earth Sciences
UNESCO regional Office for Science
and Technology in Africa
P.O. Box 30592
NAIROBI
Kenya
Tel: (254-2) 230 800 or 520 600
Fax: (254-2) 215 991
Telex: 22275
Cable: UNESCO NAIROBI

Mr. G. KITAKA (Organiser)
Programme Specialist in Marine Science
UNESCO Regional Office for Science
and Technology in Africa
P.O. Box 30592
NAIROBI
Kenya
Tel: (254-2) 230 800 or 520 600
Fax: (254-2) 215 991
Telex: 22275
Cable: UNESCO NAIROBI