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CONSERVATION AND SUSTAINABLE UTILIZATION OF MANGROVE FORESTS IN LATIN AMERICA AND AFRICA REGIONS

ITTO/ISME Project PD114/90 (F)

Project Vice-Coordinator
E.S. Diop

Part II - Africa

International Tropical Timber Organization

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International Society for Mangrove Ecosystems

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Technical Report of the Project

Conservation and Sustainable Utilization of Mangrove Forests in Latin America and Africa Regions

Part II: Africa

E. S. DIOP, Project Vice-coordinator

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International Society for Mangrove Ecosystems
and
International Tropical Timber Organization

International Society for Mangrove Ecosystems (ISME)

ISME was inaugurated on 23 August 1990 and the seat of the Society is Okinawa, Japan. ISME takes over from the UNDP/UNESCO Regional Mangrove Ecosystems projects. ISME is affiliated to ICSU (International Council of Scientific Unions) and is part of IUBS (International Union of Biological Sciences) through IABO (International Association of Biological Oceanography). The Society was certified as a Foundation on 23 October 1992 in Japan.

Foreword

The International Tropical Timber Organization (ITTO) is a relative newcomer to the area of mangroves. However, ITTO recognized the critical importance of mangrove ecosystems from the ecological, economic and social perspectives. Mangrove ecosystems are unique as they serve as an interface between land and sea. They directly support the livelihood of millions of rural people throughout the world, as well as provide habitats for the breeding of various marine resources, which feed the World's growing population. Like other international organizations, the ITTO is greatly concerned at the alarming rate of mangrove deforestation and degradation, and the lack of understanding of the public about the benefits mangroves provide to mankind. It is obvious that mangrove ecosystems are threatened in many countries and immediate action must be taken to ensure their preservation.

The workshops and information sharing activities supported by this project have been an important step for disseminating experiences from research and on-the-ground activities for the sustainable use and management of mangrove ecosystems. Nearly two-thirds of the world's mangrove ecosystems were covered by the project. During the assessment on the status of mangroves in each region the project noted that mangrove ecosystems are faced with a wide range of problems which differ considerably between countries. Urgent action is most required to formulate sound policies for the conservation and sustainable use of mangrove resources, to carry out research in specific areas and to provide training at all levels to ensure that appropriate human resources are developed.

The concluding workshop held in Okinawa, Japan from 27-28 June 1993 determined that the project has been successful in attaining its goals and has been a key factor in Latin America and Africa for networking and sharing experiences on mangroves. The two regional workshops provided a forum for learning about the nature of problems in participant countries and searching for effective solutions. The project also showed that mangroves are important from a social and economic standpoint, and through rational management, these benefits can be enhanced.

The project has set the stage for future action by identifying priorities for training, research and field activities in Latin America and Africa and should result in the development of additional proposals to support activities in these areas. People involved with mangroves can look to ITTO and ISME for continued support and leadership to ensure the wise use and conservation of the world's mangrove ecosystems.

Yokohama, Japan
9 September 1993

B.C.Y. Freezailah
Executive Director
ITTO

Preface

The eighteen reports on the African coastal countries which are published in this report result from the synthesis prepared and presented during the ISME (International Society for Mangrove Ecosystems), ITTO (International Tropical Timber Organization) workshop. This workshop was organised jointly with the COMARAF project (UNDP/UNESCO's COASTAL MARINE PROGRAM in AFRICA) and was held from the 20 to the 22 January 1993, at the UNESCO Regional Bureau in DAKAR.

Fourteen participant countries present in DAKAR gave their reports in conformity with a previously defined format which had been the subject of discussion at a first ISME meeting held at Niteroi/Brazil in May 1992, just prior to the UNCED (United Nations Conference for Environment and Development). Later, countries such as Mauritania and Liberia decided to send their reports. Thus, this work ultimately covers more than 90% of the coastal forests of the African mangrove swamps on which many coastal populations depend for their living.

The second ISME/ITTO project meeting on "The Conservation and the Sustainable Utilization of Mangrove Forests in Latin America and Africa Regions" took place in Dakar, with the following objectives:

- To review the present state of the mangrove forests, taking into account the assessment of the available data on their distribution, their biological diversity, the biochemistry and hydrology of their environment and the anthropogenic actions;

- To evaluate the state of their utilization, their socio-economic importance, and the various impacts on their environment;

- To analyse the strategies and methods for their development, the needs for research, the policies, laws and regulations for a sustainable development of the African and Latin American mangroves.

Considered from that point of view, the Dakar meeting made possible that has preparation of this synthesis document, can be considered as an essential step. Thus during the January 1993 workshop, all the participants, coming mostly from Africa but also from Asia, Latin America and Europe laid particular emphasis on the urgency of research aiming at a better management for sustainable development of the mangrove forests. The Dakar workshop also recommended the organization of training courses in order to increase the competence of specialists in the domain of mangroves studies.

All participants stressed the need to elaborate adequate legislation relative to the management of the mangrove zones, taking into account the traditional experience and practices favourable to the protection and rational use and management of the resource

In this ISME technical report, the order of presentation of contributions follows the geographical order of the coastal African countries according to latitude: from North to South for the Western part of Africa and from South to North for the Eastern part. The island of Madagascar is the last one (Map; Fig. 1)

The report of the African mangroves is the first attempt at a synthesis of the present status in the domain of the research and management of the African littoral environment. It will doubtlessly be of a great utility to scientists, universities, decision-makers, governmental and non governmental organisations, in one word to all organisms interested in the future of the coastal zone in general, the African mangroves in particular.

This technical report has been achieved thanks to the important collaboration of the COMARAF project and the UNESCO COMAR program

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Fig. 1. Breakdown of mangroves in Africa and Madagascar

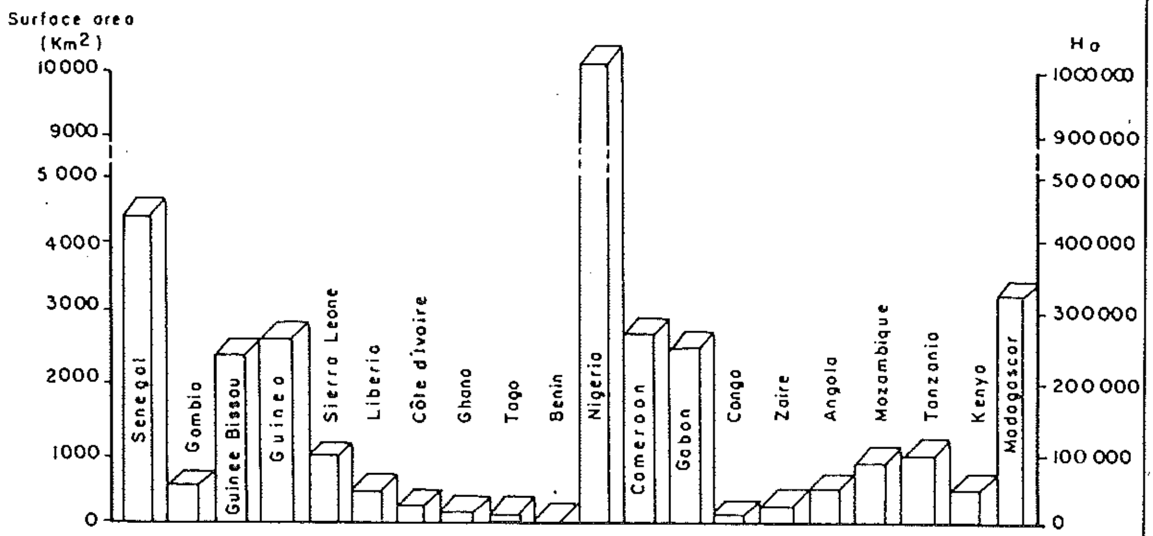
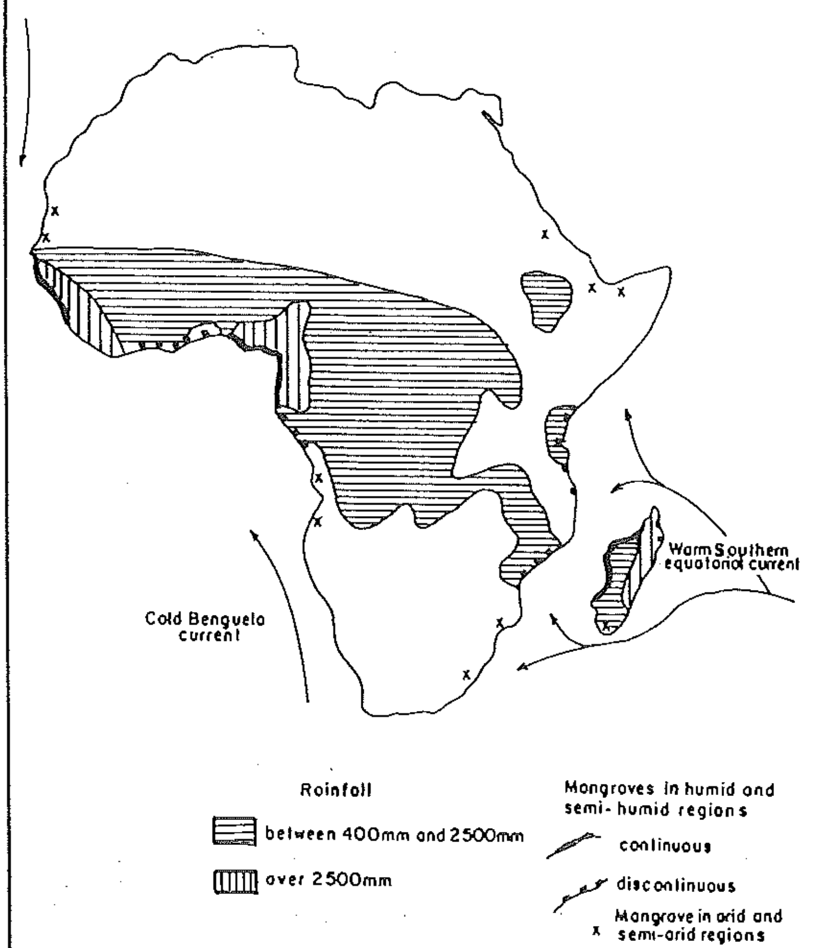


FIG. 2 - DISTRIBUTION OF MANGROVES IN AFRICA AND MADAGASCAR



Source: Extracted from the courier/ACP-EEC - n° 109 May - June 1988
updated by E. S. DIOP

Acknowledgments

The International Society for Mangrove Ecosystems (ISME) acknowledges with gratitude the interest and financial support of the Government of Japan, without which this project would not have been possible. ISME is also grateful to the International Tropical Timber Organization (ITTO) and its officers, for supporting the project. In particular the assistance of Mr. G. R. Burniske, Conservation Officer of ITTO, and the Steering Committee for this project, during the implementation phase, is gratefully acknowledged. The preliminary spade work achieved by the COMAR/COMARAF project of UNESCO under the guidance of Drs. M. Steyaert and A. Suzyumov paved the way for the successful undertaking of the present project.

Introduction

Although the last censuses carried out on the African shorelines have reported an intensification of the studies and researches in the domain of estuaries, deltas, coastal lagoons, and coral reefs, so far, nowhere else a synthesis of the African mangroves has been made available. Thus, this work is a first step to fill this gap. The African mangrove ecosystems is among the most interesting and complex coastal ecosystem, but is also the most threatened by natural as well as anthropogenic phenomena.

We have now a better knowledge of the role played by the mangrove forests as a transitional domain, where continental and sea waters merge: it is a high biological productivity ecosystem, usually with a high production of organic matter (as a result, there are rich fishing zones favorable for fish breeding). On the other hand, it is an environment subject to an important farming activities and to sometimes is intense exploitation (source of firewood and timber, intense extraction of salt and shells, silvi-agriculturel, aquaculture, tourism and port developments)

These diverse aspects of the use of the African mangroves have been often thoroughly discussed within the context of the research activities developed in the COMARAF project (research and training on the African coastal marine systems) which is part of the UNESCO COMAR program.

If we consider all the mangrove areas described in this report, we will realize that their extent and distribution, their present state and biocenosis as well as the ecology and the related problems have been carefully considered. Beyond the qualitative aspects mentioned in this report, it is time to undertake methodical quantitative studies and even to foresee the possibilities to carry out measurements and experiments "in situ" and "ex situ": for instance in laboratories. This should allow, in the near future, to obtain a better knowledge of the functioning of the mangrove ecosystems. This will also enable to envisage the possibilities of studies related to the productivity and genetic resources problems of these ecosystems, in order to find a solution to the problem of their progressive degradation by replanting and transplanting more adequate species with the view of preserving some coastal areas where the mangroves are disappearing.

In fact, it is impossible to enumerate concisely the series of steps to be taken in order to re-establish the balance for a sustainable utilization of the mangrove ecosystems. Indeed, they are among the most important tropical coastal ecosystems owing to their vital roles in coastal protection, to their richness in essential nutrients for some varieties of fishes, crustaceans and other precious species such as oysters and other molluscs. Moreover, a lot of products that can be obtained from the mangrove ecosystem (firewood, medicinal plants, products to make canoes, fish traps and for houses and huts.

Present state of the mangrove ecosystems in Africa

In fact the most important mangrove ecosystems is distribution and extent along the African coasts are situated in three large areas characterized by Quaternary formations and active and recent sedimentation.

The mangrove forests and their resources as well vary from one region to another and depend essentially on rainfall, fresh water and nutrient supply, temperature and quality of the substratum.

The latter factors are noticeably more favourable on the eastern coast of Africa; this partially explains why the diversity of mangrove species in the Indian ocean coasts is greater than on the Atlantic coasts of Africa. Over ten common mangrove genera can be found in East Africa among which: *Rhizophora, Avicennia, Ceriops, Sonneratia, Bruguiera, Xylocarpus* and *Heritiera* (ref. Tanzania, Kenya and Madagascar contributions). On the West African coasts, the mangroves are limited to four or five genera which are *Rhizophora, Avicennia* and *Laguncularia* and *Conocarpus* (refer to the Senegal, Guinea, Guinea-Bissau, Côte d'Ivoire, Togo and Benin contributions). But again thorough and systematic studies of the composition and the variability of species and the live resources within the mangrove areas are essential.

As regards the most significant quantitative measurements that have been obtained in the African mangrove (biomass, primary productivity, estimated stand volume among others), we can state that the Niger delta, in zones relatively well provided for, can produce the double if not the triple of estimated yields of the Senegalese mangroves: 100 to 250 m^3 per hectare in the Niger delta against 60 to 70 m^3 per hectare in a *Rhizophora* population of a relatively well established mangrove in Toubacouta, Senegal.

In the latter case, the limiting factors are mainly due to recent climatic changes including drought phenomena. In fact, we are already on the Northern limit of the West African mangroves, if we make an exception of the relict stands still found in the surroundings of the Tidra Island in Mauritania (refer to the Mauritania and Senegal contributions).

The limiting situation of pressure gradients on the Senegalese coasts explains the presence of vast bare surfaces of saline efflorescences named "tannes" which are very often associated in this part of Africa with the mangrove ecosystems. Here, the substratum is generally sandy and poor in clay, the nutrient supply is weak and the salinity rate is high (from 35‰ to 90‰ and sometimes more than 120‰. on some upstream rivers). Of course, in these cases, the size of the mangrove trees is greatly reduced (less than 20 cm of diameter and less than 5 m high have been measured on the best stands of the Saloum mangroves).

In the Niger delta, the height of some species living under favourable conditions can go beyond 20 m (*Rhizophora racemosa* and *Avicennia africana*). The estimated stand volume, can reach an average of 127 m^3 per hectare on the Tanzanian coast in particular in the Rufiji delta. It is as much as 200 m^3 per hectare under favourable conditions. On that coast, we have the most important biological diversity of the continent (refer to the Tanzanian contribution).

Thus, in this ISME technical report, a few specific case studies of the African mangrove ecosystems have been presented and several uses are mentioned in the various contributions.

The diverse natural and human impacts on the African mangrove have been dealt with by different authors. However, different types of strategies remain to be defined and to be adopted for a better development and for sustainable utilization of the African mangrove forests. It is in this context that proposals have been made during the Dakar workshop, which appear as recommendations and were published "in extenso" in the Proceedings of the ISME/ITTO workshop which took place in January 1993 at Dakar, Senegal.

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Contents

Mangroves of Mauritania

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I.G.E.S.T.; Nouakchott, Mauritanie.

1. Background

Mangrove swamps have been, contrarily to what may seem at first sight, present in Mauritania for ages.

The radiometric dating of a "Lumachelle" of Tin Ouiech - 15 km East of Nouakchott - gives a reading of 35,000 B.P., and has *Anadara senilis* and *Crassostrea gasar*. The latter is an oyster that still occurs nowadays in some mangrove swamps, fixed on the roots of mangroves (*Rhizophora* sp.). As they grow most of the shells take the shape of the supporting roots and as a result a "rhizophoric" inprint is left (Fig.1)

There are many places in Mauritania where, mangrove swamps existed in the past.

During the last 40,000 years, two major transgressions took place: Inchirian: 35,000 BP and Nouakchottian: 6,500 BP.

Thus, 6800 years ago (Noukchottian), the sea gradually invaded the lands, forming a large gulf to the North of the present capital Nouakchott and a narrow bay on the border of river Senegal, squeezed between the big massive dunes, built during the preceding dry period, the Ogolian. Rivers bring fresh water between the dunes during the wet seasons.

The fauna and the flora that live in these still warm and shallow waters are adapted to great changes of salinity, such as *Dosinia, Anadara* and *Cerastoderma*.

To the West, the lagoon is bordered by a forest of mangroves; to the East the hollows between the dunes are occupied by lakes with variable water levels.

Toward 4200 BP, three events dominated the paleogeographical evolution and engendered the present coastline and the mangroves swamps.

1) The sea retracted progressively (regression)
2) A strong wind driven coastal current,"the littoral drift", builds a continuing beach ridge and isolates the old lagoons. To the West of this beach ridge, the area is agitated whereas to the East, it is confined.
3) The climate becomes more and more dry, the old lagoons change into sebkhas where different salts (mainly gypsum.) cristallize.

This Tafolian episode indicates the end of the Nouakchottian level and the gradual disappearence of most of the mangrove swamps.

2. Extension and Distribution

Mangrove swamps are not often seen nowadays, (Fig. 4,5, 7) but there are:

1) in the delta of river Senegal: pure or mixed stands of *Avicennia africana* and *Rhizophora sp.* (Fig. 4);
2) at cape Timirist: pure stands of small size *Avicennia africana* (Fig. 5, 6, 11);
3) in the Tidra, Nair, and Niroumi; pure stands of *Avicennia africana* (Naurois and Roux 1965):
   - small size trees in the sparse area between Nair and Niroumi (Figs. 5,6,7,9 - transect II Fig. 12);
   - normal size trees in the set to the South of Niroumi island and next to Tidra (Fig. 5,6,7 and 10 - transect III - Fig. 13).
4) in the West part of Iwik headland (Fig. 5,6,7) where some rare dwarf plants may be seen.

3. Physical Environment

- at the delta of Senegal river, a classical estuary in sahelian climate, and
- at NPBA, an atypical environment for a mangrove swamp.

The general climate is of the saharian type and aridity is well marked by weak rainfall and limited or absent supply of fresh waters.

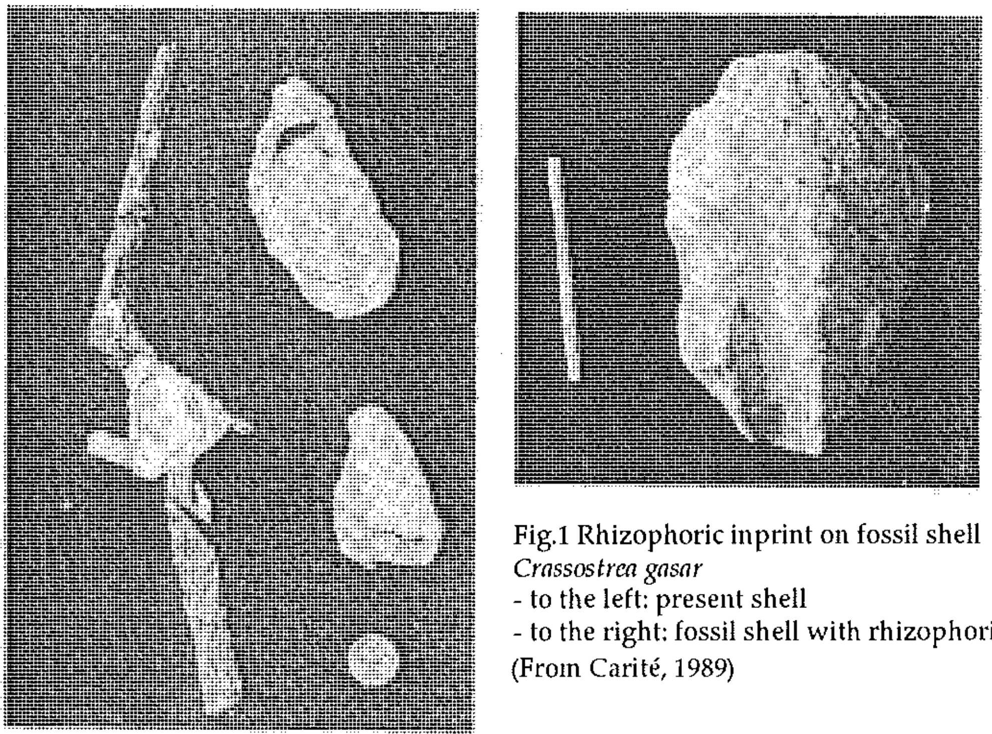
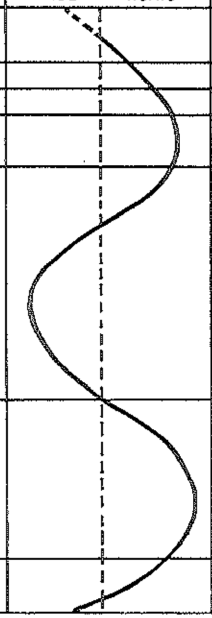


Fig.1 Rhizophoric inprint on fossil shell
Crassostrea gasar
- to the left: present shell
- to the right: fossil shell with rhizophoric print.
(From Carité, 1989)

Table 1. A: Inchirian sedimentary cycle. B: Nouakchottian sedimentary cycle. The last forty millennia of the Quaternary in West Mauritania (From P. Elouard, H. Faure and L. Hebrard)

AGE(YEAR B. P.) | PERIOD | CLIMATE ARIDE HUMID | CLIMATIC AND GEOLOGICAL INTERPRETATIONS

AGE(YEAR B. P.)	PERIOD	CLIMATE (ARIDE – HUMID)	CLIMATIC AND GEOLOGICAL INTERPRETATIONS
0 (B)	Actuel		increasing aridification; some humid pulsations
	Tafolien		Regression and aridification evaporites (gypsium)
	Nouakchottien		Transgression Marine lagunal deposits sand and shells
10 000	Tchadien		Humid climate. lacustrine deposits
20000 (A)	Ogolien		Important regression Sea-level decreases until -50 to --100m (Arid climate) Formation of a vast erg which dunes are oriented SW/NE
30000 – 40 000	Inchirien		Important trangression: a vast gulf penetrating 100km for inlands lagoonal and marine deposits (shells sandy and clays) Humid climate



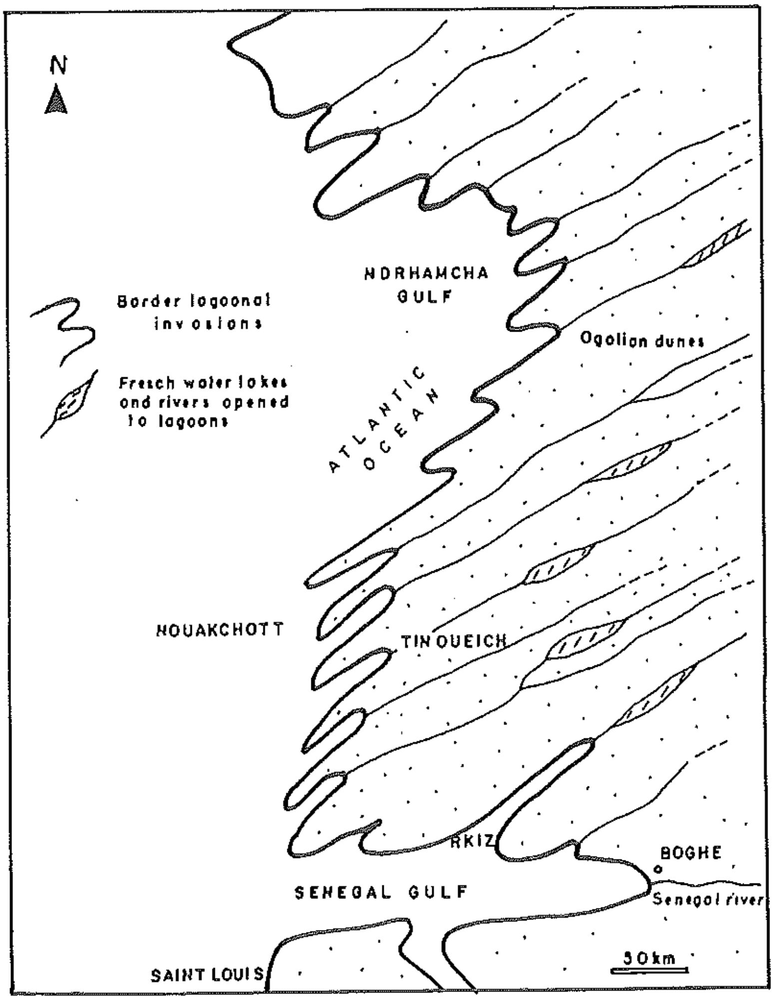


Fig. 2. Transgression and paleogeography during the Nouakchottian (from the works of P. Elouard) (by Carité 1989)

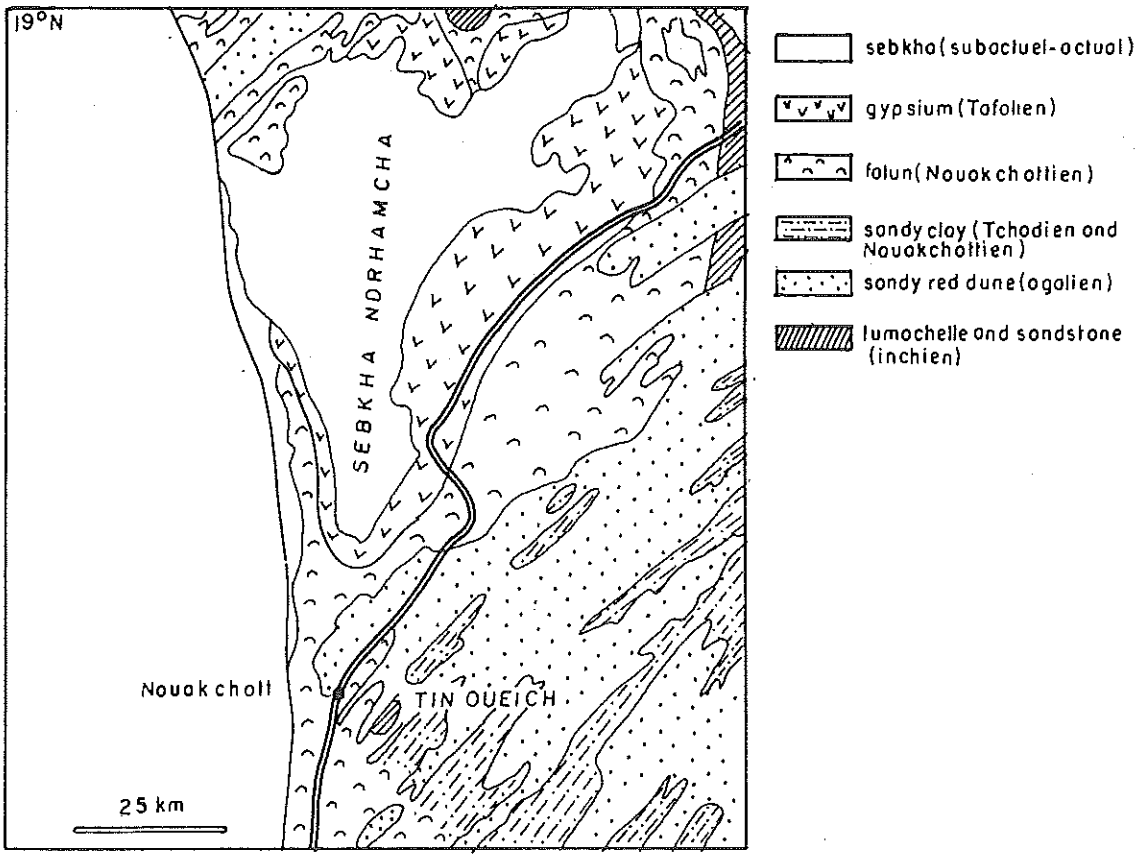


Fig. 3 Geological map of the recent Quaternary of the surroundings of Nouakchott (From P. Elouard, revised) (by Carité 1989).

Avicennia africana of N.P.B.A grows poorly without any supply of fresh water. *Rhizophora mangle* and *Rhizophora sp.* are unable to survive. They suffered seriously or disappeared at many place of the delta of the Senegal river as a result of poor rainfall, the low water supply during the past decade and impact of destruction of the *Rhizophora sp.* At the same time and in the same areas, *Avicennia africana* managed to survive and even to prosper without serious problems.

4. Biological Characteristics

- *A. africana* of Cape Timirist and the Tidra island are a habitat for many species both animal and vegetal, characteristic of the mangrove swamp, such as:
  Periophthalmus papilio (mud-skipper)
  Sarmatium curvatum (crab)
  Goniopsis cruentata (crab)
  Diatoms

- In the surroundings, many species - more particularly the fish are tropical, adapted to their present environment of high salinity waters of river mouths or of lagoons:
  Elops lacerta
  Ethmalosa fimbriata
  Mugil cephalus.

By the way, this "isolated lagoon off shore", according to the expression of de Naurois 1969, is a live relic of a large delta.

The gradual deterioration of the climate has, pushed back to the North and the South, many species that seek refuge on the coast. Several species of birds testify to this situation, some of them nest locally and have become endemic.

- The pale heron of the Banc (*Ardea cinerea monicae*), is an endemic sub species perfectly adapted to this very particular environment; it nests on the ground and more often on the slabs at the summits of Kiaone and Arel islands; the nest is made of *Zostera* sp., bones and other pieces picked up on the foreshore.
- The white spatula of the Banc (*Platalea leucorodia balsaci*) endemic like the pale heron, nests on the clumps of *Suaeda* sp., and very often, on the ground, among the fallen rocks more or less lined with *Zostera sp.* of the islands of Kiaone.

There are endemic invertebrates among Diptera, Collembola and others.

5. Surrounding Areas

In the surroundings of the mangroves:

- of the delta of rever Sénégal
  * to the West, the littoral spit and the Ocean
  * to the East, the classical sahelian environment: steppe more or less covered with trees very much transformed by man.

- of the P.N.B.A
  * to the West, the high bottoms (mudflats) with *Zostera noltii* and *Cymodocea nodosa* where there are some beautiful sea grass beds with *Spartina maritima* (southwards);
  * to the East, the dunes, less important which alternate with Paralic sebkhas.

6. Human Impact

In the delta of Senegal river man: has largely contributed to the disappearence of *Rhizophora sp.* during the last two decades (de Naurois, 1969).

7. Research and Training

Fieldwork, started in 1983 by the E.N.S is still carried out under the aegis of P.N.B.A and I.G.E.S.T. (Inspection Générale pour l'Enseignement Secondaire et Technique).

A dynamic detailed follow up is particularly desirable as well as attempts at artificial replanting of the mangrove swamp.

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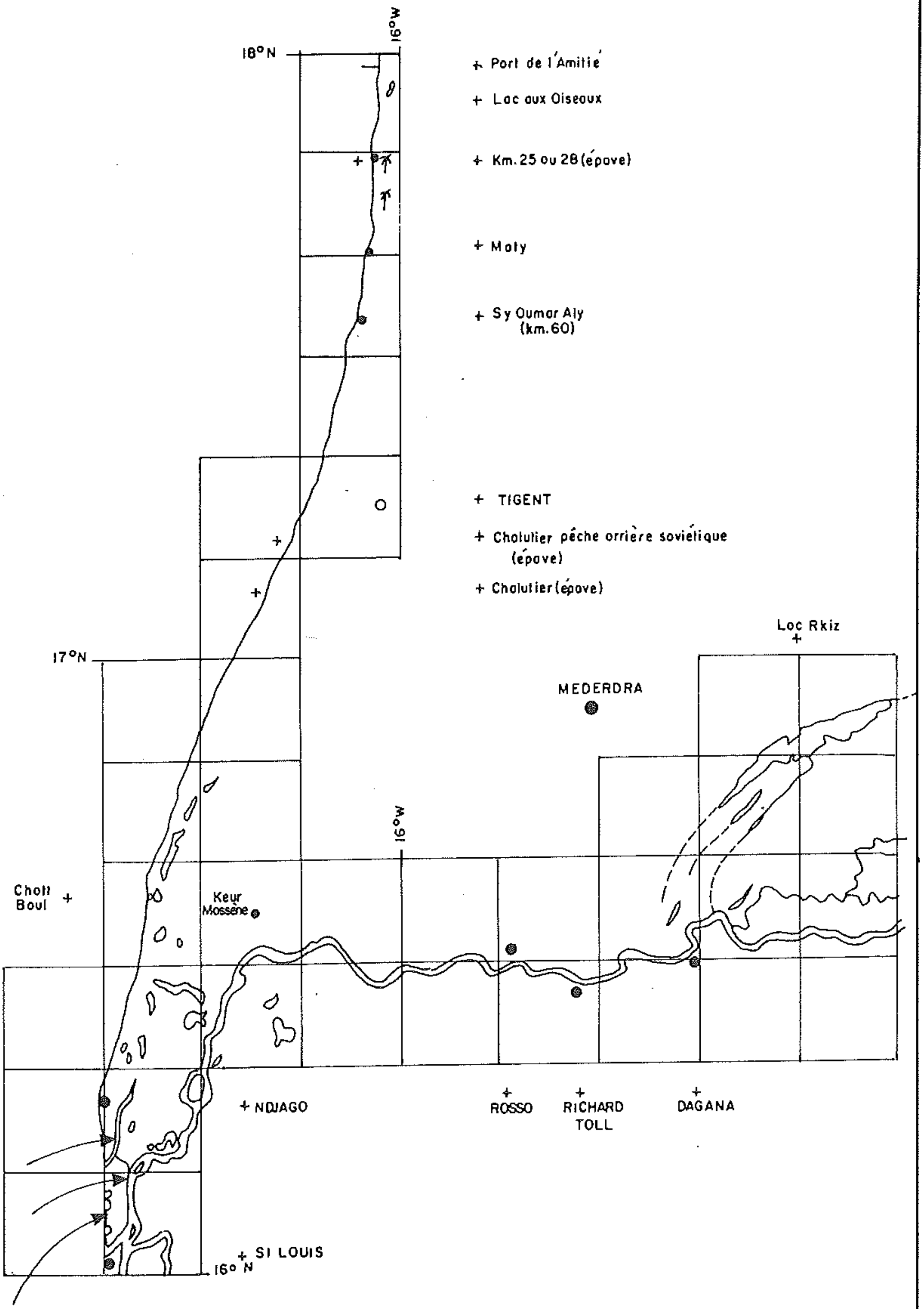

FIG. 4 - LITTORAL FROM SAINT-LOUIS TO NOUAKCHOTT

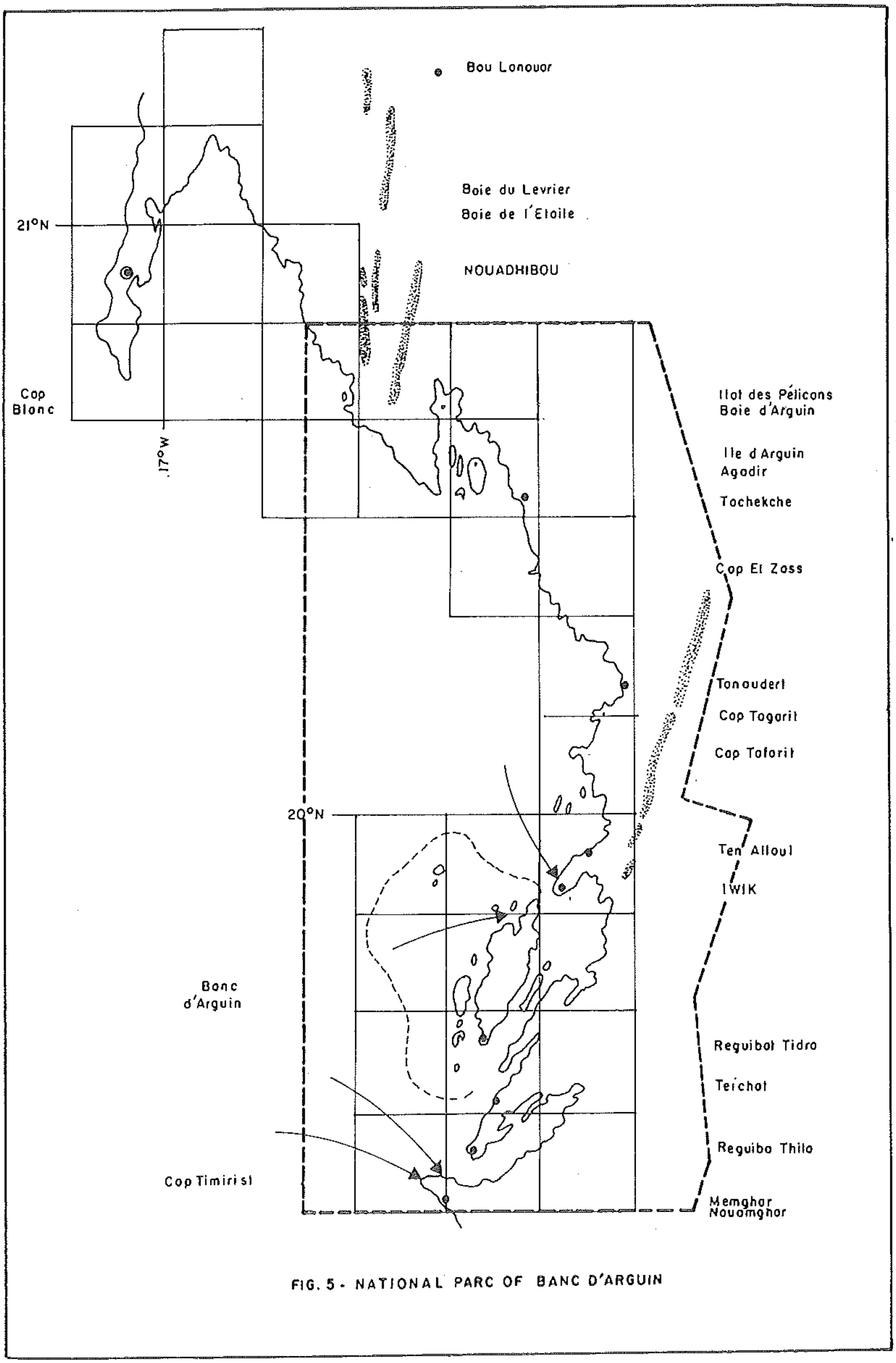

FIG. 5 - NATIONAL PARC OF BANC D'ARGUIN

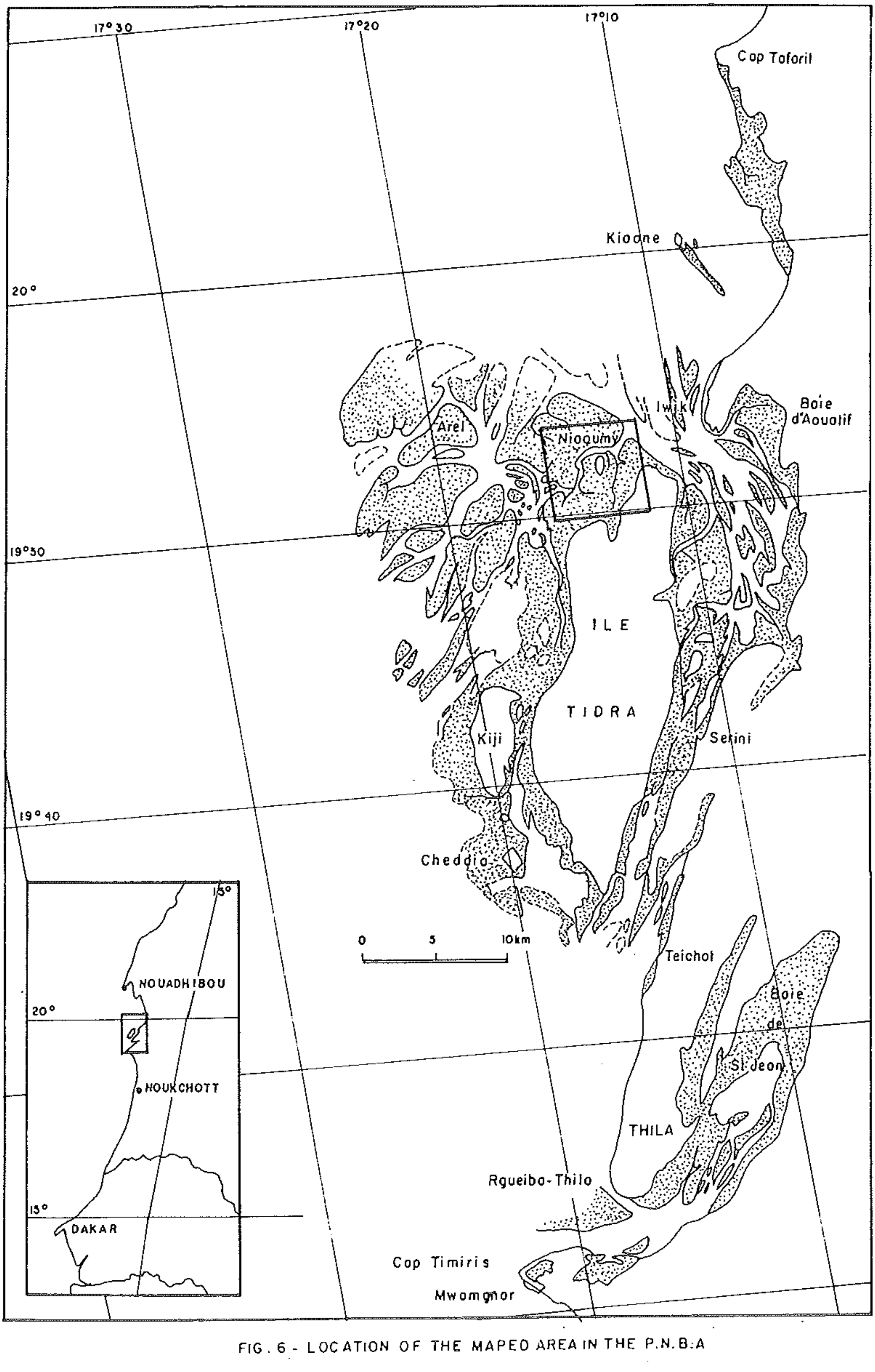

FIG. 6 - LOCATION OF THE MAPED AREA IN THE P.N.B.A

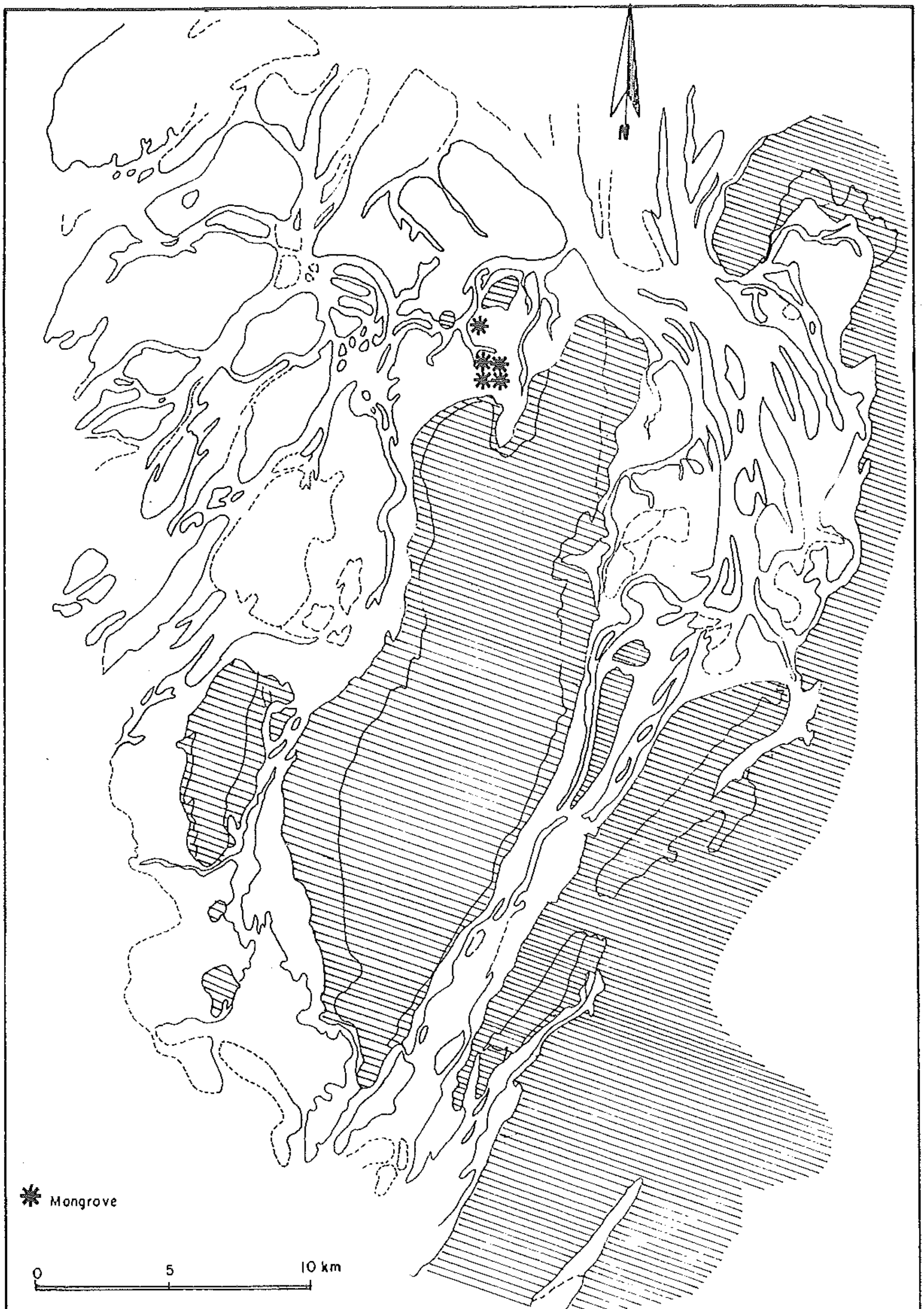

FIG. 7 - LITTORAL OF P.N.B.A
(CENTRAL PART TIDRA ISLAND AND CAP IWIK)

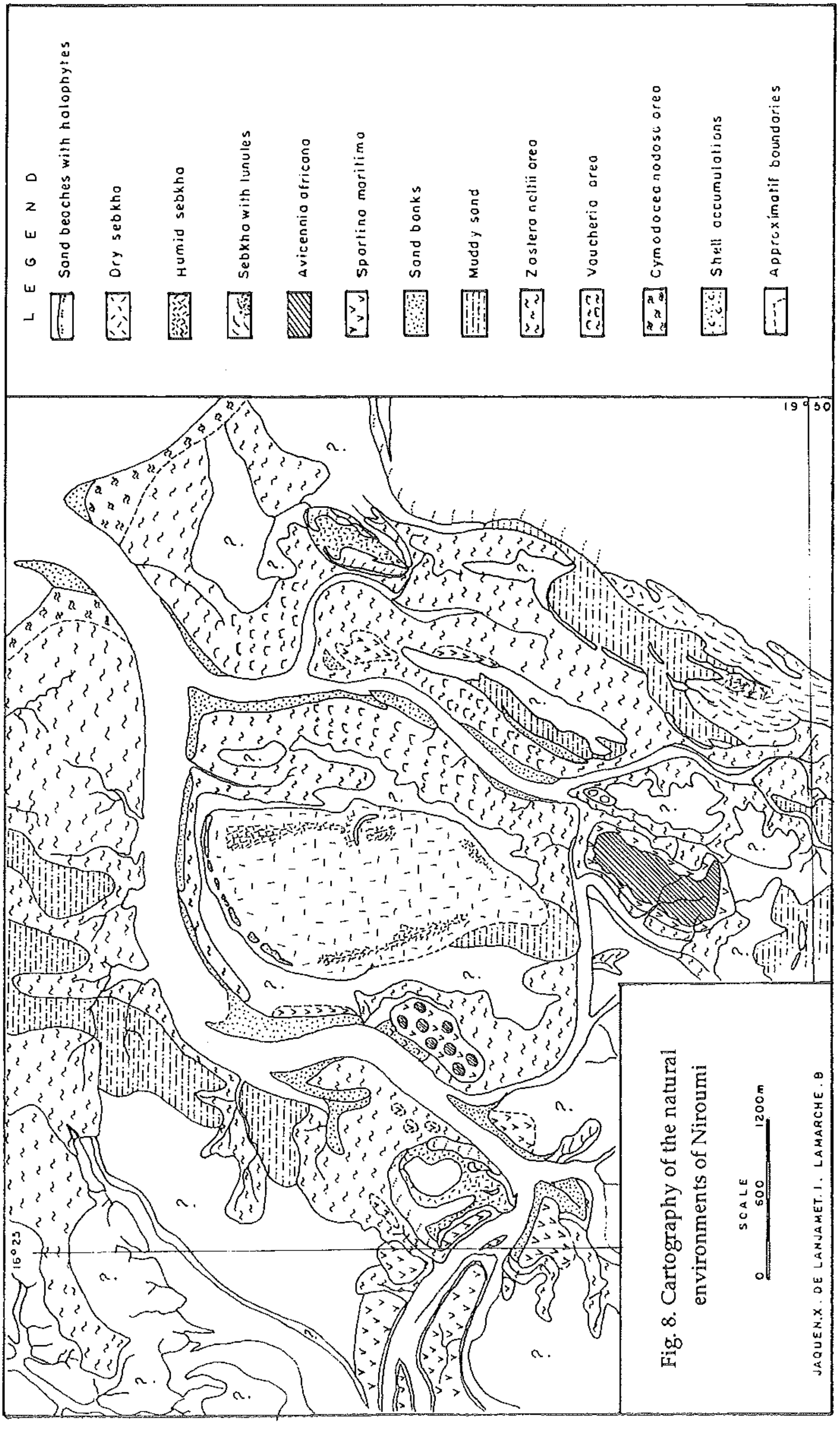

Fig. 8. Cartography of the natural environments of Niroumi

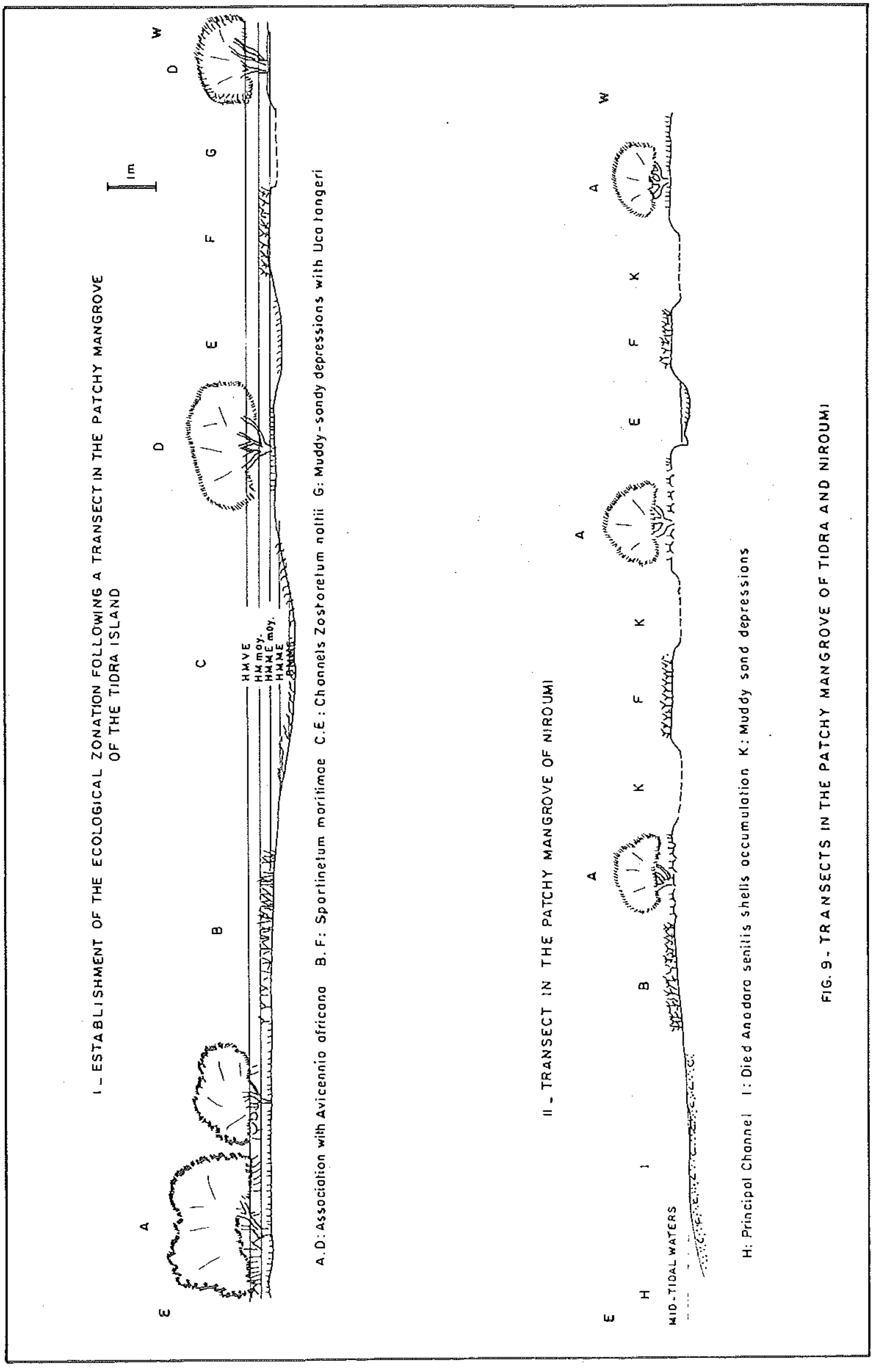

FIG. 9 - TRANSECTS IN THE PATCHY MANGROVE OF TIDRA AND NIROUMI

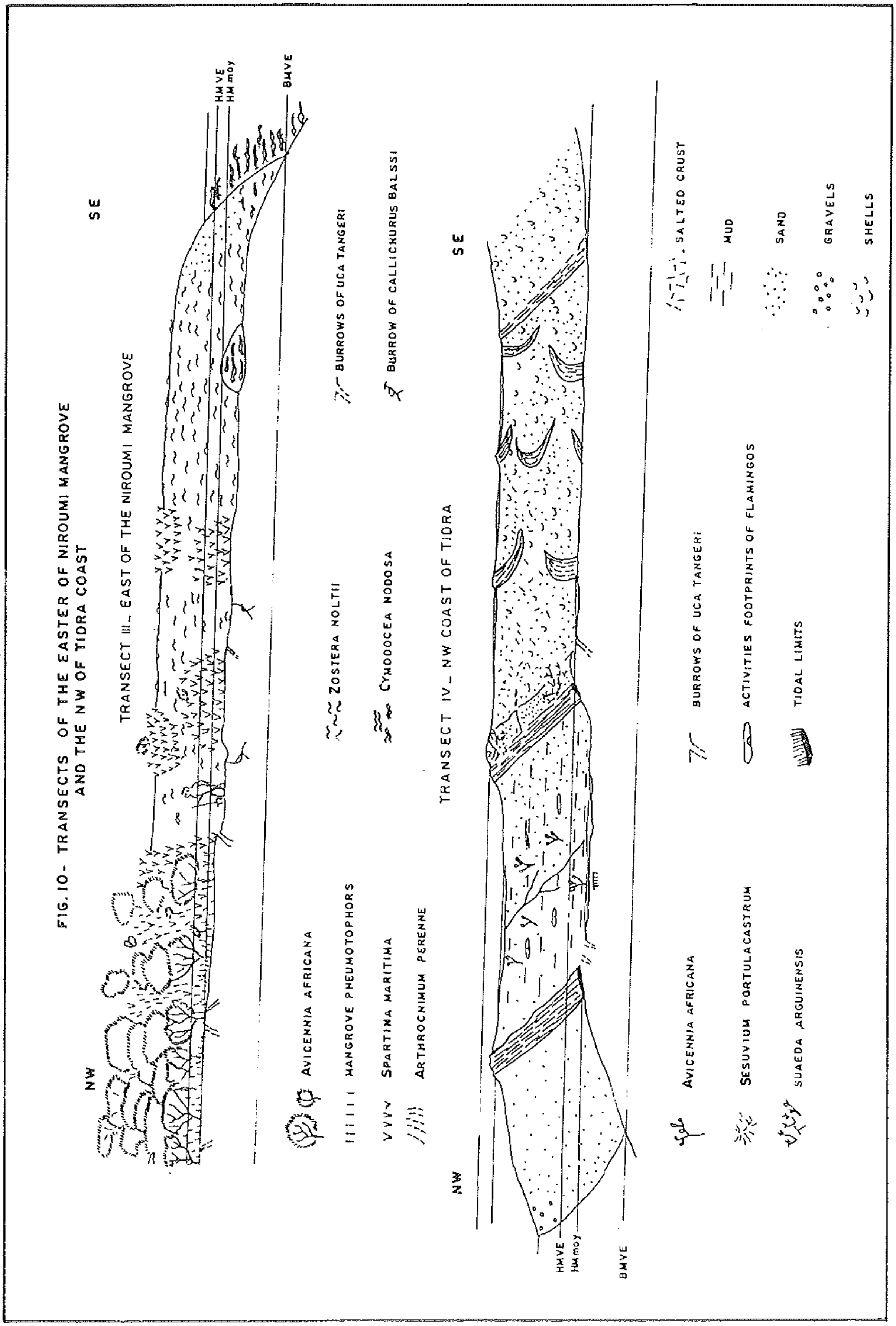

FIG. 10- TRANSECTS OF THE EASTER OF NIROUMI MANGROVE AND THE NW OF TIDRA COAST

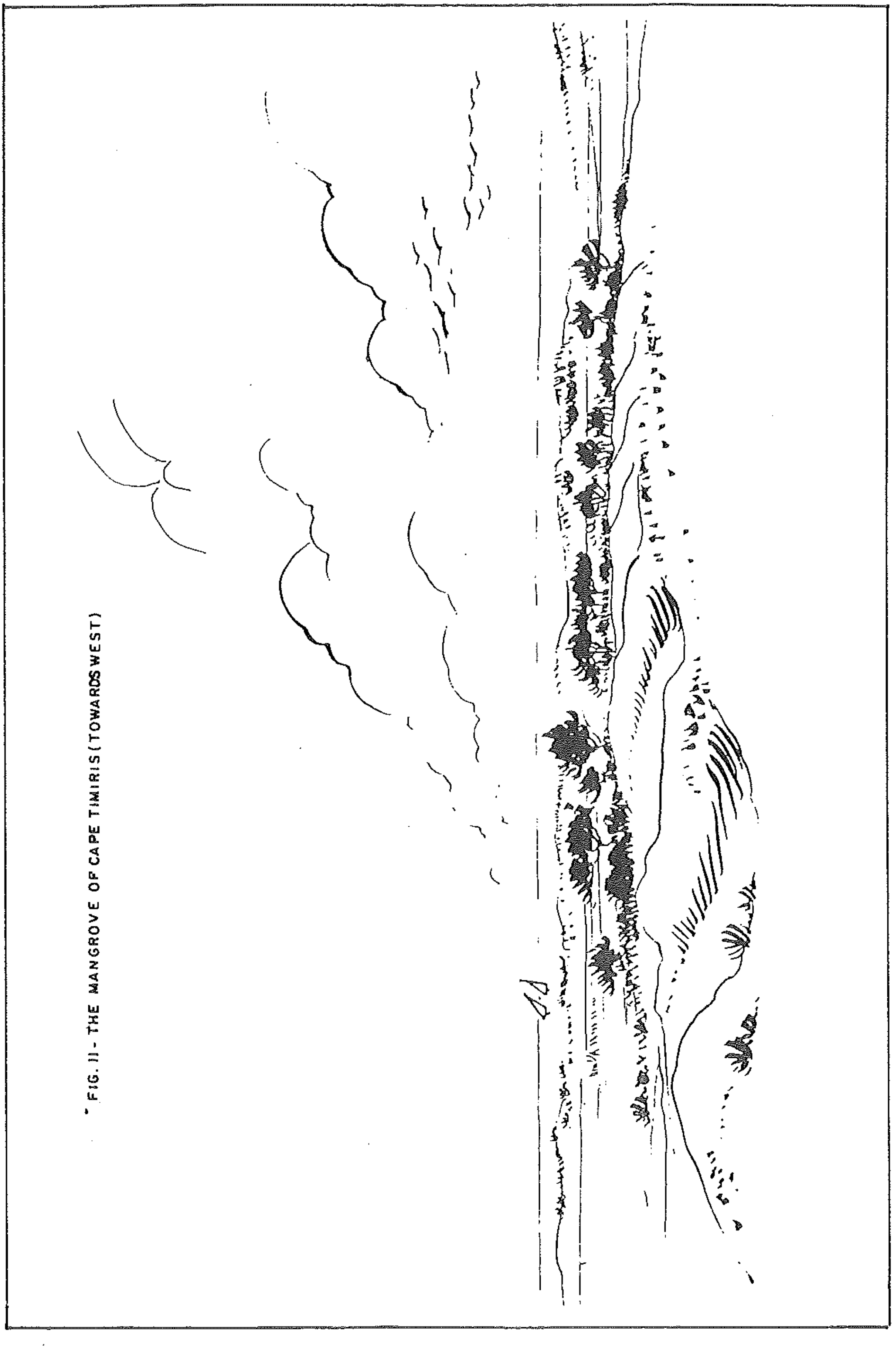

FIG. 11 - THE MANGROVE OF CAPE TIMIRIS (TOWARDS WEST)

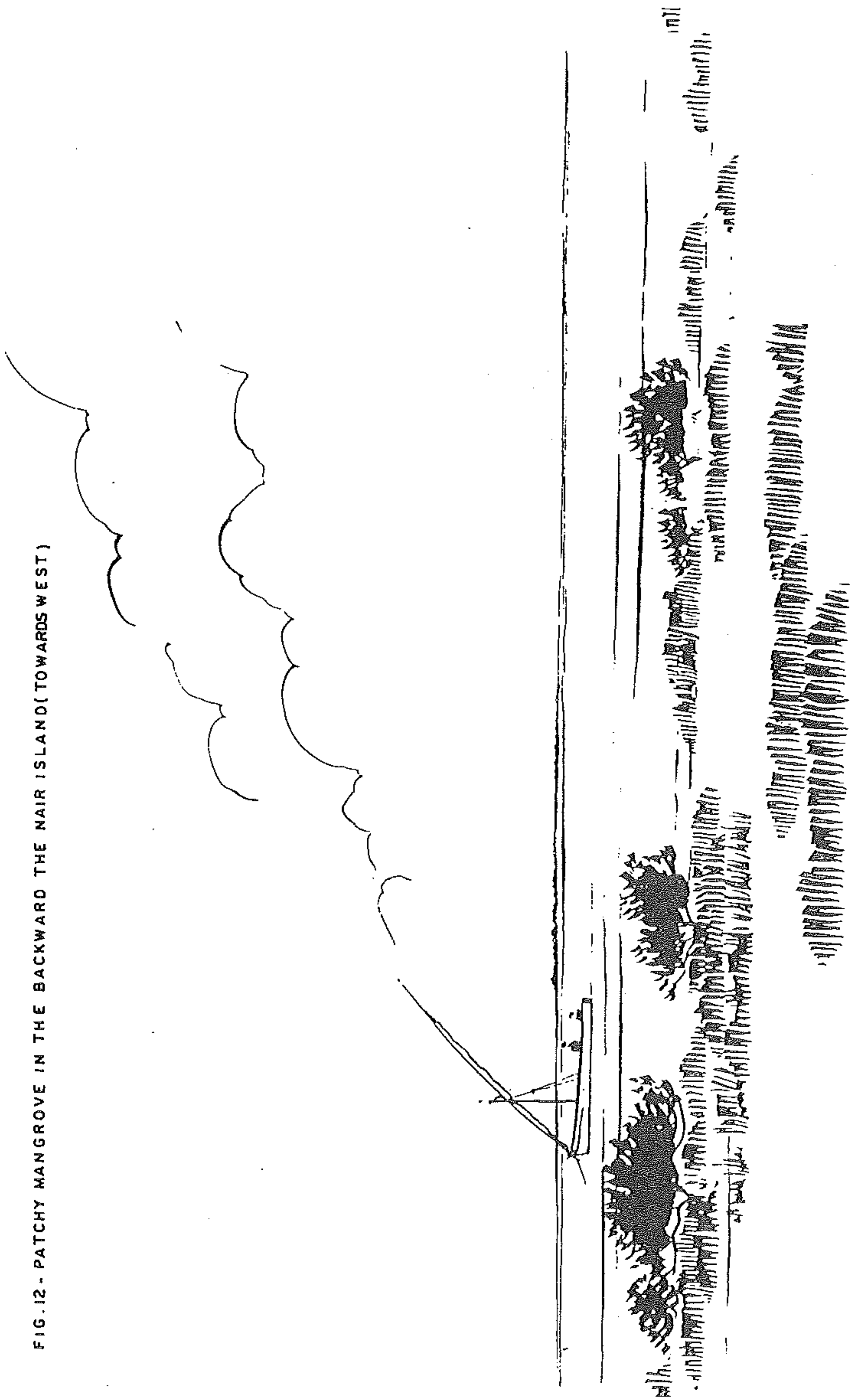

FIG.12- PATCHY MANGROVE IN THE BACKWARD THE NAIR ISLAND(TOWARDS WEST)

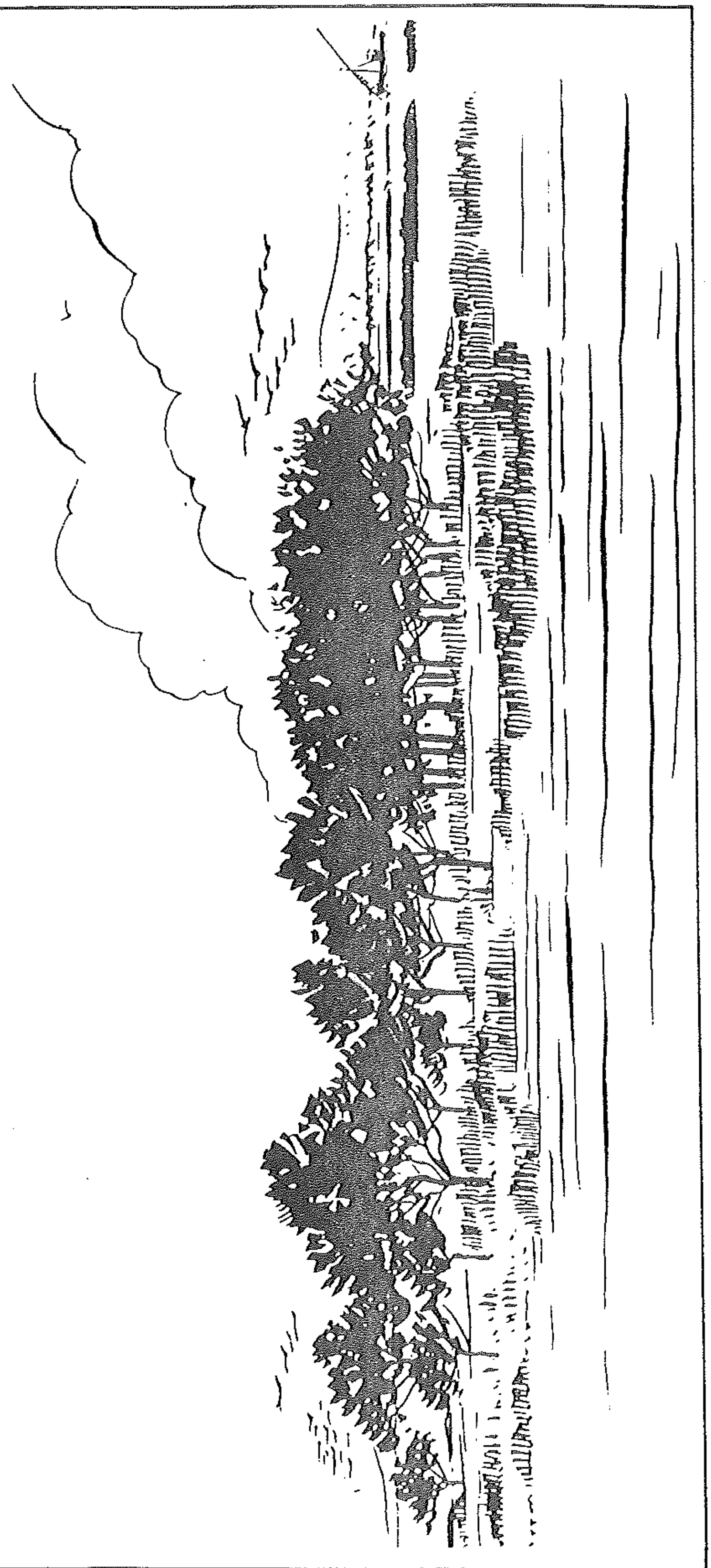

FIG.13 - DENSE MANGROVE IN THE BACKWARD TIDRA ISLAND (TOWARDS EAST)

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Mangroves of Sénégal and Gambia

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1 Brief Outline of the Mangrove Ecosystems and Their Resources

In West Africa, mangrove swamps spread out on vast surfaces in Nigeria, Cameroon, Gabon, Sierra Leone, Guinea, and Sénégal.

From the South of Sénégal to the South of Sierra Leone, they extend over 1,000 km of coastline and cover a surface of over 1,500,000 ha.

In Senegambia, the traditional societies that occupied the littoral domain before the 16^{th} century, in a very discontinuous way, have used the mangrove swamp as places from where they provide themselves with wood (energetic sources and firewood, timber), but also as places for fishing and agriculture.

Thus, in harmony with the environment of the mangroves, human populations (Diolas, Balantes, Tabous, Bagas) have traditionally managed to transform the fragile places and used techniques locally adapted to exploit, in a balanced way, these mangrove lands. Thus, they managed to settle a rice civilization along this littoral.

The balance achieved through the conversion of these places was such that the least degradation could have nasty consequences.

A few decades ago, diverse actions: natural catastrophes such as drought, disturbing actions of Man, excessive tree cutting, unfit hydro-agricultural soils conversions tended to break the balance of these ecosystems.

In fact, a long time ago, the use of the mangrove was very different: the houses found in the zone now are, most of time built with mangrove wood: framework, ceiling, fences, dikes, and fish traps. In Diola villages rhizophora wood is much more in demand, it is sometimes transformed into charcoal. Other uses are: roots, barks and branches as ingredients for traditional medicine; the extraction of tannin and dyes, and the picking of wild fruits.

2 Localization and Extension of Mangroves of Sénégal and Gambia

The mangroves of Sénégal, located between latitude 12°20' and 16°20'N are the most northern ones in West Africa apart from the mangrove swamps of Mauritania which are only in a relict state.

The map of the distribution of mangroves in Africa (cf. Courrier ACP/EEC n 109 May/June 1988), shows that the mangrove ecosystems of Sénégal and Gambia occupies 5,000 km^2, or about 500,000 ha. The more recent evaluations however give an area under 300,000 ha that shows the natural or man made degradation that has occurred during the last 20 or 30 years.

They are all estuarine mangroves located in the lower parts of the rivers: Sénégal, Gambia, Saloum, Casamance (Fig. 1).

2.1 The Estuary of the Sénégal river

On the 170 km downstream of Dagana, and on a surface of about 4,000 km^2, the mangroves survives only in relict state between the Diama Dam and Gandiole. The mangroves prospered in the estuary of river Sénégal until a relatively recent period, as proved by the presence of numerous shells mounds containing mainly *Anadara senilis* and *Crassostrea gasar* (Monteillet J. and al. 1977).

The disappearance of these species would have occurred toward the middle of the 18^{th} century (Joire J. 1947; Rosso J.C. 1974 II).

2.2 The Estuary of the Saloum

The estuary and mangrove swamp sites of the Saloum are composed of three important groups of islands extending on over 80,000 ha; the Gandoul in the North, the Betenti and Fathala islands in the South, separated by three main marine channels.

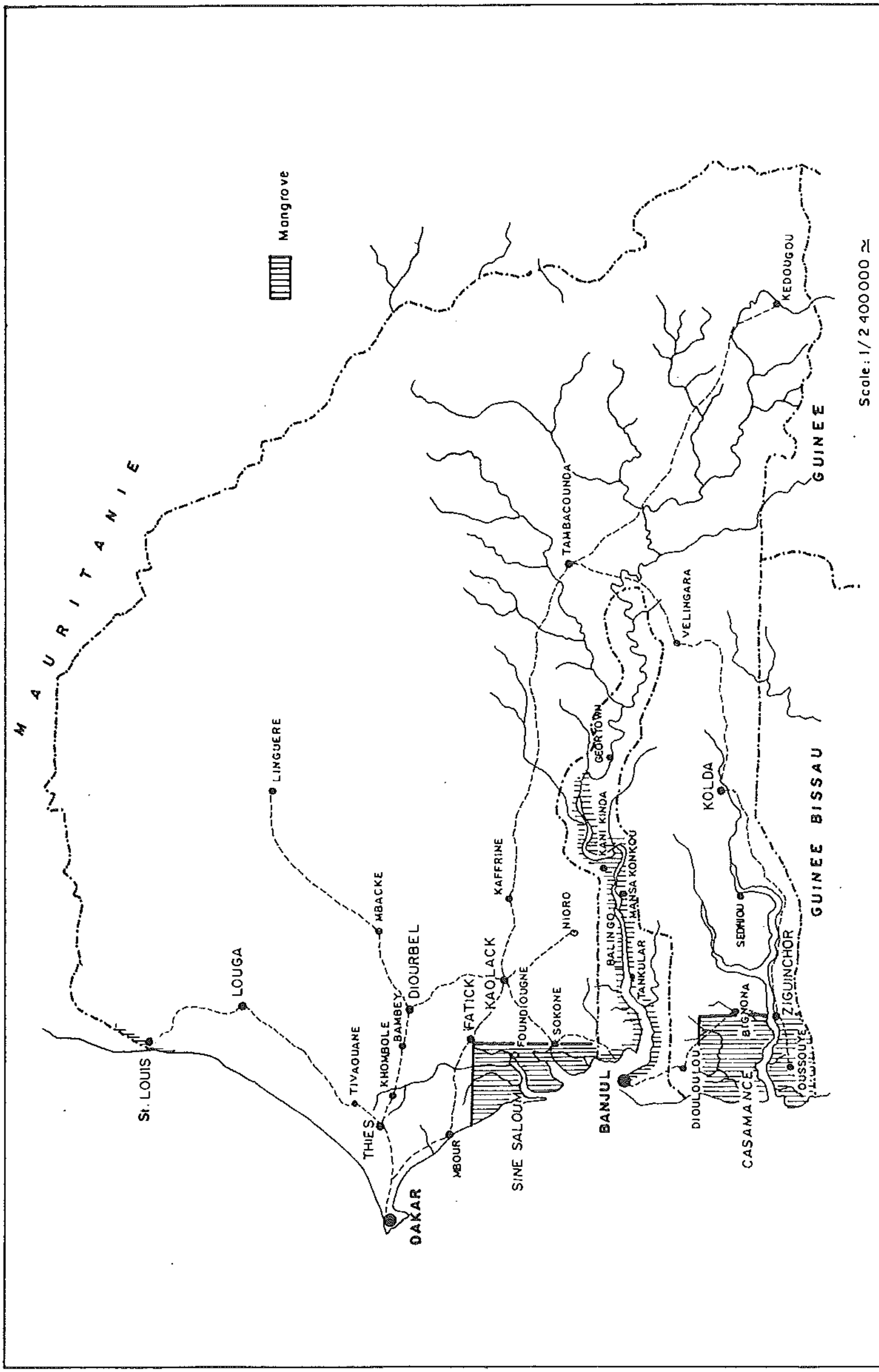


FIG. I - MAP OF LOCALISATION OF THE MANGROVES IN SENEGAL AND GAMBIA
FROM F. BLASCO 1983

The Saloum estuary should rather be qualified as a ria, the channel being totally invaded by marine waters. The tide is the essential factor of the movements of water when significant river discharge is absent (Barusseau J.P. and al. 1986).

2.3 The Estuary of the Gambia

In spite of a long range influence of the tide in the lower part of the river, the extension of the mangrove swamp is reduced and mainly located on the borders of some small affluents (Bintang Bolong and Bao Bolong).

2.4 The Estuary of the Casamance

The estuary of the Casamance is in fact an inverse estuary, with increasing salinity upstream, as also in the Saloum. The fluvio-marine zone covers about 250,000 ha between the ocean and the plateaus of Bignona, Ziguinchor and Oussouye.

It penetrates in the plateaus through the Casamance and many of its affluents are under the influence of the tide on the major part of the flows.

3. Physical Environment

3.1 Climate

Between the North and the South, from the Sénégal river to the Casamance, the climate varies significantly according to the latitude; and it progresses from a semi-arid to a humid tropical climate of the Guinean type.

The annual average rainfall at different stations from the South to the North between 1937 and 1967 is shown on Table 1.

We notice that, in all the cases, we are concerned with a climate having two contrasted seasons : a rainy season that lasts five months in Casamance (June - November); three to four months in the Saloum and in the estuary of Sénégal (July - October), followed by a longer dry season, during which rains are rare.

Beginning in 1968, there is a general decrease of rainfall in Sénégal, like in all the sahelian zone with years of drought (1968, 1972, 1973, 1974, 1977, 1979, 1984); there is simultaneously a contraction of the rainy season which lasts only three or four months in Casamance (June or more frequently October being a dry month) and two months and half in the northern part of the country.

The temperature varies on average from 24°C in St-Louis to 28°C in Kaolack and 26°C in Ziguinchor, the warmest months (28°C - 30°C in average) being April and May in Ziguinchor and in Kaolack; September and October in St Louis, whereas in Dakar the rainy months are the warmest ones. The minimal temperatures (15°C - 17°C) are reached in December - January.

The evaporation is a very important element of the climate in Sénégal since it is the cause of aridity. The evaporation is generally far more important than the rainfall. The yearly variations are directly linked to the temperature and inversely proportional to the pluviometry, the rainy months being less evaporating. Hydric deficiency "Evaporation Rainfall" is recorded about 9 Months out of 12.

3.2 Marine hydrology

The tide is of a semi diurnal type with an average range of 1 m (1.6 m at spring tides). The tidal currents are generally weak: 0.2 - 0.3 knots (Robert and al, 1974).

A surface coastal current goes South-West from St. Louis to Dakar from November to May during the trade winds period; South-East, from Dakar to Cape Roxo down to the Gambia, and then to the South. Under the influence of this current, an equatorial counter-current causes upwelling of deep cold water mostly on the Northern coast. The temperature varies between 18°C and 19°C. The salinity is about 35‰ (Masse, 1968).

3.3 Hydrological networks

Before the closing of Diama dam, the estuary of the Sénégal river was submitted to two forces: the tidal currents and the river flow. The saline intrusion could go up as far as Podor 300 km away from the river mouth and salinity rates higher than the sea water were recorded up to 70 Km in July 1982 (Gac and al. 1986).

Since the closing of Diama dam, 50 km away from the mouth, the river is isolated from the sea during the major part of the year. Thus the hydrodynamics and the hydrology of the Sénégal river have changed. The estuary of Sénégal river up to the Diama dam is from now on under the exclusive influence of the sea (35‰) for 8 months out of 12. During the flood periods, from July to November the dam floodgates are opened and allow the flowing of fresh waters. The implication of this new regime is not yet known in detail but a modification of the fauna has already been shown by Monteillet (pers. comm.).

Table 1: Rainfall in Sénégal estuarine zones in mm (Marius 1985)

Region	Station	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
Low Casamance	Oussouye (31-60)	10	128	458	552	430	185	18	1,780
	Ziguinchor (31-60)	10.8	125.1	362.4	532.4	361	146	8.1	1,546.1
	Bignona (53-65)	10.6	118.6	320	453	315.2	132.9	22.7	1,364
The Gambia	Mansa Konko (31-67)	7	27	236	327	299	93	4	992
	Nioro du Rip (31-61)	10	79.6	185.6	354.9	221.2	2.5	1.5	925.3
Saloum	Sokone 10 years		42.7	146.2	301	231.6	86.4		807.9
	Foundiougne (31-61)		42.4	153.8	328.7	218.3	64.6		807.8
	Dionwar 10 years		32.7	153.5	314.4	252.5	83.2		841.3
Delta of the Sénégal	St-Louis (31-60)	1.2	12.4	54.5	159.4	110.7	31	4	373.5
	Rosso	2.4	9	40	147.5	79.7	31.7	2.6	313.6

Table 2 : The annual variation of the rainfall from 1980 to 1989

Station	The most humid year	The driest year
	mm	mm
St. Louis (Sénégal)	1987: 342	1983: 95
Kaolack (Saloum)	1988: 705	1983: 285
Djibelor (lower Casamance)	1985: 1371	1980: 691

The whole estuarine systems of Saloum and Casamance function as an inverted estuary. The fresh water supply being poor, salinity increases upstream (Fig. 2). In the Saloum, about 100 km from the mouth, the salinity was 55‰ in the dry season and 50‰ in the rainy season in 1990 (Gningue 1991). In the Casamance, Debenay and al. (1991) recorded a salinity higher than 100‰ at 238 km from the mouth at the end of dry season in 1990. Hypersalinity plays an important role in the metabolic efficiency of plant species and particularly on the productivity of the mangrove swamp that tends to be reduced in these zones.

The Gambia is less subject to seasonal fluctuations but undergoes important deficiencies owing to evaporation in the dry season.

3.4 Main characteristics of the soils

The substratum of mangrove zones is essentially composed of quartzitic sands and kaolinite type clays mixed to an important organic fraction due to the accumulation and decomposition of mangrove litter.

The formations of mangrove swamps, clayey silts or sandy silts are usually not very thick and do not exceed 20 m above the "Continental Terminal". The series are generally clayey on the surface and sandy at depth or more rarely show alternate clayey and sandy beds.

The soils evolve in a confined hot and dry environment. They present the following two main characteristics:

- salty to oversalty with prevalence of NaCl and, secondarily, of magnesium sulphate.
- very dense accumulation, in the root system, of iron sulphide, mainly in the form of pyrite owing to the presence of organic particles biologically

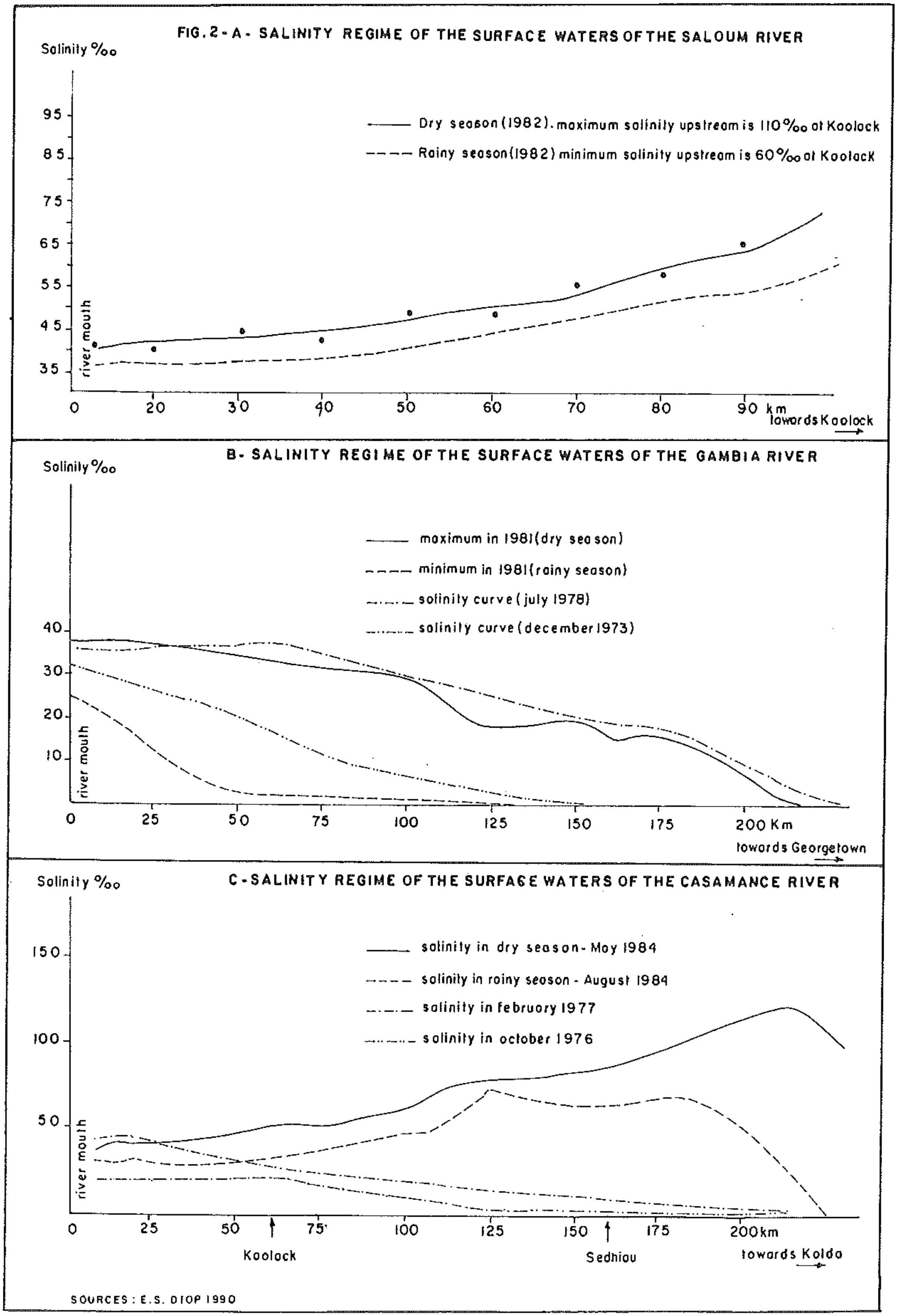


FIG. 2 - A - SALINITY REGIME OF THE SURFACE WATERS OF THE SALOUM RIVER
Solinity ‰
Dry season (1982). maximum salinity upstream is 110‰ at Koolock
Rainy season (1982) minimum salinity upstream is 60‰ at Koolack
95
85
75
65
55
45
35
river mouth
0
20
30
40
50
60
70
80
90 km
towards Koolock
B - SALINITY REGIME OF THE SURFACE WATERS OF THE GAMBIA RIVER
Solinity ‰
maximum in 1981 (dry season)
minimum in 1981 (rainy season)
salinity curve (july 1978)
salinity curve (december 1973)
40
30
20
10
river mouth
0
25
50
75
100
125
150
175
200 Km
towards Georgetown
C - SALINITY REGIME OF THE SURFACE WATERS OF THE CASAMANCE RIVER
Solinity ‰
solinity in dry season - May 1984
solinity in rainy season - August 1984
salinity in february 1977
salinity in october 1976
150
100
50
river mouth
0
25
50
75
100
125
150
175
200km
Koolock
Sedhiou
towards Kolda
SOURCES : E.S. DIOP 1990

decomposable. These sulphides are produced through reduction of the sea sulphates supplied to the mangrove. Reduced amount of sulphides are in balance with the mangrove swamp and are not toxical; but they have an important acidity potential. In particular, these sulphides become oxidized to acid sulphates when the area is aerated due to the action of *Thiobacillus* type bacteria.

Thus, there is, first a production of elementary sulphur, then with a sudden correlative decrease of the pH that can reach extreme values of 2, they become salty sulphated acid soils.

Secondarily, these sulphates can be partially neutralized and give origin to formations of basic sulphates of the potassic jarosite type or natrojarosite type. In very acid conditions, aluminium sulphates can be associated whereas in presence of calcium (shells), there can be formation of gypsum (J.Y. Loyer, 1983).

In general, the "tannes" soils of the Saloum estuary are less acid than those of the estuary of Casamance. This is mainly due to the very high salinity of soils in the Saloum estuary that buffers their normal acidity.

The pH is generally more acid in the bare "tannes" than in the mangroves and varies between 3.5 in Casamance and 5 in the Saloum.

4 Biological Characteristics

4.1 The vegetation

Different observations made on the littoral show that the mangrove swamp formations are present in three main forms (Figs. 3, 4):

- A primary mangrove swamp with little clearing, rarely seen in that domain.
- A secondary mangrove, more frequent, resulting from the exploitation of the primary mangrove. This mangrove swamp shows signs of degradation with an increase of dead individuals as we go upstream and salinity increases.
- A mangrove swamp converted into ricefields, very frequent in Casamance.

The distribution of the vegetation is linked to the topography and to the nature of the substratum. The formation of mangroves suffers the effects of high salinity, stemming from the recent drought. The zonation along a transect is as follows (E.S. Diop, 1990):

+ An external zone constituted by the silty parts of the coast, dominated by *Rhizophora racemosa*. The prop roots, allow this species to resist the wave action and the anoxic conditions of generally clayey soils, particularly in the South, at the same time as they constitute efficient traps for the sediments.

In the Saloum and in Casamance, tall *Rhizophora racemosa* are replaced by groups of *Rhizophora harrisonii* and *Rhizophora mangle* that constitute low and extended mangrove swamps, easily recognizable.

+ An internal zone which, in the Saloum and in Casamance constitute the favourite domain of *Avicennia africana* and which is located in the higher limit of silty zones, irregularly submerged by tides in places where the water is shallow and salinity higher. It is the place where drought introduced important pedological changes. As for *Laguncularia racemosa* and *Conocarpus erectus* among others, they are much rarer in this latter domain and are found in areas flooded only at spring tides.

Associated to mangroves, halophytic marshes are locally called "herbaceous tannes" as against "bare tannes" deprived of vegetation. They are composed of *Sesuvium portulacastrum, Philoxerus vermicularis, Paspalum vaginatum, Heleocharis mutata, H. caribbea, Scirpus maritimus, Sporoblus robustus.*

In halophyte marshes there are also Cyperacea such as: *Cyperus sp., Typha sp., Phragmites vulgaris.*

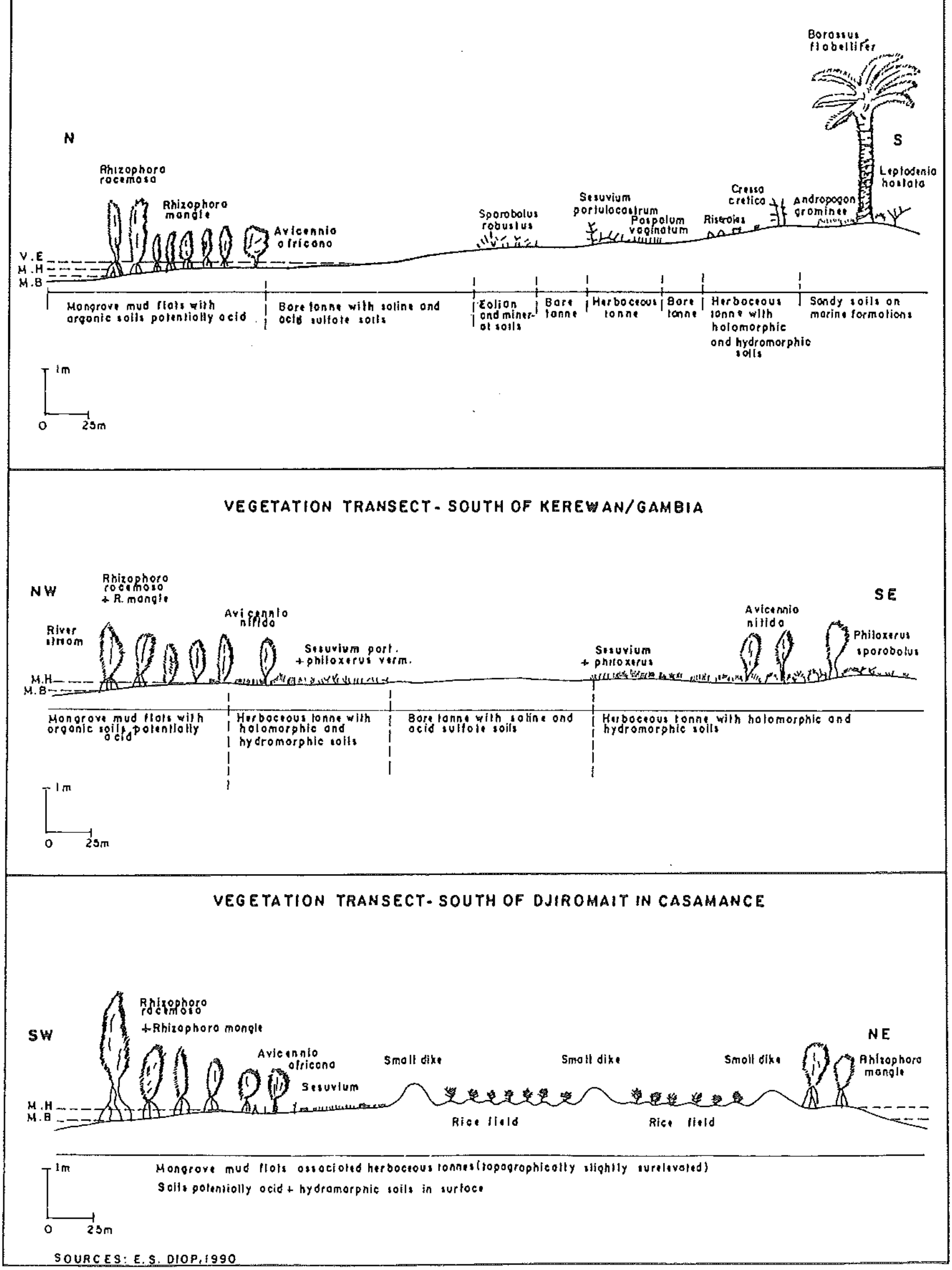
As an example, an ecological analysis and measurements of biomass density and total net primary productivity were carried out on populations of *Rhizophora racemosa* at stations located in the eastern part of the Saloum and more precisely at Toubacouta (cf. EPEEC/MAB report published by A. Doyen and C. Agbogba, 1985). In this section, the best represented forest species is *Rhizophora racemosa* that grows relatively well.

The results of measures realized are the following : in a first station (Fig. 5) :

- total maximum height of dominant species: 10.60 m
- estimated density: 3,400 stems/ha
- average circumference at the basis of the stem: 42.4 cm
- average age of the stock: 35 years

FIG. 3

VEGETATION TRANSECT - SE OF BANDIALA/SALOUM



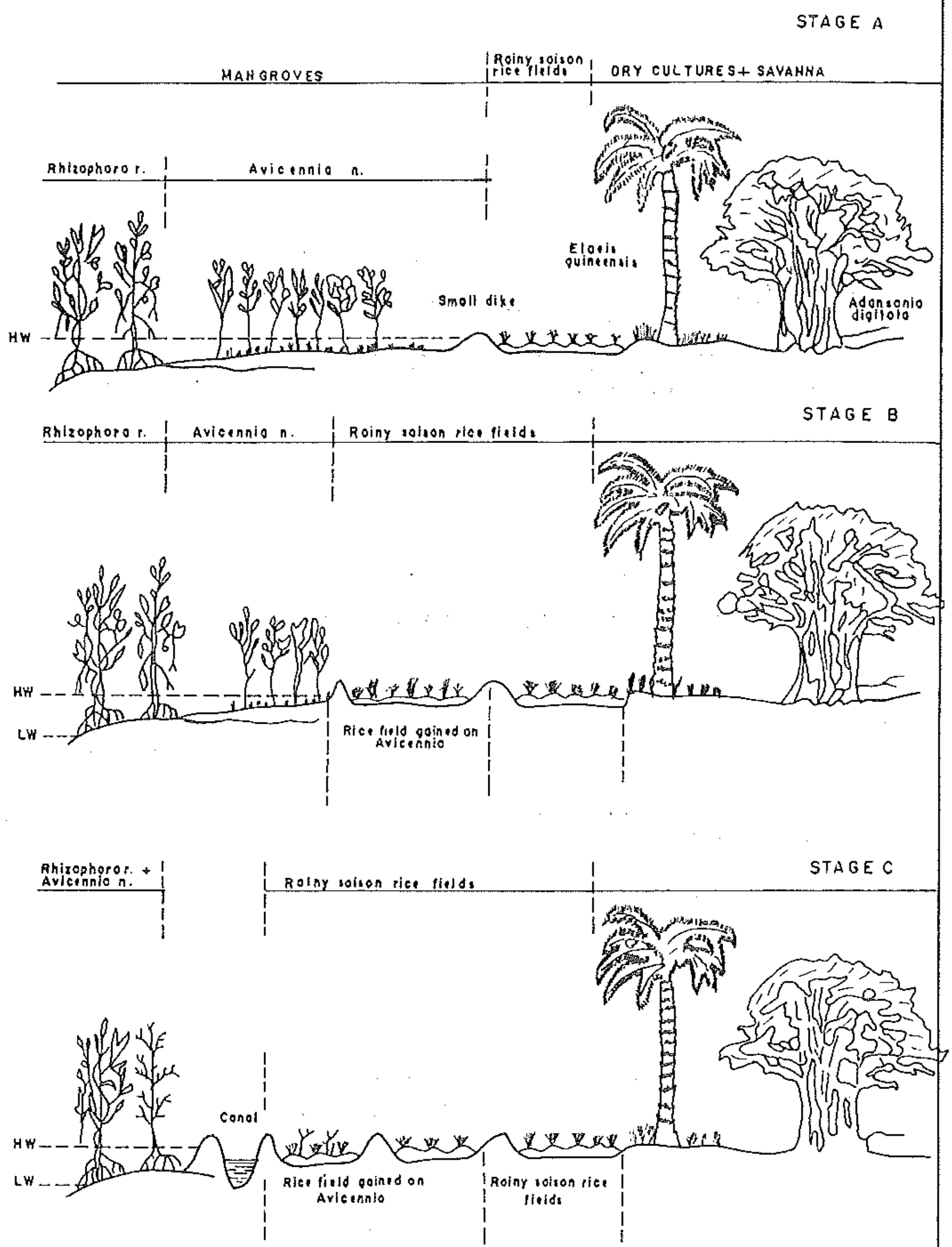
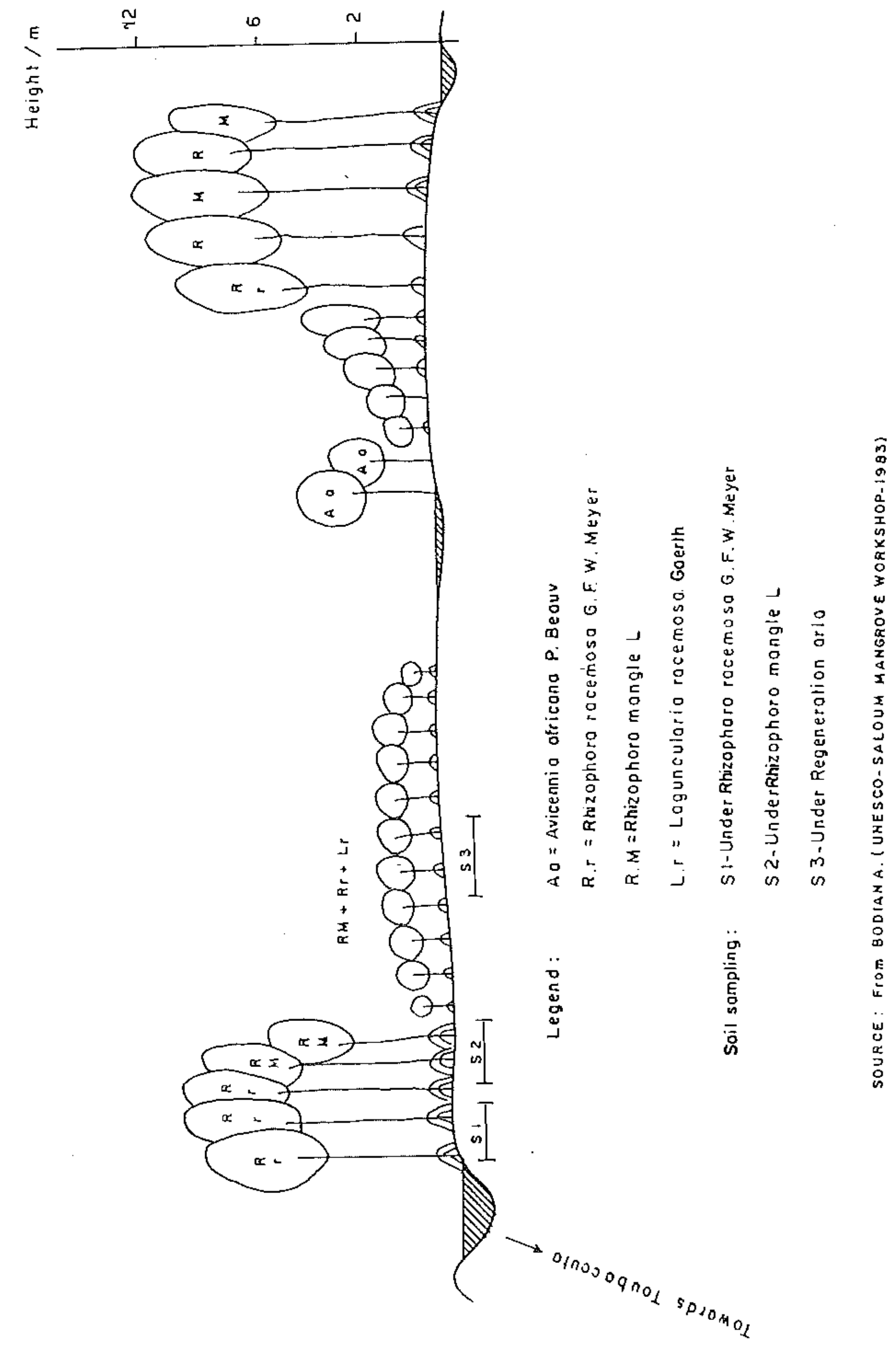


FIG.4 - MANGROVE SOILS CONVERSION FOR RICE CULTURE IN CASAMANCE (SENEGAL) FROM F. BLASCO, 1983

FIG. 5- PRESENTATION OF THE STATION 1



- total aerial biomass: 61,730 kg/ha of dry matter or 92,595 kg/ha of fresh matter
- net primary productivity: 1,764 kg/ha/year of dry matter or 2,646 kg/ha/year of fresh matter
- ligneous biomass: 53,475 kg/ha of dry matter or 80,213 kg/ha of fresh matter
- net ligneous productivity: 1,529 kg/ha/year of dry matter or 2,292 kg/ha/year of fresh matter.

in a second station the following characters were recorded:

- density: 3,000 stems/ha
- stand volume: 62 m^3/ha
- dominant height: 9.6 m
- total height observed: 10.60 m
- average circumference at the basis: 33 cm
- average age of the stock: 28 years
- simple foliar surface: 13,692 m^2/ha
- aerial biomass: 60 tons/ha of dry matter or 90 tons/ha of fresh matter
- total net primary productivity: 2,145 kg/ha/year of dry matter or 3,217 kg/ha/year of fresh matter.

The recorded data on the Toubacouta *Rhizophora racemosa* mangrove swamp were compared with the world average data. They attest the small biomass and the low primary productivity of the mangrove swamp of the Toubacouta area as against the much healthier and more productive mangrove swamps in the delta of river Niger or in Eastern Africa and the Asian mangroves.

Senegambia is near the Northern limit of the West African mangroves where there are steep gradients. They are very often linked to ecological stress enhanced by the drought of the past twenty years.

4.2 Fauna

In the Saloum, Elouard (1977) distinguishes four types of mollusc associations:

- species linked to mangroves in sandy-silty places and characterized by low energy *Tympanotonus fuscatus, Crassostrea gasar, Littorina angulifera, Tagelus angulatus* and *Tellina nymphalis;*
- a characteristic lagoon formation with euryhaline, eurythermic molluscs, living in the mediolittoral and upper infralittoral levels: *Anadara senilis, Dosinia isocardia, Loripes aberrans, Tellina nymphalis, Natica maroccensis, Semifusus morio* and *Bullastriata adansonii,*
- species living in a marine environment: *Mactra glabrata, Natica collaria* and *Terebra senegalensis.*
- association of *Anadara senilis* and *Natica fulminea* at an intermediate biotope between the lagoon and the intermediate zone.

The crab *Uca tangeri,* and mudskippers supplement the marine fauna typical of these mangrove swamps.

In Casamance, the marine fauna is poorer. There are *Tympanotonus fuscatus, Crassostrea gasar,* mudskippers and sometimes *Uca tangeri* (Marius 1985).

5 Factors Determining Ecological Processes in Mangrove Swamps

The basic components of the mangrove swamp ecosystems, Man, flora, fauna and the physical environment are linked by processes through which a continuous exchange of energetic flux occurs. (Diatta and al. 1985). Many factors are considered determinant:

- fresh water supply
- organic matter supply
- the substratum

5.1 Fresh water supply

Plants and animals living in the mangrove swamp are particularly resistant to salinity. However, they need fresh water and tidal movements to maintain a tolerable rate of soil and water salinity and oxygenation of the place. In the Saloum and Casamance, lack of fresh water is translated into degradation of the mangroves which are subject to hypersalinity and acidity of soils.

5.2 Organic matter supply

An adequate supply of organic matter is essential to maintain the biological productivity of the mangrove ecosystems. Organic matter in the soils of the senegalese mangroves, is essentially of continental origin and mainly composed of particles from the decomposition of leaves, roots and fibres of mangroves and more particularly of *Rhizophora* (Marius, 1985). The nutrients resulting from decomposition of organic matter by bacteria, are brought by land runoff and by rivers and their affluents.

5.3 Stability of the substratum

The estuarine environment is continuously modified. Erosion, deposits and consolidation of the sediments are regulated by seasonal and episodic activities linked to the flowing of fresh water and the action of tides.

Studies carried out in the Diomboss and Bandiala rivers showed that the dynamics of sedimentation of different morphological units does not seem to have varied for millennia, even if a recent phenomenon appears at surface layers, such as insertions of silty materials between sands of diverse profiles which presume an eolian contribution.

6 Traditional Use of the Mangrove

Traditionally the mangroves were used for food, medicine, agriculture, fishing and wood (tannin, firewood, charcoal, timber and more recently pulp; Rollet, B.1975). Nowadays, the main activity is rice-growing in Casamance, and fishing in the Saloum.

Rice-growing

The mangrove swamp areas have been traditionally used for rice-growing by some local populations (Sereres Niominka in the Saloum but mainly Diola and Balantes in Casamance).

Local techniques have always been well adapted to these former mangrove fields. Generally they consist in polders built at the expense of the mangrove swamps to prevent the penetration of saline water (Fig. 6). It is important to notice that the traditional conversion that people have been practicing for centuries, have always had an ephemeral character. Whenever the works are abandoned, natural vegetation overruns the fields.

Fishing

Fishing in estuaries and in continental waters is generally exclusively artisanal. The production, about 35,000 tons, although inferior to that of the sea, plays an important role in the supply to local populations. The most important fishing species are mullets, ethmaloses, tilapia.

The rain deficit of the past years has modified the aquatic environment and reduced production. In the Saloum estuary, resources are not well known. Experimental trawling in 1983 showed a disparity between the Bandiala and the Diomboss rivers; the average output is 7 times higher in the former (59.4 kg/hour against 8.7 kg/hour). Fishing is mainly practiced in the sea front and at the mouth of the three sea arms. Upstream waters seem to be underexploited because of the precarious life conditions in this part of the islands. During a large part of the year, most fishermen migrate to urban centres or to other places and come back only in the rainy season.

The number of fishermen is estimated to be 4,000 to 6,000 individuals, with a migration rate that can reach 95% in some islands. The annual production is estimated at 6,000 or 8,000 tons.

In the estuary of the Casamance, resources are related to the variation of salinity. Two censuses carried out in April and in September 1984 showed respectively 6,104 and 4,922 fishermen. The difference is due to migrants leaving Sine-Saloum, Cap-Vert and St Louis.

The production in 1984 was estimated at 24,000 and at 13,000 tons in 1987. The annual catch of shrimps is roughly between 800 and 1,000 tons, but can reach 1,600 tons in good years.

Pisciculture

This activity is traditional in Casamance, and is closely linked to rice-growing. The basins that can be flooded, serve as enclosures for fish before being planted with rice. Unfortunately, this practice is less and less in use. Among the 51 villages visited in 1984, only 29 still use the practice in 1988. In Lower Casamance, 312 basins out of 688 have been abandoned.

Intensive pisciculture is hindered by the competition of sea fish transported to markets by isotherm vehicles, or of locally fished products.

Shell picking

It is an activity that goes far back in history, testified by the numerous shell mounds scattered in the mangroves. Some of these mounds serve as sanctuaries and are considered sacred sites.

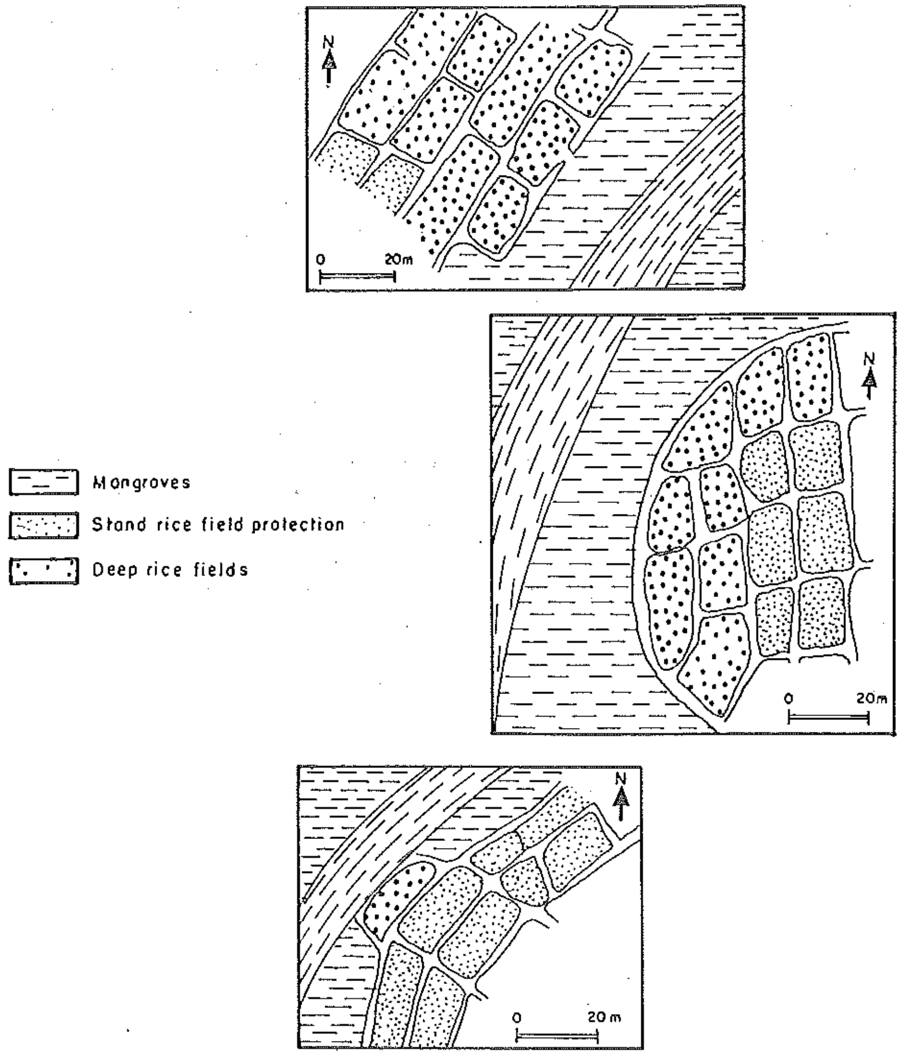
The species exploited are mainly *Crassostrea gasar* and *Anadara senilis* with varying importance according to islands. In the small lagoons such as: Somone, Fasna and Joal-Fadhiout, the marked degradation of the mangroves limits the exploitation of *Anadara*.

In better preserved systems in the Saloum and Casamance, oyster dominates. Sometimes *Murex hoplites*, *Semifusus morio* and *Tympanotonus sp.* occur in the shell mounds.

This activity is practiced by women and children as far as shell picking is concerned and by women for oyster picking. They are transported to places by men who help them as they do in Casamance.

Most of the products are transformed, boiled and dried (*Anadara*) "pagne", or smoked and dried

FIG. 6 - THREE EXAMPLES OF DEEP RICE FIELDS PROTECTION SYSTEM AGAINST THE TIDAL FLOODS (AT NIOMOUN KAGNOUT AND SIGANAR - LOW CASAMANCE
From P. PELISSIER 1966



(oyster) "jokhoss".

It is impossible to evaluate the annual production, because it is most of the time intended for family consumption and the surplus is sold or bartered. In Casamance where tradition is more lively, Cormier-Salem (1986) suggested a margin between 10,000 tons and 15,000 tons of oyster and probably a real production of 1,000 or 1,300 tons which means 20 to 26 million dozens.

In the Saloum islands, considering the listed shell mounds, oyster production must be important but the only sure figures are concerned with the quantity commercialized in Dakar by the cooperative of Sokone and Joal who stock in these islands.

Wood

The mangrove forests (*Rhizophora*) have been used in different ways and for a long time. Most of the houses are made with mangrove wood: frames, ceiling, fences. The Diola architecture in Casamance can be imposing and well elaborate as for instance the impluvium huts. Dikes and fish traps also are made of mangrove wood.

Firewood is taken from the mangrove, and the pressure on the mangrove is nearing to the critical point. *Rhizophora* is an excellent firewood because it burns well even in the rainy season. In certain areas, wood is transformed into charcoal.

There are other uses, namely in medicine : The yellow leaves of *Rhizophora racemosa*, when crushed and applied on wounds, are an efficient remedy. Fresh leaves are supposed to heal headaches when tied on the head. Root brewage are use to calm toothaches. Women, after delivery, inhalate vapor from the brewage of *Rhizophora mangle* leaves, massage with the same leaves can stop bleeding. The upper parts of *Rhizophora mangle* roots are used to heal diarrhoea. The leaves, when dried and crushed give a powder to dye clothes. They can serve too as varnish or detergent according to the mixing and the concentration.

7 Conversion to Other Uses

Aquaculture

In addition to the traditional pisciculture, two forms of aquaculture are practiced: oysterculture and shrimpculture.

Oysterculture started in the 1940's in the lagoon of Joal-Fadiouth and was quickly structured into a cooperative. Production increased until 1955 with 166,000 dozens, and then diminished and stabilized at 100,000 dozens per year until 1973. Production has continuously regressed since that date, going from 57,000 dozens in 1981 to less than 20,000 dozens in 1988. This decline probably is caused by three factors:

- Decrease of demand: raw oysters are intended for foreign customers, but these decreased in number in the years following independence,
- The degradation of the mangrove swamp caused by drought and by man through excessive tree exploitation,
- Ageing cooperators.

International tourism which started ten years ago can give a boost to this activity, but it requires better marketing: constant supply, sanitary supervision.

Shrimpculture consists essentially of an experimental farm, established near the bolon of Katakalousse in Casamance. Several species, local and foreign, have been tried: *Penaeus notialis* (local), *Penaeus kerathurus* (local and imported), *P. vannamei*, *P. indicus*, *P. monodon*, *P. japonicus*, *P. semisulcatus* (imported). Local species gave poor results: *P. notialis* is attacked by parasites like *Thelahamia* (microsporidia), and life rates of *P. kerathurus* are mediocre. The best results are obtained with *P. monodon*, *P. vannamei* and *stylirostris* from New Caledonia.

Shells

The accumulations of *Anadara* shells are often exploited to replace gravel for building of tracks or houses by incorporating fragments in the cement.

Tourism

Tourism started to be developed fifteen years ago and has become the second most important economic activity in Sénégal. Fishing is first. Tourism is well developed along the bolons where the mangroves grow (Joal, Saloum, Casamance) and the majority of conversions take place along that littoral.

8 Impacts of Natural and Anthropogenic Factors

8.1 Natural factors

Since 1968, Sénégal has gone through a drought period that lasted 20 years. This phenomenon caused many changes on all the coastal systems in Sénégal namely the reduction of mangrove areas to the profit of possibly bare tannes surfaces. This can be clearly observed through satellite imagery in the Saloum and in Casamance as well. In the latter, Sall (1983) showed an increase of 107 km^2 of the tannes surface to the detriment of the mangrove mudflats (-87 km^2).

The receding of mangrove swamps from the external borders of lagoons seems to be linked to the progression of the sahelian zone towards the South according to the increased drought of recent years (Degeorges and Samba, 1982). Considerable growth of salinity and acidity of soils explains how the natural vegetation of the mangrove swamps and of the grass lands has been partially but gradually replaced by bare tannes with saline efflorescences (Le Brusq, 1985). Changes in inundation and river regime, reduction of fresh water supply and flooding by saline water, high salinity of the surface and ground waters are the primary causes of these modifications. Contamination of ground waters by salinisation is a secondary cause. This can explain the mortality of the mangroves, in Gambia, notably in the bitang Bolon, and in the mangrove swamp of Tendaba. Comparable areas have been spotted and studied from satellite imagery at Foundiougne, in the NE of Diouloulou and in the SE of Ziguinchor. The degradation of the vegetation is explained by the same factors.

All these transformations due to worsening of climate have been showed by Marius (1984), Marius *et al.* (1986) by changes in the geochemistry of soils (acidification, oxidation, neogenesis of gypsum and amorphous silica). In Casamance, the drought lead to the following consequences:

- development of an horizon with brown spots, deepening jarosite horizons, silicification of mangrove roots, and presence of gypsum on the surface and down to some ten cm depth.
- spectacular decrease of *Rhizophora mangle* and increase of decadent mangrove swamps or of a *Sesuvium* carpet, and the development of bare "tannes" at the expense of grass covered tannes.

It is clear that the fragile balance of the mangrove swamps in the Northern areas is still exposed to climatic hazards. Changes related to climate, in the mangroves result in:

- biological impoverishment of the aquatic and the land areas,
- adaptation of animal and plant populations to gradual hypersalinity,
- tendence to confinement.

The vegetal associations, healthy in the lower reaches of the estuary of the Saloum, show signs of progressive degradation with an increase of dead individuals in the medium section of the estuary and a marked shrinkage of the mangrove swamp. Farther in the North, the mangrove swamp disappears at stations that are far from the river mouth.

The micro and macrofauna also show changes. The ecological stress is doubtlessly one of the causes of the phytopathological troubles noticed in the Gambian mangrove swamp (Teas and Mc. Wan, 1982; Checchi and *al.*, 1981); these are secondary eco-dependent alterations.

8.2 Anthropogenic factors

Overexploited biological resources, sometimes show signs of a heavy pressure through shortening of individuals. Thus, in the lamellibranch zones, there is a constant reduction of *Anadara* (Joal Fadiouth) and oysters (Casamance). Women who pick them are obliged to go farther and farther and have to hire canoes.

The mangrove swamps near villages are particularly damaged, often completely destroyed. However, the destruction of the mangroves by populations is nothing in comparison with the havoc caused by management entreprises such as ILACO who have definitely sterilized zones intended for rice-growing (Tobor in Casamance).

The construction of anti-salt dams across some affluents of the Casamance gave results which are far from being positive as far as the prospect of gaining soils for agriculture is concerned. For some marine fish species and for the shrimp *P. notialis*, the migration route is obstructed. The reduction of exchanges from upstream to downstream has had negative repercussions on the estuarine productivity.

In an unstable zone that is sensitive to every modification of the environment, the action of Man can cause constraints that worsen the imbalance. All this shows that Man has to moderate his actions on the ecosystems. So far, the communities of agriculturers have displayed an extraordinary skill when they have to adapt their activities to the natural hazards. The Diolas, in Casamance, after intensifying rice-growing, abandoned momentarily some rice-fields and developed other activities (fishing in basins, oysterculture, picking). The intervention of Man in a prospect of hydro-agricultural conversion is entirely dependent on the full understanding of the functioning and evolution of the environment.

9 Social and Economic Implications

These implications must be analysed according to the human factors and the activities proper to local populations. No matter whether it is in the delta of the Sénégal river or in the estuaries and mangrove domains of the Saloum, of the Gambia, and of the Casamance, numerous and profound transformations have marked the lives of local populations since their first settlements that started a long time before the 16th century (E.S. DIOP, 1990).

Besides historical transformations, there are parallel ecological and socio-economic transformations (namely linked to the great conversions undertaken in the delta of Sénégal river and in Casamance), with their impacts on the local populations.

The economic activities of populations living in these estuaries and mangrove zones are always centered on fishing (with seasonal migrations on the larger part of the West African coast), on agriculture, on commerce (salt, wood, shells, fishing products) combined with more or less permanent migrations to towns. However, even if it's not the case everywhere on the Senegambian coast, a profound crisis (linked to the influence of monetary economy and to the rural exodus but mainly to the drought) has markedly affected the local populations. In spite of the great conversions (e.g: hydro-agriculture) that have been undertaken and achieved in these zones, the solution found by local populations has been a great diversification of activities and a multiplication of trades that often allowed them to adapt to the modifications of the environment. We can also add migrations that had been so far temporary and that are becoming in these late years more and more permanent. Elsewhere in the South (Casamance in particular), we noticed efforts for the gradual rehabilitation of the traditional techniques (piscicultural basins, picking of oysters, barriers and dikes), and to the conversion of local populations to maritime fishing with the adoption of new techniques (M.C. Cormier-salem, 1992).

We can include in the factors having a noticeable impact on the socio-economic aspects: demographic pressure and climatic hazards during these last three decades. The tendencies, described above constitute some interesting hypothesis that deserve to be deepened, for they illustrate the interaction of social and economical conditions on the relationships between men and their environment, particularly in the estuaries and mangrove zones.

10 Research and Training Programmes and the Pluridisciplinary Teams for Research on the Coastal Zone

Efforts have been made during the late fifteen years to give a boost to training and research activities on the African coastal zones. This intensification of studies in the estuaries and mangrove domains is justified, for these zones are among the most interesting and the most complex, but also the most threatened coastal ecosystems. The threat comes as much from natural phenomena as from human actions.

One of the most important training and research programmes that have been launched during the latest five year period after many years of preparation, is that initiated by the COMAR programme (Coastal Marine) of UNESCO, namely its African component COMARAF.

Thus, in the area of "the functioning and the productivity of mangrove ecosystems" (one of the three major programmes launched by the project COMARAF), researches are focused on the Western part of Africa, even if elsewhere, studies more directed on the mangrove swamp are carried out as well in the Gulf of Guinea as in East Africa. To reach their aims (creation of pluridisciplinary study teams / EPEEC in Sénégal) or even national COMARAF committees that managed to integrate in their research programmes not only the mangrove ecosystems but also all the coastal zone, including impact studies.

Now, the problem consists in the co-ordination of the activities of EPEECs with the national programmes underway in the coastal zone. In this context important efforts of collaboration have been made through the organization of joint activities with other governmental or non-governmental organizations such as UNDP, UNEP, ICSU, IMO, UICN, IOC and research structures such as ORSTOM, BRGM.

However, in close relationship with the local populations and the national plans for the environment and the land management, efforts should be made in order that a greater respect be accorded to laws for the protection and the reasonable management of the mangrove zones.

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Mangroves of Guinea-Bissau

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1 Historical background

The coastal zone represents an important wealth for Guinea-Bissau. Its numerous estuaries surrounded by mangrove swamp forests explain the importance of the sea resources, mainly shrimps.

The mangrove constitutes a balance and a transition between the land and the sea. It contains food chains mainly from the sea, owing to its high primary productivity.

It constitutes also an area of reproduction and growth for many sea species added to the species typical to the habitat. Moreover it is a direct or indirect source of an important variety of goods for the population (fish, salt, shellfish, molluscs, medicines, honey, firewood, timber). Mangroves are also places for rice-growing.

The majority of the population in Guinea-Bissau (65%) lives in the coastal areas and has maintained a close relationship with the mangrove swamp for centuries. Guinea-Bissau is composed of roughly thirty ethnic groups among which three groups (41% of the total population) are characterized by their close link to the coastal ecosystems: Balanta, Felupe (Baiote) and Papel.

2 Extent and Distribution of the Mangrove Ecosystem

Guinea-Bissau with its 36,125 km² of territory had a surface of 4,760 km² (476,000 ha) of mangrove swamp. Nowadays, the mangrove extension has decreased down to 2,484 km² (248,400 ha - around 8% of the national territory) mainly located on the littoral plateau that includes the Bijagos archipelago.

The tide goes as far as 150 km inland, and thus limits the border of the mangrove swamp habitat.

The analysis of the mangrove swamp distribution for each region shows that the most important part is found in the North of the country, second in importance is in the South including the archipelago, and the smallest part is in the centre (map).

3 Biophysical Characteristics

1) Geomorphology

The relief of the estuarine lands of Guinea-Bissau is relatively simple. The continental shelf, from the Upper Miocene is part of the Senegalese main sedimentary basin with an altitude of 0 to 3 m. It is composed of clays. Being intersected by numerous rivers and constantly flooded, it is covered with mangrove swamps.

The estuarine lands can be subdivided into estuarine terraces and recent estuarine sediments :

a) The estuarine terraces are ancient sediments, which can be occasionally and partially flooded by tides. They are located on a level higher than the recent estuarine sediments and are occupied by an herbaceous vegetation that is relatively high (straw) and others.
b) On the recent estuarine sediments, we can find a vegetation of *Rhizophora, Avicennia*, or *Laguncularia* associated to sand beds.

2) Climate

The Guinean-Bissau climate, tropical and humid, is characterized by two seasons, the rainy season (June - October) and the dry season (November - May). The annual temperature under the influence of trade-winds is 24°C to 27°C.

Nearly half of the territory is occupied by the coastal zone where there is no drought. The annual rainfall varies from 1,500 mm in the North to 2,000 mm in the South, and constitutes an average favorable to the survival and the development of the mangrove swamps and for rice-growing. It is worth mentioning that recently, the rainfall situation of the Guinean mangroves, mainly in the coastal zone, is significantly decreasing:

a) in the South, from 1924 to 1991, the rainfall decreased from 2,400 mm to 1,800 mm.
b) in the Centre, from 1942 to 1991, the average decrease goes from 2,200 mm to 1,600 mm.
c) in the North, from 1942 to 1991, the rainfall decreased from ,1600 mm to 1,200 mm (refer to the enclosed tables)

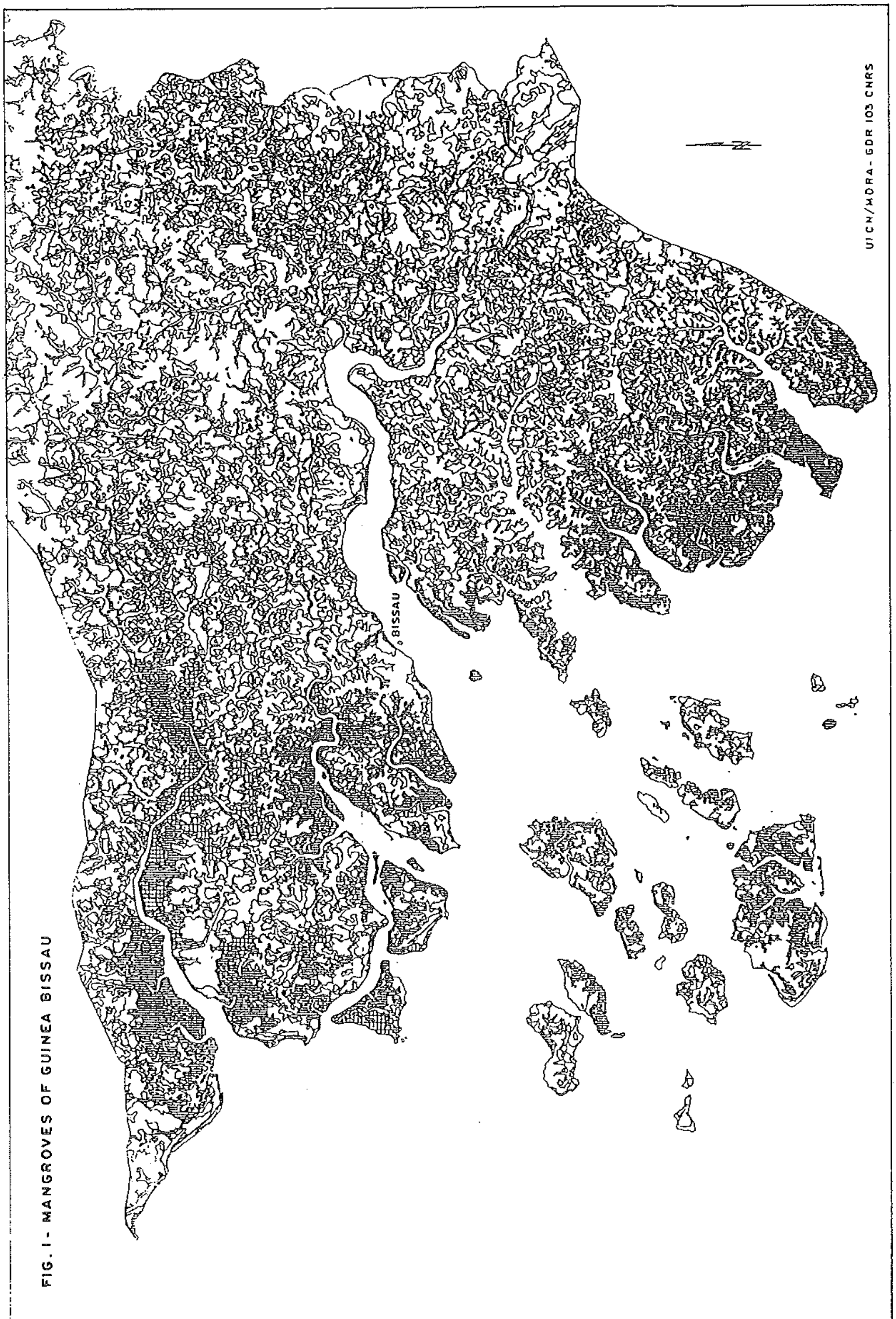

FIG. 1 - MANGROVES OF GUINEA BISSAU

Table 1: Synthesis of rainfall data (North)

		1953-80	1990	1991	1992	
May	Varela	10		190	6,2	Total 1992
	S.Domingos					
	Cacheu	16,5	0	0		
	Canchungo	9,8	03	0		
June	Varela	129,4		12		
	S.Domingos					
	Cacheu	163,4		8,9		
	Canchungo	142,0	69,3	32,3		
July	Varela	399,5				
	S.Domingos					
	Cacheu	391,0				
	Canchungo	389,5		396,7		
August	Varela	519,5				
	S.Domingos					
	Cacheu	531,1				
	Canchungo	548,5	478,9		473,6	
September	Valera	362,1		255,7	255,7	936,6
	S.Domingos		205,2	231,1	205,5	
	Cacheu	363,2			171,6	
	Canchungo	369,3		170,6	228,1	1185,8
October	Varela	147,2				
	S.Domingos					
	Cacheu	166,0				
	Canchungo	131,0		212,3		

From coastal planification project: IUCN/MDRA-DGFC, 1992.

To the far North of the Guinean littoral (Varela), the rainfall reaches a level inferior to 1,000 mm, which is considered to be the lower limit required for the growth of the mangrove swamp.

3) Soils

The most important phenomenon linked to the mangrove swamp soils is the oxidation of sulphur and iron compounds (pyrite) which is responsible for the possible acidification of the soil profile. The chemical reactions which cause acidification, start when the conditions of the area become anaerobic. This process, called thioxidation is catalysed by bacteria of the Thiobacillus groups, living in highly acid areas (pH 3 to 2). This process consists, in reduction formula, in the oxidation of the pyrite (in the presence of sulphur). The final product is jarosite, which normally accumulates in the root pores in a form of a bright yellow material.

The populations specialized in rice-growing on mangrove soils have traditional processes to avoid the tioxidation of the "bolanhas" (ricefields) by letting sea water enter the ricefields during the dry season, a process which favours the reduction of the soils. There are two kinds of mangrove clayey soils: under *Avicennia* and under *Rhizophora*.

The simple observation of the vegetation does not necessarily indicate the type of soils; for example, in a soil occupied by *Avicennia*, we can find a thin layer of clayey soil under *Avicennia* located on a thick clayey soil layer of *Rhizophora*. These clayey soils under *Rhizophora* result from a slow

FIG.2- RAINFALL AT BISSAU (CENTER)
1942-1990

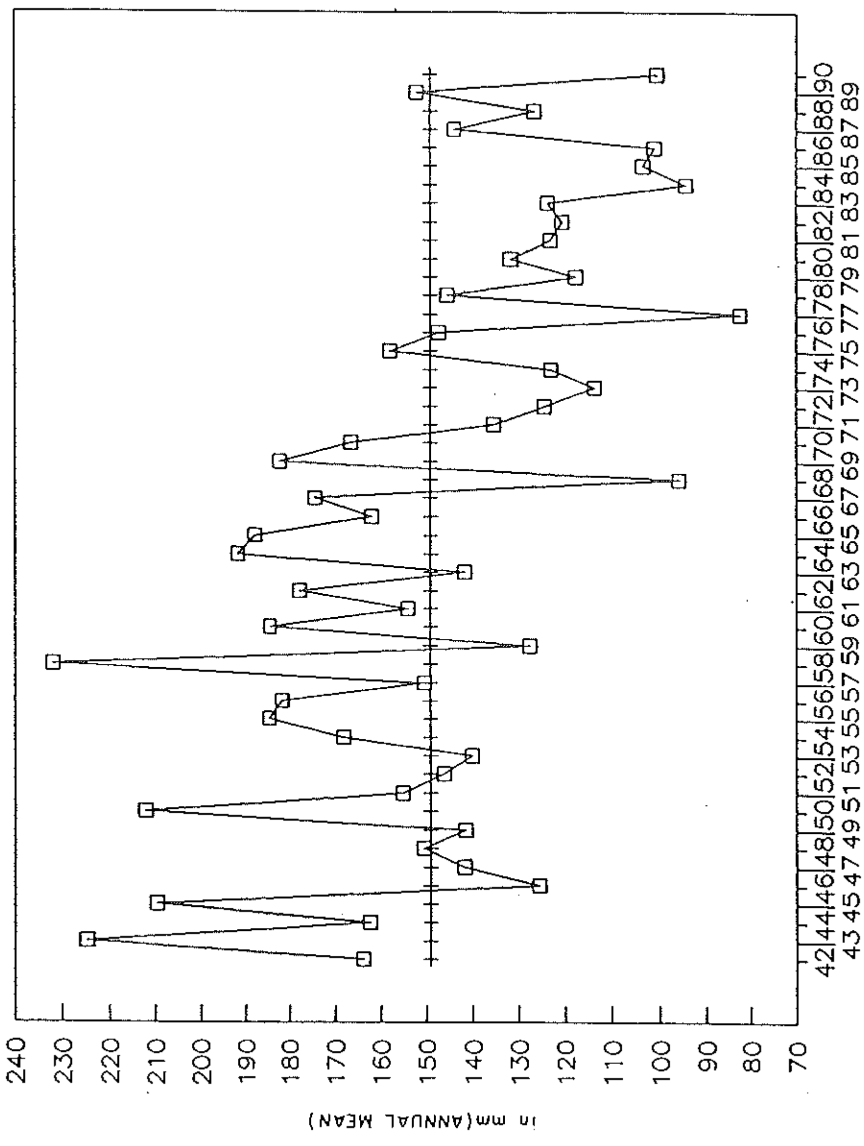

FIG.3 - RAINFALL AT BOLAMA (SOUTH)
1924 - 1990

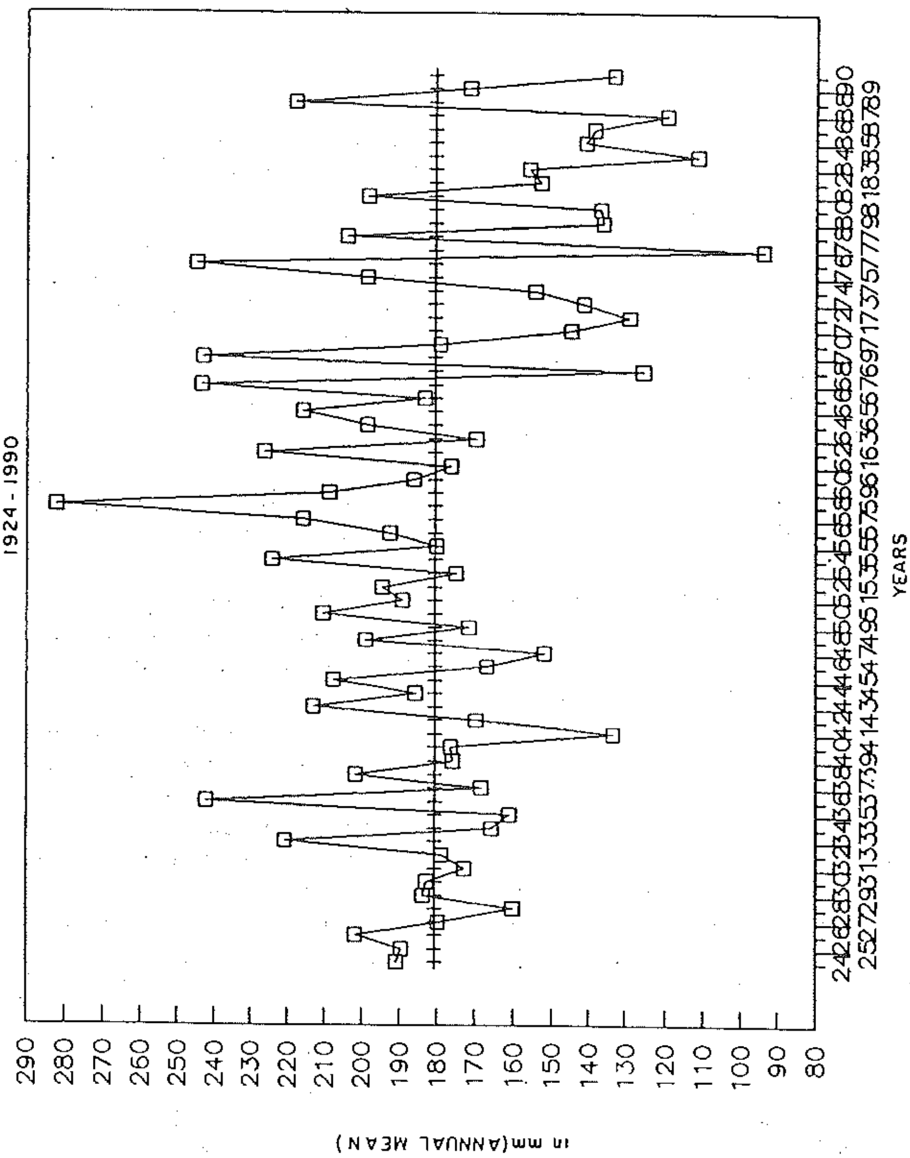

Table 2: Major differences between *Avicennia* and *Rhizophora* soils

	Avicennia clayey soil	*Rhizophora* clayey soil
non-mature and non-oxidized soils	rare brown spots	--------
semi-mature soils	predominance of brown spots (iron oxides)	predominance of jarosite spots (yellow) and a few brown spots
well mature soils	predominance of brown spots and red spots (goethite)	predominance of red to dark red spots (hematite)

sedimentation where a thick pyrite layer is formed, which in contact with the oxygen, is transformed into acid sulphate soils, highly acid. As for the *Avicennia* clayey soils, there is a more rapid sedimentation deposit with minor pyrite formation. The drainage of these soils does not necessarily lead to sulphate acid soils.

"Tannes" can be formed without human interference. These soils are acid sulphate and they are developed from the highly pyritic sediment of the estuarine terraces.

When they have a sandy texture, they are responsible for the formation of bare tannes with a crust of aluminium and iron sulphates. They are very acid.

When they have a clayey texture, they are covered with straw (*Pennicetum* sp).

4) Water

a) Temperature

The temperature of the water in the coastal zone varies according to the depth. On the surface, it fluctuates between 20°C and 24°C, at 100 m deep, between 5.4°C and 5.5°C. These surface temperatures constitute an optimal range for the growth of the mangroves.

b) Salinity

Salinity also varies according to depth. On the surface, the recorded salinity varies from 35‰ to 35.4‰, at 100 m depth; it varies from 35.6‰ to 35.7‰, and at 1,000m depth, from 34.7‰ to 34‰. In conclusion, the salinity of the coastal waters of Guinea-Bissau is homogeneous regarding space variation. As for time variation, we can say that the salinity is at its minimum after the rainy season.

The salinity is a determining factor of the richness or the poverty of the mangrove swamp as well for the diversity of the flora as for its constitution. The rainfall is tightly linked to the salinity. The Guinean-Bissau mangrove swamps are less affected by drought than the other sahelian regions.

The salinity that is favourable to all the species varies from 5‰. to 20‰. From 40‰ to 80‰, there is degradation of the mangrove swamp, and from 90‰ and above, the "tannes" process starts. In total, in Guinea-Bissau, there is no matter for concern because the salinity varies from 34‰ to 36‰.

4 Biological and Ecological Characteristics

Ecological functions:

The biological and ecological value of the mangrove swamp forests goes beyond the borders of the country.

1 - They have a real importance for the transafrican migration of many birds. In fact they constitute an important genetic reserve.
2 - They contribute to the formation of soils by retaining residues that are taken away by the water run-off.
3 - They filter waters containing residues, and thus, renew the organic matter of the land.
4 - They work as a stabilizing factor of the coast, protecting it from the erosion caused by waves and natural catastrophes (hurricanes, typhoons, tidal waves).
5 - They are essential for the production of silt in depth and sand layers. Birds depend on these habitats.
6 - They stabilize and protect ricefields.
7 - They supply food to fishes and shellfishes at the same time they serve as nursery-grounds.
8 - They play an important role in biological production of the Guinea-Bissau and the Senegalese coasts.

Flora and vegetation

The most frequent species in the mangrove swamp of Guinea-Bissau are:

- The Rhizophoraceae (*Rhizophora harrisonii, R. mangle* and *R. racemosa*)
- The Verbenaceae (*Avicennia africana*)
- The Combretaceae (*Laguncularia racemosa,* and *Conocarpus erectus*)

The herbaceous "tannes" are covered with the main halophyte species, *Sesuvium portulacastrum* and the bare tannes are deprived of vegetation owing to the excess of salt and the degree of acidity.

The associated vegetation fringing the mangrove swamp is composed of the following species:

- *Conocarpus erectus*
- *Hibiscus tiliaceus*
- *Phoenix reclinata*

Fauna

The Fauna which dwells in this rich and diversified habitat is composed of the following species:

- *Tragelaphus scriptus scriptus*
- *Cercopitecus aethiops*
- *Trichechus senegalensis*
- *Hippopotamus amphibius*
- *Crocodilus niloticus*
- *Mellirora capensis*
- *Tragelaphus spekei*
- *Sousa teuszii*
- *Herpestes paludinosus*
- *Crouta crouta*

The avifauna alone is represented by 125 species, among the most important are:

- *Tringa nebularia*
- *Phalocrocorax carbo lucidus*
- *Streptopelia semitorquata*
- *Egretta alba*
- *Egretta gularis*
- *Halcyon leucocephala*

The *Rhizophora* and the *Avicennia* do not bear fruits eaten by birds. Food, at the tree top, are only insects and on the ground, crabs (mainly *Uca tangeri*) and the "saltão" *Periophthalmus papilio.* The macrobenthos is probably neither rich nor diversified owing to the anaerobic conditions of the soils. In rivers, food consists of fishes, shrimps and insects.

The mangrove swamps are important also because they serve as shelter (during the night at flood tide) and places for nesting.

Formation layout, structure and succession

The distribution in space of species and the structure of the mangrove forests are determined by the variation in the topography, in the sediments and the seasonal fresh and salt waters fluxes. These latter can be modified artificially with important consequences. After the sedimentation, *Rhizophora* is the species that colonizes the lower lands that can be easily reached by the tides and where there is a slow sedimentation. *Rhizophora racemosa* comes first and it appears rarely in a pure stand stock.

In the alluvial deposits or in areas with a rapid sedimentation, the flora grows with the dominance of *Avicennia,* given the fact that the pneumatophores require a maximum oxygen and prefer the less flooded lands. In its general aspect there is a very well separated layout with *Rhizophora* occupying a narrow strip of the coastal fringe and reaching a height of 15 to 20 m. This strip of *Rhizophora* is then replaced by a larger strip of *Avicennia* of 6 m high and a level of 1 m on the forest borders. Toward the highlands the *Avicennia* forests are then replaced by the tannes. *Laguncularia* with its less imposing morphology, settle in the silts. It is then replaced by *Rhizophora* and in the rear formations by the *Avicennia.*

Rhizophora and *Laguncularia* can also be met jointly less frequently, in the intertidal zone, generally below the level of flood tide.

R. harrisonii and *R. mangle* are found together in the open forest of *Avicennia,* and sometimes associated to *R. racemosa.*

5 Traditional Uses

Among the numerous ethnic groups living in the coastal zone (about 60% of the total population), three have a close relationship with the mangroves:

- Balanta
- Felupe (Baiote)
- Papel.

They have kept for centuries a form of traditional use of the mangroves which goes from the rice-growing to the exploitation of some products that are daily consumed. These foods constitute the main protein source (90%) in the coastal villages. The main products are:

- "Cacre" (Ocypodidae)
- "Carangis" (Portunidae)
- "Camarao" (Penaeidae)

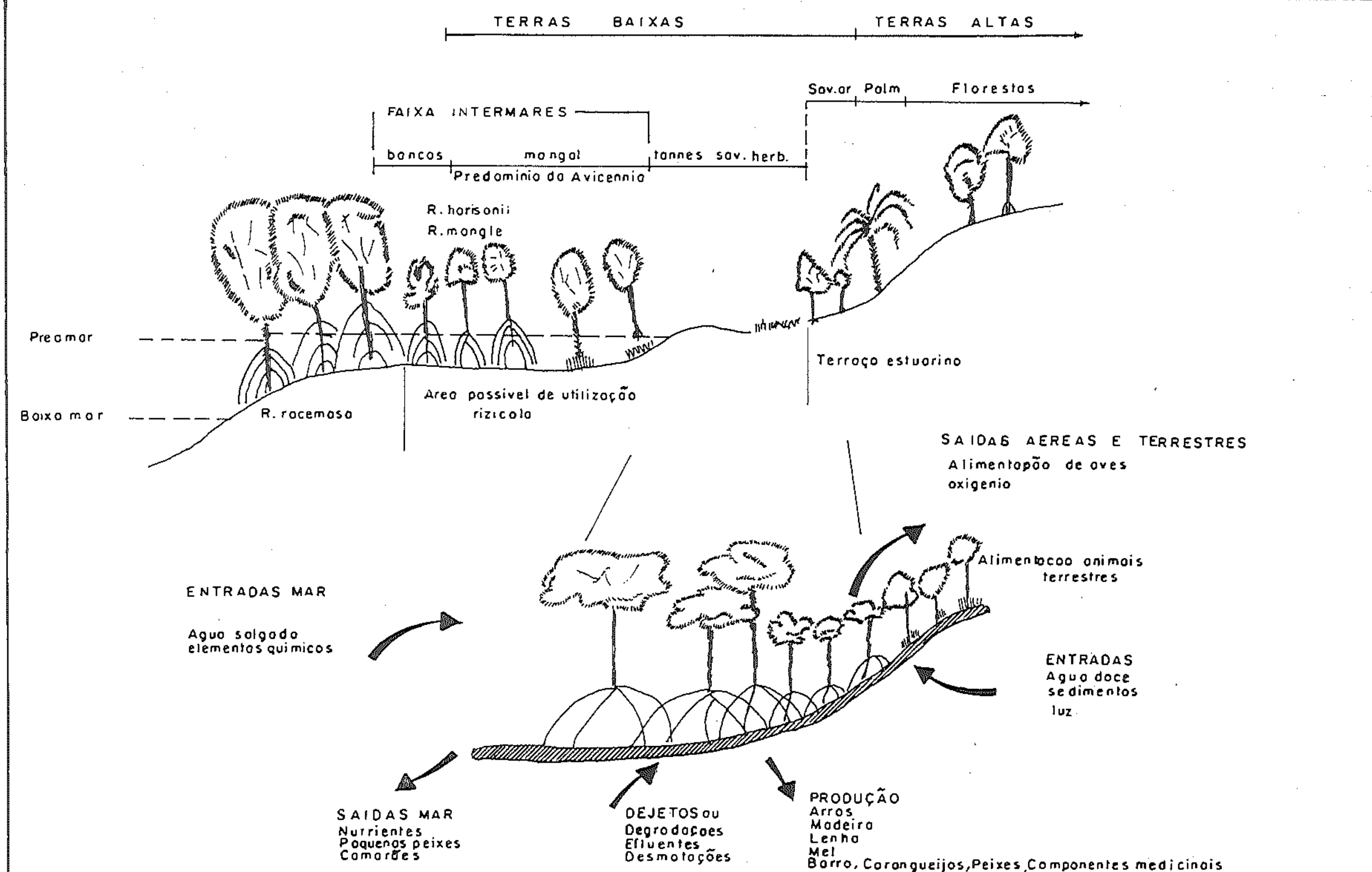

Fig. 4. Sea side end and land side end of the mangroves

- "Ostra" (Ostraeidae)
- "Lingrao" (Solinidae)
- "Combe" (*Anadara senilis*)

For the fishes, the products are:

- "Tainha" (Polynemidae)
- "Bentana" (Cichlidae)
- "Barbo" (Polynemidae)
- "Bagre" (Ariidae)
- "Curvina" (Sciaenidae)

It is from the mangrove swamp too that they get supplies in firewood, timber and wood for construction, fruits of *Avicennia* as food and roots of *Avicennia* as medicine.

The ethnic groups, Balanta and Felupe, are specialized in the mangrove swamp rice-growing. Women and sometimes men practice subsistence fishing (fish and shellfish).

The Papels are typical fishermen for subsistence and marketing. The other ethnic groups living on the coastal zone maintain a less close relationship with the mangrove, but somehow use or work on its products.

In conclusion we can say that the sand layers and the intertidal zones of the littoral are intensively exploited by the local population mainly during ebb-tide.

6 Conversions and Use

Formerly the mangroves spread on 4,760 km² (476,000 ha), now there remains only 2,484 km² (248,400 ha in 1990), rice-growing being the main activity that erodes this fragile ecosystem, followed by the tannes process, the expansion of towns, ports and road building. In accordance with the most recent data, the rapidity of clearing of the mangroves is drastically increasing (from 1953 to 1976, it was 2,000 ha/year and between 1977 to 1990 it went up to 3,830 ha/year).

Agriculture

The most important loss in surface of the mangrove is due to rice-growing. This activity could be accepted with some reserve if in compensation we could notice an increase in production and productivity of rice, the basic food of Guinean people. But it is unfortunately not the case. For many reasons (the liberation war, the sahelization, the evolution from a traditional to a free market economy, the government policy of the prices and the rural exodus of young people), Guinea-Bissau is a great rice-importing country whereas it should have been for a long time self-sufficient (or even exporting).

In 1978, nearly 50% of the ricefields in the N-W of the country were abandoned and in many regions we can notice a resettlement of the mangrove swamp.

The clearing of the mangroves for rice production very often abutts to a transformation into tannes. In the South and the Centre, the anti-salt dams construction have led to the creation of vast acidified areas. In 1953, the total surface of ricefields in Guinea-Bissau was 124,770 ha. In 1976, the surface of ricefields reached 170,600 ha.

7 Impact on the Mangrove Ecosystem

In the littoral zone of Guinea-Bissau, the problems of degradation are not yet significant; however we can notice some manifestations of degradation as a result of human or natural factors:

a) Natural factors such as:
- decrease in the rainfall and salinity increase
- sand and silt sedimentation.

b) Human factors such as:
- road building (São Vicente)
- anarchic woods exploitation (São Domingo)
- rice-growing in all the coastal zone.

The consequences caused by these factors are:

- coastal erosion
- dwindling of the sea production
- reduction of the vegetation
- restriction to numerous products (for the construction, fuel, food and medicine).

8 Research Programmes

The coastal planning project has settled and begun many research programmes:

- Implementation of the National Park dos Tarrafes (mangrove swamps) of Rio Cacheu
- monitoring of the mangroves of Rio Cacheu
- preservation and rational management of the mangrove swamps: to quantify the use of the resources and their economic values, to measure the evolution and the causes of the regression and to propose a national legislation for the regulation of their use.

- training at an institutional level of the EPEEC (the Pluridisciplinary team of the coastal systems study).

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Mangroves of Guinea

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Introduction

This report on the mangroves of Guinea is a synthesis of works realized in parallel at CERESCOR, at the National Forestry Commission and at the University of Conakry. The studies on the Guinean mangrove swamps were achieved at the beginning of the 1950s. Since the 1980s, there has been a revival of research in that domain in the institutions mentioned.

However there are domains where the studies are at the start, for this reason, some sections suggested by the ISME (International Society of Mangrove Ecosystem) are not treated in this report. Nevertheless, we believe that what has been realized in Guinea (the essential part of which is treated in this report) is of interest and deserves to be presented to this workshop.

1. Historical Background

In the rural areas of the tropical zone, populations use local forest resources to satisfy their needs of ligneous fuel and timber for constructions. Generally, wood is channelled through self supplying circuits, but when the density of the population grows, as a corollary wood resources become scarce. There is then a progressive evolution toward the circuits of commercialization fairly well structured. The population that dwells in the mangrove swamps (villages or temporary camps) extracts from the woodland their domestic needs: firewood and wood for the construction of houses and fences.

Peasants often clear the mangrove swamps for rice-growing; the most advanced method is the Bagata, the rice is grown in furrows with the erection of small dikes that play the role of polders. Started just after World War II, the massive conversion of *Avicennia* monospecific mangrove swamps was also motivated by the faint risk of acidification of the soils developed under this species. However, the alternation of silting and drying up phases of the littoral according to seasons, is a phenomenon that disturbs the hydrologic function of the polder and reveals the unsafe character of this kind of conversion. The potential productivity of the soils remains high, the big polders on the sea front are virtually the rice barns of lower Guinea. Their real contribution to the rice production can be appreciated in accordance with the consistency of their hydroagricultural options, with the local morphodynamic evolution.

The exploitation of mangrove wood for diverse uses, mainly for cooking, for smoking of fish, for the extraction of salt in the dry season and for fishing are all traditional activities usually practised in the mangrove swamps of Guinea. These activities reduce considerably the rural exodus to the urban centres. The fishermen's camps are numerous along the coast and they are more particularly located inland along the channels. These camps bring considerable pressure on forest resources with some local situations of over-exploitation; for example, Dekhonri village has already exhausted the wood stock on the Kaback island and people are now moving to the other side of the river mouth on the island of Tannah. In the areas between Conakry and Boffa, the action of Man against the environment (agriculture, fishing, high density of human population) is so strong that salt farms (which have been active for a long time) have many problems of wood supply, the exploitation of wood plays havoc on the stock of *Avicennia* to such an extent that they can hardly regenerate.

The rice growing development projects, the absence of integrated management despite the high biological possibilities, the regression of the shoreline owing to mistakes or accidents lead to a very considerable reduction of the mangrove swamps surface. The reduction of the space and quality of the Guinean mangrove swamps is a matter of great concern.

In this framework a study has been made; the main goal is the elaboration of a management programme of the Guinean mangrove swamp (SDAM 1989, National Forestry Direction). After a study of the present situation, it forecasts the possible evolution of the natural environment and the socio-economic conditions, the study proposes management and exploitation strategies of the resources on a sustainable basis.

The objectives of SDAM is the search for an acceptable compromise between the necessary development of the Guinean coast through the mobilisation of its resources and the preservation of the most fragile areas.

2. Mangrove Ecosystem: Extent and Distribution

The mangroves are located all along the Guinean Atlantic shore. That is 300 km long, not including the secondary ranges of dolerite of Cape Koundinde (or Cape Vergas), and the central part of the peninsula of Kaloum whose dunite geologic bedrock dates from the Mesozoic. The total surface of the mangrove swamp is roughly 385.000 hectares.

The subsidence of the Guinean littoral favoured alluvial deposits and the flooding of the coastal river mouths. The tide often goes far upstream and creates a lot of rias. The main rias are : Rio Koumponi or Kandiafara (River Cogon); Rio Nunez (River Tinguilinka); Rio Kapatchez (River Kataca); Rio Pongo (Rivers Fatala, Konkoure, Soumbaya, Morebaya); Rio Forecariah (River Mellacoree). The mangroves stretch along the valleys of these rias as well as on bay areas such as those of Sangareah; muddy areas and islands like Tristao, Binari, Couffing, insular zones between Rio Pongo and Wassa-Wassa in Boffa; islands like Quito, Marara, Konebombo, Kakossa, Kaback, Tannah. In the Kaloum peninsula, the muddy shorelines of the Conakry North and South cliffs are occupied by mangroves, particularly abundant in the sector between Gbessia airport and the Soumbouya river (A.G. Diallo, unpublished).

The mangrove swamp spreads everywhere on about 10 km inland and sometimes extends for 40 km along the most important rivers. *Rhizophora* spp. occupy the low plains which are everyday submerged by the tide. They constitute, alone or associated with *Avicennia africana*, the mangrove swamp of the silty plain of the Guinean Coast. On the same coast, it can be found dwarfed, spare, composed of *Avicennia* and *Laguncularia*, on rocky areas (ferruginous crust more or less disassociated).

The diverse physiognomic and floristic types of the mangrove swamps are distributed according to the environmental conditions. In some cases, communities are divided into zones.

In the Conakry region, the ferruginous duricrust sometimes leans gently toward the sea. Bared in contact with the dryland, it covers up, toward the open sea with a layer of silt the thickness of which increases as we move away from the coast. In such a station near Conakry the following zonations division is observed (from the dryland to the open sea).

1) *Ipomoea pes-caprae* zone
2) *Sesuvium portulacastrum* prairies
3) *Avicennia* zone
4) *Rhizophora* zone (with some *Avicennia*).

On the subhorizontal soil in a bay of the river Forecariah, from dryland toward the open-sea there is:

1) *Drepanocarpus lunatus* and *Cyperus articulatus* zone
2) *Drepanocarpus*, *Avicennia* and *Rhizophora* zone
3) *Rhizophora* zone

Where the transverse profile of the sea arms and the coastal streams is relatively unchanging, *Rhizophora* are generally located on the shore of the channel and the white mangroves in the background. Where the profile is asymmetrical, we note a preferential localization of the red mangroves on the concave shore and *Avicennia* on the convex shore.

3. Physical Environment

3.1 Climate

The Guinean littoral climate is characterized by important rainfall (about 4,500 mm) in a rainy season of 6 to 7 months (May to November). The annual averages of temperature vary, for the maxima from 27°C in August to 32°C in March whereas the minima are steady around 23°C (Fig. 1). The tides in Guinea are of the diurnal type; the tidal range is 4 m in Conakry, the amplitudes are 3.70m in spring tides and 1 m in neap tides.

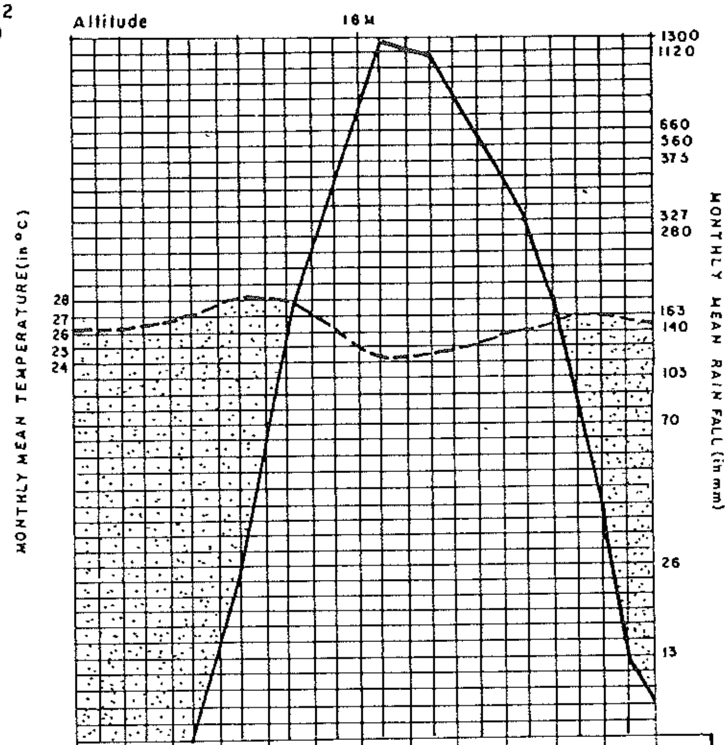
3.2 Soils

The mangrove swamp soils constitute a strip of about 10 km situated along the Guinean coast between the ocean and the continental lands. These soils were formed by recent marine sediments characterized by accumulation, more particularly at the level of mangrove roots, of iron sulphide. They contain large quantities of fibrous peat and are characterized by a very high potential acidity and problems of salinity owing to a well marked dry season.

3.3 Waters

In the Guinean region, there is a large-scale system of superficial and sub surface marine waters

CONAKRY
Longitude 13°42
Latitude 9° 30



	J	F	M	A	M	J	J	A	S	O	N	D	1 an
	1	1	5	25	155	487	1250	1109	660	318	102	12	4125
Number of rainy days	1	1	1	2	11	23	28	28	26	20	8	1	150
Mean temperature °C .	262	26.6	27.0	27.7	27.5	25.2	21.5	24.9	25.4	26.0	26.8	26.6	26.3
Minimum °C	15.4	12.2	17.2	18.5	17.2	18.2	19.2	19.4	18.6	16.4	17.8	17.9	15.4
Maximum °C	31.5	35.4	34.9	34.8	35.3	33.2	31.5	31.0	31.5	33.0	33.6	34.7	36.4
Minima mean °C	21.9	22.3	22.7	23.7	28.7	22.8	21.2	22.4	22.4	22.4	23.1	22.7	22.6
Maxima mean	30.5	30.9	31.3	31.7	31.3	29.6	27.9	27.4	28.5	29.7	30.1	30.5	30.0
Relative humidity (in %)	76	73	74	73	78	86	90	92	90	87	85	78	82
Evapotranspiration (mm)	150	155	170	185	180	150	125	130	135	150	160	155	150
Sunlight (in hours)	63	71	83	77	59	41	26	18	37	57	61	52	54
Water deficit in mm	149	154	165	160	25	-	-	-	-	-	58	143	
Winds – Direction	NNW.... NE					SW - W					NNW-NE		
Winds – Speed	4 - 10					20 - 45 55-110					4 - 10		

FIG. 1 - CLIMATIC CARACTERISTICS OF CONAKRY

F. BERTRAND (1988)

circulation (2). The main elements of this system are the North trade winds, the South trade winds, the Canary islands stream, and the inter-trade wind counter-current. In January, the presence of waters from the Canary islands streams in shallow waters, leads to a drop in temperature. In the North-Eastern part, a layer of a relatively warm water from the inter-trade wind counter-current is formed.

In November there generally is all over the shelf an anticyclonic circulation. In a vertical plan, the circulation causes the transport of heat and salt as well as of biogenic elements.

The prominent upwelling of the period from January to May weakens from June to November. The values of the vertical ascent are estimated at 10^{-2} or 10^{-4} cm/s. According to the data (2) the Temperature-Salinity index of the water masses vary in the region.

From North to South, the temperature and the salinity of the North trade wind waters vary respectively from 25.2°C to 27°C and from 34.73 to 34.78‰ whereas the South trade wind waters, vary from 27°C - 28.5°C and 35.71 - 35.80‰ salinity.

The North Eastern part of the littoral is under the influence of river inputs. The temperature and the salinity in this area are low (22.4°C - 25.5°C and 34.6‰).

In Tabounsou bay and its surroundings, the nutrients concentrations vary from one season to another in large proportions. For the phosphates, the concentrations vary from 0.08 - 1.35 mg/at/l in the rainy season, to 0.2 to 0.4 mg/at/l in the dry season; for the silicates, the variation goes from 3.4 - 33 in the dry season to 19 - 93 mg-at/l in the rainy season; for the nitrates, this variation is 0.25 to 4.0.

The dissolved oxygen concentration (3.6 to 3.9) in the coastal zone during the rainy season is higher than 4.0 ml/l in the open sea.

The primary production is estimated at 20 to 600 mg C/m^3 with maximum values higher than 800mg C/m^3 at some places.

In the Sangareah bay, the phosphate and silicate concentrations during the dry season vary respectively from 0.20 to 0.50 mg at/l and from 5.0 to 10.0 mg-at/l.

Table 1: Temperature variations in the estuary.

Depth	Temperature	Tide
0 - 5 m	29.5 - 29.54	Flood
"	30.06 - 30.05	"
"	29.88 - 29.90	"
"	29.13 - 28.94	Ebb

Tables 1 and 2 show results of studies carried out in the coastal waters of the Republic of Guinea. The results obtained indicate that the surface temperature increases from December to May. Owing to the weakened advection in that period, the increase of surface temperature is related only to that of the air. In some spots of the estuary, the temperature decreases from May to December. That decrease is dependent of the process of the vertical and horizontal advections. On the front surface, the average temperature is 27.5°C, diminishing down to 25.4°C at 15 m depth.

The analysis of the data given in (8) shows that in May according to the Loos islands - Tabounsou profile, the average increase of the surface temperature is 0.86°C near Loos islands and 0.56°C in the estuary.

The analysis of the vertical distribution of temperature shows that in the estuary we can observe during the flood a quasi-homogeneity of the waters down to 5 m depth. This relative steadiness is disturbed only during ebb tide at the river mouth near to the stations over the shelf. This allows to distinguish different layers.

The analysis of salinity in the month of May shows that in the estuary surface salinity is relatively higher than that of the stations located on the shelf. In some estuarine areas, the values at 10-12 m are lower than those at the surface. This can be explained by the intrusion of lower salinity water by a stream or by the instability of different layers.

Table 2 shows that temperature and salinity values are highest in the month of May.

4. Biological and Ecological Characteristics

4.1 Flora composition

The ligneous plants of the Guinean mangrove swamp belong to seven species (divided into 4

Table 2: Average temperature and salinity in different seasons
(Loos islands-Tabounson profile)

Period	Observation sites	Horizon (m)	Averge Temperature (C)	Average Salinity ‰
Dry Season	Estuary	0	27.4	28.00
		5		28.20
	Loos islands surronndings	0	27.2	21.15
May	Estuary	0	29.5	36.94
		5		>36.50
		0	27.3	>35.60
Rainy season (August)	Estuary	0	27.40	10-15
	Loos Islands surroundings	0	27.20	15-16
		10	27.30	23-00
		15		32-00

families). The Combretaceae are represented by two genera: *Conocarpus* and *Laguncularia* and the Verbenaceae by *Avicennia*. *Banisteria leona* is the only Malpighiaceae. The most widespread taxon are the *Rhizophora*. Some other species often appear in the floristic composition of those mangroves *Drepanocarpus, Dalbergia, Dodonea, Terminalia, Baeria, Sophora, Thespesia*, herbaceous plants (*Paspalum, Sesuvium, Philoxerus, Pycreus, Sporobolus, Ipomoea* and a fern, *Acrostichum*. Altogether there are more than 20 species. Number of these species are susceptible to grow in mangrove areas, but they occur only locally. They are: *Dialium, Anizophyllea, Lonchocarpus, Ximenia*.

4.2 Vegetation

From the physiognomic point of view, the Guinean coast vegetation presents seven formations which are:

a - Exclusive formations, composed of a forest of tall *Rhizophora* with an average of 15 - 20 m height;
b - Exclusive heterogeneous formations: forest formations constituted of juxtaposed small trees (<8m) and tall trees (>15 m). Their relative layout in space precludes a distinct classification;
c - Exclusive small formations: where the smallest size of trees is under 8 m;
d - Small open formations correspond essentially to a degraded phase of the previous formations with the appearance of halophyte lawns;
e - Mosaic formations group together the typical trees of the previous formations grouped together, the tannes and possibly the rice-growing converted zones.
f - Tannes: Uncultivated plant formations deriving from natural or man made degradation, not irreversible, with dwarf mangrove trees and associated lawns.
g - Ricefields : These include,
    - rice-growing polders;
    - traditional ricefields of the sea front;
    - estuary ricefields;
    - open ricefields;
    - rear mangrove swamp shoals;
    - ricefields on colluvium sand;

By analyzing the growth curves of successive leaves of *Laguncularia* annual shoots, we notice a uniformity in the growth curves whereas they look more like one another when the leaves are on the same internode (A. Diallo 1992).

Thus, an annual pause increases continuously but in an irregular way. In the dry season (December - February) the plastochrone and the growth duration increase while the rapidity of the growth and the dimensions of adult leaves decrease. There is on the one hand a positive correlation between the plastochrone and the growth duration on the other hand. In contrast, the rapidity and the growth duration are in negative correlation (Fig 2).

The trees of the mangrove swamp are characterized by an average transpiration. The minimal transpiration (about 3 mg/cm²/hour) concerns *Dalbergia* and *Canavalia*, whereas the highest transpiration rate (20 mg/cm²/hour is that of herbaceous species:

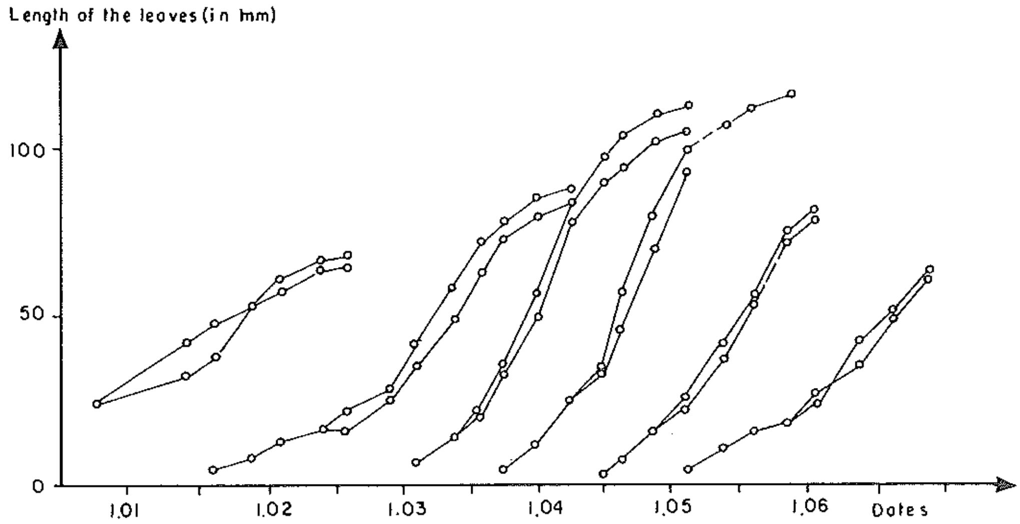


FIG. 2 - SUCCESSIVE LEAVES GROWTH OF ONE ANNUAL LAGUNCULARIA RACEMOSA SPROUT

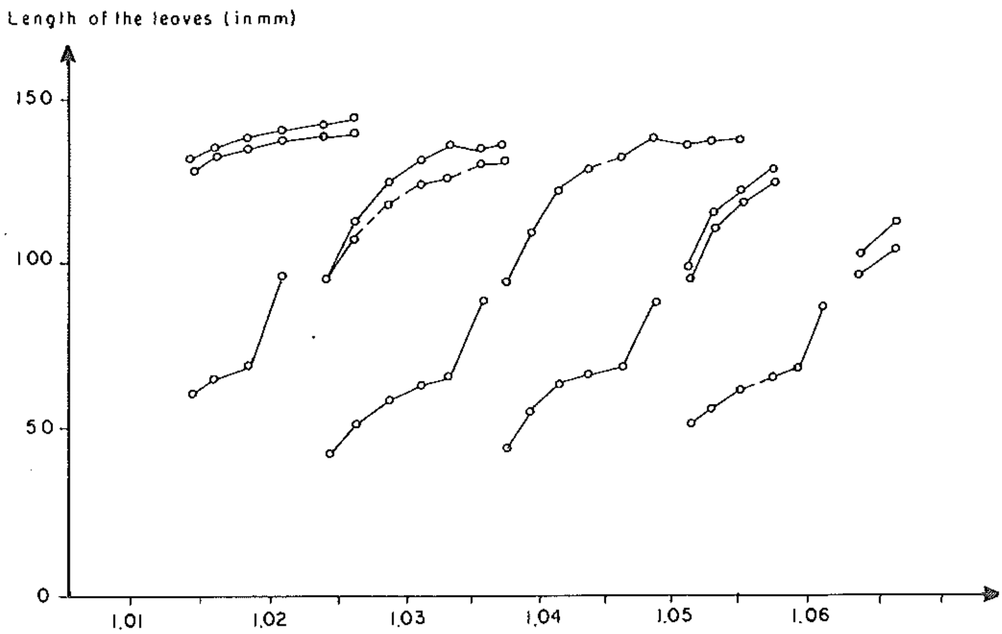


FIG. 3 - SUCCESSIVE LEAVES GROWTH OF ONE ANNUAL RHIZOPHORA MANGLE SPROUT

Table 3: Spatial variability of the estuarine zooplankton; May 1989.

No Station	Depth (m)	Total Number of species	Quantity per group					Dominant Sizes
			Cope poda	Cala noida	Cyclo poida	Harpac ticoida	Miscellan eous	
32	4.5	28	12	6	2	5	16	0.3-0.5 0.5-0.7 0.3-0.5
29	17	27	10	5	4	1	17	0.5-0.7 0.2-0.3
26	12	20	9	4	3	2	11	0.5-0.7 0.3-0.5
20	20	31	11	7	2	2	20	0.5-0.7 0.1-0.2
14	16	30	12	6	3	3	18	0.3-0.5 0.2-0.3 0.3-0.5
11	7	26	13	5	4	4	13	0.5-0.7 0.2-0.3 0.5-0.7
10	4	6	5	2	2	1	1	0.3-0.5 0.2-0.3
9	4	21	10	4	4	2	11	0.5-0.7 0.3-0.5 0.1-0.2
8	5	29	13	6	4	3	15	0.5-0.7 0.3-0.5
7	8	38	17	5	5	7	21	0.5-0.7 0.3-0.5
6	16	53	23	7	6	10	30	0.5-0.7 0.3-0.5
5	18	31	15	6	4	5	18	0.7-1 0.3-0.5
4	17	49	16	7	3	6	23	0.7-1

and *Canavalia*, whereas the highest transpiration rate (20 mg/cm^2/hour is that of herbaceous species: *Philoxerus, Sporobolus*.

5. Animal Resources

Knowledge of the fauna of the Guinean mangrove swamps is succint. The species list is well known, at least for the land mammals and the reptiles; but it is mainly the distribution in space, the numbers, and the movements of the individuals that are still poorly known. The Guinean humid zones, added to those of Guinea-Bissao are of an international importance from the ornithological point of view. There also is neither a complete inventory of species nor an evaluation of the total number of individuals. At most about 350.000 paleartic limicols are known to winter on the Guinean littoral, just like thousands other water birds. It must be emphasized that the rice fields are of a great interest to the birds. Each year, thousands of migratory paleartic species winter in the Guinean ricefields. Peasants suffer a lot from the damages caused by grain eating passerines, but other birds can be useful against crabs: (sandpiper, curlew.)

5.1 Zooplankton

The analysis of the taxonomic composition and abundance in the Tabounsou area shows that the composition estimated at 20 - 54 species at each station, increases gradually from the river mouth, it reaches the maximum (54 species) towards Loos islands.

5.2 Ichtyoplankton

The spatial distribution of the species composition is heterogenous in the bay. The analysis of their vertical distribution reveals a difference in the daily habitat of species. *Sorogobius schlegelii* is cosmopolitan. Tabounsou bay is a zone of intense anadromic and catadromic activity of juveniles migration. The results of ichthyological studies during the two seasons of 1989 shows the presence of five fish species grouped together in three families (Sciaenidae, Mugilidae, Clupeidae) in July and two species grouped in two families (Mugilidae and Clupeidae) in May.

Researches carried out in 1992 by Tamoikin in the tidal influence zone during the dry season in Konkouré and in the Loos islands, allowed to collect specimens of 26 fish families which belong to different ecological groups. The interaction of these planktonic communities within the mangrove ecosystem is summed up in the diagram.

6. Human Habitat and Traditional Use

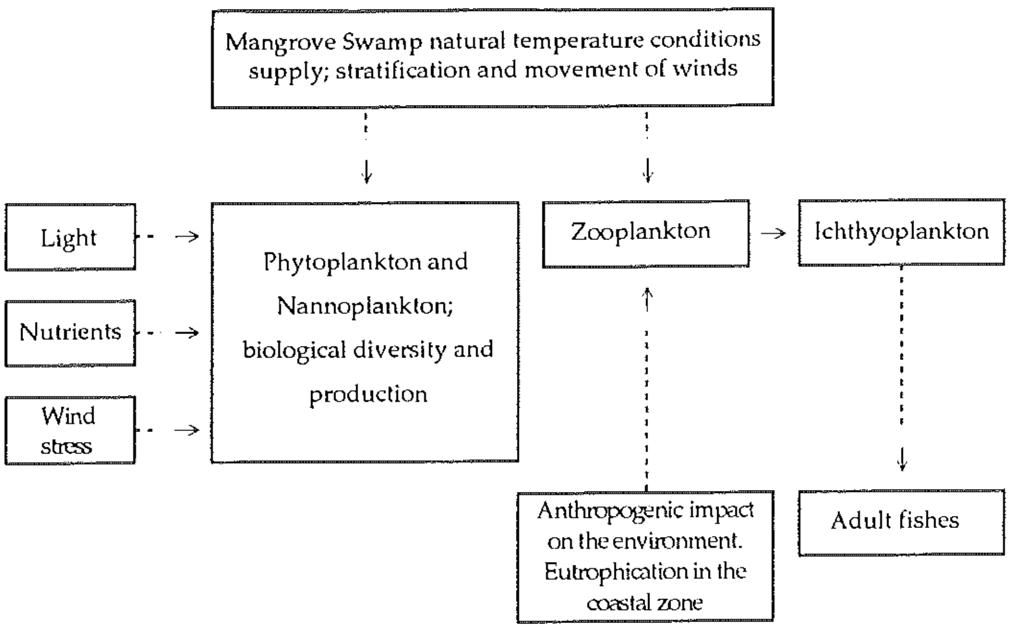
The Guinean coastal population is relatively dense but unequally distributed. The villages are located on the beach ridges, some distance away from the inner reach of spring tides and on dry lands behind the mangrove.

The conversions made of the system are mainly of a traditional type. They have many interesting aspects and it is advisable to examine the most important ones.

Rice-growing is the main purpose of conversion practised in the coastal zone of Guinea. Conversion consists essentially in the construction of anti-salt dikes which prevent the sea to spread over large surfaces of cultivable land. On the landward end, an opening of the barrier permits to recover rainwater through a canalization system. Traditional pisciculture is developed in the canals. The period following rice harvest gives the fishermen an opportunity to practise fruitfull fishing. In fact, the place contains a lot of carps and silurides.

In the zones located in Northern Guinea (Boffa, Boke), open spaces become pasture land intended for cattle during the rest of the dry season. Owing to the hydromorphy of the zone, cattle raisers make drinking holes at the same place.

In the South, we can see smaller conversions in the shoals adjacent to the drying river beds. The



Simplified diagram on the functioning of the planktonic communities in the tidal influence zone within the mangrove ecosystem.

zone is also favourable for rice-growing, banana and pineapple.

In all the coastal zone, the multiplication of fields has important drawbacks for the mangrove swamps. Its wood is used for timber and for cooking. As for the cattle, they are concerned with a settling process, thanks to the presence of open land, and drinking holes. The mangrove favours traditional fishing. Small harbours are created there to the detriment of the mangrove areas. Mangrove oysters are also collected. The extraction of salt is an activity that favours more exchange between the mangrove villages and the urban centers. This activity is practised to the detriment of the mangrove because boiling seawater requires the use of wood; and the urban centers are also supplied preferably with *Rhizophora* wood.

7. Commercial Exploitation

The places where wood is marketed are rare. They first appear near fish smoking centres when villages become larger and people go farther and farther to seek wood.

In the surroundings of Conakry, the exploitation and marketing of wood have become very important. Commerce is centered at least, on two ports and marketing places : Dixin Port in Conakry and Dubreka, 45 km from the capital. Wood is sold to the skilled dealers of the town, or to firewood retailers in the districts.

Salt extraction is a seasonal activity : It is practised on abandoned rice fields ; sometimes by rotation of plots. The salt is kept in bags and dispatched to Conakry.

Traditional fishing is intensive in the Guinean coastal regions. But it is more developed in the North of Conakry (Kamsar, Taboria). Smoked fish is sold all over Guinea. During 1990, a study of oyster markets was carried out. From this study sampling was organized. The results show that the oysters respond to the requirements of the market.

8. Conversion to Other Uses

Rice-growing and fishing are the main economic activities in Lower Guinea. They are practised along the coast or in the plains that are liable to flooding or in cleared mangrove swamps.

In the 390,000 ha of salty tidal water, potentially occupied by the mangroves, 78,000 ha have been more or less converted into ricefields. Only 40% of converted lands are effectively productive. The largest perimeters are found (from North to South) along Rio Kapatchez and in the Monchon plain (Tongnifili), towards Taboria, Coyah, on the Kaback and Kakossa islands. But everywhere in the mangrove swamp, along all the rivers and channels and near Conakry, there are ricefields of lesser importance. These latter are located in cleared mangrove swamps that may be covered daily by tides. In the rainy season, the tides push back fresh water that thus overflows on the cleared zones.

Aquaculture is underway in the project located in Koba-Lamodia (shrimp-culture). The first results appear to be technically promising with the prospects of a good market. Possible extensions are being studied on the cleared lands which are occupied by abandoned ricefields. The restoration of these fields being very expensive, aquaculture could be an alternative solution to develop them.

9. Impact on the Mangroves

The pressure of rice-growing activities on the mangroves is locally important. Thus, the major part of the land on the border of the Monchon plain has been cleared. The same goes for Kaback and Kakossa islands where the mangroves are found only along the channels. On the borderline of the rivers Forecariah and Farmoreah, the mangrove survives as a discontinuous belt a few meters wide; most of the mangrove trees are in a pitiful state or dead. The erosion on the concave banks of these rivers is intensive. The shore on the West side of the Kaback island is regressing and has now reached the first beach ridges which are occupied, at some places by villages (Fig. 4).

There is no mining and no sand quarrying in the mangrove. Drillings have been made near Kanfarande to evaluate the content in pyrite. However important that may be, no exploitation is planned for the time being. Extraction of bauxite in Fria has been for a long time the cause of the pollution on the river Konkoure and the mangrove swamp located downstream. Owing to the modification introduced in the processing of the bauxite by acid, pollution seems to have receeded and vegetation has started growing on the river banks. However the consequences of pollution, are still visible: the river bed is hollowed by very large pits and craters.

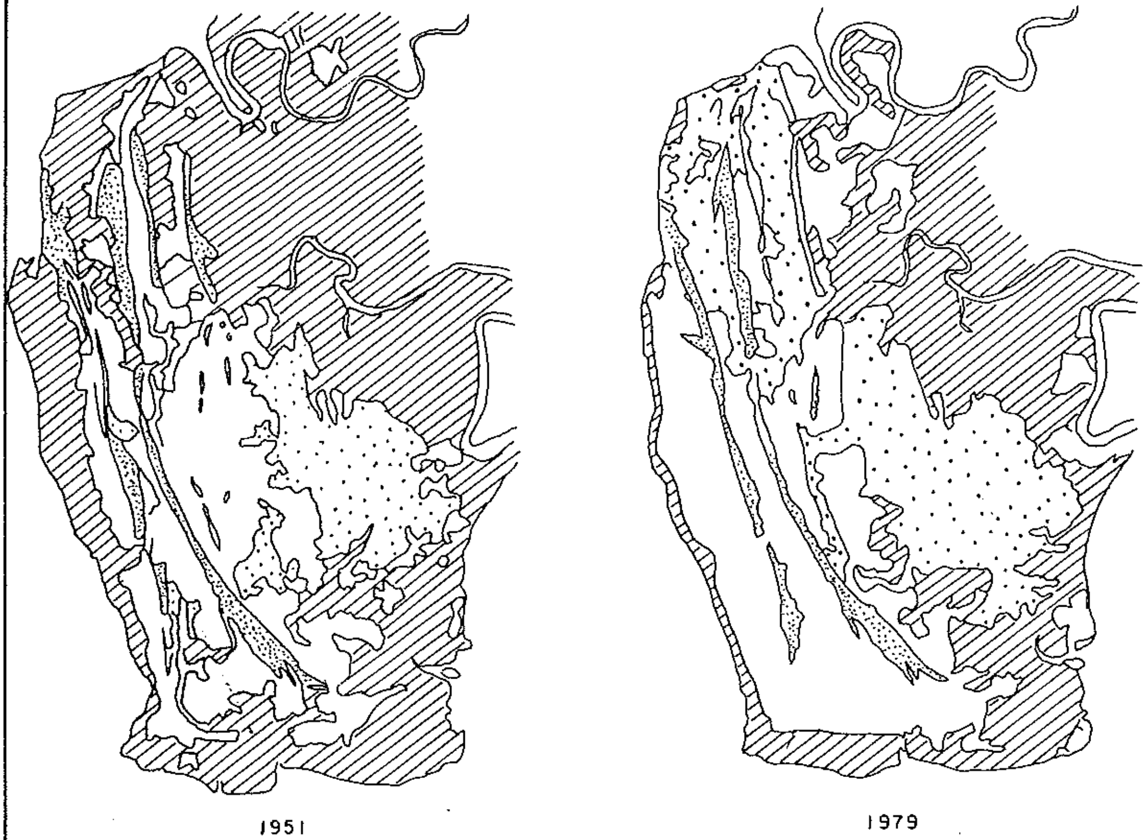


FIG. 4 - RICE FIELDS EVOLUTION OF "KABACK ISLAND"

0 1,2km

Mangrove

Degraded mangroves, salt exploitation areas, abandoned rice fields

Rice fields

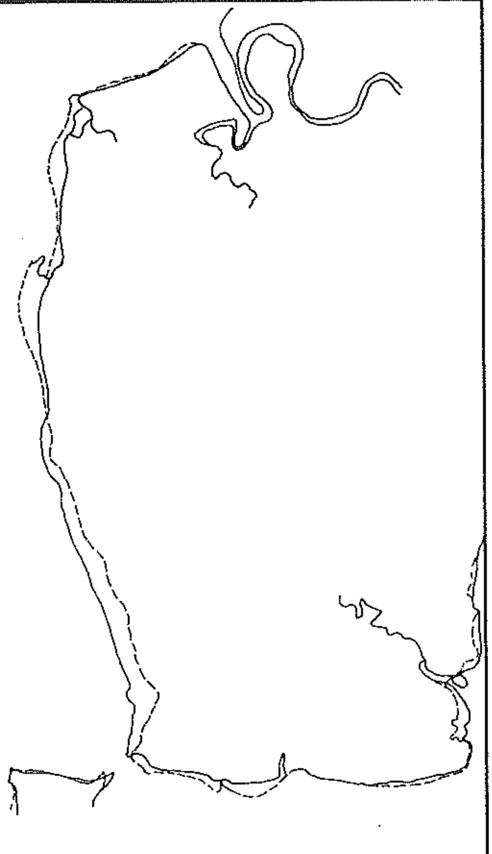
Sandy beach ridges

COASTLINE EVOLUTION OF KABACK ISLAND

0 1,2km

------ Coastline in 1951

——— Coastline in 1979



Lastly, it would be interesting to examine the effects of pollution caused by the emission of dust in the zones near the crushing factory of the "C.B.G/Kamsar" and the port of Conakry where pollution by hydrocarbon was reported to occur.

According to photographic documents, nearly 140,000 ha of mangrove swamp were formerly converted into ricefields. Now, only 78,000 ha remain. Of the 62,000 ha that have been abandoned, 27,000 ha are recolonized by shrubs that are not very productive. But almost 35,000 ha are remaining definitely barren (resulting from acidity, toxicity of soils, oversalinity); they are covered by a poor lawn of halophytes, when the soil is not completely bare.

10. Research Programmes

Today in Guinea, there are two projects, specialized for the study of mangrove swamps:

1) The project on "Coastal studies" started in 1987, results of which have been discussed at the national and sub-regional levels, and.
2) The pilot project of mangrove swamp management in the Sangareah bay, initiated by the National Forest Commission for 18 months.

At the same time, CERESCOR and the university of Conakry started studies of the Guinean mangroves. These studies focus on the biology, the ecology, the sedimentology, the pedology of different species. However, it must be noticed that Guinea lacks co-ordination in the field of mangrove research, despite its faunistic and ornithologic richness.

Therefore, in order to ensure a better follow up, it would be desirable to set up a functional structure that would mobilize all the research efforts undertaken in that domain.

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Mangroves of Sierra Leone

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1. Historical Background

Mangrove woodlands in Sierra Leone occupy 47% of the coastline, covering a total area of 171,600 ha (Chong, 1979). The environmental role of this natural resource includes coastal barriers in storm protection, flood and erosion control and habitat nursery ground for fish, shrimps and other marine fauna. The productive areas in Sierra Leone at present include the area North of the Great Scarcies River, and in the Yawri Bay and the Sherbro River estuary. The rich mangrove forests of Sierra Leone have since long been exploited by the local population of the coastal areas whose main occupation is fishing. The mangrove forest and trees had been used basically for fish smoking which is an indigenous traditional way of preserving fish caught for sale, and also as an important source of fuelwood.

In recent times, fuelwood has played a very significant role in Sierra Leone exacerbated by the recent (for the past 10 years or so) energy crisis in the country. Both electricity and fossil fuel energy had been in short supply which led to the majority of the population even the so called elites turning to the forest (which was formally predominantly exploited by rural and coastal dwellers) for fuelwood. Domestic energy accounts for about 85% of total energy consumption. For urban families, fuelwood supplies 80% - 87% of household requirements. The mangrove wood had in the past been utilised particularly by rural and coastal dwellers for house building. Up to present day the mangroves are being used for this purpose and the demand has increased due to the rising price of manufactured building materials.

At present the uses to which this resource is put is diversified, for example it is also being used as beverages and medicines. Our knowledge of the resource has improved including the mechanism by which it propagates, the peculiarity of its habitat and the usefulness of this resource.

The rate of exploitation of mangroves in recent times has been alarming due to a number of factors; the coastal population has dramatically increased, poor economic performance of the country and lack of alternative fuel sources are but a few. Investigations have shown that if the present rate of exploitation is not abated, the resource will collapse. Indiscriminate over-exploitation especially in the coastal areas of Freetown has led to the destruction of wild life, nursery ground for juvenile fish, prawns, shrimps, crabs and to the siltation of estuaries and streams as a result of increased tidal action on bare mudflats.

Recent investigation has given us a better perception of the role the mangrove resource plays not only as a natural protective coastal structure but also for its biological role in providing a favorable environment for varied species of plants and animals. It is in this perspective that steps towards proper development management and sustainable use of the resource has been taken by the government in collaboration with international agencies such as the UNDP.

2. Mangrove Ecosystem

2.1 Extent and distribution

Sierra Leone has a total coastline length of about 500 km of which 47% are covered by mangroves which form a substantial area of the general estuarine swamps occupying an area of about 2,337 km^2 (FAO, 1979). In Sierra Leone the mangroves are concentrated in four major locations. These include those found around the Scarcies Rivers, the Sierra Leone River, Yawri Bay and Sherbro River (Fig. 1). These are concentrated along the fringes of Mahel, Sasiyek and Kambiadi Creeks. Limited mangrove stands can be found in Yelibuya Island.

Around the Sierra Leone River estuary and the Bunce River, an extensive fringe of shrubby mangroves can be found. Along Yawri Bay, the mangroves occur as a coastal belt of varying width, stretching from Tombo to Shenge. The mangroves are denser in the estuarine plains of the three main rivers, namely Ribi, Kukul and Kargboro Creeks.

In the Sherbro River, the mangrove vegetation has colonised large areas of the tidal swamps North of Sherbro Island. This belt is indented in several places by the Thuaka, Tetibul, Bagru, Moteva, Tese

FIG. I- MAP SHOWING MANGROVE SWAMP AREA

KEY

(1) YAWRI BAY

(2) SIERRA LEONE RIVER ESTUARY

(3) SCARCIES RIVER

(4) SHERBRO RIVER ESTURY

(5) FREETOWN

and Jong Rivers. Commercial stands of mangrove are also located at Rongotok, Gbangbaia, Kanga, the upper reaches of Moteva and Titibul Creeks. Mangroves are also found in Turners Peninsula.

The total area of mangrove vegetation amounts to about 838 km² (FAO, 1979). This can be seen from the table given below which shows the distribution of mangroves in four principal areas.

Table 1: Distribution of forest areas in Sierra Leone.

Types	ha
Closed high forest	365,200
Secondary forest	261,000
Forest regrowth	3,774,400
Savanna	1,619,200
Mangroves	283,761
Total	6,303,561

Source (FAO) Field document N°1

The productive mangroves are located mainly in Yawri Bay and Sherbro River area within the coastal districts of Moyamba and Bonthe. The chiefdoms with significant areas of mangroves are given in the table below.

3. Physical Environment

3.1 Climate

The physical environment within which the mangroves of Sierra Leone are found lies within the tropical coast of West Africa, in the inter-tropical or trade wind zone which extends from 30°N to 20°S, where the distinction between winter and summer is of little significance. There is however, usually a well marked alternation of wet and dry seasons, particularly in the region of the doldrums. On the whole, rains occur one or two months after the sun has reached its zenithal position, except where the monsoonal regime is well developed.

Sierra Leone experiences a well marked alternation of wet and dry season. The wet or rainy season lasts usually from May to November, whilst the dry season usually lasts from December to April. Also two squall periods are recognised; May - June and September - October and the monsoon period which is from July - August. In Sierra Leone, it is during the monsoon period that the heaviest rains are experienced. Figure 2 shows the distribution of rainfall throughout a year for a coastal climatic station in Freetown.

Table 2 : Chiefdoms with mangrove resources.

District	Total Mangroves area	Chiefdom	Area (miles²)	Mangroves area (ha)
Port Loko	27,095 ha	Koya	275	Degraded
"	"	Loko Massama	275	-do-
"	"	Maforki	320	-do-
"	"	Kafu Bullom	80	-do-
Moyamba	24,505 ha	Ribbi	205	6.080
"	"	Bumpe	146	2.011
"	"	Kagboro	225	12.056
"	"	Timdel	188	2.500
"	"	Bagruwa	282	5.284
"	"	Banta	280	1.2788
Bonthe		Imperi	156	8.735
"		Jong	150	2.788
"		Bendu-cha	90	
"		Dema	55	
"		Sittia	151	

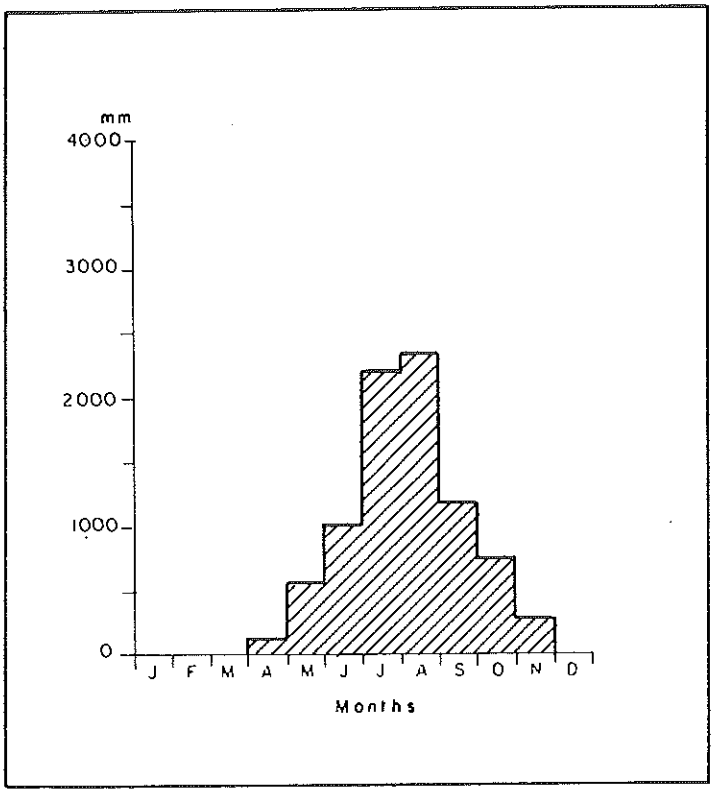

FIG. 2 - ANNUAL DISTRIBUTION OF RAINFALL AT FALCON BRIDGE FREETOWN

From this distribution the main features of rainfall which is characteristic of the country as a whole can be discerned. It is however necessary to note that the coastal areas of Sierra Leone experience more rainfall than the rest of the country, due to the relief. During the dry season, the diurnal range of temperature is from 21°C to 32°C becoming rather hot as the season progresses. Winds are mainly from the South-East and East at the beginning of the dry season, backing to North-West later and reaching a maximum intensity in March or April. The mean temperatures are lower in the middle of the rains than at any other times of the year, with a diurnal range of about 22°C to 28°C. Relative humidity varies between 65% and 90% during the day.

The two principal winds are the Northeast trades and the Southwest monsoon. The former are the prevailing winds of the dry months from December to April and the latter during the rainy season from May to November.

In the interior of most of the mangrove swamps in Sierra Leone, particularly in the Northern part, *Avicennia nitida* tends to become more abundant. This may be due to the fact that this species appears to be more salt tolerant and can grow under very unfavorable conditions.

3.2 Soils

No extensive and intensive soil survey has yet been fully carried out in Sierra Leone though various efforts have been made in particularly localised areas to analyse the soil types of the country. With the exception of those in the swamps and valleys, the soils are found to be light and penetrable. They are acidic, lateritic and low in potassium content. Also characteristic of these soils is the prevalence of lateritic hard pans. Along the river banks, in flood plains and in tidal estuaries are found deposits of rich alluvial soils very suitable for rice cultivation.

The coastal swamp, consist of alternating banks of silt, sand, gravel and clay. Silt is predominant in the North-West. In the South, large areas of coarse sand are alternately water-logged or very dry. The mouth of most rivers are deposited with rich alluvial, saline-clay soils of the mangroves.

The soils of the swamp lands are naturally rich. Thus primarily it is in the swamp areas that permanent cultivation has proved successful.

3.3 Waters

Sierra Leone is endowed with numerous rivers, streams, bays, lagoons and estuaries. The hydrological regime of these bodies of wateris to a great extent influenced by the prevailing climatic conditions and Atlantic coastal waters. Evaporation and evapotranspiration during the dry season consume a great part of the precipitation; in the coastal areas and further inland. The small coastal rivers hardly retain any water during the long dry season which normally lasts for six consecutive months. The medium and large ones show a peak around August-October. Evaporation from the coastal lagoons, swamps and marshes reduces even more the outflow to the sea; and may even become negative, (uncalculated).

The estuaries and coastal waters are tidal and of semi-mixed type with saline water from the Atlantic ocean entering them on a diurnal cycle. The maximum tidal range goes up to 3.3 m at equinoctial springs with the highest spring tides at 3.3 m. Mean high water springs are 2.5m around and mean high water neaps are 2.15 m.

The tides bring in fair quantities of silt from the upper reaches of the estuaries and bays which inundate the coastline and mangroves. Tidal currents or streams have varying velocities ranging from 0.5 - 0.75m/s for flood streams to 1 - 1.25m/s on the ebb for time durations of about 5 hours to 7 hours respectively. In the rainy season, however, when the volume of fresh water discharge increases from the rivers, the ebb attains velocities of 2.5m/s and more. Heavy precipitation during the rainy season and low to absence of precipitation during the dry season is responsible for the strong seasonal fluctuation of salinity in the coastal waters. There is also a tendency towards a two-layered transport system with offshore movement of relatively brackish water compensated for by an onshore counter current of saline water close to the bottom of the larger estuaries.

4. Biological and Ecological Characteristics

4.1 Flora and Vegetation

At the foot of the coastal terraces lie estuarine swamps, resulting from the deposition of silt and clay along the major river channels. The typical vegetation of these swamps, which are under the influence of tides is mangroves. They are also found in the lagoons which are associated with the extensive beach ridges that fringe the coastal plain. Apart from the uniqueness of their habitat, other important aspects of the mangroves are the paucity of the species comprising them and the mechanisms of adaptation to this rather unusual environment e.g., stilt roots and high incidence of trees with noticeably lenticellate bark.

The mangrove forests are evergreen and the paucity of species occurring in them is due to the peculiar conditions under which they survive. Few plants are able to tolerate and flourish in saline mud and to withstand frequent inundation by sea water. They differ from inland forests in that certain species are particularly gregarious over extensive areas. The flora in Sierra Leone is confined almost entirely to a few natural families, viz; Rhizophoraceae and Avicenniaceae. The mangrove flora in Sierra Leone is therefore not too varied and rich.

4.2 Fauna

A fairly rich fauna is present in the estuarine and surrounding mangrove areas of Sierra Leone. In the estuary of the Sierra Leone River, the *Venus* community occurs near the mouth in the deep channel on shelly-sand and fine lateritic gravel. The dominant members of the community include small crustaceans, poriferans, 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 lateritic gravel in the deep channel of the Sierra Leone River with fauna consisting mainly of such species as *Astringia sp., Thelapus sp.* and *Arca imbricata*. The fauna of other regions is poorly studied but has identical distributional patterns.

4.3 Community stability properties

4.3.1 Zonation

Vegetational patterns or zonations are often recognisable in mangrove vegetation. These are important as a guide in silvicultural management, especially in determining the optimum ecological habitat appropriate for the dominant wood producing species. Problems associated with regeneration can often be reduced by avoiding planting species outside their natural habitats.

Salinity plays an important role in the distribution of the species of mangroves in Sierra Leone especially during the dry season, when hypersaline conditions are common on the landward fringes. The zonation patterns are also modified by coastal morphology, fresh water outflow and climate.

On the Island of Yelibuya and the sheltered riverine fringe of Sasiyek Creek, *Laguncularia racemosa* occasionally colonizes newly formed soft mud-flats which are inundated by all high tides. The species appears to flower freely, and during the dry season forms low spreading shrubs along the banks of inland tidal channels.

Avicennia nitida colonizes the mud flats which are inundated by medium high tides. It is also found on drier sites in association with *Laguncularia racemosa*. Along the better drained river banks, *Rhizophora racemosa* is commonly found in association with *Avicennia nitida*, growing up to 23 m in height.

In the Kambia district and on the shallow laterised shores along the Freetown peninsula, *Laguncularia racemosa* is common as a pioneering species as the land builds up through sedimentation. It is also common in the Sherbro River area where the rainfall is higher and with minor fluctuations in salinity. Along the Sierra Leone River banks, creeks and coastal estuarine plains, where the soil is better consolidated and at a higher level *Rhizophora racemosa* secures a foothold and flourishes. Towards the swamp interiors which are less well flooded by tidal wash, the tree becomes stunted thickets with malformed stems or become multi-stemmed dwarfs as in the case along some parts the Freetown Peninsula. In the interior of most of the mangrove swamps in Sierra Leone, particularly in the Northern part, *Avicennia nitida* tends to become more abundant. This may be due to the fact that this species appears to be more salt tolerant and can grow under very unfavorable conditions.

4.3.2. Succession

The results of ecological studies into plant succession are highly relevant to the formulation of appropriate silvicultural systems and operations. Plant succession takes place within the mangrove complex of Sierra Leone; as micro-environmental changes take place new mudflats suitable for plant colonization are formed.

As the land builds up through sedimentation, mangrove species such as *Avicennia nitida* and *Laguncularia racemosa* colonise the site under suitable conditions as in the Kambia district and on shallow laterised shores along the Freetown Peninsula. It is less common in the Sherbro River where the rainfall is higher and fluctuations in salinity may be more limited.

When the soil is better consolidated and raised to higher levels, *Rhizophora racemosa* secures a foothold and develops into luxuriant stands up to 35 m in height spreading crowns and characteristically darkish green leaves. This species is found on firm but well inundated sites typically along river banks, creeks and coastal estuarine areas but looses its vigour very rapidly towards the swamp interiors that are less well flushed by tidal wash. In such situations, the trees become stunted thickets with malformed stems or transform into multi-stemmed dwarfs or scrubs. Such formations are referred to as "edaphic poor forests".

Moving from the fringe of the swamp towards the centre, the canopy becomes more irregular as the larger trees become more sparse. Moribund trees are commonly found and when they fall, a gap is created and regeneration is often very abundant. In other cases the canopy can become very regular as the forest takes on the appearance of a pole crop plantation.

When *Rhizophora* stands are cleared for swamp rice cultivation and later abandoned, the secondary regrowth is more likely to be colonised by *Avicennia nitida*. It would appear that in the interior of most mangrove swamps, particularly in the Northern part of Sierra Leone, *Avicennia nitida* tends to become more abundant and this may be due to the fact that this species appears to be more salt tolerant and can grow in very adverse sites (FAO, 1979). They also occur on the river banks but are shaded out by the more vigorous growth of *Rhizophora racemosa* in the better inundated sites. It is reported that *Rhizophora mangle* and *Rhizophora harrisonii* are dominant upstream at the tidal limits (FAO, 1979).

4.3.3 Accretion

The deposition of sediments is closely associated with channel processes which are subject to natural periodicities in the intensity of both physical and biological processes. These in turn are related to seasonal changes, including increased river flow and sediment transport during the rainy season and high biological activity during the dry season. Also density stratification of the estuarine waters is greatest at this time and as a result, the sediments are deposited at the seaward fringes of the sheltered mangroves. Warm weather during the dry season may also cause biologic agglomeration of clay particles and the flocculation of particles due to increased salinity.

4.3.4 Erosion

Channels are regularly formed on the tidal mud flats and the channel processes continue to erode sediments. The erosion on bare tidal flats is due mainly to direct fluid shear on the substrate, action of small scale waves against the channel banks and rotational slides. On the vegetated flats, similar processes act on the channels, but here bank undercutting and subsequent slumping and rotational sliding of root-bound blocks of mud seem to be more important. Bioturbation by animals in the well vegetated mangrove areas loosens compact sediments during their feeding and burrowing activities. Large scale erosion in the mangrove areas of Sierra Leone is however due mainly to extensive deforestation.

4.4 Interaction between biotic and abiotic ecological factors

During the period when the biological activity is high, the production of faeces and pseudofaeces by suspension feeders may supply large quantities of sediments to the mangroves. Many of the diatoms, bacteria and algae secrete mucoidal substances that not only help trap newly settled particles but increase the resistance of fine grained sediments to erosion.

4.5 Productivity, energy flow, trophic relationships, nutrient cycling

Productivity of the mangroves has not been thoroughly investigated due to the lack of appropriate equipments e.g.^{14}C kit. However indirect investigations suggest that the productivity of the mangroves on the average is fairly high.

Seasonal variations in productivity are brought about by a number of factors including fluctuations of light intensity and temperature, of availability of nutrients and the grazing patterns of herbivores. Productivity appears to be higher during the months of October through April and lower during the months of May through September.

The mangroves of Sierra Leone yield tons of organic matter per hectare annually through litter fall and wood production. These yield a substantial amount of dissolved organic Carbon. A portion of this organic matter is cycled within the mangrove system while some is exported and supports the nearshore fishery.

5. Mangrove related ecosystems

5.1 Marine benthic community

In the mangrove intertidal areas of Sierra Leone, a rich epifauna is present on hard and to a lesser extent on soft substrata, feeding on the plankton and detritus in suspension in the water. These include barnacles, polychaetes, sedentary molluscs and crustaceans of various types, gastropods and echinoids. The most abundant epifauna species include *Tympanotonus fuscatus* and *Periophthalmus sp.*

There is also a rich fauna which is present in burrows or, is buried within the sediments or rocks and in the soft substrata provided by muddy and sandy sediments.

The most abundant species found in the mangrove environment include *Uca tangeri, Tympanotonus fuscatus* and *Metagrapsus curvatus.* The benthos in the estuarine and bay system and the associated mangrove environment of Sierra Leone are made mainly of the following taxonomic groups: Polychaeta belonging to the phylum Annelida, Gastropods and Bivalves belonging to the phylum Mollusca and Ophiuroidea (brittle stars) belonging to the phylum Echinodermata. The most abundant and dominant group in the macrobenthos are the polychaetes found basically in the bay and estuarine areas.

Towards the upper reaches of the river, these animals tend to decrease in abundance. The gastropods show identical distributional patterns as the polychaetes. The bivalves form large communities basically in the bay and estuarine areas including the intertidal mud-flats. There are also the small crabs concentrated on the intertidal mud-flats and in the bays, but are found in considerably small numbers in the estuary. Small shrimps show similar patterns and character of distribution, but unlike the crabs, they are found in large numbers in the estuarine areas.

The tidal mud-flats of Sierra Leone are areas of calm water often colonized by mangrove vegetation and bounded by strongly meandering second and third order channels, bordering the main channels of the bays and estuaries. They are the results of global aggradation through the settling of suspended particles on the flats which have accumulated in a pre-Holocene or Holocene substrates varying in depth from less than 1m to over 10m.

The tidal flats also contain minor forms. These are respectively, bare flats and grass-herb depressions. The bare flats are flooded only at high spring tides and consist of poorly to well sorted fine quartz sands with small amounts (< 5%) of silt and clay. The grass herb depressions are commonly situated in the contact zone between deposits and the tidal flats and they consist of very poorly to poorly sorted sand, silt and clay.

5.2 Pelagic community

The pelagic community of the mangrove related ecosystems are made of a limited number of animal species living at the surface, part of whose bodies project through the air e.g. (pleuston), some the hydrozoans and the chondrophores; planktonic diatoms which include *Biddulphia, Coscinodiscus, Rhizosolenia, Triclodesmuim and Thalassiosira* become very abundant especially during the period from December to February.

The prominent members of the pelagic community however are the nekton, perhaps because of their direct impact on the welfare of the local population. Amongst this rather broad group of organisms are pelagic fishes and shrimps, oysters are of great commercial importance.

The pelagic fish species live in surface waters and feed on other fish or plankton. They mainly belong to the members of the Clupaeid family, namely *Ethmalosa fimbriata, Sardinella eba, Sardinella aurita* and *Ilisha africana.*

6. Human Habitation and Traditional Mangrove Usage

According to the 1985 National Population Census, the population in Sierra Leone was 3.52 million with more than half a million living in the Western area, making it one of the most heavily populated countries in Africa (48 persons/km^2). The national growth rate is 2.31% per km year, despite the high infant mortality rate of 175/1000 births, the second highest in the world. In Freetown, the annual growth rate is 4.95 % and that in the rural villages is 7.02% .

Over half of this population lives in more than 100 coastal villages scattered along the whole length of the 570 km coastline. The main occupation of the inhabitants of these villages is fishing, which is carried out by traditional methods. These coastal fishing villages have been named artisanal fishing villages.

The relevance of the preoccupation of the coastal inhabitants for the mangrove resource becomes apparent when one considers the traditional methods which are used for fish preservation. The main method used for the preservation of artisanal catch as opposed to industrial catch is that of smoking. These villages have more than 1,200 fulltime sea-going fishermen with about twice that number engaged in fish handling, processing and marketing activities. These people are responsible for an annual catch of between 25-30 thousand metric tonnes of fish, for consumption by a population of over 3 million.

The size and importance of these fishing villages is dependent on their accessibility from market centres from which the wholesale dealers come, proximity to cheap fuel sources and a beach where their boats can be beached since landing jetties or quays are few. Of the three stated factors responsible for the size and importance of these villages, the most pertinent is the accessibility to cheap sources of fuel for the traditional pre-processing of the fish catch. This cheap fuel source is provided by the mangrove forests. For instance the mangrove areas along the Kagboro and Thauka Creeks are vitally important for the Shenge Fishery. They are the source from which most of the wood required for fish processing is obtained. The most common method of preservation of fish in many developing countries including Sierra Leone is smoking.

Another traditional use of the mangrove areas which leads to its destruction is that of salt making. When producing salt the mangroves are first cleared and the top soil remaining is gathered and leached with brackish water to obtain a brine solution which is then boiled until the water is evaporated.

The mangroves are also used as poles for house construction and in traditional ovens known as "bandas", for fencing and finally as fuel wood for cooking. Fuelwood plays a very important role in Sierra Leone, as domestic energy accounts for about 85% of the total energy consumption. For urban families, fuelwood supplies 80-87% of household requirements (Freetown only 60%). While in the rural areas the proportion is 97-98% . The mangrove forests supplies a substantial percentage of this demand. Other uses include construction purposes as timber for scaffolds, railway sleepers, boat building, deck piling, flooring. Within the fishing community in the coastal environment mangroves are also used for making poles for fish traps, and production of tannin for net and line preservation. Other products derived from mangroves includes food, drugs and beverages.

7. Commercial Exploitation and Marketing

Commercial exploitation and marketing of the mangrove products are at present done nationally. Export of mangrove products to other countries is at present negligible or unknown. The exploitation has been carried out as and when the demand arises. In populated areas, firewood is being cut throughout the year with slack period during the busy planting and harvesting season.

The trees are felled using axes but in some areas with the help of handsaws. They are then packed into dug-out canoes which vary in length of between 4 to 8 meters using paddles or outboard motors as means of propulsion and transported to nearby villages, where they are sold. Depending on which use the product is to be put, the trees can either be sold as poles, or they are cut into small pieces and tied into bundles and sold as firewood.

Measurement of the firewood stacks along the river confirm that generally only small-medium sized trees are felled (7-16 cm diameter). The standard length for firewood is about 1-1.6 m but larger pieces are cut to shorter lengths to reduce their weight. The existing method of wood extraction based on selective felling is slow and not geared towards large scale economic production.

The red mangrove provide some very durable poles, and one of the species *Rhizophora racemosa* can grow to substantial timber sizes. Tannin is also produced from the bark of the trees, but its marketability is being hampered by artificial products.

8. Conversion to Other Uses

The conversion of mangrove swamps to other uses in Sierra Leone has not been widespread. Apart from the requirement of the mangroves for fish smoking the most notable conversion is into rice fields for rice culture. The mangrove areas are also used for the traditional production of salt which is used partly in fish and food preservation. To produce salt, substantial quantities of mangrove wood are used as fuel. The main salt making sites are located around Shenge, while only a very small amount of salt is produced in Sherbro due to the heavy rainfall in this zone.

Aquaculture is widely practiced in the mangrove areas and at present culture ponds exist in many areas along the coast, the most extensive culture area being at Makali in the North.

Urbanisation at present does seem to have posed a noticeable threat to the mangrove environment as increased shoreline facilities have resulted in erosion of some of the coastal areas were the mangroves formerly grew, e.g. along the Freetown Peninsula.

9. Impacts on the Mangrove Environment

Mangrove is the single most important littoral formation in Sierra Leone it covers 47% of the coastline and forms 60% of the total tidal wetland ecosystem.

Since historical times, this littoral formation had been exploited by the country's coastal dwellers for their livelihood. This continued human activity has induced stress on this formation, especially in the Western Area of the country.

The composition of the mangrove resources in Sierra Leone is unique in terms of species all which are found in the West African sub-region. The prevailing hydrometeorological conditions often result in marked spatial variation of the mangroves in some areas. The mangroves found in areas which are less accessible and far from the coastal settlements are often underexploited. The over exploitation of the accessible mangrove areas leads to the destruction of particular species and this often produces a dramatic change in the ecosystems involved.

The effect of this deliberate or inadvertent exploitation cannot be overemphasized. It ranges from the destruction of wildlife, elimination of spawning grounds for juvenile fish and crustaceans to coastal erosion leading to the silting up of our bays and estuaries.

Marine pollution in Sierra Leone and its effects on the mangrove environment can be temporarily serious but most of the time is almost insignificant. Oil pollution of the coastal area from oil sources external to Sierra Leone is a common characteristic, being normally weak but sometimes quite heavy thus creating temporary serious nuisance. Siltation in the rivers along the diamond mining areas is very heavy and although this area is located quite inland, the Sherbro estuary for instance, which is widely opened to the sea is partially polluted; siltation problem is also present in the Rockel estuary at Freetown.

Erosion of the mangrove areas is widespread along most parts of the Sierra Leone coastline. This is due to the deforestation of the mangrove areas which has been and is being carried out in an uncontrolled manner. Excessive silt deposition is going on in the estuary of the Sierra Leone River which now creates problem for the Sierra Leone Ports Authority. The effects of the adjoining ecosystems although not assessed is in no doubt great, on the other hand accretion provides the needed silt for the formation of the mangrove swamps.

10. Research and Training Programmes

Research and Training Programmes for mangrove management and conservation is at present at a very low level. Research is episodically undertaken by the Institute of Marine Biology and Oceanography, Fourah Bay College, University of Sierra Leone. The facilities at this Institute are very modest and are in urgent need of international assistance if research is to be meaningfully carried out. Training programmes carried out so far have been within the framework of UNESCO's COMARAF project.

11. National Mangrove Committees

11.1 National policies for mangrove management

In Sierra Leone at present national mangrove committees are absent. The mangrove vegetation in the country falls under the jurisdiction of the Ministry of Agriculture Forestry and Fisheries in Sierra Leone. National policies for mangrove management at present are lacking in the country. In October, 1985, phase one (1) of a UNDP funded fuelwood project entitled "Alleviation of fuelwood supply shortage in the Western Area" (F.O.DP/SILL/84/003/01/C) was started by the FAO and the then Ministry of Agriculture, Natural Resources and Forestry (MANR&F) in Sierra Leone. Phase II began in October, 1988 under the new title "Community Participating Forestry for Fuelwood Production in the Western Area" (SIL/88/008). The project had some outputs which could form the basis for mangrove management and a National Policy on mangrove utility. One of the main output under phase I was an assessment of the mangrove resources and their development potential in the country, and submission of a report to Government proposing a strategy for their sustainable management and integrated use (Chong, 1987).

In Sierra Leone a national agency - the Forestry Department, has primary responsibility for the management of mangroves. The management can also be traditionally community-based. The problem of mangrove management is made difficult by the land tenure system amongst which public ownership is the most common. Control however is exercised by the forestry Department. This agency also carries out the major supervisory role. The major legislation which provides for the supervision of activities on mangrove systems is the Forestry Legislation. There are however some informal mechanisms, such as traditional community management, which also contributes to mangrove management and probably should be included in a formal management system in order to increase its effectiveness. One basic aspect which is lacking in mangrove management is an environmental impact assessment component which is required when development activities in the mangrove systems are proposed. This can be done at ministerial or administrative level. At present, reserves have not been created to protect the mangrove systems. However day-to-day management of mangroves is carried out by clear felling and replanting.

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Liberian Mangrove Ecosystem

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Introduction

Mangrove plants are tropical evergreen trees or shrubs that grow along the seashore and margins of tidal marshes and rivers.

The plants are peculiar for the remarkable way in which they produce numerous prop, or stilt roots creating an almost impenetrable jungle called a mangrove swamp. The trees grow almost in single layer and may achieve a height of up to 30 meters. The mangrove forest is halophilous and because of its growth in the intertidal parts of the tropical and subtropical zones, its physical, chemical and biological characteristics are derived from the sea and the freshwater coming from upland. They thrive well in both kinds of water. The most common species have thick scarred branches and oval leathery leaves. Small four-petaled yellow flowers are followed by cone-shaped, reddish brown fruits about an inch long. Each fruit contains a single seed and develops a long shoot while still on the tree. Upon falling the seed often floats a long distance before taking root. One of the most important species is the red mangrove which thrives well in Liberia. The red mangrove supplies much of the tannin (substances that impart an astringent, bitter taste to tissues in which they are present) used for tanning leather. The white mangrove also grows well in Liberia.

1. Historical Background

Mangroves and mangrove forests along most shorelines have attracted man's curiosity from the earliest time (Snedaker, 1984). The knowledge about the existence and usefulness of the mangrove and mangrove forests is as old as the longtime human coastal dwelling in Liberia.

With urban migration gaining momentum from the late 1920s and that is still growing, the former rural inhabitants who could not readily find familiar hardwood used for constructing their homes, the sheds for their domestic animals, and for firewood in their rural settlements, made and are still making good use of the mangroves in these areas.

The rapid accumulation of sediments at the fringes of the mangrove forests once the trees have been cut, gives fast rise to land reclamation for these new urban dwellers providing them land for constructing homes and making backyard gardens.

Though man has known and used mangroves for centuries, there are still many values of these plants that require man's understanding and appreciation. There is a gradual progress in the protection and management of the mangrove ecosystem in many parts of the world because of fisheries, bringing forth forest products, and contributing to the stability of the coastal zone.

2. Mangrove Ecosystem: Extent and Distribution

Mangrove ecosystems are mainly found in three climatic divisions of the earth (Walter, 1977): (a) the equatorial zone, between approximately 10°N and 5° - 10°S, (b) the tropical summer rainfall zone, North and South of the equatorial zone, to approximately 25° - 30°N and S: partly in the sub-tropical dry zone of the deserts still further poleward, and (c) partially in warm temperate climates that do not have really cold winters, and only on the eastern border of the continents.

According to Snedaker (1984) tall dense, and floristically diverse mangroves are almost exclusively found either in the equatorial zone (Malaysia, Indonesia, Colombia), in the "tropical summer-rainfall zone" (most coastal areas of India, Burma, Thailand, Indochina). Thickets of low scattered or sporadic mangrove species prevail in the subtropical dry zone" (North-Western Indian coast, Pakistan, Red Sea); and in "warm temperate" climates (Australia, New Zealand); their floras are simplified.

Worldwide, mangrove forests are found in two main zones, the Eastern zone (East African Coast as well as Pakistan, India, Burma, Malaysia, Thailand, the Philippines, Southern Japan, Australia, New Zealand, the South Pacific Archipelago), and the Western Zone (the Atlantic coast of Africa and the

Americas including the Galapagos Islands). Liberia, on the Atlantic coast of Africa falls in the Western Zone. The mangrove forests of Liberia consist of two main genera: *Rhizophora* and *Avicennia* and associated species (Kunkel, 1965). The thickets of the forest are evident but the trees are not very tall as to the near average of 30 to 40 meters. The forest has other resources which together with the forests themselves are highly neglected.

The area of the Liberian mangrove forest is estimated at 20,000 hectares (Nature and Res., 1990) and is found growing naturally in regosoil within the narrow coastal belt.

3. Physical Environment

3.1 Climate

Liberia is at the heart of the zone of wet tropical forest. The average annual rainfall along the coast where mangrove forests grow is five meters in the interior. The isoyets run parallel to the coast with slight deflections caused by the mountains. The only seasonal variation is the "wet season" from December to April. In some places along the coast (e.g., the Monrovia area), the mangrove areas have less wet periods lasting one to two weeks, usually in August, May and November, which can be included in either the wet or the dry season depending on the year. There is little variation in temperature between an absolute 30°C depending on the month, with the maximum and minimum values occurring in the interior. Little information is available about evaporation. The Penman method is still used to estimate the evaporation from a free surface on the basis of meteorological data from two stations at Robertsfield and Harbel, Firetone.

3.2 Soils

Latosol or lateritic soil which are heavily leached and occur on undulating and rolling land covers 75 percent of the land area and is mostly found in the hilly areas. Regosoil (peat soil) in which the mangrove grows are found within the narrow coastal belt. They are very poor in plant food, highly acidic, sterile and infertile and are mainly made of marine sediments. The sands are heavily leached and bleached to an almost white colour. The percent of clay and organic matter is very small. Therefore in areas where drainage is poor, swamps mainly of mangrove develop (Hasselman, 1979).

3.3 Waters

The whole country is well drained by rivers flowing almost parallel to each other into the Atlantic. Two categories of river basins open to the sea: about 20 large basins and small coastal basins which cover only three percent of the country.

Liberia's lakes and mangrove swamps coexist along the 560 km coastal zone from Grand Cape Mount Country to Cape Palmas in Maryland Country. All of the Country's lakes are suitable for fish farming, tourism and sport activities. With little attention development and management the mangrove localities could add and or improve this suitability.

The saline waters of the mangroves are not used for domestic purposes first because of their salinity and also because of the huge amount of domestic waste and sewage emptied into them.

3.4 Tidal Pattern

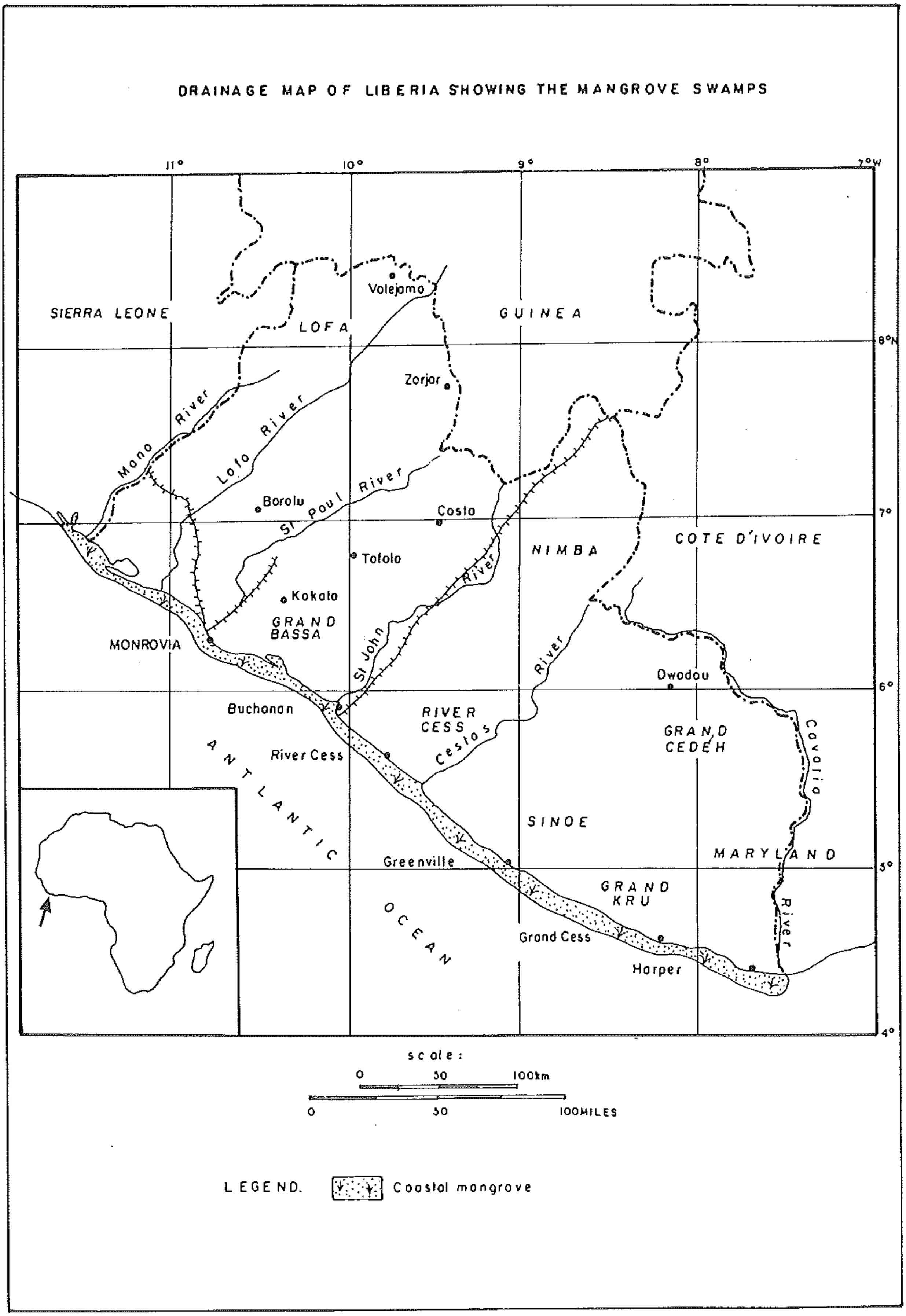
Tidal pattern is semi-diurnal equal tides. Two successive high waters have the same height and two successive low waters will have nearly the same (lower) height in 24 hours (Pond and Picked, 1981). This tidal pattern is characteristics of the Atlantic sea coast.

4. Species Composition

Gunkel (1965) has classified the mangrove vegetation in Liberia as a forest vegetation. The two major species described are *Rhizophora* and *Avicennia*, with:

- *Rhizophora racemosa*, *R. harrisonii*, and *R. mangle;*
- *Avicennia africana* is the only one of the genus. Mangrove plants dominate the ecosystems and *Rhizophora* quantitatively dominates *Avicennia* in Liberia. The mangrove trees seldom grow above 22 meters. The trees grow in a single layer canopy and are equipped with sclerophyllous leaves and various kinds of stilt roots, peg roots, knee roots and pneumatophores.

The *Rhizophora* often grows at boarders between high and low tides and at borders of deltas, and in muddy estuaries and lagoons. The stem is straight and has a fine textured brittle hard wood. It has stilt roots and numerous aerial roots suspended from the branches. The *Rhizophora* are usually taller than the *Avicennia africana* and may attain a girth of 200cm. *Avicennia*, the white mangrove, grows on sandy soil,


DRAINAGE MAP OF LIBERIA SHOWING THE MANGROVE SWAMPS
11°
10°
9°
8°
7°W
8°N
7°
6°
5°
4°
SIERRA LEONE
LOFA
GUINEA
Volejomo
Zorjor
Mano River
Lofa River
St Paul River
Borolu
Costa
Tofolo
Kakata
NIMBA
COTE D'IVOIRE
GRAND BASSA
MONROVIA
St John River
River
Owodou
Buchanan
RIVER CESS
Cestos
GRAND CEDEH
Cavalla River
River Cess
ANTLANTIC OCEAN
SINOE
Greenville
MARYLAND
GRAND KRU
Grand Cess
Harper
scale:
0
50
100km
0
50
100MILES
LEGEND.
Coastal mangrove

second to the *Rhizophora* from the seaward side of the swamps. They lack stilt roots and possess breathing roots (pneumatophores). The boles are straight, they have white sapwood and light or pale-brown heartwood and the wood is generally fairly hard and fine textured (Nature and Resources, 1990).

Snedaker (1984) suggests that on a broad basis, species and sea level are interrelated by the zonations from the seaward edge to the landward edge at extreme high water mark. This inter-relationship is such that *Rhizophora, Avicennia,* and *Acrostichum* grow in this respect from the seaward to the landward margin.

5. Biological and Ecological Characteristics

Judging from the canopy, which appears homogeneous, one may conclude that the mangroves grow exclusively together. This is, however, ruled out in many cases by the presence of taller palm trees and raffia palms that indicate the dominance of freshwater as compared to salt water in the swamp. The palm trees are of economic importance as sources of edible palm oil and palm kernel oil.

The bamboo palm (raffia palm) provides "bamboo wine". This wine is consumed as it comes out of the palm or it can be fermented and distilled into gin.

The population of these palms is unknown and the extent to which they are found among the mangrove trees is also unknown. The quantity of alcohol they produce has not been investigated, it is the main source for local distillation. The palms within the mangrove belt grow naturally and they perpetuate themselves through seedlings. On the sandy beaches or sand ridges raised above the muddy swamplands, coconuts grow in abundance (Iloege, 1970).

The Liberian mangrove forest is rich in animals, though the animal population of the forest and its classification has not been undertaken. There are many microbes and bacteria which carry on the decaying process of the fallen leaves, twigs, flowers, and branches of the mangrove and other trees.

Mangrove dwelling animals are composed of a few dominant groups, the main representatives being polychaetes, gastropods, brachyurans and a sipunculid. These animals live in the soil, on the roots, stems, leaves, and dead wood. Land dwelling animals (birds and monkeys) and marine dwelling fish and crustaceans also live in the mangrove shore. Some mud lobsters and crabs live in the mud and burrows. The tree-dwellers, dwelling on prop roots and lower trunks of trees includes bivalves (e.g. oysters), barnacles, and gastropods. Mangrove fringed-shores also provide habitats for many species of fish.

Mangrove leaf litter fall may be caused by senescence or stress, or by death and weathering of whole plants (Kozlowski, 1973). The leaf litter provides an important nutrient base for food webs leading to commercially important food fishes and invertebrates. The leaves may be poor in nutrients when they fall from the tree, but Odum (1971) suggests that they become nutritious due to microbial enrichment process.

The mangrove has a characteristic root system with numerous sizeable aerial stilt-roots, and a network of weaker underground roots (Longman & Jenik, 1931).

6. Conversion to Other Uses

The Liberian mangrove swamps have more to offer than mere fuelwood for domestic use. There are great potentials in agriculture, mining, aquaculture and carbonization.

In agriculture, local residents reclaim the swamps converting them to backyard gardens. Experience has shown that rice, sugar cane, banana, eddoes (cocoyams) and a variety of other garden plants; pepper, eggplants do extremely well in the reclaimed land.

The co-existence of fresh water fishes and sea water fishes, thriving well in the mangrove could be an indication of good potentials for silvo-fishery and agro-fishery and agro-silvo fishery.

The mangrove is the home of many kinds of animals. In the Cape Mount area where monkeys are less hunted for their meat, they fare well in the mangrove. Other mammals such as many kinds or rats and other rodents inhabit the mangrove forest.

Crocodiles, lizards, tortoises and snakes constitute the reptile population. Should the mangrove forests be properly managed in the future, these animals would be protected making attractive national parks for tourists.

All of Liberia's major rivers empty into the sea and some of them flow through mined (mainly for diamond and gold) terrains. This seaward flow enhances the transportation of diamonds and gold into the mangrove forest deltas and open way for mining activities such as beach sand mining especially at the mouth of the Lofa river in Grand Cape Mount country.

Reclaimed land within the mangrove forest (eg. the low pasture grounds in Monrovia) provide an evergreen grazing land for cattle. Enlargement and improvement on such pastures will highly contribute to raising these animals within the mangrove area with less fear of pests such as tse-tse flies and mango flies which hardly inhabit the coastal regions where they are easily blown away by the sea breeze.

Liberian coastal cities have proven to be very improper for construction of roads as the cities develop on small islands separated by mangrove swamps. Road construction must include many land-fill works or bridges which are very expensive for the government. Since the mangrove forests have semi-navigable rivers flowing through them, developing such river routes for boat traffic will alleviate the transportation problems caused by the lack of adequate roads and the resultant traffic jams. Moreover the boat routes will be more direct, shorter and less fares will be charged.

The scenery, traveling through a tropical forest by boat will also fascinate future tourists.

7. Impacts on the Mangrove Environment

As more and more people continue to settle along the periphery of the mangrove swamps they turn to the mangroves for survival and other activities. Survival activities include fishing in the swamps.

The need for backyard gardens and additional construction of dwelling places give rise to reclaiming the mangrove land which involves cutting of the trees and reformation of land surface. The usage of mangroves for firewood is also a factor in cutting down the trees.

The damages that man does to his environment are quite evident in the mangrove areas. Latrines are constructed in the swamps for easy disposal of human wastes. The wide use of the swamp for disposal of domestic garbage, metallic materials, chemicals, and oils have rendered them highly polluted.

The ability of the stilt roots to accumulate sediments and eroded soil materials and to deposit them gives rise to compensating erosion on a large scale and consequent depletion of soil nutrients on the adjoining terrestrial ecosystems. Natural stresses such as poor growth of plants promoted by the wearing away of small plants and over undercutting or removal of soil off the roots of larger trees kills them.

Naturally in waterlogged environments, such as bogs and swamps, the decay of dead plant debris by bacteria and fungi gives rise to a dark-brown jelly-like humus. Part of this soaks into the cells of wood, bark, roots, twigs. They are also humified, and the cellular structures of these remains are in consequence often wonderfully well preserved. These humified products, together with a variable proportion of the less destructible materials, such as resins and the waxy pollen cases and spores, accumulate to form deposits of peat (Holmes, 1978).

This process of peat soil formation is evident in the Liberian mangrove ecosystem. The rapidity of peat soil formation and its accompanying high rate of deposition places speedy solidifying natural stress on the bogs and swamps in which the mangrove grows.

8. Socio-Economic Implications

From paleontology (Leakey, 1964), we have learnt that the evolution of man took place somewhere near the margins of the tropical and subtropical forests, presumably near rivers and lakes in the open savannahs. Since then, man has had a profound influence on these tropical forests in most cases to his own injury. He has so much over cultivated and over grazed the lands that they are no longer fertile. The building of roads, quarrying and mining are other factors responsible for fertility depletion of trees and subsequent changes in the tropical forests. The alternative to these tropical forests for farming is pointing to the "virgin" mangrove forests. For many ecological reasons, one would predict that in the nearest future most of the farming for rice, oil-palm and many other cash crops will be done in the mangrove swamps or on mangrove-related shores. Coupled with fishing, tourism and other numerous uses of the mangrove themselves will contribute positively to the socio-economic enhancement of the tropical dwellers including Liberians.

9. Research and Training Programs

The mangrove ecosystem is neglected worldwide and Liberia is not an exception. The country runs a national University and three technical schools that conduct research and training in agriculture and agriculture-related disciplines, but none has ever given attention to research and training programs on the mangrove ecosystem.

There is, however, growing interest in research studies focusing on mangroves and the mangrove environment as a result of public and scientific interest in their roles in nature and value to mankind. To facilitate this in Liberia, it is encumbent upon the University of Liberia and other agricultural teaching institutions to include mangrove ecosystem studies and research in their Curricula.

Conclusion

National Mangrove Committees and or National Policies for Mangrove Management are non-existent.

Liberia has a Forestry Act (1953) together with the Supplementary Act for the Conservation of Forests (1957) which provide the framework for the use of forests and wildlife resources, and for the creation of national parks. The reorganization of the forest administration was accomplished under the Forestry Development Authority Act (1976). A series of regulations on logging and timber transport; timber export sales contracts; control of non-concession logging operations; and forest land management of private owners have been made under this act (FAO Forestry, 1986).

The many uses of the mangrove ecosystem outlined in this paper present the need for proper management of the ecosystem if the country is to reap the benefits. This can be initially approached by setting up a National Mangrove Committee to formulate regulations and management policies and enforcement measures.

Formulating a Mangrove Act similar to this Forestry Act will go a long way in protecting and rehabilitating the mangrove forests and in formulating meaningful national mangrove management plans in the future.

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Mangroves of Cote d'Ivoire

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Introduction

Mangrove forests are coastal tropical ecosystems typical of the intertidal zones found on the Ivorian littoral (500 km long) between long. 2°50'W and 7°30'W. and between lat. 4°20'N and 5°10'N. The mangroves grow all around the borders of the Aby, Ebrie and Grand-Lahou Lagoons in the East. The estuarine mangroves are developed at the river mouths of Sassandra, Cavally and the coastal rivers located in the West.

The Ivorian littoral is influenced by a tropical humid climate which has four seasons, two rainy seasons alternating with two dry seasons. The annual rainfall varies from 1,600 to 2,800 mm per year. The East and West extremes record respectively 2,200 mm and 2,800 mm of rainfall per year, while the axis Sassandra/Grand Lahou in the centre records only 1,600 mm year.

Temperature fluctuation is about 2° to 4°C and remains roughly the same everywhere along the coast with an average of 25.5°C.

As far as the flora in concerned, the mangroves of Côte d'Ivoire are composed of three species only : *Rhizophora racemosa* G.F.W. Meyer (Rhizophoraceae), *Avicennia germinans (L.)* L. (Avicenniaceae) and *Conocarpus erectus* L. (Combretacae), as compared to six in West Africa.

Activities in the mangroves of Côte d'Ivoire used to be focussed on wood exploitation, tannin extraction from mangrove bark and fishing. Nowadays, the mangrove swamps participate also in touristic activities. They are exploited for agriculture and fish ponds are set in lagoons bordered by mangroves. Crustaceans and molluscs are exploited in some regions.

There are no serious studies of the Ivorian mangroves and they do not receive the interest and protection they deserve; instead, they suffer from multiple agressions. Data on the limits and area of the ecosystem are missing. Salinity, the major factor of the exclusive location of the intertidal zone mangrove and other physical and chemical data have been rarely studied. Due to lack of means, the research and training programmes, initiated in the laboratory of botany of the National University, have difficulties to be implemented. The few results obtained since 1984 relate only to the flora, the vegetation and the installation of a few experimental sylvicultural stations.

The mangrove swamp is a tropical ecosystem composed of plant species that grow on hydromorphic soils subject to daily tidal influence. Côte d'Ivoire has more or less luxuriant mangroves along its 500 km coasts provided with lagoons and rivers. They are suffering from anarchic exploitation and lack of a management programme. They are not object of a proper management policy and they are threatened with disappearance whereas the major part of the coastal zone activities and the populations living in these lagoonal zones is essentially dependent on them. The productivity of lagoons to which the mangroves are linked as well as their aesthetic attraction and health are seriously endangered.

1. Historical Data

The mangrove swamps in Côte d'Ivoire in the past were not located in the present day areas. For example, there were no mangrove swamps in the region of Audoin (West of Abidjan) before the Vridi canal was opened in 1950. But there were many *Rhizophora racemosa* mangroves in the area where Abidjan is located to-day. Several places (Vridi, Marcory) have been transformed into housing complexes. Sand has been extracted from the lagoon bottom to stabilize the soil and make some areas suitable for development.

Wood from the mangrove swamps serves to build houses, bridges and to make furniture and many other petty things such as netting spools and needles.

Substances extracted from the bark of the mangrove trees were used by local populations such as, the Ebrié, Ahizi and Brignan to tan or dye their materials and fishing nets to make them more resistant. According to Rollet (1975), extracts from *Rhizophora* *racemosa* were used to tan things black or brown while the extracts from *Avicennia germinans* were used to obtain a red color. Whereas those substances are no longer extracted, exploitation of wood has increased to the extent that the mangroves are now disappearing in Côte d'Ivoire.

Some mangrove swamps which have lost their vegetation are being turned into rice-fields, banana and coconut plantations. Others are being transformed into trap fishing areas, natural fishing reserves and touristic sites.

It is worth pointing out that, because of the lack of knowledge on the mangrove swamp ecosystem and of awareness education campaigns, very few activities (timber and oyster exploitation, sports, hunting) are particularly planned or carried out anarchicaly. To-day, there is still no mangrove swamp development policy in Côte d'Ivoire. Thus, this vegetation is endangered.

2. The Mangrove Ecosystems: Extent and Distribution

Although no quantitave data exist as far as mangroves extent is concerned, we know that the mangroves spread along the coast (500 km) from the East to West, from Kacoukro (Assinie) to Bliéron (Tabou).

Broadly speaking, they are located in a strip just about parallel to the Equator, between 2°50'N - 7°30' long. W, and 4°20'- 5°10' lat. N (Fig. 1).

The marine influence on the mangroves, which explains their geographical locations, allows to distinguish two main groups (Egnankou, 1985):

- From Assinie in the East to Fresco in the Center, they border Aby-Sud and Ebrié lagoons, the Grand-Lahou and Gni lagoon complex; then go up North around Potou lagoon to the river Mé estuary, the Comoé and the Bandama rivers. The two last ones respectively flow into Ebrié and Grand-Lahou lagoons;
- From Fresco to Bliéron: there are estuarine mangrove swamps at the mouths of two big rivers, the Cavally and the Sassandra, and at those of the much smaller rivers, Dodo, Niéro, San-Pedro, Nidia, Niéga and Dagbé.

The following mangrove swamps are the most important:

- **The Aby lagoon mangrove**
  The Aby lagoon is located between 2°51'- 3°21' long. W and 5°05'- 5°22' lat. N. The mangrove vegetation is thick all around Aby-Sud, and especially in the delta zone. The vegetation is reduced to a few scattered trees in the northern part of the lagoon even though the area undergoes some tidal influence.

- **The Ebrié lagoon mangrove**
  This lagoon is 140 kilometers long and has a surface area of 550 km^2. The Ebrié lagoon is connected to the Aby lagoon by the Assinie canal (28 km), and to the Grand-Lahou lagoon by the Azagny canal (17km). The lagoon is between 0.4 and 7 km wide. Before the Vridi canal was opened in 1950, the only way to go from Ebrié lagoon to the Atlantic ocean was by a channel located in the Grand Bassam area. To-day, access to the sea is secured by the canal which leads to the port of Abidjan. Freshwater input comes from two small rivers flowing through a forest (the Agnéby and the Mé) as well as from the big Sudanean river, the Comoé.

  The mangrove vegetation is relatively more important in the East than in the West of Abidjan. Its finest section is between Abata (Region of Bingerville) and Moussou (Grand Bassam). It stretches Northwards through Potou lagoon up to the mouth of the Mé river. To the West of the Vridi canal, there is a thick mangrove swamp vegetation at Audoin which becomes sparse from the village of Ako and all around Boulay Island (West of Abidjan), till Deblay and Tiégba islands at the mouth of the Azagny canal (at the western end of the lagoon).

- **Mangrove of the Grand-Lahou lagoon system.**
  The Grand-Lahou lagoon complex is about 230km^2. A channel at the mouth of the Bandama gives access to the Atlantic ocean. The mangrove swamps in this area spread from the Azagny canal to Ebounou where is the finest mangrove vegetation in Côte d'Ivoire with more than 20m high trees in some areas.

- **Mangrove of the Sassandra river**
  A *Rhizophora racemosa* mangrove population occurs at the Western mouth of the river where it is being encroached upon by Sassandra city. Throughout the city, there are red mangrove

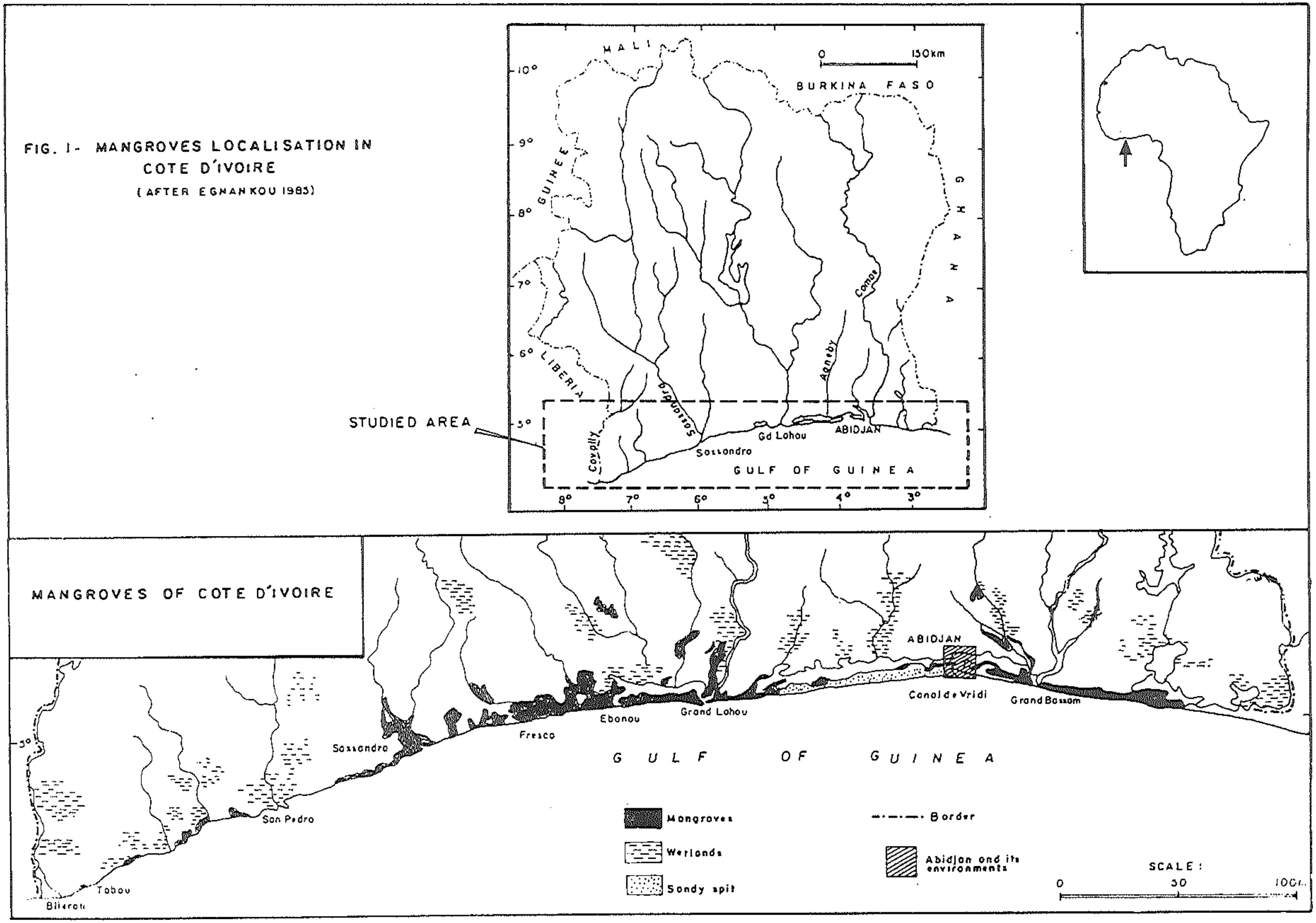


FIG. 1- MANGROVES LOCALISATION IN COTE D'IVOIRE
(AFTER EGNANKOU 1985)

trees between the houses with family ricefields, banana and sugar cane plantations. At the Eastern mouth, the mangrove swamp is luxuriant and a mixed stand of *Avicennia germinans* and *Conocarpus erectus* has also been found in that part of the Sassandra mangrove.

- **Mangrove of the Cavally river**
  There is a good stand at the Ivorian banks of the river mouth which consists of two tree species: *Rhizophora racemosa* (dominant species growing along the Northern part of the river), and *Avicennia germinans* (by the village of Bliéron). The Cavally river flows directly into the Ocean, which enhances the development of the ecosystem.

- **Mangrove of the coastal rivers**
  There are mangrove swamps in all the coastal river mouths; although their flows are irregular, the rivers (Brimé, San Pedro, Niéro, Dodo, Nidia, Tabou) have a more or less luxuriant vegetation.

- **Mangrove of Fresco**
  There are in Fresco both a lagoon mangrove swamp (all around N'gni lagoon) and an estuary lagoon mangrove swamp (at the mouths of the Bolo and Niouniourou rivers) which are undoubtedly the country's best mangroves because of the size of the *Rhizophora racemosa, Avicennia germinans* and *Conocarpus erectus* some of which are forty meters high and 0.5 meter in diameter. It is in this area that the wildest exploitation of trees is carried out.

3. Physical Environment

3.1 The Climate. Role of the climate (Egnankou, 1985)

Humidity plays an important role in almost all the ecosystems of a tropical country like Côte d'Ivoire. It depends on the rainfall, on the number of "dry months" (monthly rainfall inferior to 50 mm), and on the relative humidity and the importance of evapotranspiration.

Most meteorologists who give detailled information on the important atmospheric phenomena causing rain acknowledge the existence of a "line" called the Intertropical Convergence (ICT) which determines the climate subdivision. Indeed, when it moves from the North to the South, the Intertropical Convergence line separates two air masses of different nature. The air mass which originates from the desert up North becomes a hot wind and blows Eastwards (Harmattan). The humid sea air from the South turns into a wind that blows Westwards (Monsoon).

It starts raining when the layer of humid air becomes more important than that of the hot and dry air in the ICT zone. The interface movement brings about the succession of seasons which can be described as follows (Fig. 2):

* In June, the Intertropical Convergence Zone (ITC) is located at the North; as a result, it rains throughout the country: the big rainy season lasts 4 to 5 months.
* In August, the ITC moves northwards bringing rains. As a result, there are no more rains along the coast at this time of the year: it is the small dry season (2 months).
* In October, the ITC comes back to the center which result in a concentration of cumulus-nimbus that bring rain to the areas located at the South of the 7th parallel: the small rainy season starts and lasts 2 months.
* In January, the ITC reaches the coast. Clouds gather above the ocean. In the meantime, a dry and hot wind blows through the hinterland: it is the big dry season (4 months).

In conclusion, one can say that Côte d'Ivoire has a humid climate characterized by a big rainy season with quite steady rains in June, and a small rainy season with regular rains in October; and between them, two seasons with less rainfalls: the small and the big dry seasons (culminating respectively in June and in January).

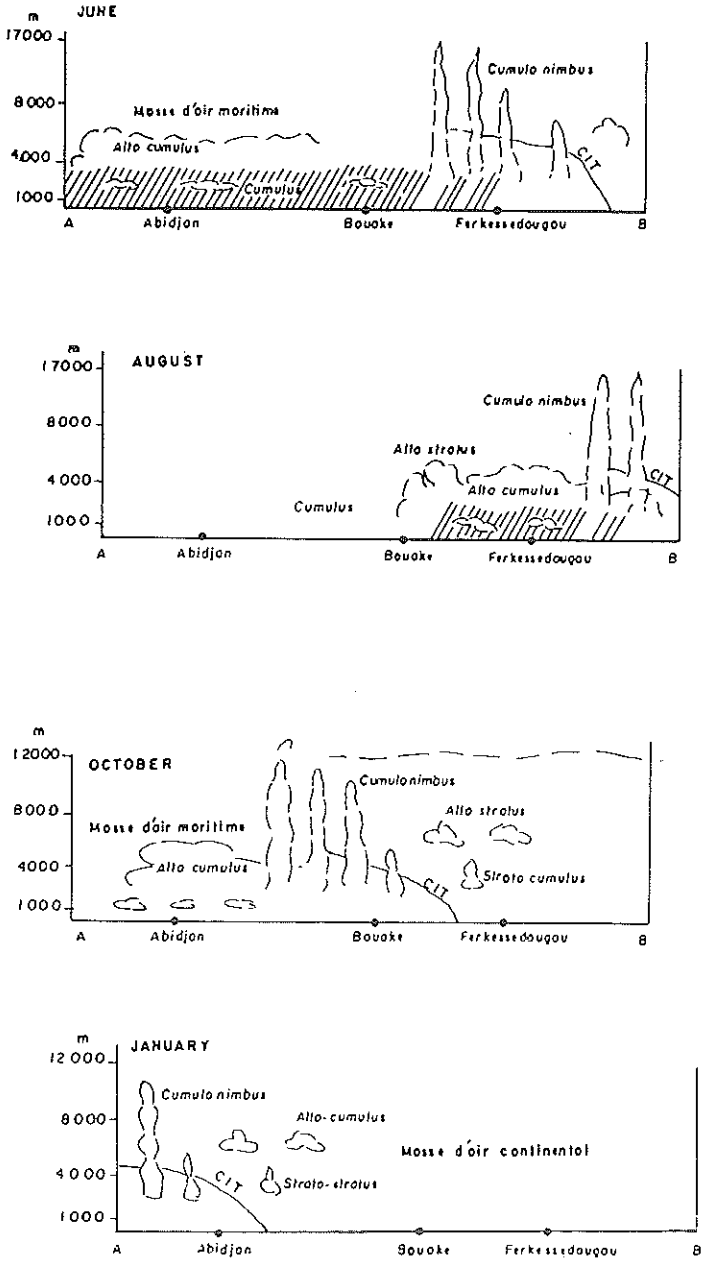
3.2 Rainfall

Annual rainfall on the coast varies from 1,600 mm to 2,800 mm. The rainfall average, which is very high in the Bliéro region, (2,800 mm/year) gradually decreases around Sassandra/Grand-Lahou (1,600 mm/year); and following a U shaped curve, increases as one goes eastwards up to 2,200 mm/year in the Assinie region (Fig. 5 & Table 1).

3.3 Salinity

Because the mangroves are located in the intertidal zone, the salinity and its daily, seasonal, or annual variations play an important role in soil formation (Egnankou, 1985). The salinity degree also has an influence on the vegetation.

In Côte d'Ivoire, salinity varation studies have not yet been conducted in most of the mangrove zones. The few measurements taken in some lagoons



Situation in June

Large rainy season on the coast

Situation in August

Small dry season on the coast

Situation in October

Small rainy season on the coast

Situation in January

Large dry season on the coast

FIG. 2- SCHEMATIC REPRESENTATION OF THE INTERTROPICAL CONVERGENCE ZONE (CIT) in EGNANKOU 1985

A - Littoral

B - Continent

FIG. 3 - OMBROTHERMIC DIAGRAMS OF THE ESTUARINE ZONES (1941 - 1983)

IN EGNANKOU, 1985

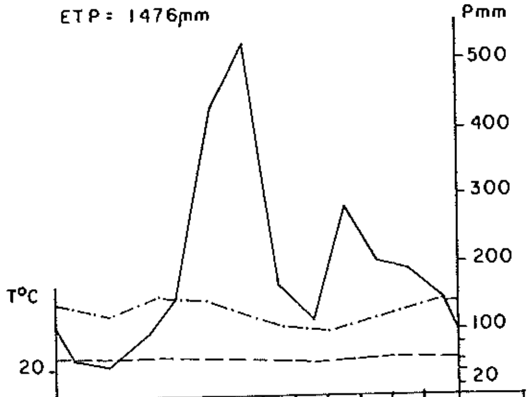
TABQU

Long. 7°22 W

Lat. 4°25 N

R = 2368 mm

ETP = 1476 mm



	J	F	M	A	M	J	J	A	S	O	N	O	year
P	33	48	90	144	430	525	168	108	280	192	183	149	2368
T	26	26	27	27	26	26	25	24	25	25	27	26	26

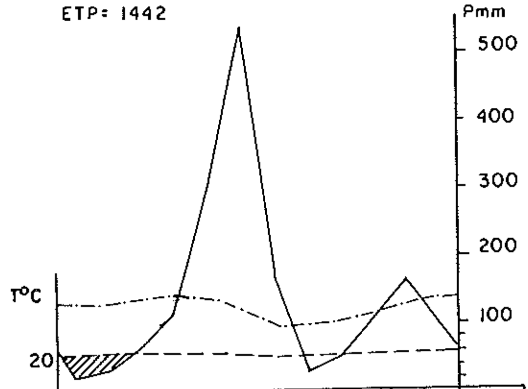
SASSANDRA

Long. 7°78 W

Lat. 4°58 N

R = 1645

ETP = 1442



	J	F	M	A	M	J	J	A	S	O	N	D	year
P	21	32	63	112	291	537	161	25	50	106	158	87	1643
T	26	27	27	27	26	25	24	24	24	25	26	26	26

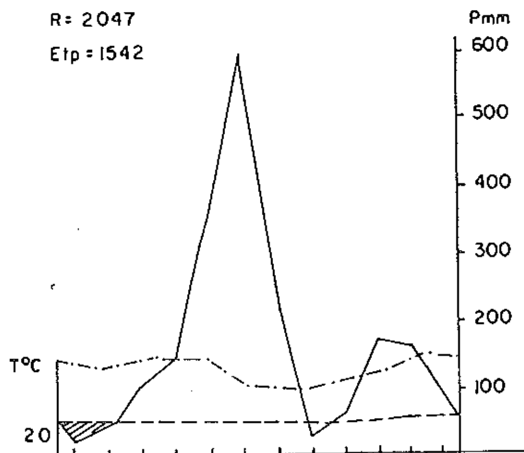
ABIDJAN

Long. 3°56 W

Lat. 5°15 N

R = 2047

Etp = 1542



	J	F	M	A	M	J	J	A	S	O	N	D	year
P	23	49	112	158	342	612	221	29	81	177	169	94	2047
T	27	27	27	27	26	26	26	25	24	26	27	25	26

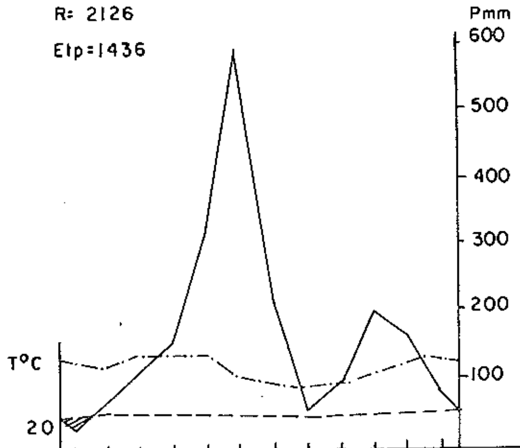
ADIAKE

Long. 3°15 W

Lat. 5°18 N

R = 2126

Etp = 1436



	J	F	M	A	M	J	J	A	S	O	N	D	year
P	31	71	118	164	324	680	212	60	100	202	161	83	2126
T	26	27	27	26	26	25	25	24	25	26	26	26	26

----- Thermic curve ——— Rainfall curve -·-·- Etp curve do not allow a scientific interpretation, as salinity varies with both the seasons and the years.

In the Ebrié lagoon where the water salinity has been studied, it was found that the maximum salinity occurs in the dry season (30‰), whereas minimum salinity is obtained during the rainy season (3‰). Since 1950, these figures have increased significantly around the Vridi canal (from 30 to 35‰) regardless of the season, which contrasts with the Eastern and Western ends of the lagoon where the average salinity change is between 0 and 5‰ (Fig. 6).

3.4 Temperature

Because of their latitudinal location, the mangroves of Côte d'Ivoire have about the same temperature at any single period of the year. Broadly speaking, the warmest months are from December through April (in the dry season), whereas the coolest starts in June and ends in September (in the rainy season). The most important differences in monthly temperatures are between 2°C and 4°C in the mangrove areas located on both sides of the 5th parallel. The monthly and annual mean temperatures along the coast are given on Table 2.

3.5 Tides

The tidal currents are relatively weak and vary from 0.5 to 1.5 meters all along the coast of the Gulf of Guinea. They are semi-diurnal: two high tides and two low tides almost every day. According to Paradis (1988), the maximum difference occurs in September whereas the minimum difference takes place in June. The tide can be felt in the lagoons and downstream the rivers. It has a permanent influence on Ebrié lagoon since the opening of the Vridi canal, and a more or less permanent influence on the other lagoons.

3.6 Marine Currents

According to Paradis (1988), there are two main coastal marine currents: - one running eastwards, on the surface, and about 20 - 50 meters of thick water mass; - a westwards running undercurrent located about 15 - 80 m depth, and moving a 50 meter thick mass of water.

3.7 Swells

They originate from the South: heavy South easterly swells in the Southern winter, and weak South westerly swells during the summer. They all hit the coast where they form a dangerous bar. Because of both the sediments they deliver to the coast and the erosion they cause, the swells have some influence on the coastal vegetation.

3.8 Coastal drift

It is directly engendered by the swell breaking on the shore. The southerly swells bring sediment deposits on the beaches. The South easterly swells facilitate the eastwards drifts, thus moving the sediment deposits and closing the natural outlets of the rivers and lagoons to the Atlantic ocean in the dry season.

Table 1: Monthly and annual averages of the rainfall in estuarine zones (in mm) from 1941 to 1983; in Egnankou,

STATIONS	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
TABOU	53	48	90	144	430	526	163	108	280	192	185	149	2,368
SASSANDRA	21	32	65	112	291	537	161	25	50	106	158	87	1,645
Gd-LAHOU	17	34	81	137	269	552	184	20	44	128	158	78	1,702
Abidjan	23	49	112	158	342	612	221	29	61	177	169	94	2,047
Adiake	31	71	118	164	324	600	212	60	100	202	161	83	2,126

Table 2: Monthly and annual averages of temperatures (in °C) from 1960 to 1978; in Egnankou, 1985.

STATIONS	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
TABOU	26	26	27	27	26	26	25	24	25	25	27	26	25,8
SASSANDRA	26	27	27	27	26	25	24	24	24	25	26	26	25,5
Abidjan	27	27	27	27	26	26	25	24	24	26	27	25	25,9
Adiake	26	27	27	26	26	25	25	24	25	26	26	26	25,7

In conclusion coastal formations such as the mangrove swamp depend on the nature of the lagoon and the river waters, and on their seasonal changes. The latter cause seasonal fluctuations of the underground waters located in the sandy areas. The fluctuations play a paramount role in the evolution of the soil and the water supply of the plants which grow on those soils.

Finally, man's activities have always been a factor of large scale changes of the coastal environment.

4. Biological and Ecological Features

4.1 Flora and fauna

The mangroves of Côte d'Ivoire are floristically very poor. Out of the 60 tree species in the world and the 6 species in West Africa, only three are found in the country: *Rhizophora racemosa* G.F.W. Meyer (Rhizophoraceae), *Avicennia germinans* L. (Avicenniaceae) and *Conocarpus erectus* L. (Combretaceae).

These three tree species often mix with others which grow accidentally in the mangrove swamp. These casual components are also found in the vegetation formations which colonize other substrata. The most frequently identified are: *Drepanocarpus lunatus* G.F.W. Meyer (Papilionaceae), *Dalbergia ecastaphyllum* L. Taub (Papilionaceae), *Paspalum vaginatum* L. (Poaceae), *Hibiscus tiliaceus* L. (Malvaceae), *Phoenix reclinata* Jacq (Arecaceae), *Acrostichum aureum* L. (Adiantaceae), *Pandanus candelabrum* P. Beau (Pandanaceae) and *Sesuvium portulacastrum* L. (Ficoidaceae). Like most of the mangroves throughout the world, those of Côte d'Ivoire consist of two main types of plant formations: a dominant arborescent or mangrove formation and a scarce herbaceous halophite swamp.

4.2 Mangrove formations

The three tree species are distributed in separate zones according to the nature of the soil, the salt tolerance of the species, and their tolerance vis-à-vis man's influence. Each species generally grows in one part of the mangrove swamps; but not all of them are represented in all the mangroves. As one procedes landwards the ground elevates slightly, and the marine influence on the soil gradually becomes less important. The species grow where they can find suitable ecological parameters. When both the ecological and anthropogenic conditions permit the development of all three species in the same mangrove, the serial succession from the water to the land is as follows:

* The first zone is occupied by *Rhizophora racemosa*. The red trees develop in muddy/sandy soil. They cannot survive long on dehydrated soils with high salt content;
* *Avicennia germinans* grows in the next zone. The white trees occur on rougher substrata and can support higher salt content;
* The *Conocarpus erectus* zone is closer to the land. The grey trees are less frequently found; they grow in the less "anthropogenic" areas where they are found in association with other species such as *Drepanocarpus lunatus, Hibiscus tiliaceus, Phoenix reclinata.*

4.3 Herbaceous stratum

Its presence within the Ivoirian mangroves is more the result of anthropogenic actions than ecological conditions. A herbaceous stratum develops after the mangrove trees are felled for wood. Hence its presence depends on both the intensity and the scale of the exploitation. When many hectares are exploited, and the trees take a long time to grow again, a stratum which looks very much like a grassland and comprises essentially of *Poaceae* and *Cyperaceae* develops in the area. In the mangroves where wood exploitation is reasonable, the herbaceous stratum is right next to the land forest: it mixes with casual arborescent and tree species, and forms a tree savanna.

Unlike the neighbouring countries, Ivory Coast has no herbaceous halophyte "tannes" called "tannes herbacées" or "grassy tannes" as actual ecosystem formations. The tree savannas are limited in time and space by both the size of the exploitation and the time it takes for the trees to grow again. The herbaceous formations mainly consist of the following species: *Paspalum vaginatum* L. (Poaceae), *Sporobolus virginicus* R. Br. (Poaceae), *Cyperus articulatus* L. (Cyperaceae), *Eleocharis variegata* (Poir) Presl. (Cyperaceae), *Hypolytrum purpurescens* Cherm (Cyperaceae) and *Mariscus ligularis* L. (Cyperaceae).

4.4 Fauna (Egnankou, 1987)

The aquatic fauna is the most important one by number of species most of which have an economical value. It comprises three big groups:

Crustaceans found in all mangroves. There is always a larger number of crustaceans in the lagoons than in the river mouths. The most-commonly found are: *Alpheus pontedervae, Ampelisca sp, Balanus amphitrite, Callinectes latimanus, Excirolana latipes,* *Gastrosaccus spinifer, Heteropanope capenti, Panopeus africanus,* and *Penaeus duorarum.*

The molluscs most frequently seen are oysters which live in every mangrove swamp throughout the world. The common oyster here is *Crassostrea gasar.* Among others are: *Corbula trigona, Littorina angulifera, Loripes aberrans, Nassa argentea, Neritina adansoniana, Tagelus angulatus* and *Tympanotonus fuscatus.*

Among fishes beside the Periophthalmus that is present in every mangrove swamp, the most common are: *Acentrogobius schlogelii, Chrysichthys sp., Elops lacerata, Tilapia sp* and *Pellonula afzeliusi.*

Among the land fauna, apart from a few reptiles (crocodiles, snakes) and mammals (monkeys, seacows) the land fauna comprises birds and insects. In fact, very few birds actually live in the mangrove areas which are temporary shelters for many migrating species. The most frequently observed are: *Anhinga rufa, Ardea goliath, Bubulcus ibis, Butorides striatus, Egretta alba, Numenius arquata, Phalacrocorax africanus,* and *Tringa sp.*

4.5 Interaction between Ecological, Biotic and Abiotic Factors

No research on this subject has been conducted in the mangrove swamps of Côte d'Ivoire. All we can say is that the thick, humid littoral forests are an adequate environment for the weathering of rocks and the development of plants. They have the most favorable conditions for soil formation: abundance of water, relatively high temperature (Table 2). In addition, many rivers deposit suspended substances in the lagoons. Man's activities have significant consequences on the hydrology and the physical and chemical parameters of the lagoon (canals, roads, bridges and other engineering works).

4.6 Productivity, Energy Fluxes, Trophic Relations, Nutrient Cycles.

The study of the productivity, energy fluxes and trophic relations between the various types of organisms which live in the mangroves of Côte d'Ivoire was included in the research program of the University of Abidjan; but it has not been realized so far because of lack of means. Therefore all the information summed up in Fig. 4 are of general nature only.

5. Traditional Uses

Because of ignorance, people cannot realize how important the mangrove swamps are. There has been no change in the way they exploit the mangroves; as in the past, the trees are felled for timber (to build houses, bridges) and for firewood. Substances are also extracted from the barks to dye materials and fishing nets, and to make fishing traps.

6. Commercial Exploitation

The only direct commercial exploitation is conducted by the lumber-jacks in the Fresco and Sassandra mangroves. This wild exploitation of one tree species (the red mangrove) which represents 70 to 100 % of the plant cover is seriously damaging the mangrove of Côte d'Ivoire. Also exploited are: oysters (Fresco and Assinie mangroves), crabs in every mangrove swamp from Ebounou (West of Grand-lahou lagoon) to Assinie, and shrimps.

7. Conversion to Other Types of Utilization

7.1 Agriculture

Agriculture is not a popular activity in the mangrove areas. Only rice is grown in Grand-Bassam and Sassandra mangroves. It is worth pointing out that people started growing rice in those areas after the mangrove swamps had disappeared. Coconuts, banana, manioc (cassava) are grown at the back of the mangroves in some regions (Assinie in the South of Aby lagoon and in San Pedro).

7.2 Mining

No mining activity is taking place in the mangroves

7.3 Aquaculture

Very few mangroves are transformed into fish breeding areas. However, fish culture is done in the large lagoons which are surrounded by mangroves.

7.4 Urbanisation

Many districts such as Abidjan and Sassandra are built in the midst of mangrove areas.

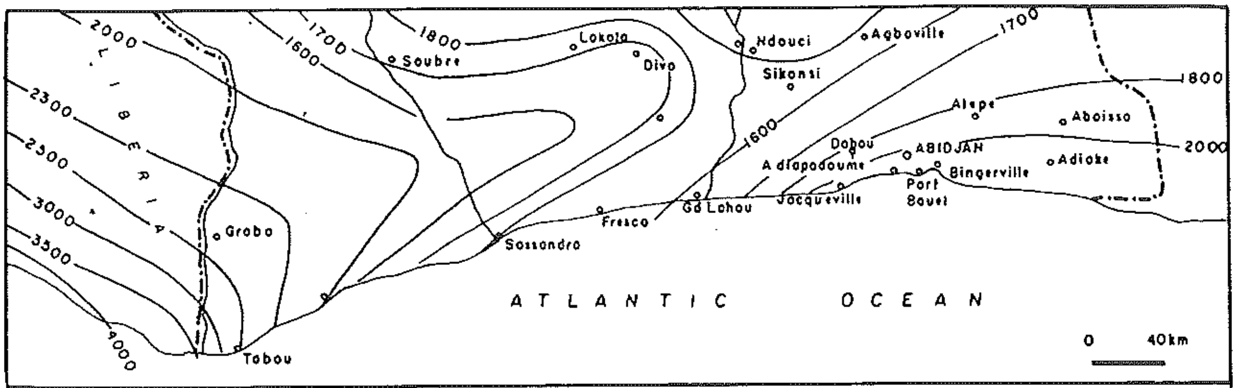


FIG. 4 - MAP OF THE ISOHYETS ALONG THE IVORIAN LITTORAL

(FROM THE RAINFALL MAP OF ELDIN) IN EGNANKOU 1985

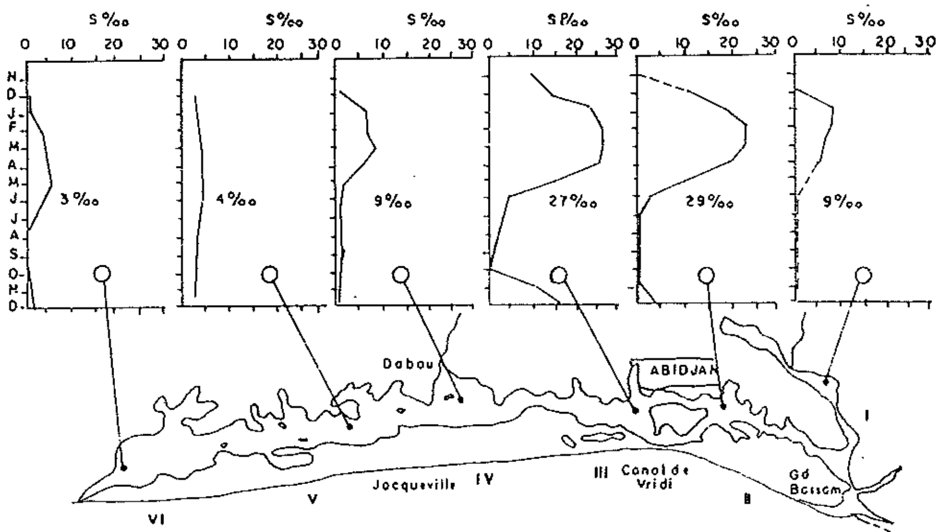


FIG. 5 - ANNUAL VARIATION OF THE SALINITY IN SIX STATIONS FROM WEST TO EAST BETWEEN THE CENTRAL CHANNEL OF THE EBRIE LAGOON

(PAGES & al. 1979 in DURAND & SKUBICH 1979)

The roman numbers indicate the lagoonal sectors

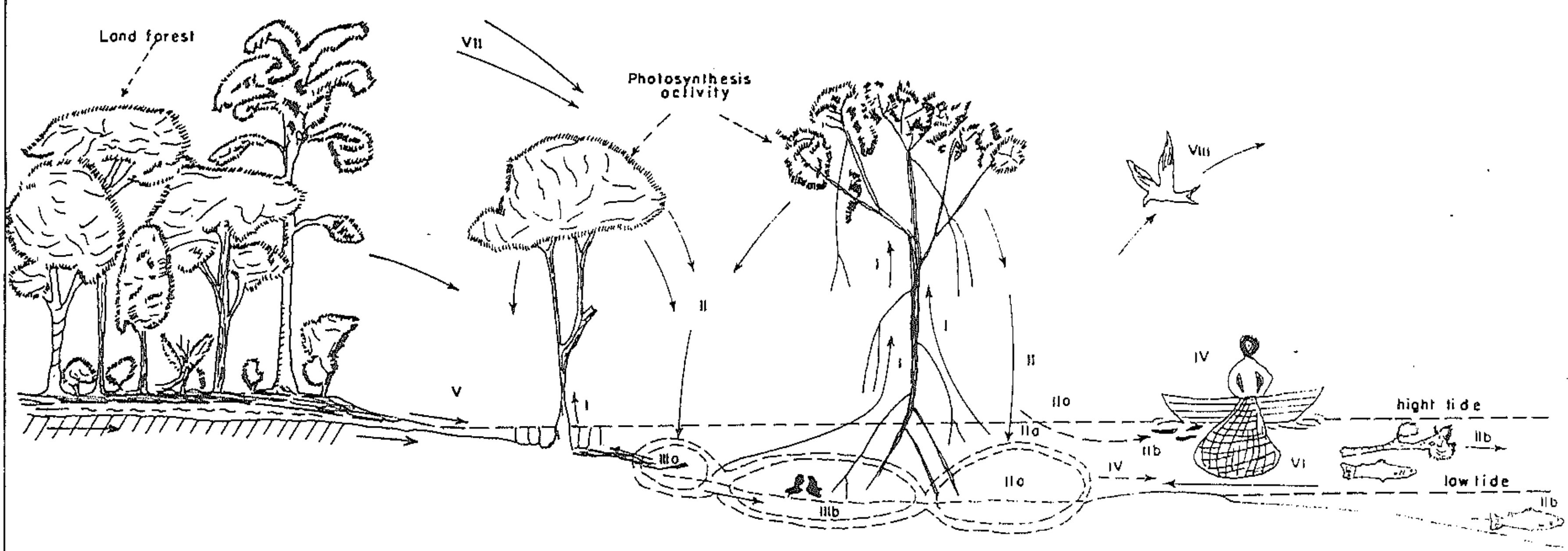


FIG. 6 - SCHEMATIC REPRESENTATION OF SOME NUTRITIVE ELEMENT CYCLES IN THE MANGROVE ECOSYSTEMS

FROM (BLASCO 1983, GOA INDIA COURSE) IN EGNANKOU 1985

I - Nutritive elements obsoption and biomasse accumulation II - Organic matter production

IIa - Mineralised organic matter fraction in the ecosystem II b - Organic matter fraction exported by tides

IIIa - Mineralisation of the orgamcmatter by decomposer micro-organisms

IIIb - Larval cycle and faunal alimentation IV - Exported ions

V - Nutritive elements inputs through the rivers (dissolved elements and elements included in the sediments)

VI - Inputs by the tides VII - Eolian inputs

8. Impacts on the Mangrove Environment

8.1 Historical causes (Egnankou, 1985)

Because the local people who lived on the seaside found it difficult to cross the thick and humid forest spreading all along the country's coast up to the savanna regions, people eventually decided to build their villages at the river mouths and around the lagoons, as it was easier to get to the hinterland from these areas than to cross the tropical forest.

The first colonizers settled in Bingerville, Grand-bassam and then in Abidjan (the first three capital cities) which were located in the middle of mangrove areas. Their development brought about the destruction of the ecosystems.

8.2 To-day's impacts such as

* **Overexploitation** - As fishing becomes more and more important in the mangrove lagoons and there is no means of preserving the catches, there is an increasing need for fuel wood. For example, between 50 and 70 % of the trees have been destroyed in the regions of Fresco and Sassandra as a result of unruly exploitation of *Rhizophora racemosa*.

* **Pollution** - All the lagoons and estuaries are occasionally polluted by the toxic chemicals used by the fishermen and the pesticides used in the farms located upstream. The Ebrié lagoon is undoubtedly the most polluted with the unprocessed domestic and industrial wastes poured into the lagoon. The villagers who live next to the rivers and lagoons transform them into dumping grounds (Egnankou, 1985).

* **Erosion** - Though there are undisputed proofs of recent erosion all along the coast, only a few data are available. In the mangrove areas, coastal erosion is mainly due to tree felling.

* **Sedimentation** - Deposits in the estuaries and lagoons are very important. According to Paradis (1988), sands are brought from the surrounding formations (bank erosion or streams and coastal river deposits). Clay deposits are carried in suspension by the rivers. Silty sand is often found in the mangroves as well as organic substances from plant debris, animal remains and from the plankton.

Building new roads and dams across rivers disturbs the coastal zone hydrology and disrupts the mangrove substratum balance:

- Clearing the forest to build the "Coastal road" brought about an increase in sediment deposits which accelerated the filling up of the lagoon and estuarine mangrove tidal forests;
- Building the Buyo Dam (in 1977) on the Sassandra reduced significantly the freshwater flow, it has killed many trees in the North-east of Broguié.

8.3 Impact of the natural factors.

Over the last few years, the most important natural impact has been decrease in rainfall which, together with dam building has reduced the freshwater input necessary for the development of the mangroves. The ecosystem's water supply is no longer sufficient to maintain the salinity at a tolerable level for the different animal and plant species, and to prevent the obstruction of the only access ways to the sea (the channels). Indeed, most channels are closed by excess sand deposit coming from the sea when the sea swell is stronger than the continental waters. Lack of connection between the lagoons and the sea results in water stagnation: the lagoons are closed and lose their nutrients; at the same time, they get toxic elements that eventually kill all living organisms (Egnankou, 1987).

8.4 Impact in the future

- The completion of the "coastal road" will mean more people drifting from the Center and the North of the country to the scarcely populated coastal areas. Over exploitation of the mangroves will worsen: the highly productive but fragile ecosystem is seriously threatened with disappearance.
- Fishing with toxic chemicals has very bad effects on the mangrove swamps and other adjacent areas. The coastal environment is bound to be seriously damaged if measures are not taken to put an end to this prohibited and dangerous activity. The chemicals are dangerous at all levels of the trophic chain (phytoplankton, zooplankton, molluscs, crustaceans, fish, men), for the water quality and for the higher plants which live in those waters.

Because of bioaccumulation and very slow biodegradation, these chemicals may, in the long run, destroy all the ecosystems where they are used as well as the ones with which they are connected.

9. Socio-Economical Implications

Anarchic and improvised exploitation have brought about major chaotic ecologic and socio- economic changes.

9.1 Fishing by poisoning waters (Egnankou, 1985).

The toxic chemicals used by fishermen and peasants in the estuaries, lagoons, and upstream in the hinterland have serious consequences on both the country's economy and on people's health. They increase the harmful effects of pollution by chemicals and constitute a permanent danger for living organisms. They are often at the root of many social problems.

The following points explain why the practices are still into effect in Côte d'Ivoire:

- As sea resources are depleting because of overexploitation of rivers and lagoons, the "legal", classical fishing methods with ordinary nets, hooks and castnets are no longer effective;
- The realization that chemicals such as DDT which are normally used as pesticides, can be used to catch many fishes in no time;
- People approve fishing with chemicals which they say give a special flavor to the fish.

The consequences of this overexploitation are obvious from both the ecological and biological points of view. The chemical composition of the water and the soil is changed. Precarious living conditions are getting worse. And sea resources, together with the economy of the region are in jeopardy.

9.2 Overexploitation of wood

It is limited to one species: *Rhizophora racemosa*, and is conducted in all the country's coastal regions where wood is the only energy source. The red trees are exploited by people who do not bother to undertake any compensatory planting. The trees are felled with primitive tools like machetes. In fact, it is the tools which enhance this wild exploitation: since no proper slicing can be made with a machete, the lumber-jacks are obliged to fell many trees to have a substantial quantity of wood, as they can only take the small trunks, the branches and the stilt-roots. The big trunks abandonned after the trees are felled give indeed a sad picture. This type of exploitation is a real danger: it is bound to bring about the eradication of the red mangrove which represents 70% to 80 % of the plant cover in most of the country's mangrove swamps. In Aby lagoon, they constitute 100 % of the plant cover.

The red mangrove tree is preferred to the other species because of its right bole, hard wood that burns out slowly and has a high calorific output (two tons of *Rhizophora racemosa* make one ton of charcoal). In addition, the red mangrove tree has other advantages over the other land forest trees whose wood is of the same quality: it grows in an area where there is water, where the lumber-jacks can circulate easily in canoes and bring significant quantity of logs with them.

Most mangroves will disappear with the extinction of the *R. racemosa*. This will involve a decreasing quality and quantity of the coastal water productivity which, in turn will bring about social and economical problems in the regions where poeple's lives are very closely associated to the mangrove swamps.

Finally, we would like to point out that a study and evaluation of the methods used are being considered and will be conducted as soon as possible.

10. Research and training Programmes

10.1 Research programmes

There still is a dearth of information on the mangrove swamps in Côte d'Ivoire although a large number of studies have been made on the country's various plant species. Some research on the mangrove swamps was carried out during very short periods of time, and focused on very specific aspects. Thus they do not give enough information on certain parameters whose characteristics must be known for a good understanding of the ecosystems. There is also no information on the exact limits and the mangrove area. The study of the ecosystem productivity and energy fluxes which were planned have not been carried out because of lack of funds.

We have been conducting research on the mangrove swamps of Côte d'Ivoire since 1984, particularly on the flora, the fauna, the productivity and the ecology of this environment. Because of the lack of means, we have only managed to make the inventory of the mangroves, to study the plants, and to set up woodland stations in some sites.

10.2 Training programme

A project has been designed by the Department of Botany and Plant Biology of the Faculty of Sciences and Technics of the National University of Côte d'Ivoire.

11. National Committee; National Mangrove Management Policy

11.1 National committee

The Ivory Coast section of COMARAF has not yet designed a project on mangroves. The only research project on the mangrove ecosystems is, to our knowledge, that of the Botany Laboratory of the National University of Abidjan.

The project objectives are as follows:
- To list and map the mangroves of Côte d'Ivoire;
- To determine the ecosystem ecological demands;
- To determine the productivity;
- To rehabilitate the ecosystems by forestry and preservation;
- To rationally manage the mangrove ecosystem.

As regards the forestry aspects, experimental stations have been set up in the Fresco, Audoin, and Vridi II mangroves by the "Laboratoire de Botanique de la Faculté des Sciences et Techniques de l'Université Nationale de Côte d'Ivoire".

Conclusion

The Ivorian mangrove swamps, from Assinie in the East to Bliéron in the West, include only 3 species of mangrove trees: *Rhizophora racemosa* G.F.W. Meyer (Rhizophoraceae); *Avicennia germinans* L. (Avicenniaceae) and *Conocarpus erectus* (Combretaceae).

They are considered to be wastelands and worthless, the trees are felled and the lagoon environment is more and more degraded. The population is not aware of the nasty consequences which may result from the exploitation of the ecosystem by harmful processes: such as the destruction of the biological environment, the annihilation of the productivity of the lagoons and rivers; the degradation of the living conditions of the people.

In Côte d'Ivoire, there is no management policy for the mangroves. The research programme initiated in the National University has not yet entered its operational phase because of lack of means.

Yet the mangrove, as the land forest, constitutes a nutritional and energetic reserve, and a favorite place for the multiplication of numerous animal species. Through their water; the mangroves participate also, in other activities: fishing, navigation, study of the nature.

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Status of the Mangroves of Ghana

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1. Extent and Distribution

The extent of the mangroves of Ghana is not well known. Data on this environment are very scarce. Nothing more than its present geographical distribution is known.

The mangrove occupies a very narrow, non-continuous coastal area and occurs principally in lagoons which extend from the eastern to the western parts of the country. The following areas from the eastern to the western coastline, respectively, have mangroves; the Keta lagoon, Srogboe, the Volta estuary at Ada, Sakumo-2 lagoon at Temam, Teshie, Korle lagoon, "Mighty Beach", Botwiano, Sakumo-1 lagoon, Muni lagoon at Winneba, Apan Baka at Apam, Iture (near Elmina), Benya lagoon at Elmina, Shama, Princes Town, Axim, Ankobra, Esiama, Amanzure lagoon at Amanzure, Ebi, Half Assini and New Town (Fig.1).

Areas to the West of Takoradi, where the rainfall is more than 1,250mm per annum, all the lagoons are open, since they have a permanent access to the sea: however, most of the lagoons East of Takoradi, where the rainfall is lower, are closed at least for the greater part of the year. The mangroves in the open lagoons are dominated by *Rhizophora sp*. In the closed lagoons at high-water level reached during the seasonal flooding there is a fringe of scrubby *Avicennia nitida* associated with *Conocarpus erectus* and *Laguncularia racemosa*.

2. Physical Environment

2.1 Climate

The coastal region of Ghana has a four-season climatic regime: major dry season (November - March/April) when air temperatures are generally highest, rainfall and relative humidity minimal; a two-peak rainy season (March/April - August; September - October/November) associated with lower annual air tempertures and higher rainfall and relative humidity; and a short dry season (August) between the two rainfall peaks. Areas to the West of Takoradi are relatively wetter with annual rainfall exceeding 1250mm, while the eastern parts of the country are relatively dry.

2.2 Soils

Very limited information is available on the soils of the lagoons and mangrove areas in the country.

Generally, the parent material of the soils is alluvium or alluvium and silt. The soils are clayey silt in texture, massive and structureless due to prolonged submergence. They are generally poorly or imperfectly drained, grey to dark grey in colour. Data on the chemical properties are scanty. The available data for some mangrove areas are presented in Tables 1 and 2.

3. Biological and Ecological Characteristics

3.1 Flora and vegetation

The Ghanaian mangrove vegetation is poor in genera and species but includes *Rhizophora* (Rhizophoraceae), *Avicennia* (Avicenniaceae), and *Laguncularia* (Combretaceae). Included in the floral composition of the mangrove in most places are *Conocarpus erectus, Phoenix reclinata, Acrostichum aureum, Paspalum vaginatum, Sesuvium portulacastrum* and *Cyperus* sp. Others are *Ipomoea pes-caprae, Canavalia rosea, Hibiscus tiliaceus, Thespesia populnea* and *Cardiospermum* sp. which form the characteristic strand vegetation usually of unprotected sandy beaches. The growth of microbenthic algae, usually the blue-green type, is noticeable in areas where water is available. These algae are otherwise present as dry algal mats due to prolonged exposure or occur as algal mats on both the prop roots of *Rhizophora* and the pneumatophores of *Avicennia*.

Not all the three mangrove genera are present at all places. *Laguncularia* is limited in occurence and is present at Iture, Benya lagoon, Shama and Amanzure lagoon. Most of the mangrove stands are not extensive and are of secondary or tertiary development as a result of intensive exploitation. They consist of small trees of up to about 5m in height regenerating from stumps. Mature, relatively

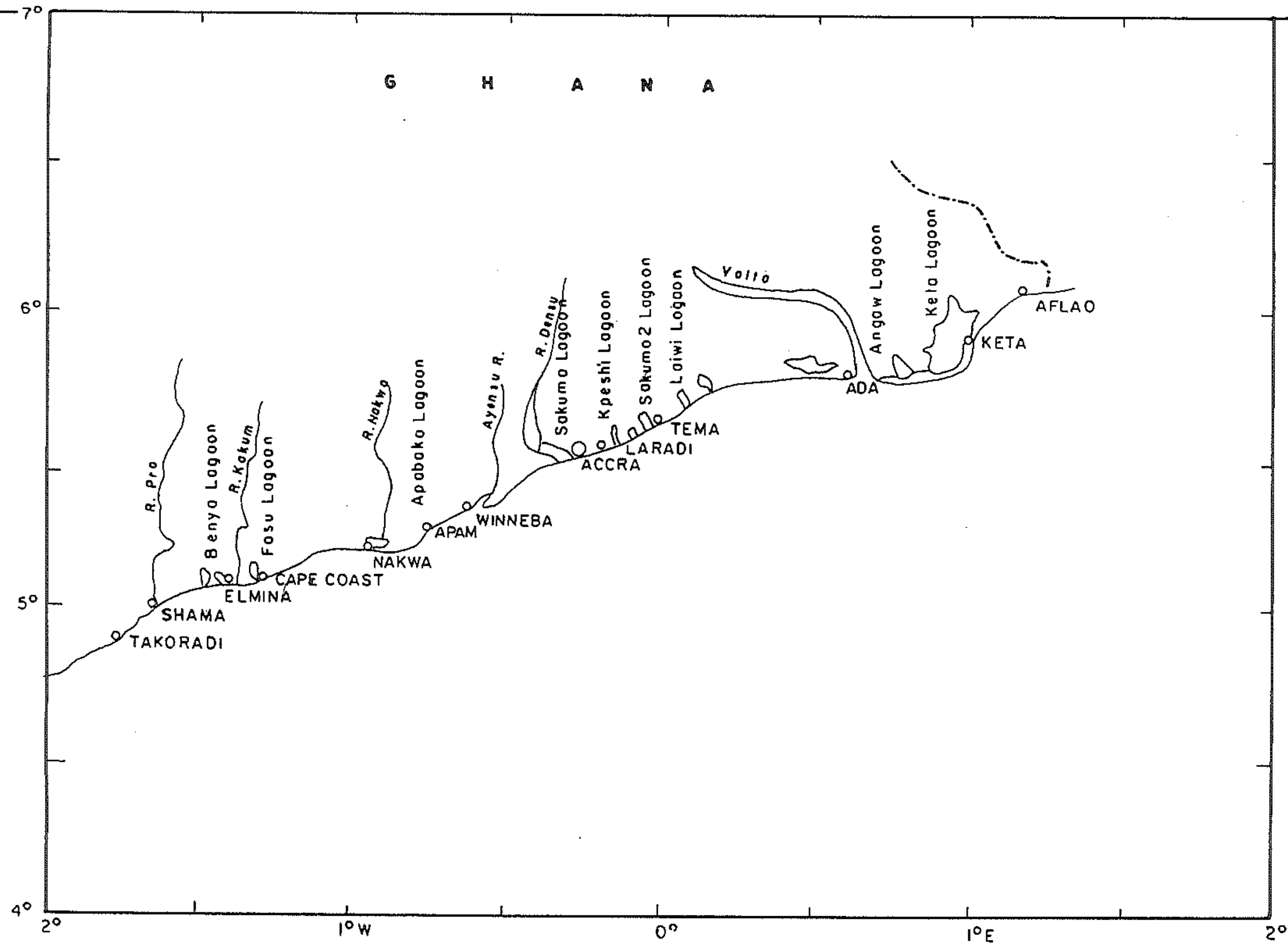

FIG. 1 - COASTLINE AND COASTAL LOWLYING LANDS IN GHANA

SOURCE: SINGH (1987)

Table 1. Chemical properties of soils at Keta lagoon area.

Soil depth (cm)	PH of dry soil in		O.M. %	Available Phosphate (mg/kg)	Exchangeable	
	Water	H_2O_2			Ca (mg/K)	Mg (mg/kg)
0-20	8.5	7.1	1.1	3.0	1846	1238
20-50	8.5	7.0	1.2	3.0	1840	1200
50-70	8.2	7.0	1.2	2.0	1858	1358
70-100	8.3	7.2	4.1	2.0	2532	1698
100-120	8.5	7.3	6.6	Nil	2772	2429

O.M. = Organic matter
Source: Singh (1987)

Table 2. Chemical properties of soils at Sakumo-1 and Takoradi

Soil depth (cm)	---------PH---------			Potential acidity (meq/100g)	O.M. en %	Exchangeable			Available Phosphate	Extractable Fe
	Dry soil in Water	Dry soil in KCL	Wet soil in H_2O_2			Al	Ca	Mg		
						---------------mg/kg---------------				
Sakumo-1										
0-20	5.6	5.2	5.0	9	4.0	Nil	-	-	2.0	44
20-40	5.8	5.2	5.1	9	1.6	Nil	-	-	3.0	17
40-60	5.6	5.1	5.1	10	5.5	Nil	-	-	2.0	65
60-80	4.8	4.2	4.0	12	1.1	Nil	-	-	2.0	Nil
Takoradi										
0-30	3.5	1.6	1.6	48	1.5	160	400	196	Nil	189,200

undisturbed *Rhizophora* patches of forest are present in Amanzure lagoon and Ebi. Trees are about 20m in height and about 30cm in girth at about 0.5m above the prominent stilt roots.

Seedlings of mangroves are abundant in most of the mangrove areas suggesting that regeneration from seedlings is a practical possibility.

3.2 Fauna

The faunal component of Ghanaian mangrove is represented by several species of crabs, molluscs, including *Burgaus* sp., *Littorina* sp. oysters, and birds.

The bird life of the coastal wetlands of Ghana has been monitored by the Save the Seashore birds Project of Ghana (SSBP-G) since 1986. Birds identified at thirteen wetland sites include migratory and resident species. An average of 51 bird species with an estimated average population of 47,700 birds at peak counts have been counted at eight key coastal wetland sites (Keta, Songor, Sakumo, Korle, Muni lagoons and the Densu delta, Elmina Salt pans and Esiama Beach; Ntiamoah-Baidu and Gordon, 1991).

The species include shore birds or waders, terns, gulls, herons and ducks (Ntiamoah-Baidu and Gordon, 1991). The occurence of three species of turtles which may be associated with the coastal wetland areas in the area between Srogboe and Ada and around Shama has been reported (Agyepong, 1992). These are the green turtle, (*Chelonia mydas*), the leather back turtle, (*Dermochelys coriacea*) and the loggerhead (*Caretta caretta*). The aquatic fauna include tilapias (Cichloidae) moslty *Saratherodon melanotheron*. Other species include *Periophthalmus* sp., the horse mackerel, *Caranx hippos*, the mullets and shrimps or prawns.

3.3 Community stability properties

3.3.1 Zonation

The vegetation around the lagoons of Ghana is divided into two distinct zones, an inner zone at the water's edge of mangroves proper, and an outer herbaceous zone of low halophytic herbs.

Subzonation of the main mangroves is not always discernible as not all the three genera are present in most places. But where all the three occur *Rhizophora* is usually present along the channels of the river and along the banks of the lagoon where there is regular inundation, while *Avicennia* and *Laguncularia* occur at the backswamps reached by tidal water usually at high tide.

The herbaceous zone is made up of a few plant species and usually occur as pure stands forming only small patches or often occurs as subzones within the herbaceous zone. At the lowest levels are *Sesuvium portulacastrum,* while the upper levels are occupied by *Paspalum vaginatum* mixed with *Acrostichum aureum* and *Cyperus* sp.

3.3.2 Accretion

Quantitative data on accretion are not available. It may not be substantial in most of the mangrove swamps as the rivers which feed the lagoons are small and therefore do not carry large sediment load.

3.3.3 Erosion

Most of the mangrove swamps are not seriously threatened by shore erosion. Parts of the Volta estuary have been eroded by the rush and the strong current of water created when the sluice gates of the Akosombo and Kpong dams are opened especially towards the end of the rainy season (Singh, 1987). Some villages are said to have been displaced by the erosion of the banks. Shore erosion is also noticeable at the mangrove swamp at Shama. Here most of the coconut trees which have been planted in place of the vegetation of the main strand zone have fallen over and the mangroves have disappeared in a number of places.

3.3.4 Productivity

Data on primary productivity of Ghanaian mangroves are not available. Available data on productivity refer to phytoplankton. Kwei (1977) measured productivity in the waters of the Mukwe lagoon (a closed lagoon) and the Sakumo-2 lagoon and found that the productivity of the latter is considerably higher than that of the former (Table 3). Pauly (1975) also measured primary production in the same Sakumo-2 and obtained mean values which were a little lower than those reported by Kwei (Table 3).

4. Human Habitation and Traditional Usage

In the coastal zone of Ghana, only a few towns and cities such as Accra, Tema, Keta, Anloga and Elmina which have mangroves of ecological interest are heavily populated. Most of the other mangrove areas are sparsely populated. Thus encroachment of housing is not common. Dry lands are usually available and most permanent settlements are restricted to these.

Singh (1987) reported the use of mangrove land around Laiwi lagoon at Tema and Apam Baka at Apam for building construction and parking lots.

Table 3. Phytoplankton production in Ghanaian lagoon systems

Locality	Month	Production	Reference
Mukwe lagoon	September	626 + 70[a] surface 600 + 83[a] bottom	Kwei (1977)
	December	828 + 77[a] surface 463 + 31[a] bottom	
Sakumo-2 lagoon	July	1413 + 322[a] surface 378 + 187[a] bottom	Kwei (1977)
	September	1992 + 392[a] surface 222 + 311[a] bottom	
Sakumo-2 lagoon	September	1420[a] surface 120[a] bottom	Pauly (1975)
	October`	1000[a] surface 240[a] bottom	
Sakumo-2 lagoon	September October	385[b] surface 321[b] bottom	Pauly (1975)

[a] mg Cm^{-3} day^{-1}
[b] mg Cm^{-2} day^{-1}

Encroachment of housing on mangrove land is also noticeable in the following areas: Korle lagoon in Accra, Srogboe, Sakumo-1 lagoon, Gomoa Nyanyano and Benya lagoon at Elmina.

East of Takoradi, mangroves in towns such as Shama, Elmimna, Iture, Accra, Tema, Ada Srogboe and Keta have been intensively exploited for fuel wood for fish smoking and other domestic uses. In the far West of Takoradi where there is abundant supply of fuelwood from other plant species due to higher rainfall, exploitation of mangroves for fuel wood is less intense. The mangrove wood is usually used in the construction of houses and pig sties. This is a common practice of the local people living around the Amanzure lagoon.

Charcoal production from mangroves is not practised because the cooking habits of the people in the mangrove areas are not used to this type of fuel.

5. Commercial Exploitation and Marketing

As stated in section 5, exploitation of mangroves for fuelwood is intensive in the eastern parts of the country, especially around the Keta Lagoon, Srogboe, the Volta estuary, Tema, Iture, Elmina and Shama. The cutting of mangrove trees in these areas is intense and the trees cut are mostly of *Rhizophora* and *Avicennia* species.

The methods of exploitation are very simple and do not favour regeneration. Cutting is done without following any sustainable exploitation technique. Usually, large patches of mangroves are clear-felled and attention turned on other areas, while the harvested areas are allowed to regenerate from coppice shoots. The rotation time (a few years) is usually very short and does not ensure proper regeneration of the logged areas. The harvested wood is cut up into about 2m billets, allowed to dry in the sun for some time and sold as round wood. Wood from the maim stem is separated from that of the stilt roots in the case of *Rhizophora*.

Data on the volume and prices of wood extracted are not available as logging in the mangroves has not been investigated.

6. Conversion to Other Uses

6.1 Agriculture

The mangrove farming system in Ghana is based on a few important crops: rice, shallots, cassava, maize and vegetables such as pepper, okra and tomatoes, and is complemented by resources provided by the ecosystem like fish, prawns, crabs and oysters.

A large portion of area potentially occupied by mangroves around the Keta lagoon area at Anloga is used for the cultivation of shallots and vegetables. The area is virtually devoid of mangroves except for some small isolated patches of mangrove vegetation consisting of only a few stunted *Avicennia* trees. The trees appear unhealthy and some are actually dying. Some dead stumps can still be observed in the areas being farmed. Swamp rice is cultivated around the Keta lagoon area and the Volta estuary. Most of the crops are only grown for local consumption. Data on quantity of food crops produced are not available.

The lagoons of Ghana are only used for subsistence traditional fishery. Most fishing is done out of simple fishing gear: mainly castnets, gillnets and hooks. In the Amanzure lagoon, crabs and oysters are exploited and their meat used as fishing bait by children. Traditional fishing traps are also used. Data on the catch are not available.

6.2 Mining

So far no mining activity has taken place in any of the mangrove areas.

6.3 Aquaculture

Marine fisheries and fish production from inland waters, mainly the Volta lake, are the two major sources of fish supply in the country. The total supply of fish from these two sources is about 140,000 metric tons per year (Rabanal, 1985).

Fish production from aquaculture is still at infant stage. Freshwater aquaculture is gaining some attention but brackish water and marine aquaculture are practically non-existent in the country. Singh (1987) reported on the potential for brackish water aquaculture development (see Fig. 2). It is necessary to increase fish production through aquaculture to supplement that from capture fisheries.

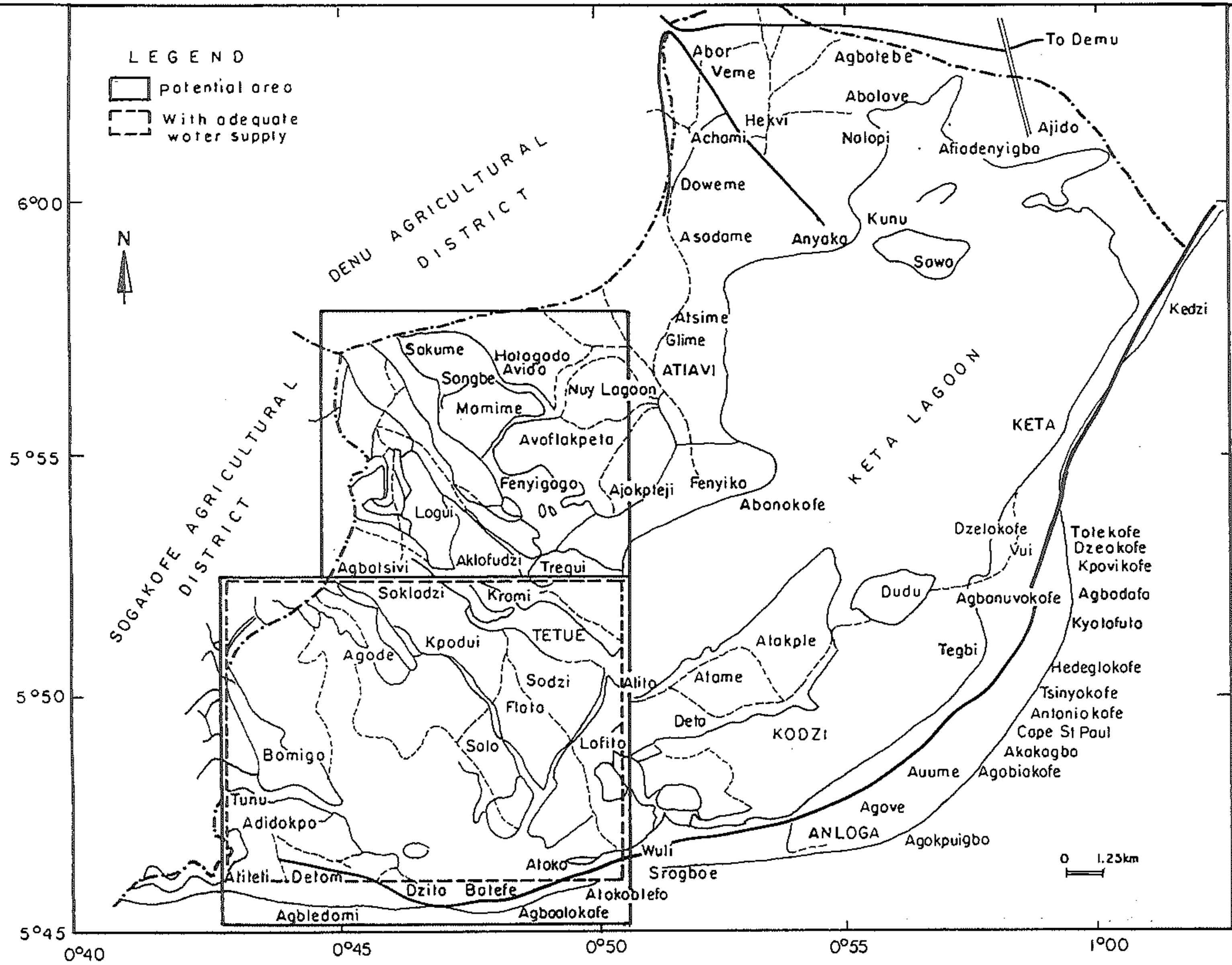

FIG. 2 - POTENTIAL AREA FOR AQUACULTURE DEVELOPMENT IN THE VOLTA REGION. GHANA

SOURCE: SINGH (1987)

6.4 Urbanisation

Urbanisation, with its attendant problems, such as pollution and increased demand for land, has had profound effect on some of the mangrove areas in the country. In the Accra-Tema metropolitan area, pollution resulting from rapid population increase has had serious consequences for the mangrove ecosystem at Teshie and around the Korle lagoon. These mangrove areas are suffering from severe faecal pollution and garbage dumping activities. Encroachment of housing in these areas is also on the increase.

6.5 Salt pans

Salt production is among the mangrove land use systems in Ghana. About half of the area occupied by Sakumo-1 lagoon near the mouth of the Densu River is intensively used for salt production by Pan Bros Salt Industries (Lawson, 1986; Singh, 1987).

Large portions of land potentially occupied by mangroves around Benya lagoon at Elmina have salt pans and are used for salt exploitation. Also parts of the Volta estuary, Apam Baka at Apam and the Keta lagoon have been used for this purpose.

7. Impact on the Mangrove Environment

7.1 Human induced stresses

Activities such as salt exploitation by local salt industries and slash and burn agriculture which takes place in some of the mangrove areas and which involve complete destruction of the mangroves alter the mangrove environment more or less permanently. Both the physical and chemical properties of the soils are altered. The soils in these areas are usually acid sulphate soils as a result of exposure, and have low organic matter content and low productivity. The bush burning which usually accompanies the land preparation exercise destroys mangrove seedlings and coppice shoots thus preventing regeneration. The mangrove fauna is killed when the vegetation is destroyed, impoverishing the mangrove.

The damming of the Volta River at Akosombo and Kpong coupled with low rainfall and other factors in the region has brought about profound modification of the hydrology and salinity in the Volta estuary and the Keta lagoon area (Singh, 1987). The dams have caused a more regulated inflow of river water to the lagoon resulting in a more or less permanent cut-off of the lagoon from the adjacent sea by a massive coastal sand bar. As a result of the restricted entry of saline water the salinity of the Volta estuary and the Keta lagoon is very low favouring the establishment of freshwater vegetation. Parts of the lagoon have dried out completely and remain bare without vegetation cover.

7.2 Over exploitation

Over exploitation through extraction of wood for fuelwood and other purposes has resulted in the degradation of the mangrove vegetation in a number of places. The method of extraction is mainly by clear-felling of patches. Drying up and hardening of the soil on logged areas usually preclude the proper establishment of seedlings. Most of the mangrove stands are of secondary or tertiary growth with poor faunal composition. Primary productivity and regeneration of the mangroves are adversely affected. The logged areas are often taken over by luxuriant growth of *Paspalum vaginatum* and *Sesuvium portulacastrum* or remain bare without any vegetation cover. This situation is found at Keta, Ada Foah, Srogboe, Iture and Shama.

7.3 Pollution

Inputs of pollutants come primarily from mine tailings, industrial effluents, domestic wastes and oil pollution (Agyepong and al. 1990). Much is carried into coastal lagoons with river run-off but considerable quantities of domestic wastes originate directly from coastal cities and villages.

Human defaecation is very common in most of the mangrove areas. This constitutes a serious source of infection to the mangrove fauna and the local people who exploit the mangrove resources, as well as researchers. Incidence of faecal pollution is prevalent in the following mangrove areas: Shama, Korle lagoon, Keta lagoon, Benya lagoon, Apam Baka and Amanzure lagoons.

Parts of most of the mangroves have been used as garbage dumping grounds. This situation prevails at Benya lagoon, Apam Baka area, Shama and Korle lagoon. Thus, these areas have become the breeding sites of disease vectors such as mosquitoes and houseflies.

In Accra, Accra Brewery Company, a beer brewing company, discharges its effluents into the Korle lagoon causing eutrophication, with serious consequences on the aquatic fauna of the lagoon.

7.4 Erosion

Singh (1987) reported of intensive erosion on the concave banks of the channels in the Volta estuary and the disappearance of the mangrove vegetation and fauna in a number of places. This is caused by the rush and the very strong current following the opening of the sluice gates of the Akosombo and Kpong dams, especially towards the end of the rainy season. Removal of vegetation and strong wave action have resulted in the erosion of parts of the mangrove swamp at Shama. Thus the mangrove vegetation and fauna have disappeared from a number of places.

7.5 Accretion, excessive silt deposition

As stated above, the rivers which feed the lagoons and the various mangroves are small and do not carry substantial amounts of sediments. Thus accretion in most of the lagoons and swamps is slow. The soil substrate is therefore less unstable. Quantitative data on accretion are not available.

7.6 Impact of natural stresses

Low precipitation, especially in the coastal zone of the Volta and Greater Accra regions, and high evaporation result in semi-arid conditions within this humid tropical zone (Singh, 1987). Drying up of areas potentially occupied by mangroves occurs with the soil showing hypersaline conditions. This situation is prevalent at the following areas: Keta lagoon, Srogboe, Volta estuary at Ada Foah, Sakumo-1 and 2 lagoons and Teshie.

8. Socio-Economic Implications

No information on socio-economic implications of the use and misuse of mangroves are available as no socio-economic studies on the utilisation of mangrove resources have been carried out.

9. Research and Training Programmes

Research programmes being carried out include studies by members of Department of Botany, University of Cape Coast on various aspects on mangroves near Cape Coast and the African Biosciences Network Support Amlalo to study the mangroves near Accra.

10. National Mangrove Committees - National Policies for Mangrove Management

Mangrove committees do not exist in the country and it does not appear that the mangrove ecosystem is taken care of by the Ghanaian forest law.

Management plans have, however, been prepared for Songor and Keta wetlands which are proposed Kamsar sites (under the World Bank G.E.F; Ntiamoa-Baidu and Gordon, 1991; Ntiamoa-Baidu, 1991). Detailed management recommendations for the entire Ghanaian coastal zone have been drafted in the "Coastal Zone indicative Management Plan" by Agyepong and al. (1990) prepared for the Environmental protection Council. Many of these recommendations have been incorporated into the policy document "Ghana Environmental Action Plan" (1991) prepared by the E.P.C.

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Mangrove Ecosystem of Togo

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Introduction

Togo's vegetation comprises five zones (Ern, 1979, and Brunel & al, 1984). The fifth and southernmost is a savannah area with a sub-equatorial or Guinean climate. It has two rainy seasons, very little rainfall, and a permanently high atmospheric humidity (Atlas du Togo, 1981). The zone corresponds to the coastal sedimentary basin constituted by a shelf covered by the Continental Terminal clayey red sands with Quaternary deposits on the coast and in the valleys (Atlas du Togo, 1981). There is a zonal swamp vegetation formation similar to that described by Paradis (1975, 1976, 1978,) and Profizi (1985) in Benin and in Côte d'Ivoire.

The only informations on the Togolese coastal ecosystems come from Ern (1979) and Brunel and *al. (1984)* who identified "the remains of mangrove swamp formations in the areas subjected to the influence of the tide which consist of *Acrostichum aureum, Avicennia germinans, Dalbergia ecastaphyllum, Rhizophora racemosa*".

We gained a better knowledge of the mangroves during a botany fieldwork in 1987. They are very well preserved although some people quoted in the bibliography do not have the same opinion. Hence, the little available information about this vegetation appears to be useful.

1. General Framework of the Study

The area studied is located to the North of the Southern boundary with Benin, between 6°15' and 6°18' N lat; and 10°37' and I°49' E long. It is a very humid strip of land along a channel called Gbaga which connects Aheno lagoon to the inferior basin of the Mano river at the South of Agbanaki. The twenty meter long channel is equally connected to some of the nearby valley streams N-S, the most important of which is also called the Gbaga. It runs through the village of Zanvé about 5 km from the Mono river. These valleys have different sizes. They are dug in Continental Terminal ferrallitic formations regularly observed along a path from Aheno to Zébé, up to Agbanaki.

The axis of the area is represented by the path leading to Agbanaki, precisely from the junction with Aheno road at Aklakou. It runs parallel to the Gbaga channel considered as the borderline between Togo and Benin. In fact, the path and the channel are not really parallel: there are 1000 meters distance from each other in the West and 100 meters distance from each other in the East.

The channel is about one kilometer away from the sea to which it is connected by the Mono river. This has been made possible with an artificial outlet called "Rio Mouth" (Fig 1). Another access way to the sea is by the Aneho lagoon located in the East of the city. But this way is only passable from time to time, and salt water flows from the eastern to the western parts of the channel (from Agbanakin to Zébé, at the entrance of Aného lagoon). Nangbeto dam (1987), which is 200 km upstream, regulates the flow of the Mono river while increasing its water level. The dam also regulates the channel waters running from East to West.

Salinity varies significantly with the seasons; Ahéno lagoon receives sea water (from February through April) from the lower Mono via the channel. The latter does not only supply the lagoon with water, but it also provides salt to the area studied.

The soils identified are mainly riverine and lacustrine deposits and recent marine deposits which

Editor's Note - Though this contribution does not refer principally to mangroves, the text is included in the report because it is a good study of mangrove related ecosystems on the landward fringe

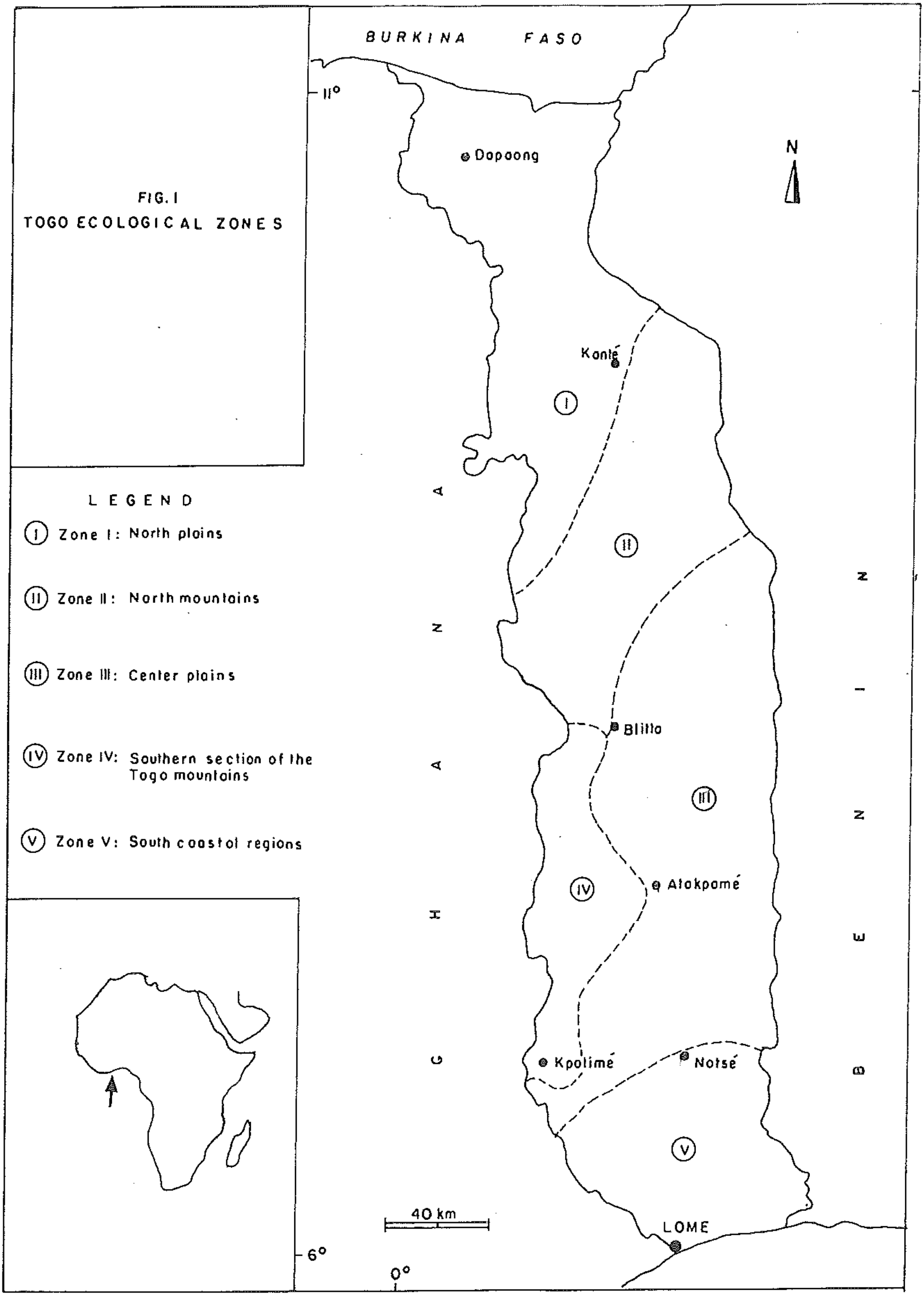


FIG. I
TOGO ECOLOGICAL ZONES

are occasionally inundated. They consist of sand and/or clay in all the low areas: along the channel and the Mono, in the North-South depressions and in the swamps and ponds at the North of the path, particularly between Zanvé and Agbanaki.

The alluvial, hydromorphous soils comprise three groups (Viellefon & *al*, 1967):
- soils on clay, subjected to more or less important salt water inundations;
- colluvial silty-sandy soils altered by water with collapsed termite mounds;
- sandy soils, rising above the previous deposits.

The climate is equatorial with two rainy seasons: a long one from March to June, and a small one from September to mid-November. The water level is fairly low and always inferior to 1000 mm (Nubukpo & al, 1987). The high temperature does not vary significantly (maximum temperatures between 24°C and 32°C; mean temperature close to 27°C). Humidity is around 80% (except when the Harmattan wind blows, in particular from December through January).

2. Methodology

2.1 Fauna and Flora

Our objective was to single out the most homogeneous groups in the plant cover. We identified some dynamic relations and built the corresponding evolving series whose stages are constituted by identified communities.

The inundated zone plant communities generally form strips that lay parallel to the axis of the depressions they occupy, or circle around the water. We made both transects and measurements. The former permit to identify the zonation and determine the development of the plant cover. Sampling was carried out at regular intervals from the moistest to the driest areas. The sampling areas were 5 m x 5 m plots in the herbaceous zones, and 10 m x 10 m plots in the forest stands. The main environmental features were recorded for each of them: presence of freewater, inundation indexes, ground-surface horizon texture and structure.

The physical aspect and composition of the plant cover was specified: strata thickness and overlapping, detailed listing of the strata (each station was given a coefficient of dominance-dominance from the classical scale (from + to 5) which takes into account the settling and the number of prevailing species.

In order to make our tables, we compared and grouped the samples according to the plant composition while taking into account environmental factors. We were able to distinguish the typical species from the associated ones. We tried to distinguish the regular from the significant causal components of the heterogeneous species groups, and concluded, when the group homogeneity was obvious, that they were associations which comprised one or several sub-groups.

The plant inventory is not given here because it would overload this report but it is available.

2.2 Fauna

The collected samples were identified thanks to the kind support of the experts from the subregion, namely Dr. Leung-Tack (for the molluscs), and a Danish research team specialized in bilharzia studies. Much appreciated help was also provided by Dr. Ntiamoa-Baidu of the University of Ghana (Legon). Several methods were used to determine the quantity of the mangrove fauna and the associated vegetation environment, namely transects, quadrats, and samplings from square plots.

The **technique of transects** was used to assess certain specific communities such as the *Periophthalmus papilio* in the areas that were particularly accessible.

The **technique of quadrats** was convenient for finding out the actual change in spatial distribution of Crustaceans such as *Cardisoma armatum* and *Uca tangeri*. It consists in making a line accross the vegetation, then delimitating consecutive 100 m^2 plots along the line (from the land to the water), and counting the holes in each plot (those whose entrances are blocked by cobwebs are considered to be unoccupied).

Sampling consists in counting the individuals of each species in each plot in order to determine the abundance of the fauna. Like the transects, this can only be done in open sites.

3. Results

3.1 Inventory of the Plant Communities

3.1.1 **The free water communities** grow for example in man-made or natural small pools, (old clearings, fish breeding ponds), depressions laid out the North-South hydrographical network complex pools of the Ggaga and its tributaries.

The *Nymphaea lotus* association is rarely found. It occurs in waterlogged stations where the water is generally over 50 cm deep. It grows on clayey substrata, and is salt tolerant: it is observed in the Ggaga and in its tributaries, just before the mangrove forest zone. It is equally found in depressions among the *Typha australis* swamps.

There are few associated species. Most individuals are of the typical species. They are sometimes mixed in freshwaters with a few floating hydrophytes (*Pistia stratiotes, Salvinia nymphellula, Lemna paucicostata* and *Wolfia sp.*), or inundated hydrophytes (*Utricularia sp.* and *Ceratophyllum demersum*). Transgressive plants from the neighbouring associations (*Eleocharis sp.* and *Echinochloa sp.*) can be seen on the edge of the association area.

The *Nymphaea guineensis* association is quite frequent. It endures long dry periods and can grow in areas where the water is shallow. It develops in rainy seasons at the bottom of all the depressions on clayey alluvial substrata. The association consists of small *Nymphaea* which blossom over the water among the *Eleocharis sp.* and *Paspalum distichum* both of which are hygrophile plants and constitute the next stage.

The *Echinochloa pyramidalis* association occupies the edges of the clayey waterlogged depressions. The association is scarce and its members are often incomplete. Some impoverished shreds sometimes grow on the mangrove side. It develops well when the waters are somewhat mineralized. Then it forms a mosaic with *Eleocharis* or *Typha* and covers large depression areas of the *Mitragyna inermis* savannah where the shepherd graze their animals.

The associated components are creepers (*Echinochloa sp., Neptuna sp., Leptochloa sp.* and *Leersia hexandra*) rooted in the mud and rafting among the nymphales. Hygrophile therophytes such as the *Alternanthera sp., Glinus sp.,* and *Ludwigia sp.* which particularly develop in the dry season can be observed on the association area edges, among the lying stems of the creepers.

The physiognomical aspect of the *Ludwigia adscendens* association is about the same. It occurs in similar areas around the freshwater ponds on sandy and alluvial substrata; the species is most resistant to dryness. During the rainy season, it actually develops in the shallow ponds which appear among the *Pycreus polystachyos* grasslands. The association components comprise a few floating hydrophytes trapped in the tight network formed by the stems of the *Ludwigia. adscendens* whose adventitious roots float on the water. Cyperaceae, namely *Oxycaryum, Cyperus* and *Fuirena* grow on the association area edges.

The *Eleocharis* association forms an 80 cm high herbaceous layer which can easily be recognized in the landscape as it remains light green all year round. The one species association occupies significant areas around the fresh water pools on the muddy substrata and on the moistest *Paspalum distichum* and *Typha australis* swamp herb layers.

The floristic association is poor and the group almost comprises a single species: the *Eleocharis mutata* density is such that there are no casual components. The neighbouring group species can only grow on the very edges of the area where the association is. *E. dulcis*, which is less frequent, more hydrophilic.

3.1.2 The mangroves

The mangroves are formations whose presence in Togo was questioned (Ern, 1979). There are many along the Gbaga river and its tributaries (Fig. 2). There are also mangrove trees scattered on the banks of the Mono river (West of Agbanakin) and at the entrance of the Aheno lagoon.

There is no obvious relationship between high salinity and mangroves: they are found in areas which are regularly flooded by the seatides, in the Western most parts of the channel and its tributaries, and within the creeks, where salinity is lower.

The mangroves of Togo have up to 20 meter high trees. Some areas are 100% covered by mangrove vegetation. and occupy over 50 meters on both sides of the water. We identified a clear zonation.

Description of a transect - All the transects showed a clear organisation although there seems to be more diversity in some areas because of the presence of the *Heteropteris leona* (Malpighiaceae).

The most frequently observed structure is:

- in the water: *Rhizophora racemosa* in pure stands; no herbs.
- behind them: *Avicennia africana* in the muddy tidal inundated areas. A few *Pterocarpus santalinoides* in some places.
- next zone at the rear has more shrubs, is inundated occasionally: *Drepanocarpus lunatus, Dalbergia ecastaphyllum, Heteropteris leona, Phyllanthus reticulatus* and *Mimosa pigra.*

Landwards above the mangrove zone: *Vetiveria nigritana* association often mixed with *Eragrostis namaquensis;* and

Paspalum distichum and *Andropogon gayanus* association. Both were mixed with small trees like *Migragyna inermis* (Rubiaceae) and *Phoenix reclinata* (Arecaceae). Old termite mounds with shrubs developing on them: *Paullinia pinnata, Aphania senegalensis, Antidesma venosum.*

3.1.2 **The fresh water swamp populations** are the largest and the most important formations occupying the bottom of the North-South depressions and plains adjoining to the Gbaga and the Mono rivers.

The *Typha australis* association can be noticed immediately when entering the studied area. It occupies significant areas on both sides of the path running around the ponds (before Agouégan). The association grows on clayey, waterlogged soils which never dry up, and can withstand high mineralization: it sometimes occurs behind the mangrove swamp. The *Typha* association is generally found in the depressions at the back of area occupied by the *Eleocharis* group which develops right behind the *Nympheae.*

This monospecific association often comprises 2 or 3 meters high individuals which grow very close to each other. Its strong rhizomes mix with the dry leaves. Together, they form abundant litter which becomes thick peat compost after decay; it can be seen on the banks of the fish breeding pools dug near Agouégan.

Other species are transgressive components of the neighbouring associations (hydrophytes and hygrophytes) which enter into the less thickly populated edges of the area.

The *Paspalum distichum* association occupies the heavy, clayey soils whose superficial back slots bear witness of recent dryness. It particularly occurs at the back of the mangrove swamps and often develops in places where the trees have been felled and *Acrostichum aureum* has taken over. They are behind the hydrophytes in the depressions and in the *Mitragyna* savanna lowlands.

Paspalum distichum is a dominant species, partly creeping then standing stem and the stiff thorny leaves of this hardy graminaceous plant make the formations look like a thick, high (80 cm) grassland. Next to the *Typhae,* in the moistest areas, there may be large numbers of *Cyperus articulatus,* sometimes the only species in significant areas. *Acrostichum aureum* is prominent and occurs on the edges of the depressions, next to the mesic bushes, behind the trees or after the *typhae.*

The association has very few other components, mainly herbaceous species of the neighbouring formations (*Pycreus* and *Mitragyna* savanna).

Like the *Paspalum* grassland, the *Pycreus polystachyos* association is found in inundated areas similar to those where the *Paspalum* grassland is; but it only occurs on alluvial, sandy substrats. It has a distinct phenology, which is dependent on inundations. The rougher surface texture horizon quickly dries up when there are no rains, which results in sparse vegetation. The association comprises many therophytes which only develop after the rainy season turning the formation into a thick, high (50-60cm), but scattered grassland .

The *Pycreus* grassland grows behind the *Ludwigia adscendens* hydrophyte belts in the depressions where it constitutes the first sub-association with 3 small, short-lived therophytes (*Exacum, Neurotheca, Lundernia*) which disappear as soon as the area starts drying up. The first sub-association is surrounded by *Mariscus ligularis.* This species forms the second sub-association with sometimes *Vetiveria.* The latter mixes with many stout, long lasting species (*Pycreus, Scoparia, Schrankia, Ipomoea asarifolia, Sporobolus* and *Eragrostis*), and more slender annual species which only develop in the rainy season (*Oldenlandia, Stylosanthes, Cassia*) The *Pycreus* grasslands are often cleared by the peasants; the fallow fields have an original composition.

This heterogeneous association is dominated by *Schyzachyrium sanguineum* and comprises ruderal

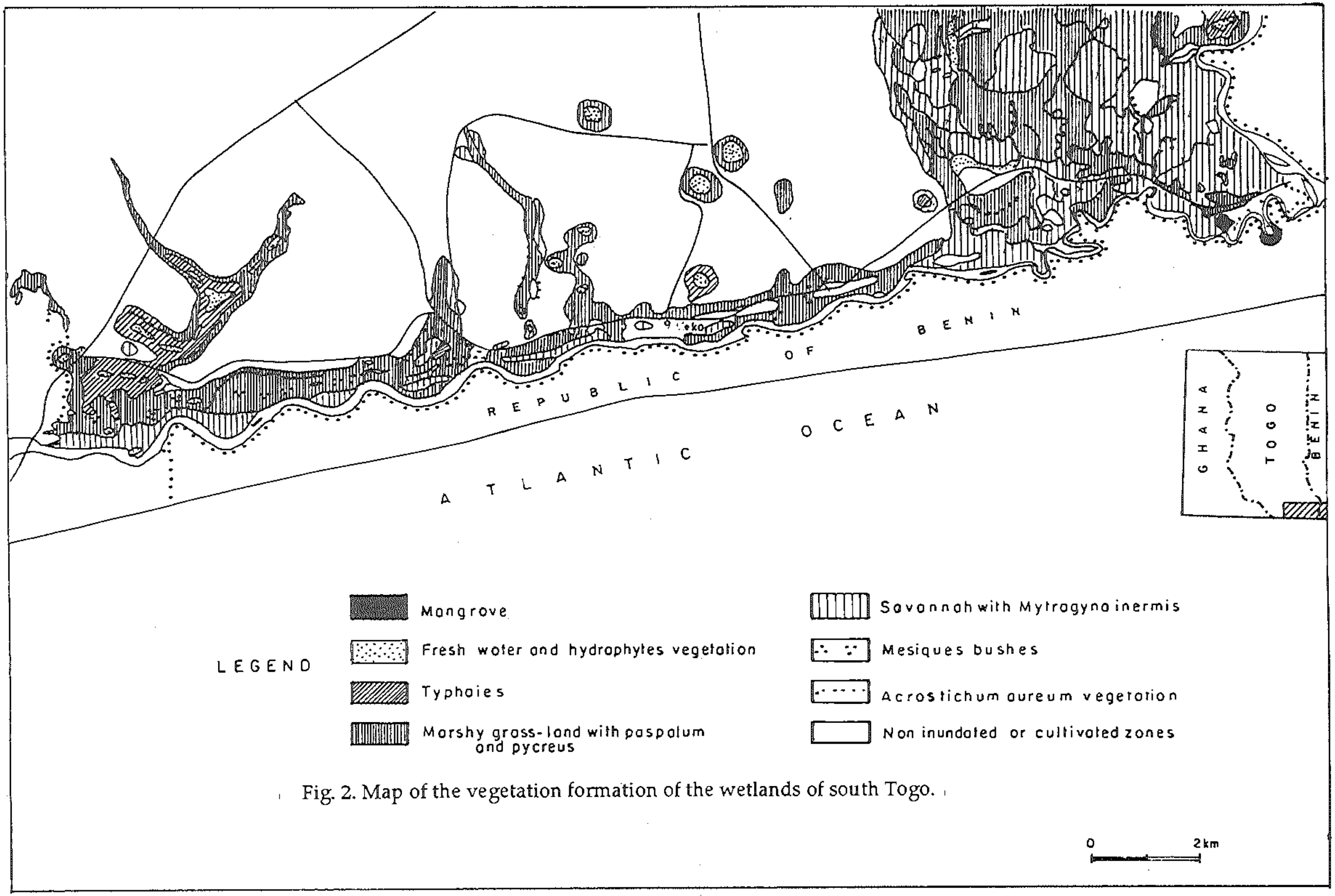


Fig. 2. Map of the vegetation formation of the wetlands of south Togo.

and casual components such as *Imperata* which sometimes occupies significant areas. Finally, there are types of *Pycreus* grassland that reappear when the area is no longer cultivated.

The last association of the swamp zones is found in the higher areas, on the muddy, alluvial substrates inundated during the rainy season, but which dry up early. It spreads in the North-South depressions, particularly in the plains around the Gbaga and Mono rivers near Agbanakin. This association occurs just behind the mangrove swamps and occupies the high river banks where there are no trees. It has a typical savanna aspect with thick, two meter high herbs mixed with a few thick bushes. The latter can be as much as 5 to 8 meters high. The formation generally catches fire during the dry season.

The herbaceous layer comprises many perennial gramineae: *Vetiveria nigritana, Sporobolus sp., Eragrostis namaquensis*. The most frequently observed is the typical *Andropogon gayanus*. Many species of the preceeding grassland associations are sometimes found in the most humid areas (*Cyperus articulatus, Paspalum distichum*) and various transgressive components of the *Pycreus polystachyos* association. The dominant shrubs are the *Mitragyna inermis*, the small *Phoenix reclinata*, and a whole set of small, humid savanna and coastal bush shrubs (*Drepanocarpus, Sorindeia, Carissa, Zanthoxylum, Antidesma*). Among the creepers the most commonly found is *Ipomoea cairica*.

3.1.3 The slightly inundated populations

Very thick shrub formations sometimes occur on the edges of the depressions, on collapsed termite mounds, on banks of man made holes. The small mesic bushes are not generally inundated, but undergo the influence of abundant water. They never occupy large areas and are often cut by the villagers who exploit the woody species or use the area to grow maize and manioc. They are therefore a very disturbed vegetation. We have not been able to distinguish any typical association in it.

The *Grewia carpinifolia* and *Zanthoxylum zanthoxyloïdes* bushes grow on muddy substrates (termite mounds, areas behind the mangroves, mounds in the *Mitrigyna* savanna). They are quite high, and often divided into strata. The top one has a sparse, 10 meter high vegetation whereas the bottom one is reduced to a few individuals growing on the edges of thickets.

They comprise many species: the most common in the Guinean savanna are *Grewia carpinifolia, Byrsocarpus coccineus, Dichapetalum madagascariense, Mallotus oppositifolius, Bridelia ferruginea, Uvaria chamae*, a few humid tropical forest species *Malacantha alinifolia, Antiaris toxicaria, Millettia thoningii, Clausena anisata*, and foreign species *Cocos nucifera, Elaeis guineensis, Azadirachta indica*. The herbaceous stratum is a mixture of sciaphiles, ruderals and transgressive species from the neighbouring groups.

Slightly different bushes are found at a few places near Seko, on the sand knolls and drier termite mounds. The upper stratum has few foreign species. The middle stratum bushes are generally 3 meter high. It comprises seaside bush species such as *Chrysobalanus icaco* (which has almost disappeared from Togo's seaside) or *Dichrostachys cinerea*. The other group members are scarce Guinean savanna and forest plant species. The herbaceous stratum mainly consists of trangressive species from the *Pycreus* grassland.

3.1.4 Discussion

Among the identified communities, the typically azonal associations are well known in Africa, from the Sahel to the Equator. They are free water and the *Typha australis* association populations. Are also well known in tropical Africa the following nymphae groupings: the *Echinochloa, Ludwigia* and *Eleocharis* associations.

The *Grewia* and *Zanthoxylum* bushes seem to be part of the Guinean savanna but there is a dearth of information on that in Togo. There also seems to be many similarities between the *Chrysobalanus* and the seaside bushes.

The other associations are typical of all the West African coastal zones. Very similar groupings have been observed in the neighbouring countries: Ghana, Côte d'Ivoire and Benin. They were identified by Brunel & *al.* (1984) who just mention them.

According to Ern (1979) and Vieillefon & *al.* (1967) there are no traces of fossile mangroves in Togo but there are actual mangrove swamps developing on significant areas. Compared with the formations described by Paradis (1988), the mangroves seem to lack *Conocarpus erectus* and *Laguncularia racemosa* have not been identified here to date.

Certain plant species described in Benin also have not been found. There are neither *Chrysobalanus* *ellipticus* thickets nor *Vetiveria nigritana* grasslands (Paradis, 1976). They grow on sandy, occasionally inundated substrata, which do not exist in Togo.

Similarly, the *Ficus congensis* swamp forest which Paradis (1975) finds associated with *Typha* grassland has not been observed. According to Ern (*l.c.*) there are some in the Southern part of Togo. We have identified very degraded ones in the Zio estuaries (West of the studied area).

On the other hand the *Pycreus polystachyos* grasslands do not seem to be as important in Benin as they are in our region; they are replaced by a *Schizachyrium sanguineum* herb savanna which we have also found where the *Pycreus* grassland has been cleared.

3.1.5 Vegetation dynamic study

a) The natural evolution

The association lay out and abutting zones have permitted to specify their dynamic relationships.

The mangrove constitutes the pioneering stage on the clayey, sandy and unstable soils. It can be preceeded by *Nymphaea lotus* in the quiet zones. *Rhizophora racemosa* is the colonizing species. The other mangrove tree species occupy the next consolidated zones. The *Paspalum distichum* association occurs in the rear zone or the same one if the trees have been felled. It is often reduced to a *Paspalum distichum* and *Cyperus articulatus* layer, and an *Acrostichum aureum* strip.

If the substrate is not too elevated and well inundated, the *Typha* grassland comes next. They occur in clayey, permanently inundated soils. However, the soils area are often lighter and better drained; as a result, it is generally occupied by a *Mitragyna inermis* savanna whose herbaceous carpet comprises a strip of *Vetiveria* and *Eragrostis namaquensis* in the contact zone. The *Grewia* and *Zanthoxylum* associations grow in the drier areas around the depressions or on the termite mounds.

The wettest parts of the clayey, non salted soils are occupied by *Nymphaea lotus* associations preceeded by *Echinochloa stagnina* rafts or by *Typha australis* species which occur in permanently flooded soils. Very often, a *Paspalum distichum* grassland with a ring of *Cyperus articulatus* comes right behind the thick belt of *Eleocharis*. The passage to the *Mitragyna* savanna takes place on the depression edges if they are less inundated. There are *Grewia* and *Zanthoxylum* bushes right behind the strip of *Acrostichum* when the substratum rises more abruptly. The latter is sometimes very thick.

In the sandy and silty substratum, the plant succession series generally starts with a *Nymphaea lotus* association if the water is deep, or with a *Nymphaea guineensis* association if the water is shallow. Then, there is a strip of creeping hydrophytes (*Ludwigia adscendens*) or *Eleocharis* grassland. The following ring is constituted by the more inundated form of the *Pycreus polystachyos* association whose distinguishing mark is the hardy *Mariscus ligularis* thickets.

Finally, there is a *Mitragyna* savanna if the substratum becomes heavier, or mesic *Chrysobalanus* bushes if the soil dries up and becomes sandier.

The evolving identified series form a network (Fig. 3) which mainly corresponds to the particular composition of the substratum and, to a less extent, to the salinity. The evolution depends on the duration of the inundation period. Like all inundated vegetations, the ring shaped successions formed around the water pools are mosaics comprising one or two species that change place when the stage is completed.

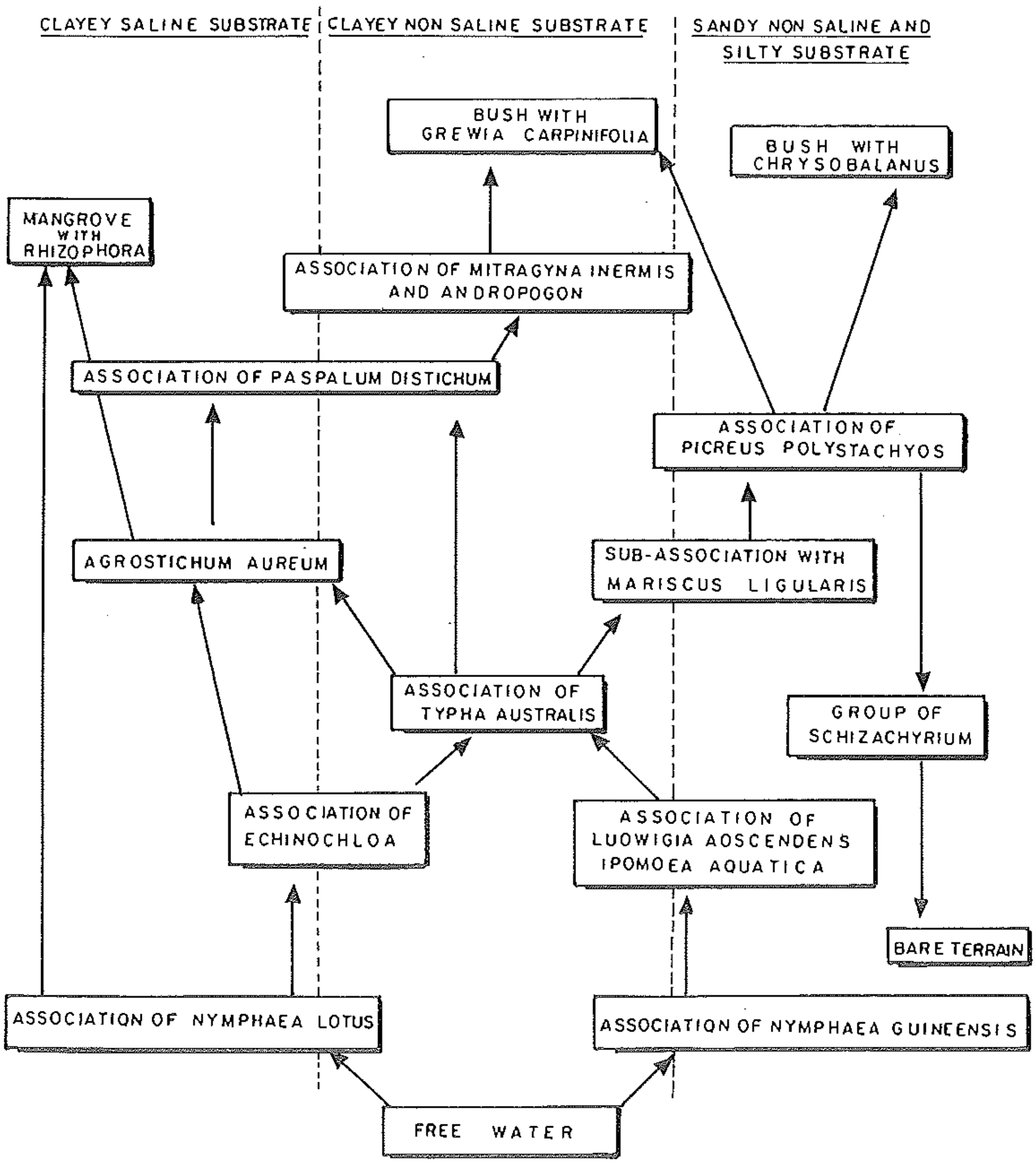
b) The anthropogenic action

At first sight, there does not seem to be significant human intervention in the swamp environment; but a closer look permits to distinguish three kinds of actions: the first long lasting action whose effect can hardly be noticed to-day because of development of the vegetation consisted in laying out the path referred to as the axis of the area studied.

The section of the road between Djéta and Agbanakin was completed in 1974. It is built above the periodically inundated zones, at the same level as the sand mounds and the plateau where the villages are located. It is built with materials from the adjacent areas, which necessitated digging shallow quarries in the Continental Terminal or in the inundated zones.

The effects on the plant population were, on one hand, the formation of more or less regular plots occupied by hydrophile species which are prone to mixing with those of the neighbouring zones; and on the other hand, the appearance of a bushy formation on the actual side of the path, similar to that at the entrance of the villages. The formations have various components: *Grewia* and *Zanthoxylum* thickets, many foreign species (mango trees, palm oil, baobab trees,

Fig. 3. Dynamic relations between different groups of flooded zones of south Togo



bamboo), and even the palm wine (in the region of Agouégan) are introduced; they are all mixed with the savanna trees and the Guinean forest species like *Antiaris, Ceiba, Millettia.*

The second action consists in the attempt at cultivation made here and there on the lowlands. The cultivated zones are very limited because of the nature of the soils. They are located at the margins of the fields (on the Continental Terminal and the sandy silts), under coconut groves. Various crops are grown: manioc, maize, cotton, banana, ochra. They are sometimes on the very slopes of the path, which recall of those grown on the collapsed termite mounds at the limit of the inundated areas after the *Grewia* and *Zanthoxylum* thickets are cleared out.

The most salty, clayey and permanently inundated areas of the mangroves generally occupied by *Typha* and *Paspalum* grassland - are not cultivated. But the *Mitragyna* savanna, the mesic thickets, and *Pycreus polystachyos* associations are regularly cleared out when the areas are not inundated , to grow hot pepper, tomato, eggplant and other species cultivated for their leaves: *Corchorus olitorius, Talinum triangulare, Celosia argentea, Solanum sp.* These are poor food crop species, grown because of lack of enough arable land to meet the needs of the growing population.

After it is cultivated, the *Pycreus* grassland lays fallow. The area is then occupied by *Schizachtyrium* (sometimes after *Imperata cylindrica* disappears), and may even become barren if the land has been overexploited.

The vegetation is occasionally subjected to accidental fires. All the formations are burnt, even the *Typha* grassland and the trees next to the *Mytragyna* savanna. Fires temporarily alter the landscape, they have no significant effect on the vegetation composition.

There are man-made fish breeding ponds in the periodically inundated areas occupied by the *Typha* or *Paspalum* formations. Some of them are located about one kilometer after the junction of the path with Alakou road. Some are being dug in Agouégan village(at the South of the path and at the North of the village). *Nymphaea* associations develop in the ponds. A few *Acrostichum* thickets and a sparse *Paspalum distichum* layer grow on the recently stirred mounds.

Gathering natural plant growth is the third classical form of man's intervention. This consists first in picking wood from the *Mitragyna* savanna, from the bushes and from the mangrove trees. There is preference for certain species, namely *Mitragyna, Rhizophora, Avicennia, Pterocarpus, Azadirachta* for fuel wood, or wood to make charcoal. The effect of this type of exploitation is growing. Increasing preference is given to *Rhizophora* because its wood is better as fuel wood and for making charcoal.

Part of the wood is used to make various crab and fish catching devices ("Acadja": trap; or "eha": barrier). This exploitation has resulted in a decrease in the mangrove areas. The process does not seem to slow down although the mangrove forest in the Gbaga channel or in some of the Mono tributaries is naturally replanting. Some people think that the regulation of the Mono flow has enhanced the development of the mangrove: when the water level is low, Mangbéto dam restore the water level of the Mono and its tributary creeks permit the water to flow upstream and carry various mangrove roots and fruits.

The cutting of different herbaceous monocotyledons: *Cyperus articulatus, Typha australis* (to make mats), *Andropogon gayanus* (for thatched roofs), *Phoenix reclinata* (for timber), and the leaves of different palm trees (to make baskets). These types of exploitation do not damage the plant cover as an important quantity of raw material is available. Only the *Typha* has decreased in some areas because of intensive cutting.

Finally, the cattle bred in the area (about a few hundreds) graze on the *Echinochloa* and *Pycreus polystachyos* grasslands. They are not damaging the vegetation for the time being.

3.2 Fauna

3.2.1 Fishes

Fishing is done both by men and women. Whereas men use nets, traps and hooks, women use baskets called "esso" to exploit the shallow ponds and the Gbaga river tributaries when the waters are low. Most of the fishes caught are *Clarias lazera* and *Tilapia sp.* They are all locally consumed except for *Periophthalmus papilio* and *Clarias lazera* because of taboos. The fish are fried or smoked.

According to the local people, there is much fish from April to August and very little from December to March when salinity is too high. Abundance of fish when the river is in spate is due to the various nutritive substances that come with the alluvium.

3.2.2 Crustaceans

Only *Cardiosoma armatum* and *Callinectes latimanus* crabs are eaten. They are sold at good price in Agouègan, Agbanakin and Ahéno. The same applies to the shrimps and crayfish like *Macrobrachium fellicinum*. Some of the fish and crustaceans sold in the local markets come from the mangroves of Benin.

3.2.3 Molluscs.

Three species of bivalve molluscs are explodite. They are *Crassostrea gasar* (mangrove oyster), *Ergeria radiata* (Volta oyster) and *Anadara senilis* (St-Jacques shells). The two last species are only exploited locally. They are fried or grilled. People also feed their poultry with the shells of *Crassostrea gasar*.

To our knowledge, none of the gastropods itentified is consumed locally. There are many *Tympanotonus fuscatus* which are consumed in other parts of west Africa. They could be exploited to feed poultry and pigs.

Not all the molluscs listed in the region are useful. Species of the Teredinidae family (*Teredo adami* and *Bankia bagidaensi*) which live in the Gulf of Guinea brackish waters seriouly damage canoes and other wooden structures..

4. Discussion

Selected edible species should be studied in detail, namely, *Ergeria radiata*, (Volta oysters), *Cardiosoma armatum*. The same applies to some fishes such as *Tilapia* that the local people have started breeding.

Field investigations revealed a decrease in the catch that is certainly due to changes in the species reproduction pathern. It seems that this is related to the Nangbego dam built up on the Mono river which has brought about changes in the ecological conditions caused by changed hydrological environment.

The only aquatic mammal identified in the region is *Atilax paludeus* (swamp mangoose) which feeds on crabs. Many faeces of carnivorous animals were found in the *Andropogon gayanus* and *Paspalum distichum* rear mangrove area. Analysis of the faeces reveals that this mammal eats *Cardiosoma armatum* and *Sesarma sp.* The latter species and *Gnonpsis cruentata* are poisonous for human beings.

5. General Conclusion

The study of the vegetation of inundated areas reveals that there is in Togo original mangrove vegetation whose importance has been underestimated to date. Research conducted in a wide network in the swampy plains has permitted to understand the vegetation development which depends on the original succession. The presence in the general dynamics of the *Paspalum distichum* grassland and the *Acrostichum aureum* fringes is not necessarily associated with that of the mangroves. The mangroves which, up to now, were considered as degraded scraps are well preserved, and even extending along the river banks.

The development of these various environments is closely connected with human activities: management of man made ponds, of river banks or road building create new conditions which enhance the development of some of these associations.

The production of the wet zones plays an important part in the local economy. The high anthropogenic pressure has no damaging effects for the time being, and it would be interesting to conduct an in-depth analysis of this pressure to find out the opportunities for a realistic development; a study that would be integrated with the traditional activities.

The mangrove zone is fairly rich in animal species. However, over exploitation of some species like the *Crassostrea gasar, Egeria radia, Cardiosoma armatum* and *Callinectes latimanus* is having some negative impact in certain areas. Intensive fishing of *Cardiosoma armatum* does not seem to threaten this species for the time being; many are caught in Agbanakin all the year round, which shows its great reproduction capacity in this area.

Because of the large variety of species in the wet zone, it seems there is a regional balance between the natural production and man's exploitation. This has been confirmed by a study of the fauna and the flora. However, like all similar environments, the country's mangroves are not sheltered from an unbalance, which is bound to bring about a complete degradation of this particular biotope. All experts must be called upon for support to prevent such negative evolution of the natural environment.

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Mangroves of Benin

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1. Introduction

The Beninese mangrove swamps at present degraded, developed in the Western lagoon complex of the country because of the quasi permanent presence of brackish waters.

According to the local populations, this mangrove was formerly so thick that it was impossible to see nearby villages from the coastal lagoon. The mangrove zones, forming a very productive ecosystem, began gradually to be occupied, mainly from the 17th century on by the Pedah and the Pla who were fleeing the war incursions of the Fon troops of the Dahomé kingdom. These zones served as refuge. The first settlers were later joined by the Fon populations. The resources of the mangrove swamps are diversified and the populations practise various traditional uses. Ichthyofauna, shells, shellfish, mammals, birds and salty soils are riches people exploit through fishing, picking, hunting, extraction of salt, and even agriculture on the ancient beach ridges.

Because of the high density of the population (200 hbts/km²) in the lagoon complex, a high anthropic pressure is exerted on the mangrove swamps.

Fishing constitutes the main activity; it is practised by men, but the products are sold in the neibouring markets by the fishermen's wives. These women also do saliculture particularly in periods when fishing decreases in yield. Over-fishing has been engendered by the demographic explosion and has lead to a considerable reduction of the yield; women have exclusively turned to salt extraction. But this activity requires the consumption of large quantities of firewood which are taken from the mangrove swamps. This fact quickened the degradation of the mangrove itself.

Tourism and scientific research have contributed to create more interest in the Beninese mangrove swamps. Researchers, in collaboration with the local administration are now calling the villagers' attention to the safeguard of the richness of this environment whose ecological balance has become precarious. Ancestral religious practices which consist in transforming some forest islands into sanctuaries, have contributed to the preservation of the mangroves. Attempts at reforestation have been undertaken since 1987 (BAGLO, 1989) and suggestions have been made, following a UNESCO mission, to consider the Beninese mangrove swamps as a biosphere reserve (BOUSQUET, 1985).

A project, whose goal is to declare the mangrove swamps as a protected area, is now being elaborated by the national MAB-UNESCO committee. Elsewhere, the Integrated Research Project for the Improvement of the Traditional Techniques of Salt Extraction (P.I.R.A.T.T.E.S), initiated by the national committee (MAB-Benin) in collaboration with the Breton salters of France, was implemented to extract salt with solar and eolian energy. This strategy was initiated to stop the use of fire wood.

Unfortunately this new policy, which in theory is to conciliate development and environment, could well be jeopardized by the negative effects linked to the construction of the hydroelectric dam across the Mono river. In fact this dam may lead to a decrease in salinity in the coastal lagoon, with serious consequences on the mangrove and the associated ecosystems.

2. The Mangrove Ecosystem. Extent and Distribution

Very sensitive to environmental changes, the mangrove swamps in Benin grow in zones around lagoons and lakes where the influence of tides is noticeable, these are located along the western littoral. The mangrove swamps extend from Togbin to Hila-Condji and even around Gbajan in Togo. To the North, the mangroves extend on the coasts of the Mono river and along the Sazué river to the South of Kpovidji and then on the coasts of Ahé. But although the banks of the Ahemé lake have in the North a thick curtain of mangroves, it looks like a degraded zone composed of a savannah of *Avicennia germinans*.

The thickest zones are generally composed of species laid out in belts parallel to the shoreline. The coastal lagoon banks are the woodiest, mainly between Togbin and Djegbadji. On these Sections, the mangrove swamp is presented in the form of "a continuous, dense curtain that tends to obstruct the lagoon" (BAGLO, 1989).

The surface that is covered with these halophytes around the littoral lagoon is evaluated at 3000 ha by BLASCO (1985) and specified by BAGLO (1989). The vegetation offers other landscapes; for example, small mangrove bushes (fetish forests), young *Rhizophora* and *Avicennia,* in more or less dense regeneration zones where the action of man against nature is manifest.

3. Physical Environment

3.1 Climate

The Beninese littoral has a subequatorial climate that is peculiar in the Benin gulf which is "the rupture zone of typical equatorial characteristic in West Africa with a particular landscape" (TOFFI, 1991). The fluvio-lagoonal zone is characterized, as far as climate is concerned, by:

- A total rainfall, decreasing gradually from East to West (Porto Novo: 1420 mm; Cotonou: 1307 mm; Ouidah: 1150 mm; Grand-Popo: 926 mm);
- An alternate seasonal rythm of
* a heavy rainy season from March to July with a peak in June
* a small dry season (with a lack or shortage of rain) in August
* a small rainy season from September to November, with a peak in October
* a well marked dry season (with an absence or shortage of rain) from December to March, with a dry fresh and dessicating wind in January, the Harmattan.

Elsewhere, there is the influence of sub-sudanian rains on the littoral. Although the bimodal South rainfall regime is responsible for the local rains that can only moisten soils, the sub-sudanian zone in Benin, is characterized by a unimodal regime; these rains increase the volume of the Southern watershed (Mono, Ouémé) which, after draining the waters toward lower latitudes, cause important floods in lagoonal zones during September and October. The peak of the rainy season is centred in August and September.

- Relatively high and constant temperature between 21°C and 31.5°C. February, March and April are the warmest months, with 31°C-33°C in sunny days, at that period temperature decreases during the night (23°C-24°C). These variation in temperatures on the coasts are due to the fact that the period of sunshine is very long, in Cotonou, and to the maritime influence, since upwellings brings cold water in July and in August.
- A relative humidity varying on average between 72 % and 95 % . Thus, the atmosphere contains haze all the year long and can compensate the rainfall deficiency of the dry season.
- Regional and local winds blow from South-West to North-East with a steady speed which changes according to the season from 3.6 m/s to 6.6 m/s. In the afternoon, the winds are stronger and they induce waves, littoral drift, movement of waters, and sorting of the surface sediments into silt or sand. These SW-NE winds quicken the evaporation and the evapotranspiration. The PENMAN evapotranspiration in Cotonou varies from 88 to 165 mm. But according to CHAPMAN, 1974, this ETP does not cause growth constraint on the mangrove swamp as long as fresh and salty water supplies are recorded.

3.2 Water

The fresh and brackish water supply are necessary to the survival of the mangrove swamp ecosystem. In fact floods (September-October) are due to the rainfall in the North and South Benin whose waters are drained toward the mangroves by the rivers Couffo, Mono and Sazoé. Fresh waters leach the soil and lower lagoon waters salinity and, at the same time bring nutrients to the mangroves. Even if NaCl is a factor of selection of the plant species in the mangrove ecosystem, the continental waters maintain the NaCl concentrations at reasonable rate of 10 to 30 g/l (BLASCO 1982). Floods allow the mangrove swamp to get rid of toxic wastes, gases and organic matter.

The mangrove populations are sensitive to sea waters penetration in the lagoons and the lower parts of rivers. Tides are the exchange mechanism between the sea and the lagoon and the concentration process, dilution of mineral salts takes place. The Benin sea waters salinity varies between 34‰ and 35‰. Salinity decreases in the rainy season and increases from December on (Table 1).

The "Bouche du Roi" (river mouth) is the area of communication between the continental waters and the ocean. Offshore, the forces which act on the exchanges ocean-continent are the following:

- a remote SW-NE swell, wavelength varying between 160 and 220 mm;

Table 1: Physico-chemical parameters of the coastal lagoon waters in Hakoue.

Station	Sampling date / Parameters	25-11-89	22-12-89	23-12-89 at 09:00	23-1289 at 17:00
Hakoue	P^h	7.8	6.6	6.4	6.7
	Conductivity Usiemens (cm)	7,290	15,840	15,240	14,830
	residue at 110C (mg/l)	3,420	7,920	7,620	7,420
	Bicarbonates in CO_3H^- (mg/l)	1,52.5	122	122	122
	Clorures Cl^- (mg/l)	2,076.8	5041	4,792.5	4,686
	Sulfates in So^{--} (mg/l)	262.5	700	650	625
	Calcium in Ca^{++} (mg/l)	56.1	216.4	108.2	105.8
	Magnesium in Mg^{++} (mg/l)	136.2	287	345.3	322.5
	Potassium in K^+ (mg/l)	32.5	112.5	100	100

SOURCE: Hachimou *et al.*, 1990.

- the Agoué current of an average speed of 1,2 knots, influences the Benin-Togolese coasts with a point of impact at Agoué in Benin;
- the Cotonou current of an average speed of 1 knot;

These two currents become stronger in the southern winter and their speed can reach 3 knots.

- the littoral W-E drift is a switchback current that carries about 1.200.000 tons of sand per year to the coasts in Benin.

In Benin, there are two daily tidal movements. Their interval is about 12 h to 12 h 30 min with tidal ranges varying between + 1.95 m and 0.20 m. The hydrological regime which characterizes the Western fluvio-lagoonal complex (Mono, Sazoé, Coufo, Ahémé, Aho, coastal lagoons) is related to the marine and continental forces.

During the lowest water level in the dry season, rivers weaken and the tidal stream penetrates in the continental waters; the salt wedge spreads in the lagoon and in the low valleys of the Mono and Sazoé rivers and in the Ahemé lake through the Aho river. This fact favours the submersion and the infiltration of NaCl in the mangrove ecosystems.

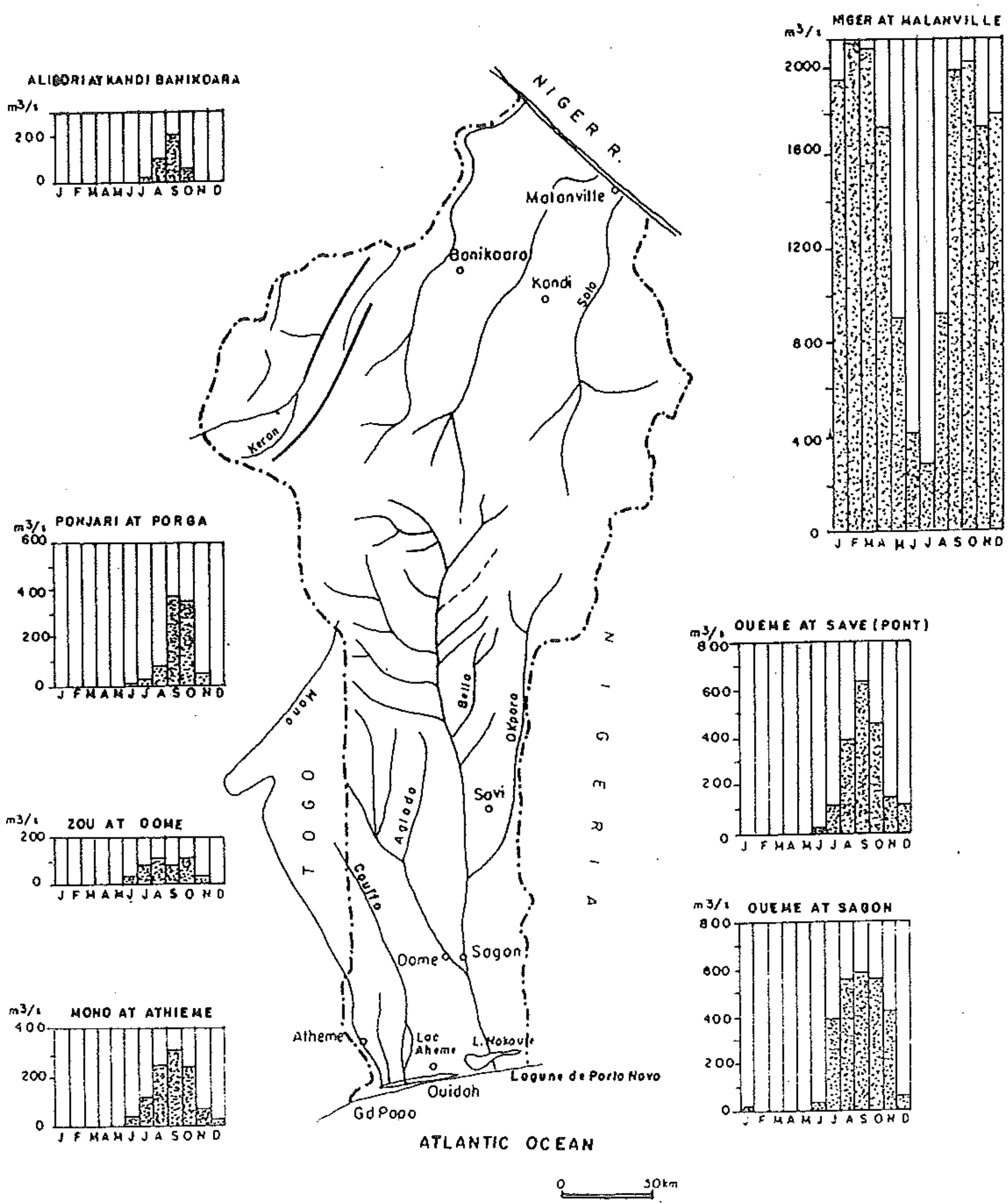
During the rainy season, the Mono river waters increase, and the flow rises from 5.68 m^3/sec to 351 m^3/sec in September. Thus, the fluvial current becomes stronger than the littoral drift. Then the sandy bar which obstructs the mouth may either be naturally cut off by the Mono fluvial stream, or be opened by the riverside residents to reduce the ravages of the flood. The hydrological mechanism is schematized on Fig. 2.

This hydrodynamism combined with the shallow waters of the lagoon (between 1 and 5m), causes spatio-temporal variations of salinity in the lagoon. In general there is a period of high salinity from January to July and a low salinity period from July to November. In general, the brackish character of the lagoon waters is more pronounced in the western side than in the eastern side of the lagoon complex (Ouémé, Sô, Nokoué, Porto-Novo lagoon). The central lagoon complex is isolated from marine influences and receives only continental deposits.

The pH of the water lagoon is around 7. Beside the September-November period when the waters are slightly acid, they remain slightly alcalin during the rest of the year.

Elsewhere, the contruction of the Nangbeto dam across the Mono river in September 1987 engendered serious changes in the hydrological dynamics and the water quality around the river mouth. Before the dam construction, the mouth opened and closed alternatively, influenced by the marine and fluvial forces (currents and sand littoral accretion). The average monthly flow of the Mono river was then 5.68 m^3/sec. But the dam and the water release during the dry period caused a permanent flow downstream of at least 40 m^3/sec. This maintains the mouth permanently open, and its Western side always under the influence of Mono fresh waters. The salinity rate is then hardly above 15‰. Before the dam was concluded, the Avlo recorded, in the western side of the mouth, a salinity of 29‰. in March

FIG. 1- HYDROGRAPHICAL NETWORK AND WATER REGIMES



(period of the lowest water level). These changes will certainly impact the mangrove swamp and its associated ecosystems.

The temperature of lagoon water changes markedly along with that of the air. The highest values are recorded in March between 12 - 13 h (33°C), and the lowest are recorded in August: 24°C at 07:00 hrs at Grand-Popo.

3.3 Soils

These soils are generally the results of sedimentation. In the South of the Ahemé lake, the speed of 4 mm/year (Oyede, 1993). This is not alarming enough at the human scale. As far as the Western estuarine complex and its mangrove swamp formations, sedimentological studies, granulometrical and geochemical analysis have been carried out by several scientists, particularly on the Ahemé lake and along the coastal lagoon.

These soils are generally composed of sediments presenting a crude detrital fraction containing quartz and feldspar. There are other minerals : gypsum, halite, pyrite. The soils of the mangroves of Benin are not very acid because there are only small quantities of pyrite.

Around the Ahemé lake, the actual and subactual sediments in the cores, 4 m deep are rich in clay (30 - 40%). At their basis are the holocene sediments, rich in sand. The sedimentation along the coastal lagoon is constituted of lens shaped deposits because this area is submitted to the variations of the tides (twice/day) and the alternation of humid and less humid periods, interrupted by seasonal floods. The marine and continental forces thus contribute to sand and silt transport which are deposited in the depressions and channels. Clays settle in calmer sedimentation places. The aerial roots of *Rhizophora racemosa*, by their entanglement slow down the speed of the brackish water, creating calm places that are favourable to the deposit of clayey and organic particles. The pneumatophore roots of *Avicennia africana* break down and fix the soil on the dry land, which prevents flowing waters (rain, rivers) from carrying away the surface nutritional layers.

The succession of the series of sediments is not always regular, perturbations often occur, caused by the vegetation or the crabs. The sedimentary layers bear, in some sections accumulations of peat, resulting from floating plants which are annually destroyed by the hypersalinity of lagoon waters and soils. Taking cores 3-4 m deep around Ahemé and Nokoué lakes and the valley of the Ouémé river revealed peats of mangrove swamps older than 5,000 years BP and which were settled during the Nouakchottian transgression of river Senegal.

4. Biological and Ecological Characteristics of the Mangroves

4.1 Flora and physiognomy of the mangrove swamp

4.1.1 Floristic inventory

Characteristic of the floristic species. The Beninese mangroves have five phanerophyte species, divided into three families "Rhizophoraceae, Avicenniaceae and Combretaceae"

The Rhizophoraceae, are represented by: *Rhizophora racemosa* and *R. harrisonii* also called red mangroves; *R. racemosa* is the most abundant species. It is characterized by its viviparity and its stilt roots. It grows around or in brackish waters. *R. harrisonii* is rarer; it is seen only at Togbin, Sehou-Gbato and on the banks of lower Mono. There is the hypothesis that it is a hybrid species of *R. racemosa* and *R. mangle*, however *R. mangle* is reported to be absent in Benin. *Rhizophora* bears fruit in December but the flowering time covers all the year (BAGLO, 1989).

Avicennia has only one species, *A. africana*, the white mangrove. It is as common in the mangrove swamp as *R. racemosa*. The white mangroves are recognizable through the pneumatophore roots around the tree; the leaves have excretion glands that excrete surplus salt. *A. africana* is semi-viviparous. In Benin, the plant blosoms from March to May-June and bears fruit from April to December.

The third family is represented by *Laguncularia racemosa* and *Conocarpus erectus*. *Laguncularia racemosa* is adapted to high salinity, blossoms after a year of growth and bears fruit from June to December. That's why it is widespread all over the mangrove swamp. *Conocarpus erectus* grows in lower salinity zones where the salinity rate does not exceed 5‰. It is generally found on sandy soils. That's why it grows on the outer zones, and tends to expand toward land.

Mangrove associated species. Seasonally submerged, the species are numerous and can be classified in three groups: small shrubs, palms and herbaceous plants. Among the shrubs: *Dalbergia*

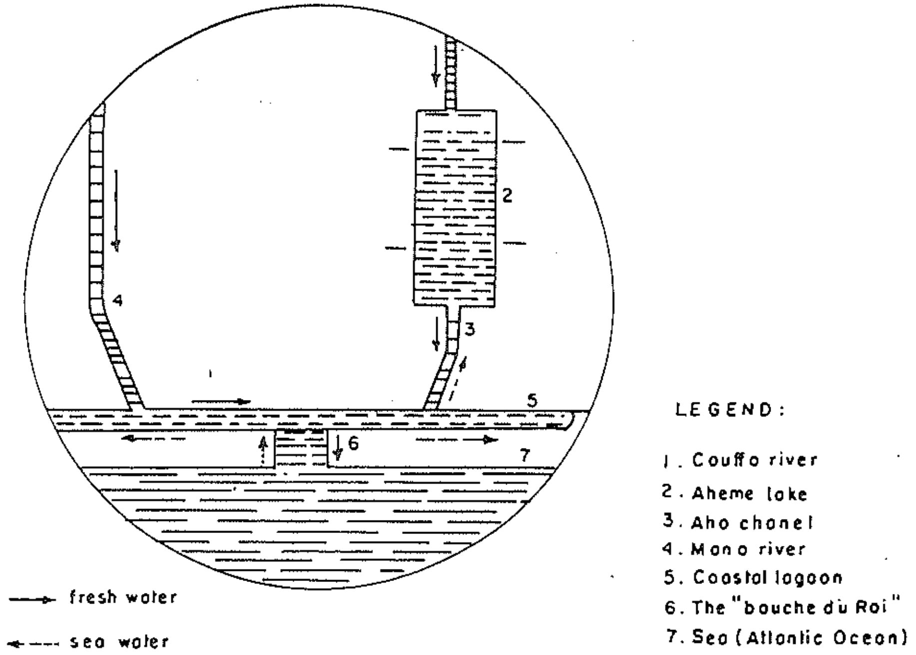
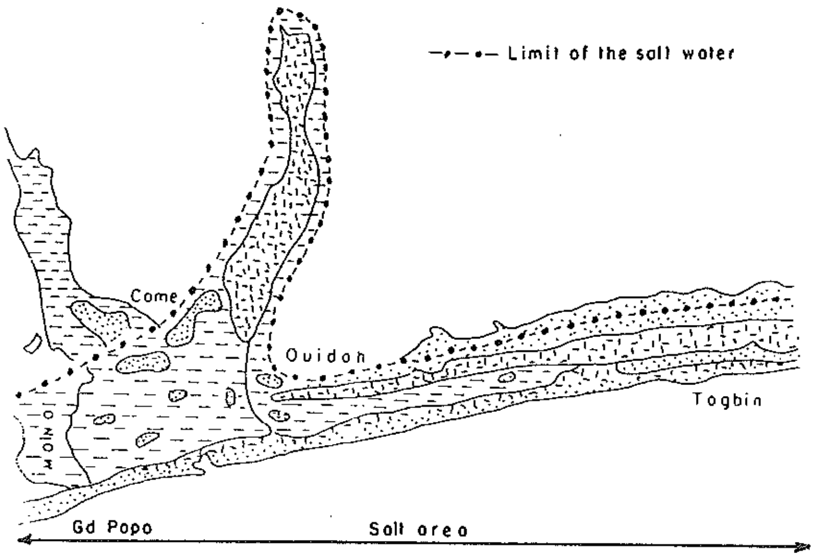


Fig. 2 Qualitative schematic assessment of supplies to Lake Aheme

Fig. 3 Northern limit of the penetration of saline waters



SOURCE: PLIYA 1980 / TOFFI 1984
Penetration limit of the tides within the Continental waters

ecastaphyllum, Drepanocarpus lunatus. Phoenix reclinata is the only palm form; herbs are numerous: *Paspalum vaginatum, Sesuvium portulacastrum, Philoxerus vermicularis, Acrostichum aureum,* the latter is the giant fern of the mangroves.

- **Accidental species.** Modifications of the soils create ecological niches that favour the growth of common (accidental) species: *Fimbristylis ferruginea, Pycreus polystachyos,* on the non saline soils grow: *Crotalaria retusa, Scorparia dulcis, Hibiscus tiliaceus, Annona senegalensis, Elaeis guineensis, Cocos nucifera, Chrysobalanus orbicularis.* All these "accidental" species disappear when the pedological conditions change.

4.1.2 Physiognomy of the mangrove swamp

The Beninese mangrove swamp is generally degraded and is found at the limit of its potential resistance to man's aggression. The vegetation presents several facies in the lanscape. The scraps that are still intact form unstratified forests. The different species are laid out in stripes that are monospecific and parallel, they are also parallel to the lagoon banks (Fig. 4).

From Hila-Condji to Djhebadji, the mangrove swamp appears to be very degraded with small trees (3 - 8 m high). It is even non-existent, from Agbanankin to Gbekon, on the banks of the Mono river and the Grand-Popo Lagoon, because of the erosion of the banks by the river floods. The selection, from Azizakoué to Djegbadji has no mangroves because of their destruction for wood which was used as firewood and for salt extraction.

From Djegbadji to Togbin the mangrove swamp is thicker; trees can grow up to 10 or 15 m. Sometimes the height goes up to 20-25 m. This exceptional development at this place stems from the fact that the mangrove swamp was provided with fresh waters by the floods of the Mono river and the lake Nokoue; their waters communicated by Houeyiho before the construction the Cotonou-Lomé road (BAGLO 1989); today, the place is obtructed by dikes on one section and has in this way only the waters of Mono and a remote tide with a salinity rate of 16‰. The zonation is characterized by: first, *Rhizophora racemosa* and *R. harrisonii*, then *Avicennia africana* followed by a meadow of *Paspalum vaginatum*, planted of *Acrostichum aureum* and *Drepanocarpus lunatus*, then on the sandy areas, *Phoenix reclinata, Dalbergia ecastaphyllum, Chrysobalanus orbicularis, Diopyros tricolor* and *Annona senegalensis* follow; and on the top there are coconut trees (Fig. 5, 6, 7 and 8).

The Aho and the Sazoé have mangroves in their lower areas. The mangroves, in the surroundings of Heve (Sazoé) give the following zonation : *Rhizophora racemosa* or *R. harrisonii, Avicennia africana,* then, in the background a meadow of *Paspalum vaginatum* with scattered *Mitragyna inermis.*

Around the Ahemé lake, mangroves are found only at places on the shores. The most beautiful mangrove is found in the North between Tohonou and Couffonou with *Rhizophora* 5-8 m high, followed by tall *Avicennia* of 6-12 m high and then a meadow of *Paspalum vaginatum* with ferns, *Drepanocarpus* and *Dalbergia.* The degraded zones are dominant with meadows of *Paspalum* and some isolated *Avicennia.*

4.1.3 Dynamics of vegetation formations

On the Sazoé banks, the degradation gives birth to a resettlement of *Drepanocarpus, Dalbergia, Acrostichum* and *Paspalum.* But in some places of the coastal lagoon, the degraded zone is occupied by *Laguncularia racemosa.* However, on regeneration zones, there is a competition between *Rhizophora, Avicennia* and *Laguncularia.* In a zone formerly occupied by the mangrove swamp the vegetation communities succeed one another thus:

- the community mainly composed of *Paspalum vaginatum* is the largest, it is found in the lower zones which are flooded from June to October. It is sparsely associated with *Cyperus articulatus, Acrostichum aureum, Fimbristylis ferruginea, Drepanocarpus lunatus, Phoenix reclinata.*

During the seasonal floods, seeds of *Avicennia* and *Rhizophora* propagules are scattered in the cleared places; the resettlement of those places by the mangrove plants starts over again when the water level drops. But this possibility requires adequate pedological, hydrobiological and morphological conditions.

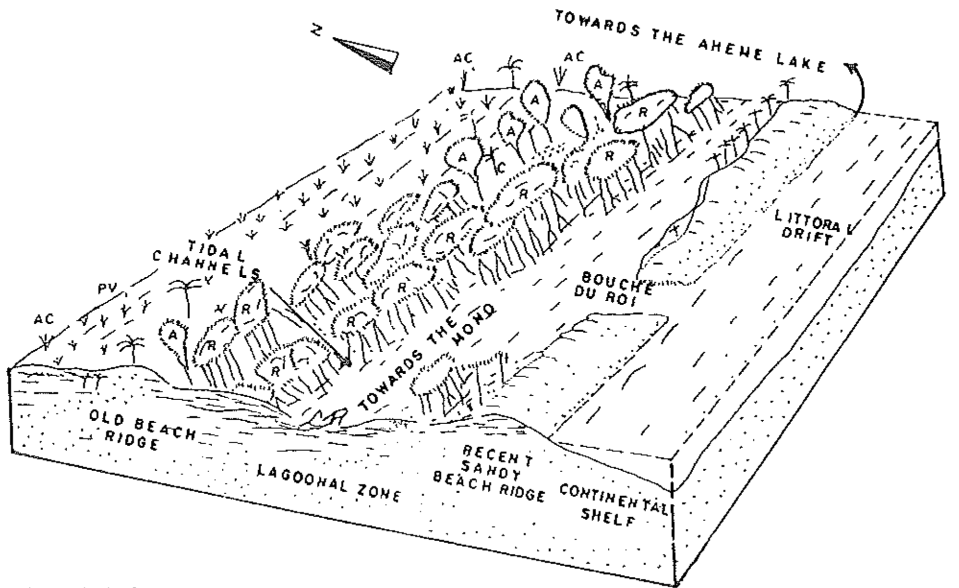
4.2 Mangrove animals populations

4.2.1 The faunistic inventory

a) Banks and intertidal zones

On the sandy and silty banks and in the tidal zone, live annelids (*Pirinereis sp.*), and isopods like *Ligia sp.* Among the molluscs there are gastropods: *Pachymelania aurita, Neritina glabrata, Corbula trigona, Crassostrea gasar, Ostrea tulipa, Bankia bagidaensis* and *Teredo petiti* that are sessile on the aerial roots and trunks of the mangrove trees. Also *Marceriella*

Fig. 4 Block-diagram showing the morphologic units around "LA BOUCHE DU ROI" and the layout in parallel strips of some mangrove species



SOURCE: OYEDE 1991

A : Avicennia | R : Rhizophora
C : Cocos nucifera | P : Palms (Elaeis guineensis)
AC: Acrostichum aureum | PV: Paspalum vaginatum

enigmatica (annelid) and the barnacle *Chtamalus rhizophorae*. They are all euryhaline species.

There are also in the same zone schools of *Periophthalmus papilio*. It is an euryhaline amphibian fish species, very abundant in coastal lagoons.

The avifauna characteristic of the place is composed of *Ardea cinerea, Egretta garzetta, Actophilormis africanus* and *Cyrile rudis*.

There are temporary resident reptiles such as: *Varanus niloticus, Agama agama*, and ophidians like *Psammophis sibiliens* and *Pyton regius*.

Mammals such as Sitatunga, *Potamochoerus porcus, Triomys swinderianus* are not common in the mangrove swamp for lack of suitable space.

b) Transitional or infralitoral zone

On the silty substratum there are lamellibranchs such as *Anadara senilis, Dreisseina africana, Donax rugosus, Tellina nymphalis, Tagelus angulatus*. Also gastropods: *Thaïs haemastoma* and *Nerita senegalensis*. This zone is also characterized by the predominance the decapod brachyuran crustaceans like *Callinectes amnicola, Goniopsis cruentata, Uca tangeri*.

c) Central aquatic zone

There are different associations of gastropods and lamellibranchs in the silty substrates: *Neritina glabrata, Neritina sp., Pachymelania fusca, Tympanotonus fuscatus, Crassostrea gasar* and *Tagelus angulatus*.

There are many species of fish: in brackish waters: *Tilapia guineensis* (dominant), *Sarotherodon melanotheron, Hemichromis fasciatus, Ethmalosa fimbriata, Acentrogobius schlegelli, Liza falcipinnis, Mugil bananensis, Megalops atlanticus*. The marine forms, that come to the mangrove zone to feed on smaller fish, are: *Caranx hippos, Cynoglossus senegalensis, Synaptura cadenati, Epinephelus aeneus, Pomadasys jubelini, Polydactylus quadrifilis, Cybium tritor, Gerres nigri, Lutjanus agennes, Elops lacerta*. During flood periods, there are continental forms such as: *Tilapia zilli* and *T. guineensis, Hepsetus odoe, Physalia pellucida, Synodontis melanopterus, Chrysichthys nigrodigitatus*.

4.2.2 Relationships between the fauna and the mangrove ecosystem

Because of the particularity of the ecologic conditions of the mangroves, only the specially adapted species live there and proliferate with no or scarce competition. However, during periods of floods, some allogen species may become temporary visitors.

a) The trophic web

Two links constitute the bases of the trophic chain in the Beninese mangroves (BAGLO 1989).

The first link is that of decomposers and detritus feeders. Leaves and vegetal particles from the mangrove fall into the water or the silt and become attraction spots for the microorganisms that decompose the plant material. The micro-organisms attract the microfauna that feeds on them. This microfauna composed of worms and larvae are eaten by detritus feeders represented by shrimps, crabs, fish such as *Tilapia guineensis, Synodontis melanopterus, Mugil bananensis, Liza falcipinnis*. Besides detritus feeders there are filter feeders and berbivores: crabs, molluscs and fish.

The second link is composed of carnivores. There are micro-carnivores: *Gerres nigri, Eucinostomus melanopterus*, the Pomadasyidae; and macro-carnivores: the Elopidae, Carangidae, Serranidae.; also the super-predators who eat fish and shellfish : *Cybium tritor*, and omnivores like man.

When the alimentary chain lengthens, it is successively short, medium and long, and passes gradually through the primary and para-primary production (algae, higher plants, bacteria), the secondary production with phytophagus and omnivorous species, then the tertiary production with the micro and macro-predators (Fig. 9).

Elsewhere, the avifauna, mainly herons hunt crabs and small fish during the ebb tides.

b) Zonation

An attempt to circumscribe the biological zone was undertaken by M. BAGLO in 1989.

According to the distribution of species, we can divide the area into two parts. The first one which stretches between Djegbadji and Avlo is the domain of marine estuary species. There is also a dominance of Brachyuran Crustacea and molluscs. The second zone includes : Djegbadji-Togbin, the lower valley of the Mono and the North of Lake Ahémé. It is characterized by a concentration of euryhaline and "fresh water" species.

On the other side, according to the biocenotic associations of flora-fauna, the zonation takes another

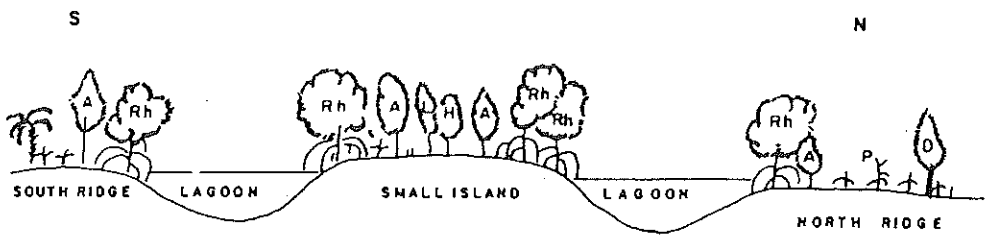


Fig. 5 Transect S-N through the island Avlo

Phœnix reclinata

Rh Rhizophora	A Avicennia	L Laguncularia
H Hibiscus	D Drepanocarpus	Pv Paspalum
F Fimbristylis ferruginea	C Cocos sp	Ml Mariscus sp

(PARADIS)

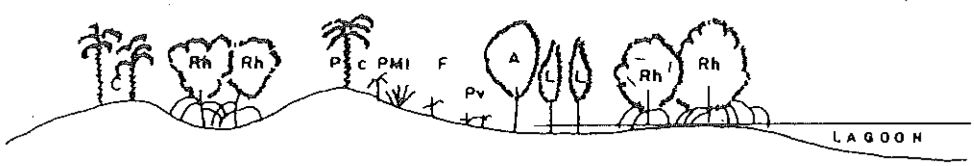


Fig. 6 Transect in the east of Hakoue

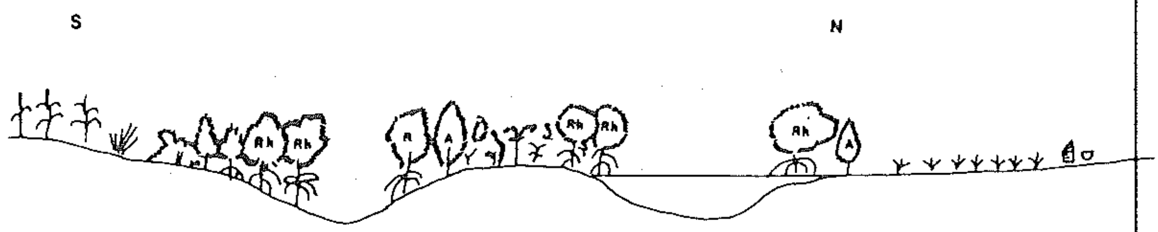


Fig. 7 Transect through the mangrove at Azizakou

Da: Dalbergia Sporobolus virginicus P Palmier et Cocotier

Salt extraction

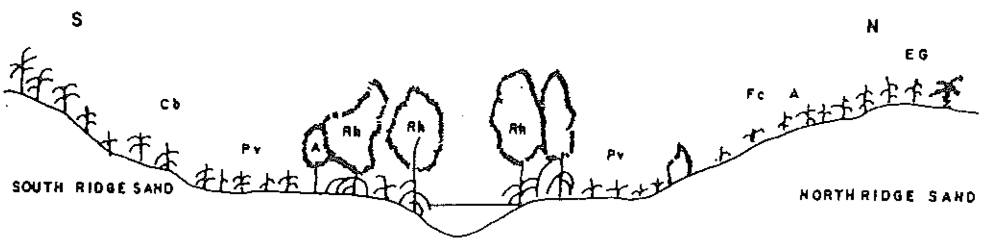


Fig. 8 Transect through the mangrove at Togbin

C. Cocos sp Cb: Littoral vegetation of Chrysobalanus orbicularis

Pv: Paspalum EG: Elaeis guineensis

aspect. Around Boca del Rio and on the recent deposits there is the favourite domain of *Cardiosoma armatum*. They dig holes in the substratum without mangrove trees but having a vegetation of *Ipomea pes-caprae* and *Remirea maritima*. This supralittoral domain in rarely influenced by the tides. It stretches all over the meadow with *Paspalum vaginatum* between the coastal lagoon and lake Ahémé.

At Dondji the aquatic fauna includes: *Callinectes amnicola, C. pallidus* and *Neptunus validus*; toward the bar beach: *Uca tangeri, Goniopsis petii* and *Sesarma sp.* This lagoon section like at Djegbadji is characterized by the association *Rhizophora-Uca-Periophthalmus*.

5. Ecosystems Associated to the Mangrove

As far as associated ecosystems of mangroves are concerned, there are brackish lagoon waters and marine waters.

Marine waters have a great influence on the mangrove swamp and on the animal species linked to it. The oceanic waters on the Beninese coast have an average salinity of 34-35‰, with higher values at the surface; the rate decreases to 24‰ in October during the rainy season which is responsible for the desalinisation owing to the fresh water input. The surface layer of marine waters is always saturated with dissolved carbon dioxide and oxygen.

Marine species that visit the mangrove swamp are mostly pelagic, among them the fish: Carangidae, Cynoglossidae, Serranidae. They live on the continental shelf that is 22 km wide in the West and 33 km in the East. It is covered, from the coast to the open sea, with layers of silty sand and sandy silts. These silt deposits come from the continent through river action. There is on the same plateau a coral barrier between Ouidah and Cotonou at 52-56 m from the coast (Fig. 10).

6. Habitation and Traditional Uses of the Mangroves

6.1 Population density

The mangrove zones in Benin are strongly marked by the human presence that goes as far back as prehistoric times: neolithic tools were dated from 4,300 - 3,800 BP (Lang and Paradis, 1984). Nowadays, many villages are scattered along the lagoons and lakes. The inhabitants are either exclusively fishermen like in Guezin, Hévé, Avlo, Djondji. or fishermen and agriculturists like in Hio, Avlékété, Togbin on the lagoon coast (Fig. 11 and 12). The lagoon zones in Benin are densely populated : 200 - 300 habts/km^2.

6.2 Traditional uses

6.2.1 Fishing

The mangroves are a favorite place for fishing because they concentrate marine, estuarine and continental species, and they have a high productivity. In the coastal lagoon, fish production was evaluated at 340 tons in 1988 whereas the output per hectare in the lake Ahémé is roughly 1 ton. But today all these figures must be reduced.

Three types of fishing techniques have impact on the mangroves. The lath barriers made of *Elaeis guineensis* or *Phoenix reclinata*, wood; laths are fixed in zigzag in the silt from one bank to the other side of the lagoons, with openings to let the canoes pass; at the angles of barriers hoop nets are laid to catch fish. Unfortunately this kind of technique is very productive but a great hindrance to the scattering of mangrove seeds. That's why there is no *Laguncularia* in the eastern part of the coastal lagoon toward Togbin.

The second technique is the traditional pisciculture (Acadja); it is a refuge park composed of branches fixed in the silt of the bottom of the lakes and lagoons. Only the ends of the branches emerge. Fish take refuge in, eat periphyton and regenerate. The only problem with Acadja is that the wood is taken from the mangroves. This technique has a positive impact on the mangrove swamp. It eases the scattering of mangrove seeds.

6.2.2 Exploitation of mangrove wood

Species of the mangroves are not yet protected by laws in Benin. They thus become the main source of domestic firewood, mainly of *Rhizophora* that is in high demand because it is also hard; it is used for pickets, piles, posts, bridges, and locks.

But the greatest wood consumer is salt making. This activity has many steps: the search for a site favourable to the extraction of the salt crusts thanks to the plants indicators (*Sesuvium portulacastrum* and *Philoxerus vermicularis*), the site is readied through weeding, fire, scraping, making of small heaps of salts crust, extraction of brine (with salinity about 200‰) by washing the crusts with a big basket with a pipe at the basis, and boiling to obtain the salt.

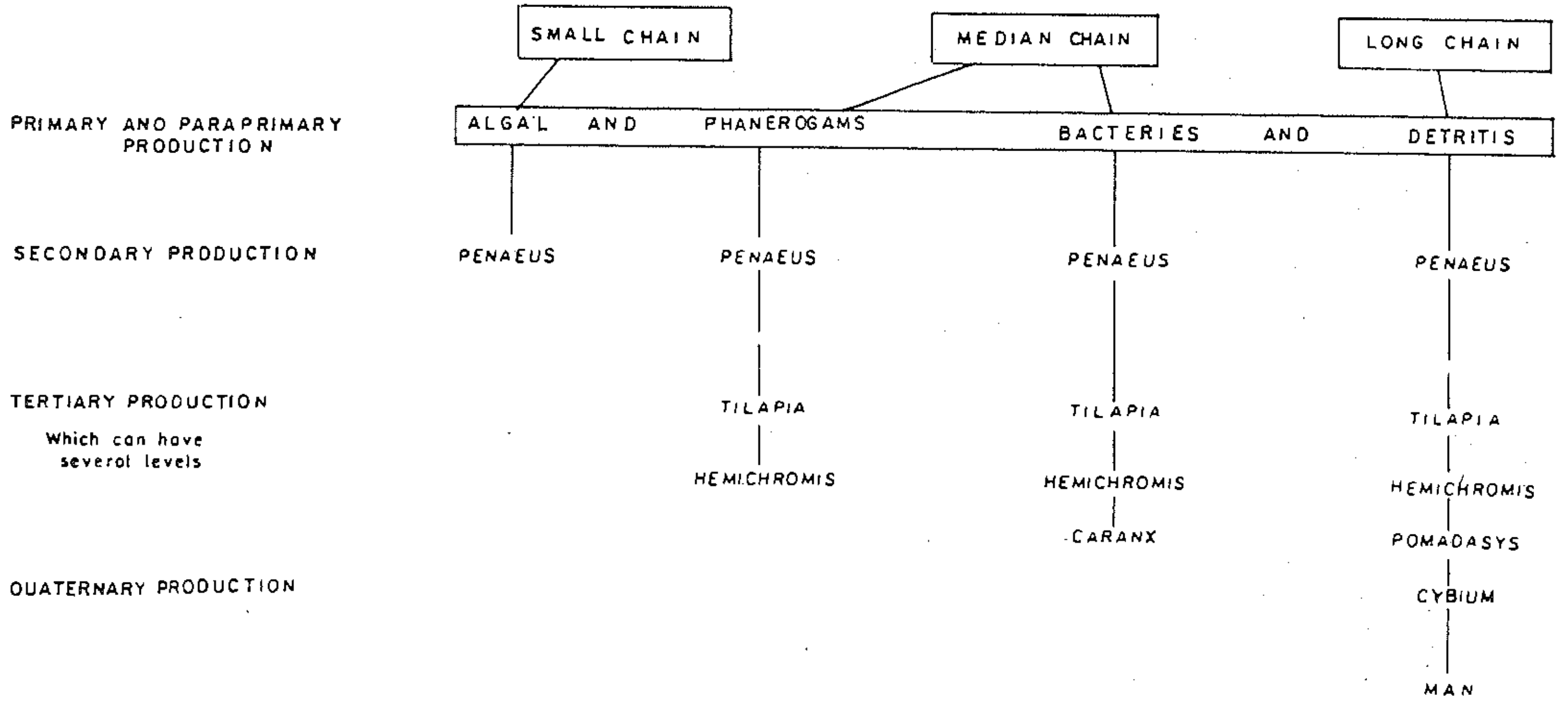


Fig. 9 Example of trophic network in a Beninese mangrove

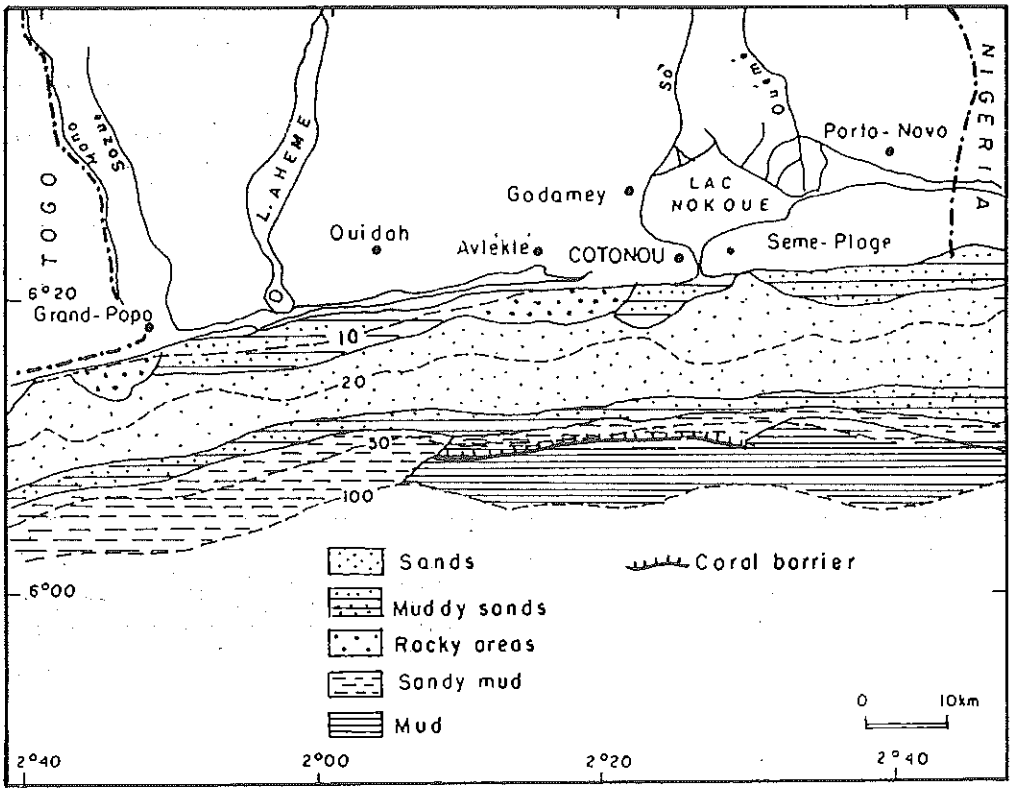


Fig. 10 Continental shelf of Benin

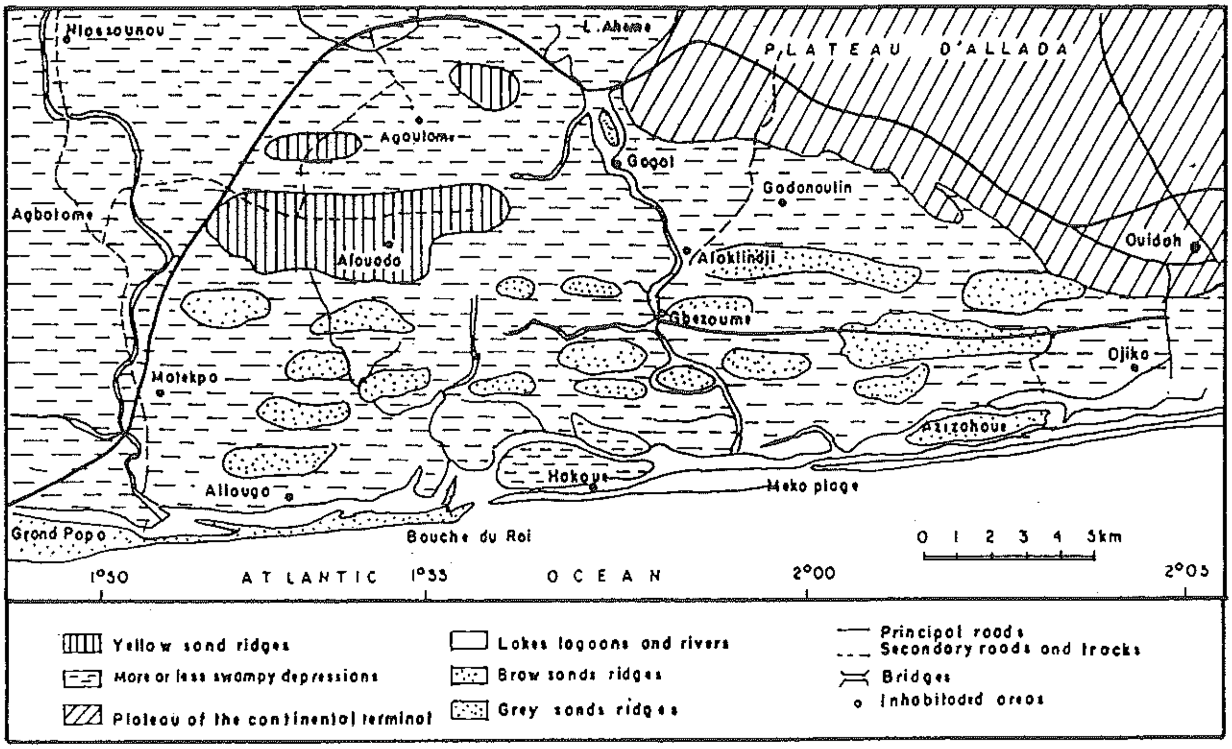


Fig. 11 Geomorphologic Units of west and central areas of the Fluvio-Lagoon zone and surrounding villages

SOURCE: OYEDE, 1991

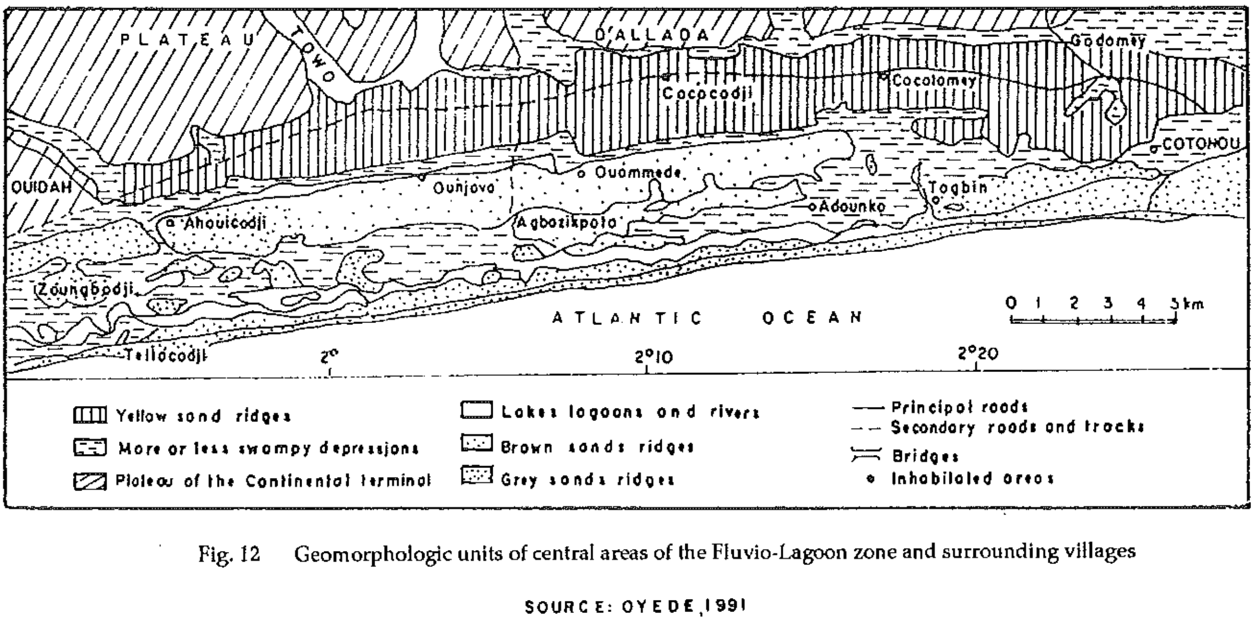


Fig. 12 Geomorphologic units of central areas of the Fluvio-Lagoon zone and surrounding villages

SOURCE: OYEDE, 1991

TOFFI, M.D. calculated in 1988 that 1 m^3 of mangrove wood is required to get 100 kg of salt. Thus the production has a negative impact on the mangroves.

The awareness of these nasty effects leads women to turn to other fuels like palm nervures. Picking of shells is another traditional form of exploitation. The shells such as *Crassostrea gasar* and *Anadara senilis* are picked up by women. The women also pick up oysters in the dry season, during ebb tide; *Anadara senilis* is harvested in the silt of coastal lagoon. *Crassotrea gasar, Anadara senilis,* and *Cardiosoma armatum* are the principal molluscs eaten in Benin.

7. Conversion to Other Uses

The mangrove swamp is not directly destroyed to settle a given activity at its place. Fragments of the forest are cut for firewood supply. After the degradation of the mangrove swamp, the bare soil is naturally degraded into "tannes" which is then exploitated by salt makers.

The mangrove swamp is also used by aquaculturers who cut the branches of *Rhizophora*. Other conversions of the mangrove swamp for agriculture included salt extraction and urbanization.

8. Impact on the Environment

8.1 Natural impact

The impacts to which the mangrove swamp is submitted are natural as well as anthropogenic.

On the natural plan, hydrological dynamics has an impact on the extent of the mangrove swamp. The mangrove swamp is not everywhere subjected to the daily influence of the brackish-fresh water because the tide is not strong: the tidal range is between 1.95m and 0.20m. Tidal currents are not strong enough to carry far the seeds of *Avicennia* and the propagules of *Rhizophora*. This fact limits their scattering. The scattering is more effectively done at the period of high waters. It is when the Mono river swells that the seeds and propagules are distributed. Unfortunately some floods are unfavourable for the regrowth of the mangroves. Floods rise the level of waters up to 1 - 2 m and may last 20 days; many shoots drown and rot away in the meantime.

The development of the mangroves is also limited by sloping coasts, banks erosion, and nature of the substratum. When the substratum is too sandy and the ground water too far, the shoots have no chance to survive; they can live only on silty-sandy soils.

From Agbannankin to Gbekon, the erosion of the Mono river banks and the Lagoon Grand-Popo has eventually created cliffs which are a hindrance to the settlement of mangrove swamps.

Added to these natural effects, the competition between the mangrove trees on one hand and *Dalbergia ecastaphyllum* and *Drepanocarpus lunatus* on the other hand. The competition, most of the time, takes place on the regeneration areas.

8.2 Anthropogenic effects

As far as the influences on the mangrove swamp by man are concerned, there is wood cutting for domestic use and salt extraction.

The beautiful mangrove of Togbin has no more fresh water supply from the lake Nokoué which was linked to river Mono. Today it has been isolated by the road Cotonou-Lomé. This portion is now underdeveloped because it is no longer under the remote influence of floods and tides.

The hydroelectrical dam of Nangbeto has had consequences on the environment that have not yet been evaluated. Constructed in 1987 across the river Mono, it has considerably reduced the silt supply downstream, and has lead to the permanent opening of the river mouth and then, to a marked decrease in salinity in the lower Mono and the lagoon Grand-Popo.

The pollution of the marine waters is taking place at Lomé by pouring out of phosphatic wastes in Lomé. But the impact on the mangrove swamp has not yet been studied.

9. Socio-Economic Implications

The exploitation of the resources of the mangrove swamp by the human population has considerable social and economic implications.

To survive in this difficult lagoon environment, populations have shared the work. Fishing is practised by men; selling is practised by women, they catch crabs (*Callinectes amnicola*), pick up *Crassostrea gasar* and *Anadara senilis*. Furthermore, they exploit salt on a small scale. Activities are more diversified for women than for men.

The degradation of the mangrove swamp ecosystem has lead to a decrease of the fishing output. Since fishermen of the coastal lagoon also practise fishing offshore, many, mainly young people who left school, abandon their villages, heading for Gabon or Congo and practise off shore fishing. These two countries have many Beninese fishermen coming from the mangrove areas. They also go to Nigeria where they work in factories.

The use of certain islands as sanctuaries of divinities such as Avlékété, Vodounto, has as a positive effect by safeguarding the biodiversity of the ecosystem. We can say that the religious power and respect of the people, partakes in the safeguard of the environment.

Some zones of the mangrove swamp which are not protected by gods as "Vodouns" are under the strict supervisions of the secret societies called "Zangbeto". The awareness of the degradation has lead Zangbeto to extend their protection to the mangroves from Ahouandji to Djegbadji, from Togbin to Azizakoué. Zones which are under protection are marked by white flags. Whoever exploits the protected zone is severely sanctioned. The sanctions can be a warning, a fine, a flogging or poisoning.

10. Research and Training

The Beninese mangrove swamps have interested many national or foreign scientists. The flora and the vegetation have been studied by De Souza S., Mondjannagni A., Paradis G., and Baglo M.A. Other scientists such as Gaillard M., Lang J., Lucas J., Paradis G. and Oyede L.M., they were mainly focused on the mangrove sedimentology and soils. The hydrological movements and the quality of lagoon waters were studied by Guilcher A., Hachimou I. and Adisso C.P., Oyedé L.M., Texier H. and Baglo M.A. But Toffi D.M. and Boko M. were interested in the specific climatic characters in the South Western Benin where mangroves are located. The macrobenthos of lake Ahémé has been studied by Maslin J.L. while Anoto C.B. and Dossou C. identified the ichthyofauna of the coastal lagoon. Baglo M.A. and Blasco F. brought to light the ecological situation of the mangroves. Adjanohoun E., Parady G., Baglo M.A and Toffi D.M. worked on the impacts of man's actions against the ecosystem.

Today, the P.I.R.A.T.T.E.S (Integrated Research Project for the Improvement of the Traditional Techniques of Salt Extraction) is teaching women how to produce salt by means of sun or wind energy and in this way safeguard the forests.

A synthesis cartography of the mangroves is planned; also a study on the consequences of the hydroelectric dam of Nangbeto on the mangroves and associated ecosystems; finally a study of the microfauna and the microflora of the mangrove swamp is also planned.

11. National Mangrove Committee; National Policy for Management

Thanks to the scientists of the MAB national committee of Benin, political authorities are more and more aware of the necessity to protect the mangrove ecosystem. A project for the classification of the mangroves as a protected area is already being studied.

Another project that will improve on the traditional technique of salt extraction was started in 1988. It consists in collecting brine from the crusts of salty earth, cristallizing the salt in evaporation basins by wind and the sunlight energy. This technique avoids the use of wood, and contributes to the safeguard of the mangrove ecosystem.

Lastly, there is as an attempt to increase the mangroves through reforestation. Propagules of *Rhizophora* are planted in the silt either in some zones periodically flooded and daily moistened or directly in the water on the borders of the river banks. With *Avicennia africana*, it's necessary to make a nursery to allow the seeds to germinate in shallow waters for two to three weeks; then transplant them in silty and sandy areas.

Taking into account the evolution of water salinity, stations have been chosen on lake Ahémé (Zounta and Kpetou), on Aho (Gogotinkponmè), on a lagoon Gbagan (Missihouncodji) near the Benin-Togolese frontier, on the coastal lagoon (Avlékété) and some sections of lake Nokoué banks in several riverside villages with Vekki-Dogbodji as the most important experimental sites. The growth of the *Rhizophora* is made in three steps: The first step, very rapid (9-10 cm per month during the first five months), the second one is characterized by a growth slowing down with ramification of the sapling; the third step growth is slow, aerial roots start to appear from the seventh month.

Acknowledgements

We should like to express our gratitude to our colleagues of the E.P.E.E.C of Benin, whose assistance has been essential to the issue of this synthesis on the Beninese mangrove ecosystem.

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Mangroves in Nigeria

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The mangrove swamp forests which stretch across the entire coastline in the Southern part of Nigeria occupy an area of about 970,000 ha (about 1% of the country's land area). Petroleum exploitation which usually has devastating effects on the ecosystem and uncontrolled exploitation of timber and other natural resources have been the prominent activities within the mangrove zone.

The latter continues to suffer neglect in terms of management leading to continuous depletion of the resources. This paper discusses the status of the mangrove forests in Nigeria and suggests how this fragile ecosystem can be managed for environmental protection and for its supply of the renewable resources on a sustained basis through an interdisciplinary line of action.

1. Historical Background

1.1 Occurrence

Occurring along most of the coastal areas in the tropics are the mangrove forests which form a link between the land and the sea, supporting a closed single storeyed layer of trees. They derive most of their physical, chemical and biological characteristics from the sea and the in-flowing freshwater from upland forests. They have the distinctive ability to thrive in salt water as well as freshwater, and their advance seaward or retreat inland is brought about by the water regime and sedimentary processes which create shallow water for the growth of seedlings.

The Nigerian mangroves cover an area of about 970,000 ha and are made up of two sub-zones: the freshwater and brackishwater swamps. The mangrove zone consists of an area of low-lying land fringing the coastal swamps and creek areas across the whole Southern Nigeria. Beginning as a narrow strip in Lagos, Ogun and Ondo State in the Western side of the country, it widens out around the Delta and Rivers States. It finally tapers from Cross-River to Akwa-Ibom State in the Eastern side of the country (Fig. 1).

1.2 The resources of the mangrove

The resource wealth of the mangroves particularly around the Niger Delta, has generally been well publicised. They are mainly petroleum and natural gas, wildlife, fish and shrimps and the mangrove forests.

1.2.1 Petroleum and gas

Oil, the most important export product of Nigeria occnrs mainly in the coastal and off-shore zones. Some estimates put the contribution of the Niger Delta area at over 50% of the total national production (NEST, 1991). The frequent oil spillage resulting from oil exploration and exploitation activities has been a major causes of pollution of water and of the environment at large leading to contamination of drinking water, death of some marine animals (including fishes) and loss of agricultural crops.

1.2.2 Fishes

It is a known fact that the real wealth in Nigeria fisheries lies around the coastal waters and Delta creeks of Southern Nigeria (Table 1). It is not surprising therefore, that several fishing ports exist around the coast. The fishing ports being referred to are actually fishing settlements.

1.2.3 Tree species and wildlife

The Nigerian mangrove forests are also rich in plant and wildlife species. Considering the wood production potentials, the Nigeria mangroves consist mostly of the following:

Families	Genera	Species
Rhizophoraceae	Rhizophora (Red mangrove)	R. racemosa
		R. harrisonii
		R. mangle
Avicenniaceae	*Avicennia* (White mangrove)	A. africana
Combretaceae	*Laguncularia* (White mangrove)	*L. racemosa*

Out of the four families represented by 7 species found along the West African coasts, 3 families

FIG. 1 - FRESHWATER SWAMPS MANGROVE AND COASTAL VEGETATION OF NIGERIA

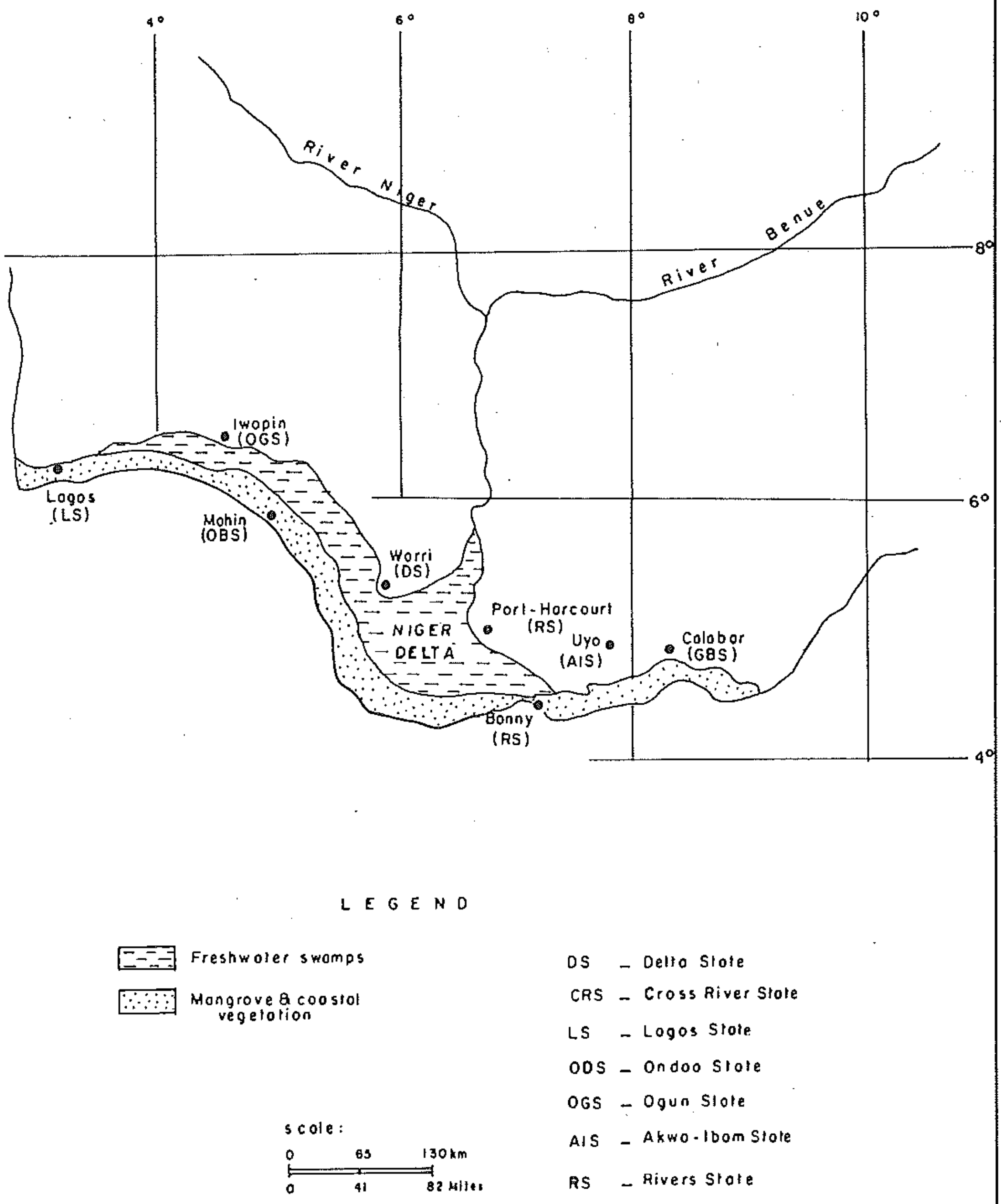

Table 1: Estimated fish output for 1983 - 1988 (in '000 tons)

Fish types/sources	1983	1984	1985	1986	1987	1988
Artisanal, Coastal and brackish water catches	370	228	140.9	133.2	145.8	171.6
Inland lakes and Rivers	132	92	60.5	107.0	103.2	50.9
Fish farming/inshore fishing	21	22	38.8	37.2	21.4	27.2
Shrimps	-	-	1.5	1.6	2.2	2.2
Distant water catches	16	25	61.7	65.2	109.1	105.3

Source: Extracted from Central Bank of Nigeria Annual Reports and Statement of Account, 1983-1988.

represented by 5 species are found in Nigeria. The other family found in the West African coasts (but not in Nigeria) is the *Meliaceae* represented by the genus *Xylocarpus* while the other two genera found are *Conocarpus* and *Lumnitzera* belonging to the *Combretaceae* family. However, there exists an order in Nigeria - the *Palmae* represented by *Raphia (Raphia hookeri)*, *Phoenix* sp. and *Nypa fruticans*, Wurmb. The latter was introduced from Singapore Botanic Gardens into Calabar in 1906 and Oron in 1912 (Whitemore, 1977) and this is now spreading across the Niger Delta.

In addition, the Nigerian mangrove forests are rich in wildlife resources such as mammals (hippopotamus, manatees, primates), reptiles (crocodiles, monitor lizards, vipers, pythons, black mud snakes, rattle snakes, turtles), birds (hornbills, king-fishers, geese, water-fowls, spoon-bills, ducks, cattle egrets). During the dry season, this zone receives some seasonal visitors such as parrots, flamingoes, white pelicans (Fred-Horsfall, 1979).

1.3 Aspects of past uses

While petroleum and natural gas extraction are ongoing with their adverse environmental effects on fishing as well as wildlife-harvesting continue unabated within the mangrove ecosystem, it is worth mentioning past uses of the mangroves. In Nigeria as well as other parts of the world, the mangrove species have been famous as pit-props in coal-mines and also as railway sleepers and construction timber on account of their strength (Banerji, 1957).

Before the 1960's, the Nigerian Coal Corporation at Enugu used to consume about 20,000m^3 of mangrove wood pit-props annually (NCC, 1975). However, as from 1965, the demands for the species for this purpose have declined sharply, first due mainly to less importance attached to coal during the petroleum oil boom era (1970 - 1980) and secondly due to its substitution by *Tectona grandis* (teak and *Gmelina arborea* (gmelina), which are fast-growing and more easily extracted, for pit-props. The slow expansion of the Nigerian railway lines has also contributed to the decline in demand for the mangrove species.

Wood extractives such as cutch (crude tannin), and dyes, could be obtained from the mangrove species in commercial quantities. Tannin popularly used in the leather industry accounts for about 15% of the weight of un-debarked mangrove logs and is obtained largely in the bark. Industrial production of tannin from the mangrove bark has been reported in Papua New Guinea with a factory output of about 3,000 tonnes of tannin annually from 20,000 tonnes of fresh mangrove bark (Hills, 1956). Other products such as adhesives, preservatives, (especially for fishing nets) could be derived from tannin by blending with chemicals. In Nigeria, although it has been known that the mangrove species contain these valuable wood extractives (Hutchinson, and *al.*, 1954), only the individual local fishermen have been exploiting these resources for their own use, and no large scale industries were set up to develop these resources at the national level. Meanwhile, the local textile industries, wood/furniture factories and other manufacturing industries continue to import these items at the expense of scarce foreign exchange. At present, the most common uses of the mangrove species are for pole and fuelwood by the coastal inhabitants. It is estimated that over 200,000 poles along with other types of wood items such as logs or billets (all estimated as over 4 million m^3 of wood) are extracted from the Nigerian mangrove forests annually.

The mangrove species could be used to provide short-fibre pulp to supplement the short-fibre pulp from other hardwood species from the natural forests and the plantation-grown *Gmelina arborea*. Mangrove species have been very popular in the pulp and paper industries in Japan (Kai and *al.*, 1974). Moreover, in the Philippines, the species are being used for production of viscose rayon from which textile fibres are manufactured (Gonzales, 1974). However, in Nigeria, it appears that the Federal Government has not taken into consideration the use of the species for the production of industrial fibres, especially with regard to paper-making, probably as this type of fibres could easily and cheaply be obtained from other hardwood species, and moreover probably to retain the mangrove for environmental protection.

1.4 Significant points in the development of understanding of the mangrove resources

Significant points in the development of understanding of the mangrove resource lie in the mobilization of idle mangrove resources to produce tangible and intangible benefits so as to improve the standard of living of the people in the coastal areas and to improve the national economy while at the same time giving consideration to the environmental protection function of the mangroves. To achieve the development of understanding of the mangrove resource, some of the major problems to be tackled will involve education and public enlightenment of all the parties that have vested interests in the mangroves, especially the traditional rulers, the government and the people at the grass-root.

First and foremost, a substantial area of the mangrove must be constituted into forest reserve as only about 3.14% of the mangrove forests is under reserve. Information on sound knowledge of the movement of the tides in the coastal areas is equally important. Management of the mangrove forests for wood production or agriculture implies that the trees may be clear-felled or partially felled from time to time. This may disturb the equilibrium of the mangrove ecosystem and such disturbance may result in ecological disasters such as flooding, or some coastal towns and/or villages, being submerged. Hence a sound knowledge of the magnitude, extent, direction and impact of the tides along submerged the coastal areas are prerequisite for the management of the mangrove. From such a study which is yet to be carried out, it should also be possible to know which particular areas of the mangrove forests could be alloted to wood production, agriculture, national parks/recreation, other uses, and areas to be kept under permanent forest cover. These objectives will be better achieved through the establishment of a coastal management authority with representatives from the various interest groups.

1.5 Present state of interest in the mangrove

Very little attention has been paid to the management of the mangrove forests in Nigeria. At present, only the Rivers, Bendel (Delta), Lagos Ogun and Cross-River States have shown some interests in development of the mangrove. These states being financially assisted by the Federal Government have been carrying on artificial forest regeneration within the mangrove. The species being raised are mainly *Rhizophora racemosa* and *Mitragyna ciliata* and the total area planted up-to-date in the above mentioned five states is about 36 hectares. The Bendel (Delta) State government has established a mangrove forest reserve with its headquarters at Warri (Fred-Horsfall, 1979) while the Rivers State government is making frantic efforts to increase its existing area of forest reserve. The Mangrove Forest Research Station set up by the Forestry Research Institute of Nigeria (a Federal Government project) at Onne, Port-Harcourt, since 1980, is yet to make any significant impact on the development of the mangroves, mainly as a result of lack of fund.

2. Mangrove Ecosystems: Extent and Distribution

2.1 Area

The area of Nigerian mangrove forests stretches across the seven coastal States of Lagos, Ondo, Ogun, Akwa-Ibom, Cross-River, Delta (Bendel) and Rivers States with the latter two having the largest mangrove areas (Table 2) and previously referred to as the Niger Delta Special Area (Fig.1).

The exact area of the Nigerian mangrove forests seems not to be exactly defined as Moses (1985) estimated this as about 709,800 ha while Okigbo (1984)

Table 2 : Distribution of the mangrove vegetation in Nigeria

State	Area of Mangrove (ha)	Mangrove in Forest Reserve (ha)
Rivers	543,596	9,062
Delta	347,032	14,375
Cross River and Akwa-Ibom	72,186	6,719
Lagos	4,220	313
Ondo	4,062	-
Ogun	1,218	-
Total	972,314	30,469

Source: FAO (1981)

quoted this as about 1,000,000 ha (about 1% of the country's land area of 983,312km²), Nigeria has the largest mangrove area in Africa (Table 3). It is also found to rank third compared with areas of mangrove formation in some parts of the tropics, being surpassed by Indonesia and India with mangrove areas of 4 - 6 million ha and 1.42 million ha respectively (Table 4).

3. Physical Environment

3.1 Climate

The annual rainfall ranges from 2,500 to 4,500mm (mean 3,000mm) with 270 - 290 rainy days, the highest rainfall occurring at Bonny (or the coast at the eastern side of the Delta) and around Calabar. The rainy season extends from March to November although the wettest months are June, July and September. The months of December and January, regarded as the dry season, still have over 25mm of rainfall per month. The minimum monthly temperatures (21°- 22°C) occur in December and January, the maximum (28° - 36°C) in February and the annual mean recorded is 27°C. The mean monthly relative humidity at 13:00 hrs (Nigerian time) ranges from 63% in December, January and February to 79% from June to September (Anderson, 1967). From December to January, there are often incursions of dry air from the North (the Harmattan wind blowing Southwards from the Sahara), but these usually last only for a few days, unlike the Northern part of the country where these are more severe and of about 3 months duration.

The mangrove swamps are regularly flooded by seawater at high tides twice daily. These characteristic tidal fluctuations of the mangrove region fall within the desirable range for development of fish/crocodile farms. Afinowi (1974) reported on the physical and chemical parameters of water in experimental stations within the Lagos lagoon system and the Niger Delta swamp land. Water temperature ranges between 26°C (minimum) and 32.5°C (maximum).

3.2 Terrain, basement complex and sediment deposition

The mangrove terrains along the Nigerian coastline are varied in form and structure. The complexity observed in the Niger Delta terrain is, by far, the greatest. By focusing discussion on this area, it is hoped that the important principles required for understanding of less complex cases will be covered

Table 3: Estimated areas of mangrove swamps in African countries in 1980 (in thousand hectares).

Country	Area
Senegal	169 *
Gambia	60
Guinea Bissau	230
Guinea	260
Sierra Leone	170
Liberia	(20)
Côte d'Ivoire	-
Ghana	-
Togo	-
Benin	-
Nigeria	970
Cameroon	272
Equatorial Guinea	20
Gabon	140
Angola	125
Zaïre	50
Mozambique	455
Madagascar	300
Tanzania	96
Kenya	45
Somalia	(20) *
Ethiopia	-
Sudan	-

Total for Tropical Africa: 3,402,000 ha

*Figures not very accurate
Fource: FAO (1981)

especially as there is less information coverage of the other areas.

The complex structure of the Nigerian coastline may be well understood if the geology and geomorphology of the Niger Delta area are described. Whiteman (1982) noted that three depositional complexes could be distinguished within the Cenozoic and Cretaceous formations of Southern Nigeria in the Abakaliki through, the Benue depression, Anambra Basin and Calabar Flanks and the Niger Delta Area. They may be listed according to their order of occurrence as:

i) Early to late Cretaceous Pre-Santonian Transgressive-regressive complexes.

Table 4: Areas of mangrove formation in some parts of the tropics (in thousand hectares).*

Region	Area
Indonesia	4,000 - 6,000
India	1,420
Nigeria	700 - 1,000
Bangladesh	629
Philippines	400
Thailand	313 - 368
South Vietnam	250 - 370
Papua New Guinea	162 - 201
Malaysia	130 - 150
Sri Lanka	120
Tanzania	100
Puerto Rico	76
Kenya	45
Zaïre	50
Fiji Islands	18 - 20
Tampa Bay (Florida)	7

SOURCES: Walsh *et al.* (1975); FENCO (1976) & Anon (1977)
* Estimated total world-wide area of mangrove formation is 17 million ha (ISME, 1992).

ii) Late Cretaceous-Paleocene Post-Santonian Anambra Delta Complex; and
iii) Cenozoic Niger Delta Complex.

The most crucial details to the current environmental geology of the Niger Delta will be provided by the information from the youngest complex, i.e. (iii). The Cenozoic Niger Delta complex developed as a regressive offlap sequence during Cenozoic times. The delta complex built out across the Anambra Basin and Cross River margins and eventually, extended into the late Cretaceous continental margin. These sediments form part of the West African part of the West African Miogeocline and eventually, spread on the subsiding oceanic crust which had been generated as Africa and South America spread apart. A constructive high energy depositional environment appears to have prevailed only since Miocene times. From Eocene to Early Miocene times three separate depocentres have been identified and lobate-elogate deltas may have been formed. The Miocene present day delta complex is a fine example of a high energy constructive lobate-accurate delta in which the ratio of deposition (Rd) to the rate of subsidence (Rs) is considerably greater (Rd/Rs>1) although there were periods when Rd/Rs = 1. The unification of the Niger-Benue delta complex had been realized since Miocene times. The delta complex has been deformed by well developed growth faults and large scale mud diapirs. The growth of the delta is closely related to the development of the diapirs.

Tons of sediments are carried down onto the Atlantic ocean by the combined Niger-Benue system into the various estuaries which divide up the Nigerian coastline. The complexity is caused by the geomorphology and the alternate deposition and erosion of sediments by the arterial system of these rivers during their travel to the Atlantic ocean. The picture is further complicated by the meandering nature of the several creeks and creeklets in the Niger Delta Basin.

A more complete picture may be produced by recognising the important role played by the winds and waves in the process of sedimentation, especially in the beach-forming or nourishment processes. It should suffice at this stage to emphasize that these physical parameters all contribute to the complex structural features observed in the Delta.

3.3 Soils

4. Biological and Ecological Characteristics

4.1 Flora and vegetation

The fringing plant community within the brackish water ecosystem is dominated by submerged macro-flora comprising of *Avicennia* and *Laguncularia* sp. and filamentous green algae, phytoplankton and other macrophytes. These constitute the primary production elements in the water through the process of photosynthesis. It is from this primary production that the marine animals derive their food.

4.2 Animal community

Animal communities in the mangrove areas in Nigeria include crabs, molluscs, fish and shrimps. The mangrove oyster, *Crassostrea* sp. grows on the stilt roots of *Rhizophora* sp. Large animals such as mammals, reptiles, birds found within the mangrove community have already been mentioned.

Editor's note - For details on soils, please refer to the following paper by E.A.Ajao, in this Report

4.3 Productivity of marine animal species

The high temperature range of 26° - 33°C with great sunlight penetration supports high biological activities in such an aquatic environment and high fish and crocodile production. The period of lowest dissolved oxygen (D.O.) level as a result of high salinities of around 6.97 cm^3/litre could be tolerated by most of the culturable warm water species such as *Tilapia* and *Clarias* species. Barnes (1980) measured primary productivity ranges of 1,000 - 4,000 dry weight/m^2/year for tropical mangrove swamps, such as that of Nigeria which form one of the most productive ecosystems in the world. Apart from the aforementioned wildlife resources, the mangrove swamp forests also are the nursery ground for some commercially important brackish water species like *Ethmalosa fimbriata*, *Mugil* sp., and the highly priced shrimp species where their larval and juvenile stages are abundant for collection. The output of inshore artisanal fisheries, consisting of demersal, pelagic and shellfish resources has been estimated as between 128,000 - 170,000 metric tonnes annually (Ajayi and Talabi, 1984).

4.4 Community stability properties: Zonation, succession, accretion

4.4.1 Species composition and zonation

The species composition of the Nigerian mangrove forests is made up of mostly three families, *Rhizophoraceae*, *Avicenniaceae* and *Combretaceae* represented by five species, viz: *Rhizophora racemosa*, *R. harrisonii*, *R. mangle*, *Avicennia africana*, *Laguncularia racemosa*.

While the detailed botanical descriptions of the mangrove species have been covered by Keay *et al.* (1964) and Hutchinson *et al.* (1954) and some aspects of the wood properties covered by Okereke (1963), Eleanor and Keating (1972) and Giwa (1977), a brief description of the mangrove species commonly found and indigenous to Nigeria is hereby given.

Rhizophora species

The most important out of the above listed three botanical families is the *Rhizophoraceae* which constitutes about 80% of the mangrove exploitable wood volume (FENCO, 1976). *R. racemosa* which accounts for the largest population of *Rhizophora* grows on the outer fringe of the vegetation between the high and low tides, being confined to the borders of the deltas, muddy estuaries and lagoons. Under favourable conditions, the species which normally has straight bole, with fine-textured brittle hardwood, could reach a height of about 40m with a diameter of about 76 cm at maturity (Dagogo, 1981). In addition to the stilt roots, other diagnostic feature of the species includes the presence of numerous aerial roots hanging from the branches. Although the *Rhizophora* species do not coppice when cut, they have a great capacity to regenerate through their viviparous propagules which are usually dispersed by the tidal movements.

R. harrisonii commonly found close to *R. racemosa* inhabits the middle belt zone of the mangrove forests where it grows on more solid mud or swamp than the latter and automatically exists between *R. racemosa* and *R. mangle*. The species also has stilt roots, fairly straight bole and is similar to *R. racemosa* in wood properties (Hutchinson *et al.*, 1954), it could attain a height of about 6m.

R. mangle, commonly referred to as the dwarf mangrove, attains a height of only about 5m in Nigeria, although in Tropical America it grows to a big tree with a height of about 45m (Keay *et al.*, 1964). The species has a dark-reddish brown or yellowish-red fine textured tough wood, often with a crooked bole, but with a bark containing a higher proportion of tannin than any of the other two *Rhizophora* species already described. All the *Rhizophora* species produce viviparous seeds which enhance their natural regeneration.

Avicennia africana and *Laguncularia racemosa*

These species known as the white mangrove grow on sandy soils in association with the other mangrove species on the landward side of the swamps. They differ from the *Rhizophora* principally by the absence of stilt roots and possession of pneumatophores. They have fairly straight boles, white sapwood and light or pale brown heartwood and the wood is generally fairly hard and fine-textured. While *A. africana* could attain a height of about 15m, *L. racemosa* hardly grows taller than 6m. The latter is however famous for its substantial amount of tannin, dyes. As well as *Avicennia* unlike the *Rhizophora* species these are capable of regenerating from the stumps when cut.

Palms

The most commonly found palms within the mangrove zone are the raphia palms. These are not mangrove species, but species commonly found in large populations within the freshwater swamps, which sometimes occur in association with the mangrove ecosystem. They are of economic importance as they are the main source of palm wine from which alcohol is manufactured. The life cycle of a raphia palm oscillates between 5 - 10 years, but like the *Rhizophora*, they are self-perpetuating through seedlings. At present, some artificial plantations of these are being raised in the riverine areas on private ownership basis. Other types of palms found within the zone, but at lesser frequency, include the Nypa palm (*Nypa fruticans*) and *Phoenix* sp.

4.4.2 Productivity of major mangrove species

The data on growth rate and standing volume of the Nigerian mangrove forests are tentative. In a volume determination survey by FENCO (1976), a standing volume of 100 - 250 m^3/ha (volume underbark to timber height of 7.5 cm diameter top) with a mean of about 184 m^3/ha was obtained from a mixed natural *Rhizophora* forest on the saline areas of the Niger Delta. The growth rate of the mangrove species could not be determined from these data as the age of the forest was not known. However, judging from the data obtained from marked trees remeasured monthly within the *Rhizophora* forest around the Niger Delta (NDDB, 1963 - 64) and the present growth rate of the plantation grown *Rhizophora* species at Abel-Kiri (Rivers State), a yield figure of 220 - 300 m^3/ha with a final crop of 300 - 400 trees/ha is anticipated on a 35-year rotation period, i.e. a mean annual increment (M.A.I.) of 6 - 9 m^3/ha/year is anticipated. Under very favourable plantation conditions such as in Perak mangrove of Malaysia, an M.A.I. as high as 9 - 10 m^3/ha/year and an underbark volume of about 210 m^3/ha in a 25-year period have been reported (Christensen, 1977). Banerji (1957) also reported a yield as high as 247 m^3/ha over the same period for a *Rhizophora* forest in the Andaman Islands, India. However, a low yield of 30 - 120 m^3/ha had been reported in a semi-natural stand in Thailand (Aksornkoae, 1976). Generally, the growth rate of the *Rhizophora* species is not all that high in a natural forest, and an M.A.I. of 4 - 5 m^3/ha/year is regarded as normal under that situation.

An inventory carried out by FENCO (1976) indicated that out of the 404,500 ha of mangrove cover around the Niger Delta, only about 30,700 ha (7.6%) were commercially exploitable and the latter were estimated to have an underbark standing volume of about 5.64 million m^3. Therefore, the commercially exploitable wood volume (for poles, pulp and paper) in the Nigerian mangrove forests as at 1988 has been estimated as 10 million m^3 based on the minimum estimated total mangrove area of 709,800 ha (Moses, 1985) and FENCO's 1976 figure (corrected for wood removal and stand volume increment as form 1976). The total wood volume within the Nigerian mangrove forests (both commercially exploitable and otherwise) could be about 50 million m^3 based on an earlier inventory data (NDDB, 1963 - 64) although Okigbo (1984) estimated this as 250 million m^3. This however emphasises the need for an up-to-date inventory to determine a better estimate of the standing wood volume.

4.4.3 Succession and accretion

Generally in mangrove formations, *Rhizophora racemosa* is the pioneer species; without this species, no typical mangrove ecosystem can be formed. In Nigeria the *Rhizophora* species generally start by colonizing the muddy sea water or swamp with their floating propagules which are deposited by tidal waters. Later the species consolidates the soil and breaks the forces of the tides before other species like *R. harrisonii*, *R. mangle*, *Laguncularia racemosa* and *Avicennia africana* start to develop. As hard soil is formed, tough grasses and ferns start to develop among the *Rhizophora* species (*R. mangle*, *Laguncularia* and *Avicennia* sp.) outside the direct influence to the tidal waves. At last, dry land covered by grasses is formed. As succession continues lowland forest species such as *Mitragyna ciliata*, *Nauclea diderrichii* start to invade the area. As this continues, the *Rhizophora* species start to disappear. In some cases, the area where succession takes place becomes an island being surrounded at the periphery by the *Rhizophora* species. These types of islands are common in the coastal areas of Rivers State. In the transitional zones, lowland forest vegetation can be seen growing into the mangrove zone liberating the previously swampy environment.

In most cases the landward boundaries of the mangrove zone merge gradually with aquatic grasslands, herbaceous swamps, freshwater swamp forests, riparian forests or forest-savanna mosaics according to local conditions. In some of the coastal areas of Ondo, Ogun and Lagos States, the aquatic grasslands and herbaceous swamps have been found to harbour the troublesome and rapidly multiplying water hyacinth which usually hinders river transportation.

5. Mangrove Related Ecosystems

Generally the mangrove related ecosystems consist of old beach ridges and former deltaic plain relics, freshwater swamps North of saline mangrove belts, and old beach ridge remnants and coastal plain terrace relicts. These three areas fall within the freshwater area which can simply be divided into three parts as follows:

a) The Southern part linked up with the mangrove area and covered with freshwater vegetation. The low-lying basins, the back swamps, are mostly overgrown by raffia palms, oil palms and alternating with higher situated narrow levees. This part is under the influence of annual flooding of the river in September and October.

b) The Central part which is also under the influence of the river floods. The levees are generally broader especially around the Niger Delta, and the alternating back swamps have a vegetation of raffia, oil palms and other trees (e.g. *Mitragyna ciliata*). In this part, young meander belts occur as narrow ridges alternated by narrow, shallow valleys.

c) The Northern part which is not influenced by river flood. Rain water usually accumulates in the valleys and is slowly drained away. In the valleys the vegetation is the same as in the back swamps except that more oil palms grow on the drier land.

6. Human Habitation and Traditional Usage

6.1 Human habitation

Even before the discovery of oil in Nigeria in the 1960's the coastal areas had been more densely populated than many other parts of the country. This has been due to the various economic activities along the coastline. These activities include loading points for slaves during the slave trade era, export and import points for goods, extraction and water-transportation of logs and the major occupation along the coastline - fishing - which usually leads to the establishment of the various fishing settlements.

The oil exploration and exploitation activities in recent years have led to substantial increase in population along the coastline which produces over 60% of the country's total oil output. The areas mostly affected by this substantial population increase include such areas as Lagos, Warri and Port-Harcourt. Human activities have adversely affected the stability of the ecosystem. The major constraints to the inhabitants is the mangrove formation zone as highlighted by Bell-Gam (1984), it includes the following:

i) Limited land resources for building or operational development.
ii) Sandbars development constitutes a major constraint to navigation of rivers and creeks and a barrier to development of fishing and shipping centres. The navigation problem has recently been aggravated in some parts of Ondo, Lagos and Ogun States by the proliferation of the water hyacinth.
iii) Poor soils make development - whether for building or other purpose - difficult and expensive.
iv) Dominating presence of salt-affected mangrove soils making conventional agriculture difficult.
v) Lack of electricity and pure clean water constitute a major barrier to private and public investments.
vi) Lack of communication infrastructure and other means of transportation apart from boats retards economic activities and commercial development.

6.2 Traditional mangrove usage

In summary, the mangrove dwellers are totally dependent on the mangroves for fuelwood and timber for building houses, canoes, causeways between households built on stilts made of mangrove poles. The mangrove timber is used for boat-building, furniture, tool handles while substances such as dyes, tannin and other compounds of medicinal importance are extracted from mangrove plants.

The mangrove dwellers obtain their food materials such as honey, fish, crustaceans, mulluscs and alcohol from the mangrove zone. There are however health problems for mangrove dwellers (Vannucci, 1992); while food is abundant and rich in proteins, it is deficient in quantity and variety of minerals and vitamins. The humid climate favours fungal infections of the skin and lungs while scarcity of good fresh water could cause kidney diseases. Except for rapid urbanisation along the coastline as well as the industrial utilisation of the mangrove zone or the mangrove products, most of the traditional uses of the mangrove are of the subsistence type usually compatible with sustainable production.

7. Commercial Exploitation and Marketing

7.1 Fuel Wood and timber production

All along the coastal areas of the country the mangrove species are the major source of fuelwood and the consumption of fuelwood in these areas is likely to be higher than the per capita consumption of about $1m^3$. This is because the major occupation of inhabitants along the coastline is fishing and additional fuelwood (in addition to the one used for cooking) is required for smoking fresh fish that could not be sold quickly enough. This follows that most of the mangrove species extracted are used as fuelwood. Three special features of the mangrove wood include their high calorific values (1 ton of wood being equal to 0.4 - 0.6 tons of oil) their ability to produce high quality charcoal with recovering as high as 22%, and their ability to burn even when green or partially dry. Other desirable characteristics include burning with even heat and without much smoke (FENCO, 1976). Burning mangrove logs as heaters in homes especially in the rainy season is a tradition in most town and villages in the Rivers State of Nigeria due to their prolonged stable heat supply. At present, a conservative estimate puts the number of people earning their living through firewood selling within the coastal areas of the country as over 20,000.

Mangrove species, principally the *Rhizophora* spp. have always been used by the coastal fishing communities for production of poles, and beams for construction and scaffolding. Mangrove timbers are utilised for boat building. The poles are also used for masts and in the construction of outriggers, while oars and other components are also made from the same mangrove species. As the species are hard and durable, they are in very high demand to make handles for tools, carvings and in some cases, furniture. The young adventitious and aerial roots or *R. racemosa* are used by the local inhabitants for weaving materials such as baskets, netted trays for marketing fish. Older roots from the same species are used for fencing compounds, yards or gardens.

7.2 Fishing

Apart from the oil producing potential of the mangrove zone, the area serves as a very important fishing ground harbouring many fishing settlements along the coastal areas of the country. In most cases, the mangrove tree species, *Rhizophora, Avicennia* and *Laguncularia* are used to enhance fishing operations. The leaves of these species are used as traps for fish, crabs and prawns while the stilt roots of *Rhizophora* are used to make dams for trapping fish and crabs. Alternatively, the roots are cut because they harbour some species of oysters which are sources of food to the inhabitants.

7.3 Wood extractives

The *Rhizophora* produce organic chemicals in large quantities. These include vegetable salt, tannin or dyes, and adhesives.

7.3.1 Salt

Vegetable salts can be extracted from the roots of the mangrove species, especially the *Rhizophora* and *Avicennia* species. The salt extracted has a very high proportion of common salt (sodium chloride) for which it is used as a substitute. Such extracted salt is commonly used in Warri areas of the Delta (Bendel) State especially by the Itsiekiris tribe and also by the coastal inhabitants of the Rivers State (Kennedy, 1932).

The process of extraction is simple. After burning the wood, preferably as firewood, the ashes, very white in colour are collected into a pot and then boiled with freshwater for a period. Next, the salt solution is carefully filtered off from the ash precipitates, and then evaporated to dryness.

7.3.2 Tannin and adhesives

Tannin which is used for processing hides and skins into leather occurs in substantial amount in red mangrove barks, accounting for about 15% of the mangrove bark log. However, the disadvantage of using mangrove tannin in the leather industry is the undesirable dark-red colour of the leather produced. However, from series of experiments carried out to-date, it has been found that the mangrove tannin when blended with tannin from *Fagara xanthoxyloides* and *Acacia nilotica* in the ratio 1:1:2 gives the desirable leather quality (Dickson, 1978).

Mangrove cutch (crude tannin) has been used extensively in the Rivers State of Nigeria by local fishermen in the treatment of cotton-made fishing nets. The nets are steeped into boiling, tannin solution for dyeing as well as to act as preservative. Mangrove tannin is also used for dyeing cloth or textiles giving them attractive colours.

Tannin has been used as raw material source of polyhydric phenols for the manufacture of certain adhesives. It has been found that certain tannin extracts combined with formaldehyde and filler form good wood adhesives (FENCO, 1976). Tannin extracts could also be used as extender for urea formaldehyde and phenol formaldehyde adhesives, as raw material for moulding resins for the production of plywood. This has been tried at the African Timber and Plywood (A.T. & P.) wood-based company at Sapele (Fred-Hors-Fall, 1979).

8. Conversion to Other Uses

8.1 Agriculture

Agriculture has not been intensively practised within the mangrove swamps except on small islands within the mangrove areas where crops like yams, cocoyams and pepper are grown. However, as far back as 1933, attempts were made to develop the mangrove swamp for rice cultivation in areas like Calabar, Oron, Warry, Mbiakpapa and Oloibiri (Onofeghara, 1990). The trials on the Warri and Calabar mangrove swamps carried out in 1934 showed promising results with yields of 2,000 and 2,700 kg/ha of paddy rice respectively. As from 1938, however, the yields obtained began to decrease, and after about a decade, the Warri mangrove swamps appeared incapable of supporting further rice cropping (Okafor, 1990).

8.2 Aquaculture

The development of aquaculture within the mangrove areas for rearing of fishes, oysters and some other marine animals will go a long way in alleviating the problem of scarcity of animal proteins. The mangrove swamps are very suitable for fish pond operations because the tidal fluctuation can be utilised in the water supply and the drainage systems. Aquaculture is at present undertaken in Nigeria at the subsistence level by private individuals and at experimental level by the government. The total aquaculture production in Nigeria has been estimated at only 7,500 metric tonnes annually (Afinowi, 1985).

8.3 Conversion to national parks

Among the current uses of the mangroves is their conversion into national parks. The Okomu National Park and the Cross River National Park are special wildlife conservation centres established within the mangrove swamp forests. They harbour a number of wildlife species that are now threatened with extinction in Southern Nigeria. More than 1,500 species of animals are known to exist in these parks and these include the lowland Gorilla (with an estimated population of 100 - 300 of various species), forest elephants, chimpanzee, leopard, royal python, crocodile (Ayodele, 1992). There is the likelihood that more national parks will be established within this zone in the future.

8.4 Conversion of the mangrove zone for building purposes

Conversion of the mangrove zone into dwelling places appears to be the most devastating use to which the mangrove can be put because in most cases this operation is very difficult to reverse. At the same time, the coastal areas are densely populated and as a result the inhabitants have resorted to building squatter settlements within the coastal areas or the mangrove zone. For example, over the last fifteen years or so, much of the mangrove swamp around the University of Lagos has given way to relentless urban sprawl. In some areas, draining and land-filling followed by building constructions have completely modified the original ecosystem with almost all the wildlife wiped out.

9. Human Impacts and Socio-Economic Implications

The Nigerian mangrove forests with a lot of resources have attracted various human destructive activities in the process of getting some of these resources exploited.

9.1 Oil exploration

Offshore and in-shore mining of minerals such as crude oil, natural gas, magnesium, sulphur, sand gravel have far-reaching adverse effects on the marine environment. The most destructive of these operations in Nigeria are the prospecting for oil and natural gas. The extensive pollution of the coastal waters by oil spills, oil-blow-outs and oil leakages from pipes is a matter of great ecological concern.

Prospecting for crude oil and natural gas involves determination of deep geological structures of the underlying seabed by means of geophysical methods (seismic reflection/refraction, measurement of fields gravity). Some of these methods implicate the use of explosives which kill fish in the vicinity in large numbers. Much of the concern in mining is, in other cases, depletion or destruction of the living resources of the coastal zone on which man depends for survival. Crude oil is damaging to marine organisms in two major ways. Large quantities of oil in the tidal zone can "coat" benthic marine organisms thus interfering seriously with their respiration and feeding. The lighter fraction of crude oil, the acids and volatile aromatics, are directly toxic to marine organisms (Amadi-nna, 1985).

Although the oil companies are trying as much as possible to maintain a clean environment within the mangrove zone, the frequent oil spillage usually destabilises the mangrove ecosystem causing serious pollution. So far, the greatest single environmental problem connected with petroleum exploitation in Nigeria is oil spillage both on shore and off-shore. Although only one spillage (of 150 barrels) was reported in the country in 1970, between the 13 year period of 1970 - 1982, a total of 1,581 oil spills involving nearly two million barrels of oil was reported (NEST, 1991). These spillages have occurred primarily in the main oil producing states of Rivers, Delta, Aka-Ibom and Imo, the first three of which have mangrove forests.

The adverse impacts of oil spills include loss of fish, crustaceans and other aquatic animals; socio-economic problems arising from abandonment of fishing grounds and consequent loss of income; degradation of the vegetation and other ecological damages, loss of drinking and industrial water and its importation or derivation at extra costs. Table 5 gives an indication of chemical changes in an oil polluted water as could affect living beings in a polluted coastal area.

Apart from pollution resulting from spillage, oil exploration has increased human activities within the mangrove zone. This has led to construction of roads or digging of water channels within the wetlands making the areas more accessible to destructive human activities, thereby destabilising the fragile ecosystem.

9.2 Deforestation

Apart from the exploitation of the mangrove species for pit-props in coal-mines at Enugu up to around 1965, wood extraction for fuel and building is the major cause of deforestation of mangroves. This uncontrolled exploitation is gradually depleting the mangroves of the wood resources and exposing the ecosystem to coastal erosion and flooding, some villages have been submerged in some places. Cases of submerged towns and villages have been often reported in parts of Ondo bordering the Atlantic ocean (African Guardian, Jan., 1988) as a result of deforestation.

Other human activities include clearing of the vegetation for farming by the coastal inhabitants. There have been cases where existing vegetation was replaced by exotic species which on the long run do not survive under prevailing environmental conditions. Furthermore, some coastline areas are constantly dredged to remove sand for building purposes. This action disturbs the movement of nutrients downstream with the subsequent lowering of productivity of various organisms at the estuaries and deltas. This practice is common in the coastal areas of Lagos. Fishing activities in some places also lead to deforestation. For example, the stilt roots of *Rhizophora* are cut and used for damming the lagoon or streams so as to trap fish and crabs. The roots also harbour some marine animals which the fisherman are searching for. The leaves of the mangrove species are also used for trapping fish, crabs and prawns. Unless all these activities are controlled, environmental disasters of greater magnitude could occur in these areas in the future.

9.3 Available information on socio-economic implication of the use and misuse of the mangrove, methods of mangrove utilisation.

Frequent oil spillage within coastal areas of the country usually result in environmental pollution which negatively affects the socio-economic life of the coastal inhabitants whose main occupation is fishing. Other adverse aspects of oil exploration and exploitation within the mangrove include increased human activities such as construction of access channels, building of roads usually by filling up of river or coastal embankments, deforestation to provide wood for human needs. These have caused damages ranging from coastal erosion where the vegetation has been depleted to overflow of coastal bands and/or submersion of towns and villages. For example, as a result of the Gulf Oil Company exploration activities which commenced at the coastal areas of Ondo State around 1960's, a town, Awoye, about 2 km from the Atlantic ocean and with over 15,000 inhabitants, now lies beneath the ocean. The ocean started creeping in gradually during the rains around 1977 when the Oil Company completed its extraction construction channels until 1987 when the town was completely submerged (African Guardian, January, 1988). Other villages also adversely affected along this coastline include Ojumale, Umolume, Ikorigho, Jirinwo, Molutehin and Ogungbeje.

Other adverse effects of oil exploitation and deforestation along the coastal areas include tidal incursions into the freshwater making it very difficult

Table 5: Parameters of water quality in oil-polluted and unpolluted sites at Bonny River.

Parameters	Site n1 Oil polluted water	Site n2 Clean water
Temperature C	27.7	26.8
Dissolved Oxygen 0_2 mg/l	6.5	8.0
Turbidity mg/l	33.0	11.0
Alkalinity in Ca CO_3 mg/l	79.0	73.0
Conductivity ms/cm	79,300	37,100
P^h	7.00	6,9
Nitrates N-$N0_3$ mg/l	1.47	0.71
Nitrites N-$N0_2$ mg/l	0.017	0.008
Chlorides Cl mg/l	11,318.0	11,175.0
Sulphates SO^4 mg/l	1,406.0	1,366.0
Phosphates PO^4 mg/l	0.032	0.035
Iron Fe mg/l	0.6	0.4
Oils mg/l	1.00	0.2

Source: Pudo, J. (1985).

for the coastal inhabitants to obain good drinking water. As a result of this, the inhabitants of the affected areas might need to undertake journeys of up to 12 hours to fetch drinking water.

Coastal erosion also affects virtually all the seven states bordering the Atlantic ocean (Lagos, Ogun, Ondo, Delta, Rivers, Akwa-Ibom and Cross River States). The erosion impact is generally more serious in areas where the environment has been much tampered with. As sea waves break on the shore, land is torn off and washed into the sea. In the actively eroding parts of Rivers and Delta States, shoreline recession is more than three metres annually (NEST, 1991). In Ondo State, coastal erosion is now a constant source of worry for many fishing villages.

Nigeria's most notorious case of coastal erosion is that of Bar-Beach at Victoria Island in Lagos, the problem is directly associated with the construction of two stone moles at the entrance into Lagos lagoon to keep it free of a sand bar that had been an obstacle to the free movement of ocean-going ships in and out of Lagos harbour. With the construction of the moles, vast quantities of sand, which normally move by longshore drift from West to East have piled up against the West Mole, building out land in the process. By contrast, the moles have cut off the supply of sand to the Bar Beach, triggering off rapid wave erosion of the beach sands.

The Niger Delta is an extensive plain criss-crossed by a maze of meandering rivers and creeks. The banks of these water channels consist of levees which slope down into backswamps and flooded depressions. When the Niger and its distributaries are in flood, they erode these banks, especially on the outside of meander bends, which are turned into vertical faces. The flooding normally lasts from 3 to 5 months each year and the height difference between low water and flood water flow may be as much as 6 - 10m. As the flood waters recede, river banks become unstable and large masses of earth collapse. Rates of bank erosion may be from 2 to 5m per year along the larger channels. Tidal movements also aid bank erosion in some places. Bank erosion poses serious threats to towns, villages and farmlands within the Niger Delta area.

10. Research and training

10.1 Research

Past and present research within the mangroves had been directed towards fishery and studies of the effects of pollution resulting from oil spillage. Some data have been collected on the growth of the mangrove tree species (FENCO, 1976), but these are outdated and therefore need to be up-dated. Agricultural crop production experiments, such as rice trials had been carried out within the Warri and Calabar mangrove swamps with yields of about 2,000 and

2,700 kg/ha respectively. However, after a decade, the mangrove swamps appeared incapable of supporting further rice cropping (Okafor, 1990).

The major problem of research within the mangrove zone in Nigeria is funding. Therefore funds should be made available for present and future research which should be focussed on the following:

a) A detailed up-to-date mapping of the mangrove areas, preferably by a National Mangrove Management Agency (NMMA) yet to be set up (Fig. 2), and the production of an inventory of the mangrove species and their relative abundance (in terms of area and available wood volume).
b) Detailed study of the mangrove ecosystem by the above Agency with a view to studying the structure of mangrove communities.
c) Monitoring the impacts of the movements of the tides along the coastal zone of the country.
d) Investigation of the socio-economic aspects of mangrove utilisation, and their associated problems.
e) Intensified artificial regeneration trials with local mangrove species in selected locations along the coastline by the Forestry Research Institute of Nigeria and the established NMMA.
f) Intensified studies on the effects of oil exploration and exploitation activities (including effects of oil spillage) on the environment and socio-economic life of the inhabitants.
g) Basic research into the biology of mangrove ecosystem species of plants and animals either by Rivers State University of Science and Technology and/or University of Port-Harcourt.
h) Research into the development of aquaculture and impacts of aquaculture projects within the mangrove zone or along the coastline by the proposed National Aquatic Resources Agency (NARA) under the National Coastal Management Authority (NCMA), (see Fig. 2).
In evaluating all the proposals, the NMMA should consider the extent of felling required, the area of land area to be filled up, the possible effects on sedimentation, possible alterations of the freshwater supply, probable soil effects, and the effects of discharge of oil pollutants on the mangrove species.

i) Research into development of National Parks/Game reserves within the mangrove zone and assessments of impacts of such projects within the zone by the Natural Resources Conservation Agency (NRCA) and the Environmental Protection Agency (EPA) (Fig. 2).

10.2 Training

There has been very little or no training on the management of the mangroves for the different uses to which it is being put. While most of the training will be based on the research project areas listed above, the most important and urgent training for the inhabitants within the mangrove zone will involve the ecology of the mangroves, the biology and ecology of different species, their importance in stabilizing the mangrove zone, their various uses, and how they can be harvested, if and when necessary, on sustained yield basis so as to minimise the frequent environmental disasters along the coastline. The other important training will be the management of some of the coastal areas for aquaculture. With regard to the training aspect, the National Agricultural Extension and Research Liaison Services (NAERLS), Ahmadu Bello University (ABU) with branches in all ecological zones of the country can play an important role.

Such trainings to be effective need to be organised in two-stages. The first stage will involve "train-the-trainers" courses and this will draw participants from the Agricultural Development projects (ADPs) and local Government Offices from all the States along the coastline of the country. The second stage will be the community-based training which will be conducted by the participants who attended the first training but also assisted by the experts who conducted the first training. This second stage training, if possible, should be conducted in local dialects and well be supplemented by illustrations and field visits.

11. Establishment of National Coastal Management Authority (NCMA)

11.1 Need for establishment of the authority

As a result of shortage of funds for development, developing countries (Nigeria inclusive) are under substantial pressure to exploit their resources in order to earn the funds for present day national development. At the same time, vast hectares of land and vegetation become damaged during the exploitation of the mineral resources. The coastal areas on which the mangrove forests are established serve several functions or various interest groups in Nigeria. Therefore, it does not appear that the establishment of a National Mangrove Committee or Agency alone will lead to tangible achievements in conserving the mangrove forests except if all the various interest groups are represented under one umbrella as a management unit. This is especially the case because all the mangrove forests have not been protected by laws, with only 3.45% of the area under forest reserve. It will be under the unifying umbrella that the representatives of the various interest groups will be enlightened about the importance of the mangrove forests and the need for their regeneration, conservation or management on a sustained yield basis.

Therefore, the development and programming of national goals with respect to the management of the coastline will require the mobilisation of the various shades of opinion (from the grassroot level) and ideologies in the country. Hence, a National Coastal Management Authority (NCMA) with representations from the various sectors will be ideal in managing the resources of the coastal areas (the mangrove inclusive). The various interest groups to be represented will include the coastal inhabitants (especially within the mangrove zone), forest development agency, fishing industries, wildlife conservationists, mineral extraction companies and environmental protection agency.

The National Coastal Management Authority (NCMA) will be headed by a director of natural resources and he should be a forester by profession. He will co-ordinate the activities of the various agencies representing the different interest groups. Such agencies as indicated, in Fig. 2, will include the Community Relation Agency (CRA), National Mangrove Management Agency (NMMA), National Aquatic Resources Agency (NARA), Natural Resources Conservation Agency (NRCA), National Mineral Exploration and Exploitation Agency (NMEEA) and the Environmental Protection Agency (EPA).

11.2 Composition and function of the various agencies under the NCMA

A. Community Relation Agency (CRA): This will liaise with the community leaders at the coastal areas of the country, identify their problems and conflicts in relation to the development of the coastal areas and try to find solutions to the problems identified. This will be mainly a service agency with some social research component.

B. The National Mangrove Management Agency (NMMA): This will liaise with or draw representatives from Federal Department of Forestry and Forestry Research Institute of Nigeria (FRIN). The NMMA will be the main core of the National Coastal Management Authority (NCMA) and will

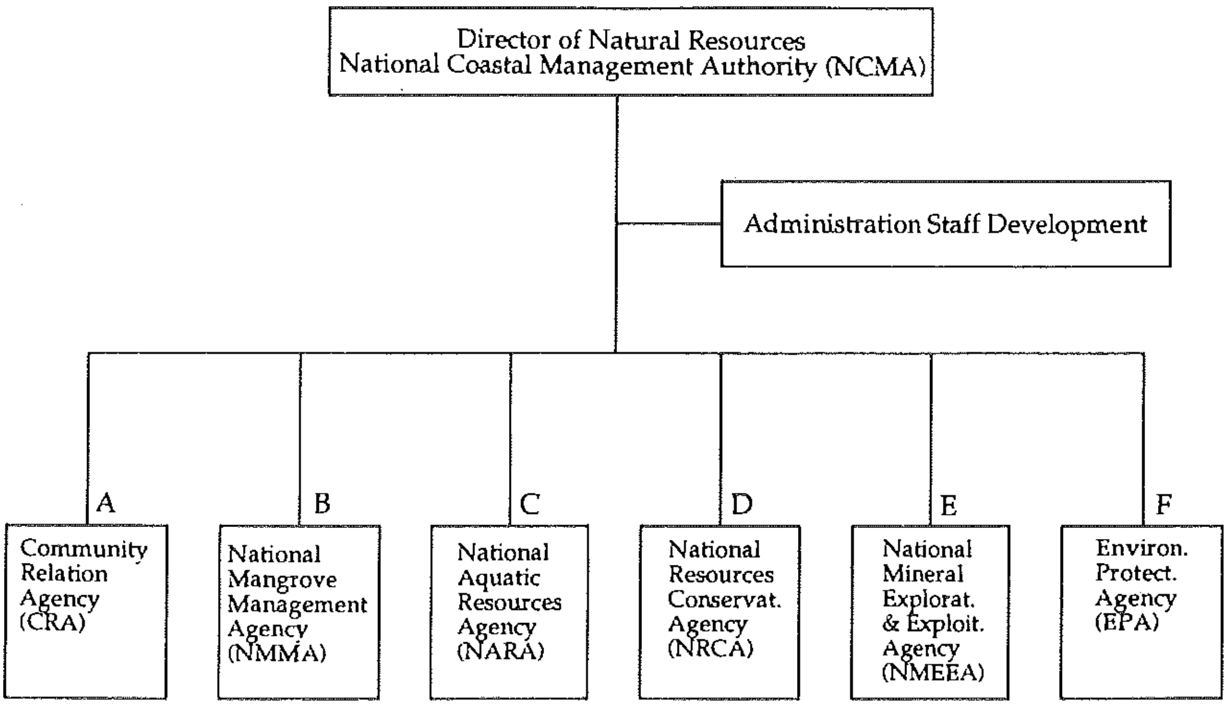

Fig. 2: Organisational set-up of National Coastal Management Authority (NCMA)

have conservation, protection, research and afforestation functions.

C. National Aquatic Resources Agency (NARA): This will liaise with or draw representatives from Federal Department of Fishery and Nigerian Institute for Oceanography and Marine Research (NIOMR) and will have research and service functions.

D. The Natural Resources Conservation Agency (NRCA): This will liaise with Natural Resources Conservation Council and Ministry of Tourism and will have mainly conservation function, i.e. conservation of wildlife and plant species for tourism and educational purposes.

E. National Mineral Exploration and Exploitation Agency (NMEEA): This will liaise with or draw representatives from the Ministry of Petroleum and Mineral Resources. Its main function shall be to control the activities of the oil companies thereby minimising environmental pollution.

F. Environmental Protection Agency (EPA): This will liaise with or draw representatives from the Federal Environmental Protection Agency. The EPA will work in collaboration with the above other agencies to promote development of pollution-free and sound environments.

11.3 Mangrove management plan in terms of objectives

In view of the importance of the mangrove zone in protection of the coastal areas from environmental degradation and/or pollution and conservation of plant and animal species, decisions on how to manage the ecosystem shall be under the definition of the following parameters:

a) Extent to which forest preservation is going on within the mangrove zone
b) The biological components and physical characteristics of the area under consideration, by means of inventories, maps and collection of physical and biological data.
c) The needs of people in relation to sustainable uses of the resource while ensuring adequate reserves for preservation purposes.
d) The relevance of the resource as habitat and as a genetic reservoir.
e) The relevance of the ecosystem in coastal stability and fisheries production.
f) The local requirements for education, recreation and aesthetic values.
g) The requirements that must be satisfied for non-sustainable uses of the resource.
h) The extent to which rehabilitation and compensation mechanisms can be used to mitigate the impact of non-sustainable use.
i) The extent to which petroleum exploitation can be controlled within the mangrove zone to minimise the environmental pollution.

The information collected from the above statements shall be used to define the areas necessary for preservation, to define strategies for management, restoration and preservation of the resource or to define areas necessary for sustainable use. Therefore decision on the use of the mangrove ecosystem shall include consideration of the need to:

i) Utilise the mangrove resources so that their natural productivity is preserved.
ii) Avoid degradation of the mangrove ecosystem.
iii) Rehabilitate degraded mangrove areas.
iv) Avoid over-exploitation of the natural resources produced by the mangrove ecosystem.
v) Avoid negative impacts on the neighbouring ecosystems.
vi) Minimise the effects of the oil pollution within the mangrove zone.
vii) Recognise the social and economic welfare of indigenous mangrove dwellers.
viii) Control and restrict non-sustainable uses so that long term productivity and benefits of the mangrove ecosystem are not lost.
ix) Introduce regulatory measures for the wise use of the mangrove zone.

States bordering the mangrove zone, other public authorities, international organisations, individuals, groups and corporations in whatever capacity they can shall:

i) co-operate in the task of managing the mangrove ecosystems for sustainable purposes.
ii) establish procedure and methodologies for assessing the status of the mangrove ecosystems and for managing them.
iii) ensure that activities within their jurisdiction do not cause unnecessary damage to mangrove ecosystems within or beyond their jurisdiction.
iv) implement national and international legal provisions for the protection and conservation of the mangrove ecosystems.

11.4 Regulation, management policies and law enforcement

Except for the Forest Ordinance of 1916 and other related ordinances or legislative acts constituting some areas of the country (including the mangrove forests) into forest reserves (Adeyodu, 1975), no other ordinance of decree has been promulgated to protect the mangrove zone in Nigeria. Although there is an increasing awareness by both the government and foresters as well as other environmental scientists that the mangrove zone is a fragile ecosystem that needs protection and proper management, there is little or nothing done to this effect at present. So far, the reserved area of the mangrove zone is about 30,469 ha out of the total area of about 972,314 ha (3.14%). Therefore having established the National Mangrove Management Agency, a decree should be promulgated by the Federal Government that at least 25% of the mangrove forests should be reserved. This will serve as a starting point while this percentage will be increased gradually with time. The decree promulgated should be followed by law enforcement measures. The inhabitants displaced from their land should be resettled in other areas outside the mangrove zone and be adequately compensated.

11.5 Silvicultural practices

While the forested mangrove areas will be kept protected, more emphasis will be laid on forest regeneration in the degraded areas where the inhabitants have been evacuated. To achieve this, both natural and artificial regeneration measures would be tried. Due to the ability of the mangrove species, particularly the *Rhizophora* sp. to regenerate themselves through their propagules, natural regeration method should be given a trial. The seeds and seedlings of the *Rhizophora* species could be broadcasted on the seawater along the already degraded coastline areas where land had been taken over from the inhabitants. Dispersal of the seeds/seedlings can be achieved using the tidal movements. When the seedlings have settled down and got established, thinning can be carried out from time to time to achieve the appropriate stand density.

Artificial regeneration involves employing silvicultural techniques for raising the seedlings (in nurseries), planting them out in plantations and then applying the necessary silvicultural treatments as appropriate at different stages. This approach has already been used for the establishment of *Rhizophora* plantations at Abel-Kiri in Rivers State of Nigeria (FRIN, 1989). Although this system is more expensive, it is more effective.

11.6 National mangrove management plan and other plans for the coastal areas

The areas to be planted up year by year should be mapped out and if necessary that tree felling shall be done without adverse environmental consequences, where such felling would take place should be marked out year by year.

All the other agencies under the National Coastal Management Authority (NCMA) should have management plans compatible with the National Mangrove Management Agency (NMMA). Each of the other agencies shall write up its development plan for the coastline of the country bearing in mind that the major objective is to minimise environmental disasters within the coastal areas while at the same time improving the standard of living of the coastal communities.

As the proposals of the various agencies are likely to cut across each other, these should be presented and defended during the annual planning meeting of the National Coastal Management Authority at the beginning of every year. Areas of conflicts should be properly ironed out before the various plans approved for the year. Execution of approved plans should be reviewed quarterly or half-yearly and necessary adjustments should be made at each stage. Approved but unexecuted plans should be carried over to the following year. The NCMA should be well-financed and the financial commitments should be met by the Federal Government, the oil companies and all the State Governments occupying the coastline zone.

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Mangrove Ecosystems in Nigeria

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1. Historical Background

The mangrove ecosystems in Nigeria are found mainly in the Niger. In this location (Fig. 1) a network of river creeks, estuaries and swamps resulting from the delta bifurcations of the River Niger and barrier Islands created by coastal dynamic forces have formed a complex and unique ecological zone. This remote and inhospitable terrain was little thought of except for fish and the fisheries resources on which the few coastal inhabitants depended and traded in exchange for essential goods with the outside world. The mangrove resources have remained underutilized and the forests in particular suffer from neglect in terms of management. Fortunately, the discovery of oil beneath the mangrove swamps in the early 1960's, has focused attention on this unique environment and has created awareness on the potentials, of this national resource which is in need of special treatment.

2. Mangrove Ecosystems

The area of saline mangrove swamps stretches through the entire coastal states in Nigeria (Fig. 1). The exact area is yet to be determined. Whereas the Food and Agriculture Organization (FAO, 1981) came up with an estimate of 970,000 ha, Okigbo (1984) came with an estimate of 1 million ha which is only about 1% of the country's area. Moses (1985) estimated the area to be 709,800 ha shared between 504,800 ha for the Niger delta (Scott, 1966) and 95,000 ha for the Cross River State (Enplan, 1974) and his own personal computation of the residual areas. Actual unclassified wetlands in the mangrove swamp cover over 750,000 ha. Adegbehin and Nwaigbo (1990) observed that even with the minimum estimated area of 709,800 ha, the country still has the largest area of mangrove forests in Africa. It ranks third in the world after India (1,420,000 ha) and Indonesia (4 - 6,000,000 ha) in total mangrove formation.

The mangrove ecosystem is essentially a vegetated tidal flat lying between mean low and high tides and thus is regularly inundated. The largest expanse is found in the Niger delta where the swamps extend over an area of 900,000 ha between the region of the Benin River in the West and the Calabar. Rio del Rey estuary in the East. Maximum width of 30 to 40 km is attained on the flanks of the delta where the mangroves occupy the angle between the boundary of the river flood plain (in the North) and the terrace of late Tertiary sediments (Ibe, 1988). The high dynamism of the system seaward sometimes results in increment of the coastal land area and contributes to the uncertainty in determining the exact areas of mangroves in many parts of the world.

3. Physical Environment

3.1 Climate

3.2 Soils

The Nigerian mangrove swamps consist of saline soils, of generally low pH of 4 - 7, varying from recently deposited soft mud (up to about 50% inorganic matter) at low tide to transitional swamps at high tides (Adegbehin and Nwaigbo, 1990). The soft mud that bear the tall mangroves (*Rhizophora sp.*) consists of mainly silt and clay which could be over 1m deep. However, peaty clays (Chikoko) occupy over 90% of the mangrove swamps in the Niger Delta. Anderson (1967) observed that these consist mostly of plant remains (vascular fibres and tree bark) of *Rhizophora*. These soils are generally poor, supporting stunted *Rhizophora racemosa, R. mangle* and *R. harrisonii* mainly.

The Nigerian coast is known to have prograded in several places by the addition of narrow sand ridges without spit progradation (Allen, 1965). These saline sands also accumulate peaty materials which support the growth of *Rhizophora* sp. The coastal and transitional swamps are low-laying and flooded regularly at high tide even in the short dry season. Detailed descriptions of the soil types have been

Editor's Note- For details on climate, please refer to previous paper by J. O. Adegbehin in this Report.

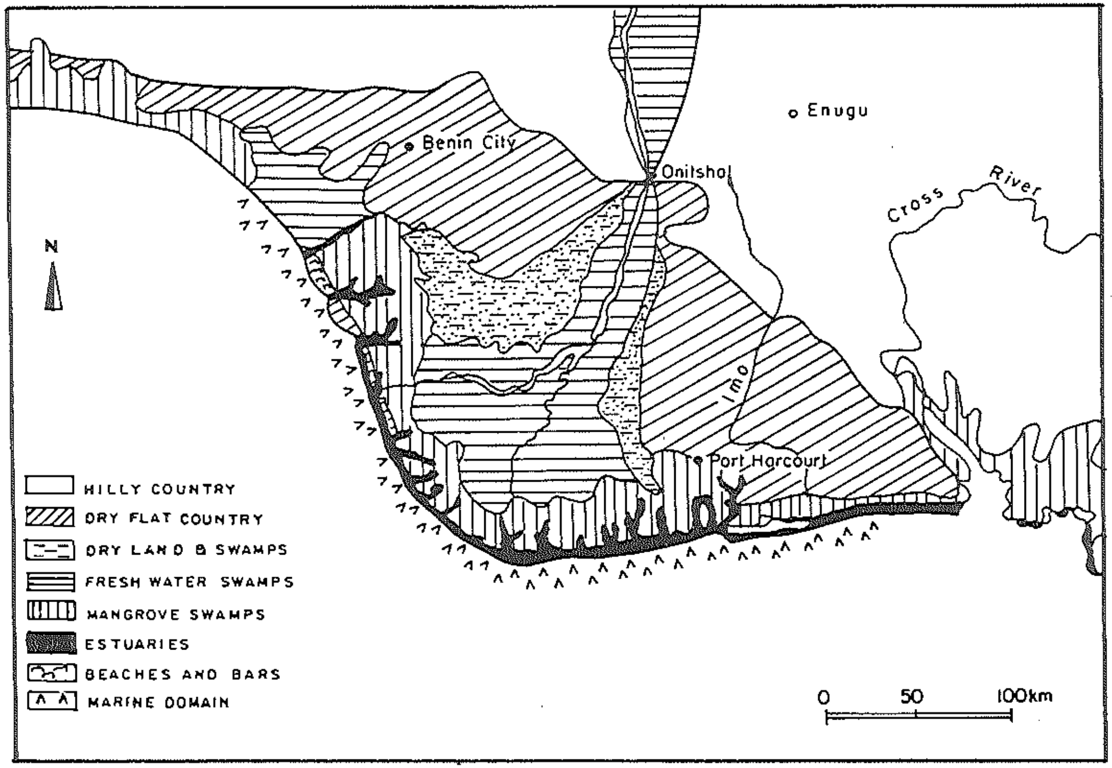

FIG. 1 - SKETCH MAP SHOWING THE MAIN PHYSIOGRAPHIC FEATURES OF THE COASTAL AND ADJACENT LAND AREAS - NIGER DELTA
(AFTER SHORT AND STAUBLE 1967)

recorded by Scott (1966), Hartoungh (1966), Anderson (1967) and Ibe (1988).

3.3 Waters

The Western Nigerian lagoon complex, which terminates at the West flank of the Niger delta, has a single opening at Lagos through the Lagos harbour. A sandy barrier known as Kuramo Island separates the lagoons from the sea. On its fringes are mangroves and swamp plants inundated by saline water passing through creeks only during the high tides. The lagoons are shallow with depths of only 1,5 - 3m. The tidal range at Lagos is only about 0.3 - 1.3m. The interconnecting creeks are also very shallow and are sites of active silting and deposition of mud. The barrier lagoon complex grades eastward into a mud beach which is backed by freshwater swamps that are criss crossed by meandering creeks.

The Niger delta special area extends from the mouth of Benin river for about 500 km to the mouth of Imo River in the East (Fig. 2). The entire coast is endowed with numerous natural inlets that occur at the entrances to estuaries or lagoons. Allen (1965) recognised 20 barrier islands between Benin and Opobo rivers. The islands are truncated by tidal channels through which oceanic waters gain access to the mangrove swamps. At the eastern extremity is a zone of persistent mixing of fresh water from the Cross, Calabar, and Kwa Iboe and other coastal rivers, and salt water from the Gulf of Guinea. The mangrove swamp behind the coast at this end is of a wide extent because of the relatively higher tidal range (Ibe, 1988).

4. Biological and Ecological Characteristics

Coastal vegetation along the barrier-lagoon coast (Fig. 1) is dominated by coconut trees and other palms. The lagoon complex grades eastwards into a transgressive mud beach which extends for 75 km before terminating at the mouth of Benin River. Vegetation along the mud beach is dominated by the halophytic red mangrove, *Rhizophora racemosa* and the white mangrove, *Avicennia* sp. Much of the vegetation has been denuded due to erosion and replaced by the hardy grass, *Paspalum vaginatum* which is often interspersed with strands of stunted red mangrove and dumps of the fern *Acrostichum aureum* (Ibe, 1988). Further inland is a belt of vegetation including the tree, *Laguncularia*, the shrub, *Conocarpus*, the fern, *Acrostichum*, and the palm, *Phoenix reclinata*.

On the North-West fringe of the mud beach vegetation recorded include the climber, *Ipomoea aquatica* and *Vigna marina*. The grasses *Andropogon* sp. and *Panicum* sp., the sedges, *Kyllinga peruviana* and *Fuirena ciliaris*, the herb *Stylosanthes erecta*, the shrub, *Dalbergia ecastaphyllum* and the tree *Cocos nucifera*.

The Niger delta has provided the best conditions for the thriving of vegetation on the Nigerian coast (Ibe, 1985). It harbours a wide variety of trees and plants; it has been ascribed to the depositional nature of the shoreline.

Although there is a variation in the distribution of vegetation, recent study by RPI (1986) recorded a species composition (Table 1) which is similar to that obtained further eastwards in the Calabar and Cross River estuaries. Three species of *Rhizophora* (*R. racemosa; R. harrisonii* and *R. mangle*) are found. Their zonation and distribution with associated species (Fig. 3) have been described (Enyenihi *et al.*, 1986). The white mangrove, *Avicennia* is often mixed with *Rhizophora* or *Laguncularia racemosa*. Some parts of the estuaries are exclusively covered by the stemless palm, *Nypa fruticans*. *Phoenix reclinata* and *Raphia palma-pinus* are often associated with the mangroves.

Table 1: Species compositon of vegetation in the Mangrove forest of the Niger delta in Nigeria (Ibe, 1988)

Climbers	-	*Ipomoea aquatica, Vigna marina, Diodia serrulata, Ccassytha filiformis, Ipomoea pes-caprae*
Grasses	-	*Vossia cuspidata, Pennisetum purpureum, Andropogon sp., Paspalum sp.*
Sedges	-	*Killinga peruviana, Fuirena ciliaris, Cyperus sp., Mariscus ligularis, Eleocharis sp.,*
Herbs	-	*Euphorbia hypossopizolia, Stylosanthes erecta, Alternanthera maritima, Lindernia crustacea Dissotis rotundifolia, Solanum nigrum Acrostichum aureum, Sesuvium portulacastrum, Murdannia simplex.*
Shrubs	-	*Dalbergia ecastaphyllum, Tetracera podotricha, Drepanocarpus lunatus*
Trees	-	*Terminalia cattappa*, remains *Rhizophora racemosa*, remamins *R.harrisonii, Syzygium sp., Carthormium altissimum, Ficus vogeliana, Avicennia africana*, remains *Nypa fruticans*, remains *Phoenix reclinata*

\+ dominant in the Kwa Iboe river area.
++ dominant in the Cross River estuary.

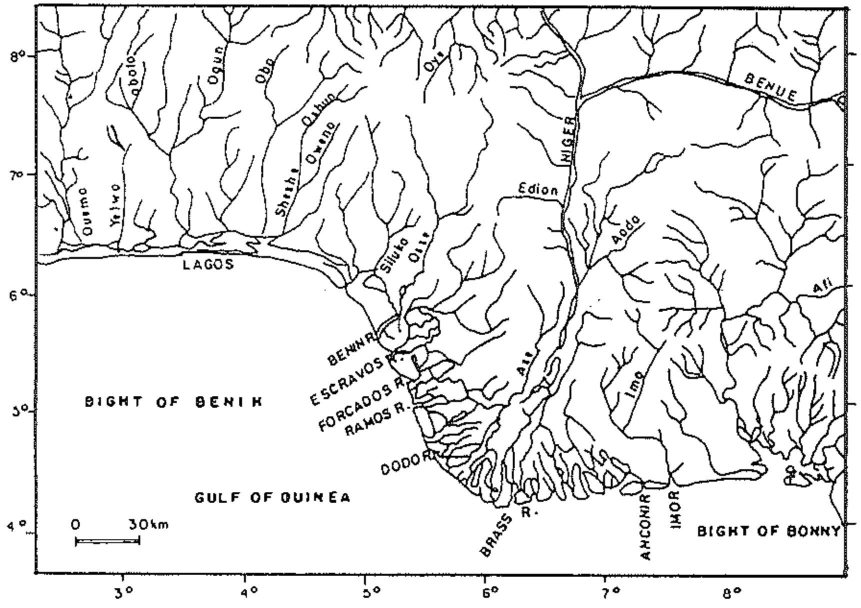

FIG. 2 - MAP SHOWING THE COASTAL REGION OF NIGERIA

Most of the climbers, sedges and grasses found in the delta area may also be found along the estuaries.

Amphibious life on the supratidal zone are typified by the sand crab, *Ocypoda africana* and the ghost crab, *Ocypoda cursor*. Intertidal fauna on the *Rhizophora* roots include barnacles, *Balanus pallidus* and *Chthamalus;* the oyster, *Crassostrea gasar*, the periwinkle, *Littorina sp.* and the polychaete, *Mercierella enigmatica*. Among crustaceans associated with mangroves are the crabs *Callinectes latimanus, Cardiosoma armatum* and the hermit crab, *Clibinarius africanus*. Dominant molluscs include the gastropods *Pachymelania* and *Tympanotonus sp.* A commonly collected and cultivable mollusc species, *Achatina* is also found in the mangrove forests. The forests are very rich in mammals (hippopotami, manatees, monkeys), reptiles (crocodiles, monitor lizards, turtles, snakes) and birds (Olaniyan, 1968, Adegbehin and Nwaigbo, 1990).

5. Mangrove Related Ecosystems

5.1 Marine benthic community, brackish and marine

A detailed account of the brackish community in Lagos lagoon (Ajao, 1990) noted the low species diversity and dominance by molluscs in the *Pachymelania* community. A prominent member of the estuarine-*Amphiophis* community is the lancelet, *Branchiostoma nigeriense*. The fauna assemblages included crustaceans and polychaetes whose distribution were governed by the type of substratum, fluctuations in the salinity regime, water movements, and other factors.

5.2 Corals reefs

Allen and Wells (1962) first reported the occurrence of dead Holocene coral banks along the Nigerian Continental shelf (32°5' E long. - 8°30'E long.). The corals found in the Nigerian shelf are dead and non-reef forming. They consist mainly of *Modracis, Denrophyllia, Cladocera, Cyathoceras, Paracythus* and *Desmophyllum* species. Echograms from several cruises undertaken at the Nigerian Institute for Oceanography and Marine Research, Lagos, from 1984 to 1989 revealed the presence of some isolated and in some cases continuous bands of dead holocene coral banks within the middle to outer continental shelf between 40 and 120m depth (Awosika, 1990). However, samples of living corals have been obtained from trawlings off Lagos waters (Ajayi, personal communication).

5.3 Pelagic community:

The species composition, distribution and resource potential of fishes recorded in bottom trawling between 50 to 200m depth off the Nigerian coast have been documented (Amady, 1982). 15 trawl hauls in the 50 - 200 m depth zone yielded 8092 fishes from 38 families comprising 48 species. *Dentex angolensis, congoensis, Priacanthus arenatus* and *Ariomma bondi* were identified as dominant (Table 2). The concentration of fish was higher at shallower depths with a marked decline from 80-100m but a slightly heavier concentration from 100-130m. Fewer species were caught in the deeper waters. The fish fauna in the survey area had a high diversity index with relatively few individuals representing each particular species. The community structure of West African fishes is controlled principally by temperature and bottom deposits (Longhurst, 1965).

6. Human Habitation and Traditional Mangrove Usage

The coastal and historical settlements in the Niger delta include Aiyetoro, Awoye, Molume, Ogborodo, Ogulaha, Twon Brass Bonny, Ibeno Eket and Calabar among several others. The inhabitants utilised mangrove wood as a multi-purpose resource for building timber, fish stakes, fish traps, boat building, boat paddles, yam stakes, fences, carvings, fuelwood. For several of the scattered villages within the mangrove forests, fish and mangrove sustained life.

7. Commercial Exploitation and Marketing

Mangrove wood has been widely used for pitprops in coal mines and railway sleepers on account of its strength. Before the 1960's, the Nigerian Coal corporation at Enugu used about 20,000m^3 of mangrove wood pit-props annually (Adegbehin and Nwaigbo, 1990). The demand has fallen due to the low rate of expansion of the railway system and the diminishing importance of coal as a primary export commodity when compared with crude oil in an oil-exporting nation. Mangrove is still felled for transmission poles and timber but the wood has declined into the category of less used wood species. Locally, it is still marketed as fuelwood for domestic usage.

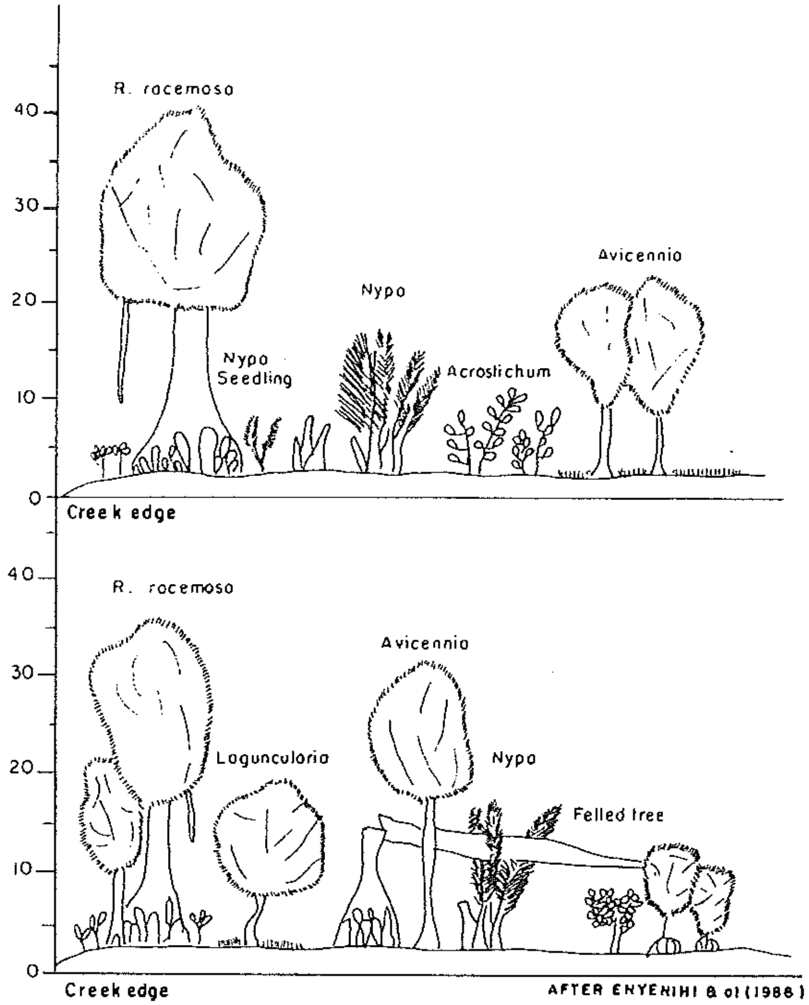

FIG.3- DIAGRAMATIC PROFILE OF MANGROVE SWAMP FOREST SHOWING ZONATION AND SPACIES DISTRIBUTION ALONG TRANSECT LINES AWAY FROM CREEK

(A): Cross river estuary
(B): Kwo Iboe river estuary

Table 2. Bathymetric distribution of fishes depth in metres (Amadi, 1982)

SPECIES	50	60	70	80	90	100	110	120	130	140	150	160	170	180	200
Carcharinus brachyurus								+	+						
Sphyrna zygaena		+	+												
Squatina oculata			+	+	+		+	+	+		+	+	+	+	+
Raja miraletus	+	+													
Dasyatis margarita	+	+													
Torpedo torpedo	+									+	+	+	+	+	+
Pterothrissus belloci										+	+	+	+	+	+
Conger conger	+														
Ilisha africana	+							+	+						
Sardinella aurita		+	+												
Saurida brasiliensis	+	+	+	+		+	+	+							
Myctophidae											+	+	+	+	+
Fistularia petimba			+	+											
Zenopsis conchifer	+	+				+	+	+							
Antigoria capros											+	+	+	+	+
Sphyraena piscatorium	+	+	+					+	+						
Galeoides decadactylus	+														
Epinephelus aeneus	+	+	+	+											
Pricanthus arenatus		+	+			+	+	+	+	+	+	+			
Descpaterus punctatus		+	+	+	+										
Decapterus ronchus		+	+			+	+								
Selene dorsalis			+	+	+			+	+						
Alectis alexandrinus								+	+						
Lutjanus agennes	+														
Spicara alta	+	+	+				+			+	+	+			
Brachydeuterus auritus	+	+	+					+	+						
Pomadasys peroteti	+	+	+												
Dentex angolensis	+	+	+				+	+	+		+	+	+	+	+
Dentex congoensis	+	+	+	+			+	+	+		+	+	+	+	+
Dentex canariensis	+														
Sparus caeruleostrictus	+	+													
Pteroscion peli	+														
Pseudupeneus prayensis	+	+	+												
Chromis cadenati	+														
Uranoscopus cadenati			+	+		+	+	+							
Brotula barbata	+	+	+												
Ariomma bondi	+	+	+	+		+	+	+	+	+	+	+			
Trichiurus lepturus	+	+	+			+	+	+	+						
Scomberomorus tritor								+	+						
Balistes capriscus						+	+	+							
Lagocephalus laevigatus								+	+						
Chilomycterus spinosus	+														
Syacium micrurum	+	+	+	+		+	+	+							
Trigla Lyra	+	+													
Lepidotrigla carolae	+	+				+	+	+		+	+	+	+	+	+
Peristedion cataphractum						+	+	+	+						
Platycephalus gruveli	+														

8. Conversion to Other Uses

8.1 Agriculture

The mangrove areas are not favoured for agricultural practices because of the quality of the soils. However, mangrove soils particularly within the *Rhizophora* zone have been described as an excellent area for rice cultivation. Such areas would have to be reclaimed and dressed with fertilizers for paddy rice cultivation (Hartoungh, 1966). Other crops presently harvested within the swamps include sugarcane, cocoyams, banana and plantains. Small-scale silvo-fishery and agro-silvo-fishery within the mangrove zone is also practiced. Apiculture is another feasible and could be developed to promote a multiple land-use of the mangroves (Adegbehin and Nwaigbo, 1990).

8.2 Aquaculture

The potential of the vast wetlands of the mangrove ecosystem of Nigeria lies in aquaculture. The total aquaculture production has been estimated at only 7,500 tons annually (Afinowi, 1985). With increasing awareness, this figure is expected to rise within a few years especially to bridge the gap between fish supply and current demand. However, the conversion of mangroves to fish ponds has been associated with the development of acid-sulfate soils. This pose a range of problems for brackish water fish farming (Dublin-Green and Ojanuga, 1988). Such problems result in slow fish growth, low fish yields and mass fish mortality. But despite the high acidity and associated effects, acid-sulfate soils are known to possess characteristics which are conditioned by topographic and hydrologic parameters that are favourable for establishing fish cultivation. Potential acid-sulfate soils can be identified by the mangrove vegetation (Marius, 1981). Wherever mangroves have been cleared for aquaculture ponds, their "buffer" function is lost. This is suggestive of a need to locate ponds further inland from mangrove forests where pond yields are often greater than in converted mangrove forest areas have been recorded (Baker and Kaeoniam, 1986).

8.3 Urbanization and industrialization

A high level of urbanization and industrialization of the few cities (e.g. Benin, Ports Harcourt, Warri and Calabar) within the delta area have resulted in human pressure on the mangrove forests. In coastal cities, civil engineering works have involved dredging and sand pumping to reclaim favoured tidal flats for various purposed e.g. residential/public buildings, roads, bridges, oil terminals, wharves. Rapid urbanization and industrialization of coastal communities have frequently resulted in degradation of the coastal amenities and disturbance of coastal ecosystems (Ajao, 1991). The degree of disturbance is heightened by increased capital-intensive coastal development, the closer the proximity of the community to the water, extension or alteration in the propagation of the tidal waves, water circulation and freshwater inflow in areas critical to fishing resources, and changes in ambient water salinities and temperatures from those optimal for marine organisms.

9. Impacts on the Mangrove Environment

9.1 Human induced stresses:

A proper assessment of environmental impacts of urbanization in the Niger delta must take into account the impact of all ancillary developments such as roads, bridges, drainage systems, oil pipelines, sewerage. Human interference with mangrove vegetation such as tree felling and clearing abound at all construction sites within the swamps. The exploration and exploitation of oil encouraged rapid industrialization (Steel plant, Petrochemical plant, Fertilizer complex, Refineries) and brought about reduction in several places of the fragile mangrove ecosystem.

Apart from the natural subsidence of the coastal geosyncline in the Niger delta which results from the compaction of its sediments with their high water content, there is a possibility that the extraction of oil and gas from porous reservoirs in sub-surface Niger delta may accelerate the rate of subsidence. The only reliable figures available reveal a subsidence rate of more than 2.5cm/yr at the site of a tank farm along the coast (Ibe, 1988). Subsidence of the coastal geosyncline would tend to enhance the impact of local sea level rise in this low-lying coastal area.

9.2 Pollution

The damaging effects of oil pollution on the mangrove environment has been documented in Nigeria and elsewhere (Ekekwe, 1981; Baker 1981). Oil pollution arises from the expanding on-shore and off-shore oil activities. Analysis of oil spill incidents (Table 3) have identified causative factors (Ifeadi and Nwankwo, 1987). The quantities spilled at off-shore location were higher than those spilled at swamps while quantities spilled on swamp locations were higher than those spilled on land for the period 1976-86 (Table 4). The responses of oiled mangrove communities at various sites have been similar and

Table 3. Causes of spill with respect to operational locations (facilities)

Operations / Spill Causes	Pipelines	Platform Flowstation Tank Farm	Well Head	Drilling Site	SMB, Bop Terminal	Depots	Refinery	Unknown (Mystery Spill)
Blow out								
No. of Spills	0	0	0	1	0	0	0	0
Volume Spilled (bbls)	0	0	0	400,000	0	0	0	0
Sabotage								
No. of Spills	221	69	109	0	0	1	0	0
Volume Spilled (bbls)	47,546	13,402	3,240	0	37	0	0	0
Corrosion								
No. of Spills	202	71	62	0	32	2	0	0
Volume Spilled (bbls)	608,392	3,296	936	0	57,148	115	0	0
Equipment Failure								
No of Spills	90	365	112	0	178	10	1	2
Volume Spilled (bbls)	45,285	45,486	1,857	0	664,941	1,506	5	12
Operator/Maintenance Error								
No. of Spills	29	106	19	0	29	22	6	0
Volume Spilled (bbls)	11,802	7,091	252	0	26,342	633	807	0
Natural Causes								
No. of Spills	25	62	39	0	14	0	0	0
Volume Spilled (bbls)	2,368	1,223	302	0	935	0	0	0
Accident from 3rd Party								
No. of Spills	23	14	8	0	5	5	1	0
Volume Spilled (bbls)	20,000	257	69	0	74	573	0	0
Unknown (mystery Spills)								
No. of Spills	9	29	3	0	8	0	2	2
Volume Spilled (bbls)	5,360	1,065	67	0	66,807	0	0	392

included defoliation and mortality of trees, mortality of seedlings, leaf deformation, large mortalities of invertebrates (barnacles, oysters, crabs etc.) and fishes. The mangrove ecosystem in several places has recovered after a short or long period of time depending on the severity of the oil contamination.

Apart from oil pollution, mangrove swamps in the delta have been affected by a number of activities such as seismic surveys using explosive charges, the cutting of pipeline routes, and gas flaring. Gas flare is usually viewed as the effect of light intensity and temperature on the environment. Egbuna (1987) reported ecological deleterious effects of gas flaring in the Niger delta. These include:

1) heat radiation and thermal conduction into the environment;

2) production of toxic gases during combustion e.g. carbon dioxide, carbon monoxide, nitrogen oxides, water vapour, soot and carbon particles which readily form acids in the presence of rain water and air;
3) generation and dispersal of particulates and incombustible materials (e.g. soot) into the atmosphere;
4) high noise levels.

The author noted that as at the end of 1986, the gas flared during oil production in Nigeria spanned over 300 field locations in the South-Eastern axis of the delta zone, this yielded wasted heat and energy equivalent to about 60×10^9 kwh which was equal to the total electrical energy generated for the country in that year.

It is common knowledge that local farmers have complained about retardation of growth and productivity of farm crops around gas flares while depression in flowering and fruiting of some species have been observed (Oluwatimilehin, 1981). Microbial species in such locations were also affected in soils around gas flares.

9.3 Erosion

The very low topography of the Nigerian coastal plain makes it easily susceptible to forces of marine erosion (Ibe, 1988). Vegetation plays a very important role in the protection of coastal soils. The prop-rooted stems; pheumatophores and aerial roots of mangroves form a stabilising raft effective in trapping unconsolidated sediment and damping the energy of tidal currents. Wherever the mangrove has been cleared, erosion results in the delta (Fig. 4). In such areas, a hardy salt tolerating grass, *Paspalum vaginatum* has flourished (Fig. 5) but this lacks the stabilising effect afforded by the mangroves.

9.4 Impact of natural stresses

Mangrove regeneration in the area of the great Kwa Iboe River (near Calabar) is hampered by the extensive fibrous root system of the *Raphia* palms which chokes out the mangrove seedlings. The palms occur in association with *Rhizophora* especially in the freshwater swamps. The dense *Raphia* canopy cuts off light penetration which is essential for the establishment of seedlings and their growth. A gradual transition to rain forest vegetation is apparent where this occurs. With time, mangroves would be completely displaced in this Eastern most sector of the Niger delta.

10. Socio-Economic Implications

Opportunities abound for the establishment of small-scale forest-based industries in rural areas yet sufficient incentives do not exist (Igugu, 1986). Optimum benefits can be derived from the mangrove forests when mangrove wood is used either for pulp and paper, chip-boards, construction timber, furniture, wooden items (e.g. toys, souvenirs), toothpick, transmission poles. The non-wooden parts (bark, leaves) can be utilized for the production of wood extractives such as cutch (crude tannin), adhesives, preservatives, dyes. Presently, textiles and wood factories in Nigeria import wood extractives which could be produced locally.

The production of these items will provide rural employment and limit rural-urban drift. It will stabilise rural population and increase the standard of living of rural villagers in the mangrove forests. A multiplier effect of greater economic potential and activities is Government attention for the provision of basic social infrastructure and amenities.

11. Research and Training Programmes

The mangrove Forest Research station set up by the Forestry Research Institute of Nigeria (FRIN) at Onne, Port-Harcourt, since 1980 has yet to make any significant impact on the development of the mangrove (Adegbhin and Nwaigbo, 1990). The uniqueness of mangrove vegetation make them attractive subject for research and the promotion of national awareness of the value of the mangrove resource. However, the effectiveness of such research is largely determined by the attitudes of Government.

12. National Mangrove Committees - National Policiers for Mangrove Management

The principal management goals of the nation's mangrove ecosystems should be the maintenance of processes which allow for their maximum productivity and ensure their capacity to provide food and critical habitat for economically and culturally important marine and brackish species. Although very little attention was paid to the management of the mangrove forests in the past, some state Governments (e.g. Bendel, Rivers and Lagos) have shown interest in the development of the mangrove. The Bendel State government has established a mangrove

Table 4: Size of Spill with respect to ecological zones

	LAND	SWAMP	OFF SHORE	TOTAL
Minor oil Spills (0 - 249 blls)				
Number of Spills	457	446	130	1,033
Quantity Spilled (bbls)	7,565	14,317	21,297	43,179
Medium oil Spills (250 - 2,499 bbls)				
Number of Spills	596	91	31	712
Quantity Spilled (bbls)	17,203	33,139	49,359	99,701
Major oil Spills (Over 2,500 bbls)				
Number of Spills	206	32	16	254
Quantity Spilled (bbls)	76,996	464,775	1,379,242	1,921,013
TOTAL				
Number of Spills	1,259	569	164	
Quantity Spilled (bbls)	101,764	512,231	1,449,898	

forest reserve with its headquarters at Warri (Delta State) while the Rivers State government is making efforts to increase its existing area of forest reserve and at the same time setting up plantation trials of the species (Adegbehin and Nwaigbo, 1990).

The major problems being experienced within the mangrove ecosystems are those resulting from oil pollution and uncontrolled wood exploitation. A suggested effective enforcement measure is the establishment of forest reserves within designated areas for easy control and conservation. The total area reserved up to 1983 has been estimated as 23,800 hectares (Okigbo, 1984).

Two types of silvicultural systems may form the basis for the management of the Nigerian mangrove forests, though various modifications of these could also be applied (Adegbehin and Nwaigbo, 1990). The systems involve natural and artificial methods of inducing regeneration. The former is the Tropical shelter wood system (TSS) adopted in the rain forests of Nigeria in the 1940s. The latter is at present being used to establish some trial plantations of *R. racemosa* at Abonema (Rivers State, Nigeria). One of the recommendations under this system is that there should be some provision for natural regeneration whereby the mother trees could provide seedlings to fill up the blanks in the planted areas. In cutting subsequent regeneration of the forests either with the artificial or natural regeneration method, it is suggested that the principle of sustained yield should be applied to prevent over-cutting. Growth studies in the Nigerian mangrove forests around the Niger delta have forecast a rotation period of 30 - 40 years (Adegbehin and Nwaigbo, 1990).

Conclusion

It is hoped that in the near future, a National Mangrove Committee will make appropriate recommendations to the Federal Government, through the Federal Forestry department, for the sustainable use and management of Nigeria's vast mangrove ecosystems both for its effective utilization and for its preservation as a natural heritage.

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Nigerian Mangrove Resources: Status and Management

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Introduction

Nigeria has a coastline of about 850 Km, which could be divided into four geomorphic zones. The four distinct divisions from West to East are; (a) barrier-lagoon, (b) transgressive Mahin mud coast, (c) arcuate delta and (d) strand coast (Fig. 1).

Earlier authors reported that most parts of Southern coastal areas of Nigeria were covered by mangrove forest, Richards (1939), Savory (1953) and Jackson (1964). The density of mangroves varies from West to the East depending on the soil type. Other authors include the works of Keay (1959), Chapter (1965) and Orebamjo and Njoku (1971), on the mangrove vegetation of Nigeria. The red mangrove *Rhizophora* constitutes about 90% of the vegetation in the mangrove swamp. The species are *R. racemosa*, *R. harrisonii*, *R. mangle* and the white mangrove *Avicennia africana*, *Laguncularia racemosa* and *Drepanocarpus lunatus*, the delta area is poor in mangrove species compared to mangroves of the Indian Ocean and the West Pacific, (Chapman, 1970). High mangrove vegetation is found along the creeks but less in the back swamps because of the interference of Nypa Palm - *Nypa fruticans* which is a quicker coloniser than the red mangrove because of its shallow root systems which also has a destabilising effect on the river banks (SECA, 1987).

The flora and fauna of mangrove resources have provided a very substantial source of livelihood for the coastal dwellers. The harvesting of fish, bivalves, gastropods, living both on the mangrove plants or in the mud flats have been the main source of protein for the coastal settlers. Fish smoked with wood of *Rhizophora sp.* has a special flavour preferred by the consumers and the products are said to be well cured. The drought in the Northern part of the country has made fishery products well sought after thereby making the fishermen to intensify efforts. Mangrove resources such as oysters, snails, periwinkles, fish even juveniles of pelagic fishes have become target fishery and are caught indiscriminately without proper management strategies. Between 1978-82, the Government introduced the "National Accelerated Fish Production Programme", fishing inputs such as boats, nets, outboard engines were supplied to fishermen at subsidized rates and their area of operation was extended as well their output. The fishermen changed from subsistence fishing around the settlements to the estuary and beyond, intensifying fishing effort and increasing the catch from the artisanal sector to 515,249 metric tonnes in 1983 (Tobor, 1984) contributing about 97.36% from the small scale fishermen. Presently, the quantity of fish and shell fish caught has declined.

Exploitation of oil and gas, canalization, siting of some industries in the mangrove belt and urbanisation have recently led to the degradation of the mangrove ecosystem.

The intertidal mangrove swamp covers about 5,591 sq.km and 708 km of deltaic coastline, Allen (1965). Width of the mangrove forest is between 16 and 90 km (Fig. 2). The swamps are separated from the open sea by barrier beach islands often broken through by tidal channels. The Central area of the mangrove swamps are 8-16 km wide intermingled with lower flood plain alluvium. The delta flanks of the mangrove swamps occur within the Lagoon Complex and fringes sections of the coast extending into the delta proper, continue to Akwa Ibom (Strand Coast), Cross River, Calabar Area and Rio del Rey (Fig. 1). Nduaguba (1983) estimated the mangrove brackish water area extending from Benin river to Cross River to be 2,003.49 sq km. Table 1 shows the distribution of mangrove vegetation along the coast of Nigeria.

1. Physical Environment

1.1 Climate

The Southern part of Nigeria is characterized by hot, and humid climate of two major seasons - wet and dry. The mangrove swamp receives the heaviest amount of rainfall, averaging about 1,500 mm per annum which depends on the interaction of three major air masses. The warm dry tropical continental air mass from the North East, the warm wet tropical maritime air mass from the South West and the cool, dry upper air mass - the equatorial easterlies which

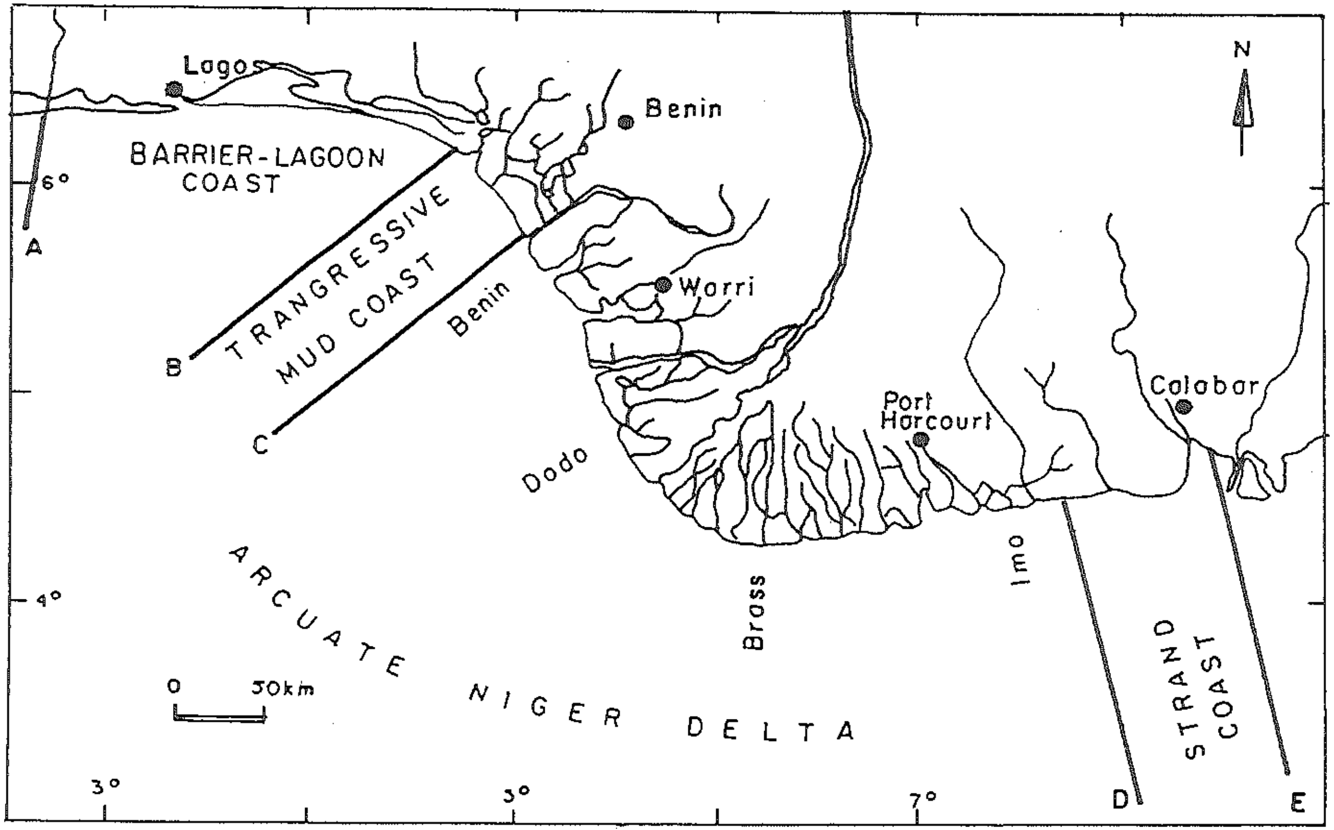

FIG.1- THE GEOMORPHOLOGICAL REGIONS OF THE NIGERIAN COAST

(from Ibe 1988)

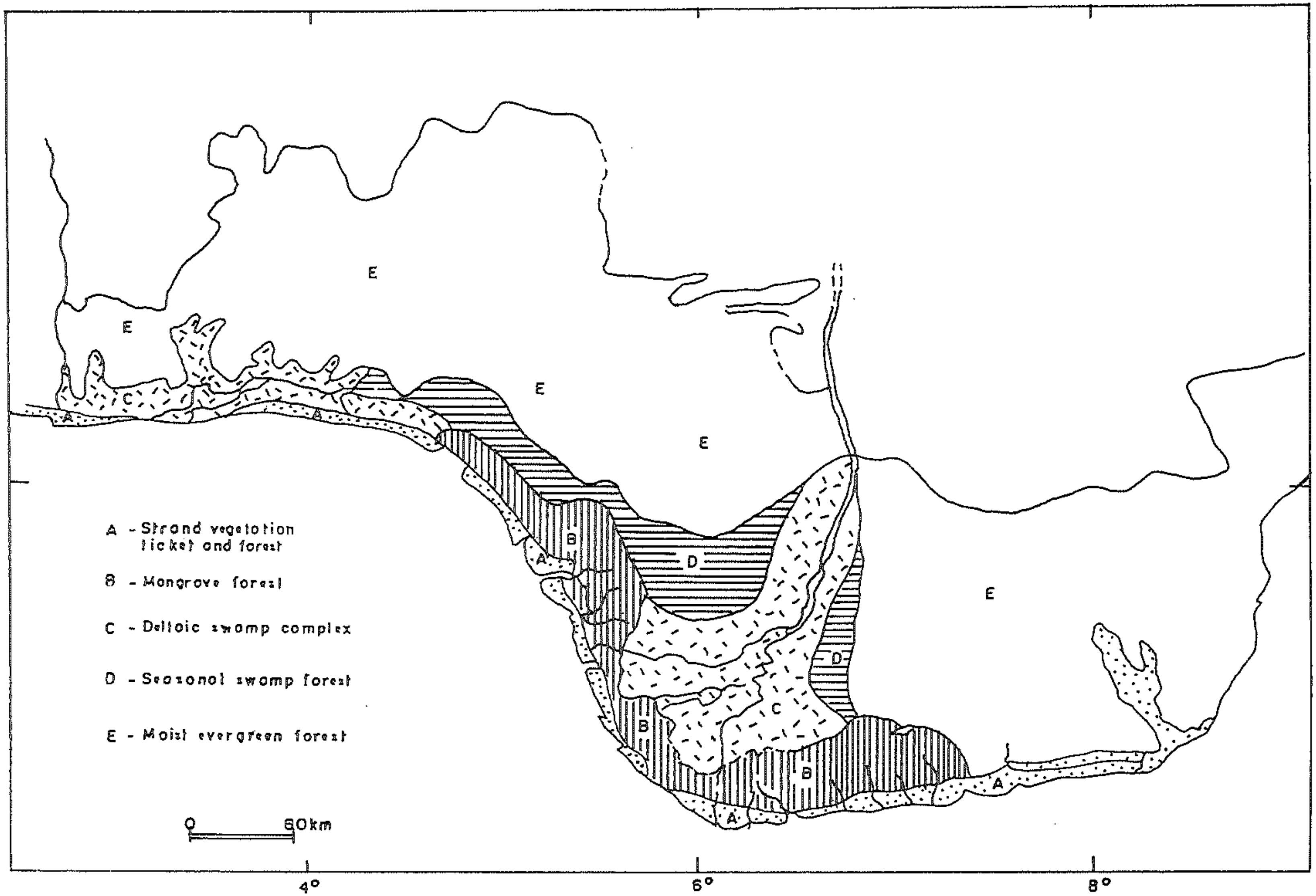

FIG. 2 - ECOLOGICAL ZONES

(Source: Atlas of Nigeria, 1978 (1st édition)

Table 1: Distribution of mangrove vegetation in Nigeria.

State	Area of Mangrove (Sq.km.)	Mangrove in forest Reserve (Sq. km.)
Lagos	42.20	3.43
Ogun	12.18	na
Ondo	40.62	na
Delta	3,470.96	143.75
Rivers	5,435.96	90.62
Akwa Ibom/Cross River	721.86	67.19
Total	9,723.14	304.69

Source: FAO, 1981, Land use Area Data for Nigeria.

blows from East to West but is occasionally deflected southwards. The arrangement of the tropical continental air mass and the tropical maritime air mass usually meet at the inner tropical convergence zone (ITCZ) while equatorial easterlies blow westwards giving rise to two types of rainfall - convectional, and frontal rainfall depending on their position relative to ITCZ. Monthly rainfall distribution shows a long wet season and along the coast, the constant convectional rains and winds from the sea ensure that there is no dry period in August but only a slight decrease in the heavy precipitation. The areas with the heaviest amount of rainfall along the coast also have the greatest number of rainy days with very short dry season. The average rainfall per annum increases from Lagos with 1,828.8 mm, Warri 2,768.6 mm, Port Harcourt 2,536.8 mm to 4,073.4 mm in Calabar.

The annual distribution of fresh waters into the delta is about $200x10^6$ cubic meters (NEDECO, 1959 and 1961). Peak water discharge is from September to October and from December to May the discharge becomes smaller (NEDECO, 1961). The lower Niger river divides into distributaries southward into the mangrove swamp. The amount of fresh water discharged varies from one distributary to another. Local rivers like Sombreiro, New Calabar and Forcados River are mainly fed by local rainfall. The clear black water has slightly acidic to neutral pH with low conductivity and high content of humic acids. The tidal fresh water area also has low conductivity and low pH.

1.2 Soils

The mangrove swamp area of the Nigerian coast is composed of silt, clay and sand of various textures with high organic content. The mangrove soil variety-Lithosoils and the hydromorphic soils are associated with alluvium. The seaward area of the mangrove swamp zone is made of Lithosoil, the composition being shallow, stony soil occurring on steep slopes where profile development is retarded by soil erosion. The hydromorphic soils which are mineral soil of the alluvium variety are found inland. Their morphology is influenced by seasonal water logging caused by underlying impervious shales, (Whiteman, 1982). The hydromorphic soils are pale coloured and mottled in the sub soil. The flanks of the delta are dominated by yellowish brown soils developed on loose coastal plain of the sandy sediment variety. About 80% of the mangrove soil is characterized by acid sulphate soils with a pH lower than four. These soils contain large quantities of iron sulphide which do not constitute a problem when submerged but become strongly acidic when oxidized by the release of aluminium and other chemicals or exposure to air.

1.3 Tidal influence

Tidal range increases from West to East. The mean tidal range at Lagos Lagoon is about one meter, at Forcados River about 2 meters and 2.8 meters on the Calabar River. Allen (1964) observed that the tidal capacity of the swamp is about 480×10^6 cubic meters and the discharge of saline water far exceeds that of fresh water during each tidal cycle. Tides approach the mangrove in the Niger delta from the South - Southwest direction through more than 28 river channels. Within the intertidal mangrove belts and the coastal waters, reversible remains tidal currents disperse sediments. During floods, sediment laden river waters are backed up by tidal currents and forced up-delta into the swamps. These currents are strongest over shallow mouth bars and also during ebb tides with velocities ranging from 60 to 280 cm/sec., (Allen, 1965). The tidal flat vary in flood frequency, sediment budget and soil type, causing the decrease in height of mangroves away from the creeks, although different salinity could have the same effect. In the Niger delta, mangroves lie between high and low tide with tidal range of 1 - 2 meters whose growth is caused by the lack of river borne clastic, to stabilize the flood plain due to diversion in the courses of the major drainage in the Tertiary (Allen, 1965b). The relationship between the swamp and the surrounding geomorphic units are erosive and replacive. In some estuaries the sandbars are very comprehensive depending on the direction of flow and the tidal volume.

1.4 Wafe and longshore current

Wind generated South-Southwesterly waves, force the shoreline along most part of Nigerian coastline, the wave generates longshore currents (Ibe, 1988); velocities of the longshore currents of the Nigerian coastline range from 0.15 to 1.5 m/s. In the Niger delta the Southwesterly waves force the nose of the delta resulting in a divergent, North-Northwest drift on the West of the delta while on the Eastern Niger delta the current direction is Eastward. Localized rip currents move seaward at the surface and bottom causing short transport of sediment seaward (Ibe, 1988). The Guinea current moves at a speed of 0.3 m/s in a West-East direction with some reversals. Fluvial discharge from the mangrove environment carries sediments into the sea, these reflect approaching waves and interrupt the longshore current. Fluvial discharge currents are strongest at the end of the rainy season when large volumes of water from land enter the sea through the numerous distributors of the main river.

1.5 Salinity of mangrove waters

The surface waters of the Gulf of Guinea are about 24°C with salinity lower than 35‰. The cold high salinity water from the Canary and the Benguela currents are separated by narrow bands of warm high salinity water. These two "fronts" migrate with the meteorological intertropical convergence hence, there is a variable seasonal surface hydrographic condition between the Southern and the Northern extremities of the Gulf of Guinea due to replacement. The surface salinity ranges from less than 18 - 28‰ from Lagos to Calabar estuary with low salinity from October to December and high salinity of 26 - 33‰ from March to June. In river channels, salinity may be as low as 0.5 - 4‰ during the wet season. Various river channels differ due to input of fresh water. The creeks are fed by local rivers or fresh water swamps while others are interconnected without fresh water supply. Their salinity changes according to mixing with fresh and brackish water hence mangrove swamps develop when the tide pushes salt water inland through the barrier beaches, creeks and estuaries giving rise to creeks and inter creek flats, which are the main morphological elements in the swamp.

The mangrove ecosystem surface water temperature varies with season, the main annual temperature values lie between 26°C and 28°C. High values are obtained around March from 28 to 30°C and the lowest in August, 23° to 24°C. The mean daily temperature is above 27°C throughout the year. Both the mean daily and mean annual maximum temperature increase from the coast towards the interior.

2. Biological and Ecological Characteristics

2.1 Flora and vegetation

The flora of the mangrove area, varies as a result of the soil composition which supports a dense mangrove forest with thick undergrowth, especially along the coast. The vegetation along the coast is controlled by lateral changes in sediment character and linearities in their deposition, which is found to be the result of the arrangements of sandy troughs and muddy hollows in the barrier islands (Pugh, 1953). The pioneering community on the sandy beaches consists dominantly of *Rhizophora racemosa* with *Avicennia africana* which also line the inner margins of the lagoon. On the seafront are *Paspalum vaginatum* and *Cocos nucifera*, inland *Avicennia africana* becomes more dominant and might exclude other species in the inner sand banks, with dense tangle of scrambling shrubs and small trees such as *Hibiscus tiliaceus, Chrysobalanus orbicularis, Thespesia populnea, Drepanocarpus lunatus* and *Dalbergia ecastaphyllum.* Herbaceous plants include *Cyperus articulatus* and *Paspalum vaginatum*. In the Western part of the country (Schnell, 1952) classification of a typical African mangrove zone are less distinct because of human interference. Pure stands of *Ornocarpum verrucosum* are found, sometimes with *R. racemosa* on the black mud areas of the Lagoon. The coastal vegetation on the muddy coast are mainly *R. racemosa* and *A. africana*. Due to erosion and tree felling, most of the vegetation has been replaced by the hardy grass *Paspalum vaginatum* mixed with some stunted stands of *R. racemosa* and *Acrostichum aureum*. Also on the mud beach are grasses such as *Andropogon sp.* and *Panicum sp.*, the shrubs *Dalbergia ecastaphyllum*, the herb *Stylosanthes erecta*, climbers, *Ipomoea aquatica* and *Vigna marina*, sedges *Fuirena sp.* and *Kyllinga sp.* and the palm tree *Cocos nucifera*.

In the Niger delta, recent study by RPI (1986) showed a general account of vegetation distribution as follows:

Climbers; *Ipomoea aquatica, Vigna marina, Diodia serrulata Cassythia fliformis, Ipomoea pes-caprae.*

Grasses; *Vossia cuspidata, Pennisetum purpureum Andropogon sp. and Paspalum p.*

Herbs; *Euphorbia hypossopifolia, Stylosanthes erecta, Alternathera maritima, Lindernia crustacea, Dissotis rotundifolia, Solanum nigrum Acrostichum aureum.*
The succulents
Herbs; *Sesuvium portulacastrum Murdannia simplex.*
Shrubs; *Dalbergia ecastaphyllum, Tetracera podotricha and Drepanocarpus lunatus.*
Trees; *Terminalia catappa, Rhizophora racemosa, Syzygium sp., Carthormium altissimum, Ficus vogeliana and Avicennia africana.*

On the strand coast (Fig. 1) which extends from Imo River to the Cross River estuary, a large part of the coast is backed by mangrove swamps. *Rhizophora racemosa* are dominant, attaining heights of 40m. Others like *R. harrisonii*, attain heights of about 7m and *R. mangle* reaching 5m in height, while the white mangrove *Avicennia africana* is found in some areas towards the sea, (Enyenihi, 1986) and are usually mixed with *Laguncularia racemosa* in muddy river mouths. The Imo river has been completely taken over by *Nypa fruticans*. Other vegetation includes *Phoenix reclinata* (Date palm) and *Acrostichum aureum* (large fern). On the Kwa Iboe river behind the usual stand of mangrove trees are *Raphia palmapinus* and *Pandanus candelabrum* with *Nypa sp.* Others are *Terminalia catappa, Drepanocarpus sp.*, sedges, climbers and grasses cover the open spaces.

In the delta area, primary productivity in form of phytoplankton is low in some places due to scarcity of phosphorus or abundant turbidity, but in the calm channels and creeks, there is abundant growth. Blue green algae abound such as *Catenella impudica. Bostrychia radicans, B. tenuis* forms a matting over pneumatophores of *Avicennia africana*, (Amadi, 1983). *Enteromorpha* occurs on the stilt roots of *R. racemosa.* Others are *Cladophora sp., Boodlea sp.* and *Chaetomorpha sp.*

2.2 Fauna

The fauna of the mangrove area is a typical estuarine community with species being typically salinity dependent. The seasonal fluctuation of salinity ranges between 0 - 0.5‰ in the rainy season and 30 - 35‰ in the dry season. The silty clay sediments enriched with abundant drifted plant debris, and root mottles forms a rich feeding and nursery ground for larvae, juveniles and adult vertebrate and invertebrae fauna.

During the wet season, the peak water discharge takes place from September to October, and the levee's are overtopped, diversion channels are occupied and crevasses develop. The salinity in the channels, gullies and creeks are lowered considerably, making the freshwater fish species to extend as far as the estuary mouths and beyond into the sea. Similarly marine fish species move into the estuaries and creeks during the dry season (November to March) with a peak in February and March. Species such as *Sardinella maderensis* move in shoals into the creeks and juveniles are found on mudflats during low tides. They are usually the first set of fish species to move back to sea at the slightest drop in salinity. Table 2 shows a list of vertebrate and invertebrate fauna encountered during an artisanal survey trip between 1984 - 1987 and 1992.

The organic rich silty clay, provides an excellent environment for the Penaeid shrimp *Penaeus notialis*, which spends the larval stages (moves in between August and September) buried in the mangrove swamp. Others are the gastropod- Potamididae; *Tympanotonus fuscatus* and *T. fuscatus* var. *radula* which feed on organic deposits. The oyster - *Crassostrea gasar* is microphagous, lives on the roots of the mangrove also with snails, barnacles, crabs and other invertebrate at (6-24‰ salinity and 25-30°C water temperature).

2.3 Wild life

There are more species of wildlife in the transitional zone between the coastal barrier and the river alluvium and the mangrove swamp e.g. the predatory African beauty snake *Psammophilis sibilans* of the mangrove. Birds usually seen on the mudflats are kingfishers, longtailed Comorant, green and white Heron, Little Bitten and Walker birds. It is also their breeding ground.

2.4 Community stability and ecological interactions

In some areas, the mangroves appear to be divided into zones in relation to depth of the water. *R. racemosa* dominates at water depth of between few centimeters to 1 meter, with long propagule it is a primary colonizer followed by *Avicennia africana* at high tidal mark on the flood plains (Jackson, 1964). *A. africana* appears to be a quicker colonizer than *Rhizophora sp.* (because it grows faster). In Araromi Ondo state *Avicennia sp.* is encouraged for felling and forms a type of subclimax if left to recover fully. Hopkins (1965) observed that most mangrove swamp communities are usually transitional, reflecting varying soil type. *R. mangle* and *R. harrisonii* are adapted to very low salinity, sandy soil and fast currents. When biotic factors such as felling are intense,

Table 2: Juvenile and adult fish species encountered at numerous estuaries and lagoons of the Nigerian mangrove ecosystem. January - December 1984-1987 and 1992.

Family	Species	Family	Species
Ariidae	*Arius heudoloti*	Megalopidae	*Tarpon atlanticus*
	A. gigas		
	A. latisculatus	Hepsetidae	*Hepsetus odoe*
Bagridae	*Chrysichthys nigrodigitatus*	Elopidae	*Elop lacerta*
	C. furcatus		
	C. aratus	Gerridae	*Eucinostomus melanopterus*
			Gerres nigri
Albulidae	*Albula vulpes*		
		Eleotridae	*Eleotris vittata*
Bothidae	*Citharichthys stampfili*		
		Belonnidae	*Ablennes hians*
Clupeidae	*Ethmalosa fimbriata*		
	Sardinella maderensis	Lutjanidae	*Lutjanus dentatus*
	Ilisha africana		*L. goreensis*
	Pellonula leonensis		L. agennes
Carangidae	*Caranx hippos*	Polynemidae	*Polydactylus quadrifilis*
	Selene dorsalis		*Galeoides decadactylus*
	Caranx senegallus		
	Chloroscombrus chrysurus	Pomadasyidae	*Pomadasys jubelini*
	Hemicaranx bicolor		*P. peroteti*
	Lichia amia		*P. rogerii*
	Trachinotus teraia		
	T. maxillosus	Sciaenidae	*Pseudololithus elongatus*
	T. goreensis		*P. brachynathus*
			P. typus
Serranidae	*Epinephelus aeneus*		
		Scombridae	*Scomberomorus tritor*
Characidae	*Citharinus latus*		
		Sphyraenidae	*Sphyraena afra*
Cichlidae	*Tilapia maraiae*		*S. guachancho*
	T. guineensis		
	Sarotherodon melanotheron	Tetraodontidae	*Lagocephalus laevigatus*
Cyprinodontidae	*Aplocheilchthys spilanuchen*	Trichiuridae	*Trichiurus lepturus*
Monodactylidae	*Psettias sebae*	Gobiidae	*Gobius sp*
			Gobioides sp
Mugilidae	*Liza falcipinnis*		
	L.grandisquamis	Periophthalmidae	*Periophthalmus koelreuteri*
	Mugil cephalus		
		Dasyatidae	*Dasyatis margarita*
Mockokidae	*Synodontis melanopterus*		

Table 3: Macrura crustaceans encountered in the creeks, estuaries and logoons of the Nigerian mangrove ecosystem. January - December 1984-1987 and 1992.

Crustaceans	
Family	**Species**
Palaemonidae	*Nematopalaemon hastatus*
	Macrobrachium vollenhovenii
	M. macrobrachion
Penaeidae	*Parapenaeopsis atlantica*
	Penaeus (Farfante penaeus) *notialis*

Table 4: Brachyura crustaceans caught on the mudflats, river channels and estuaries of the Nigerian mangrove ecosystem. January - December 1984-1987 and 1992.

Crabs	
Family	**Species**
Gecarcinidae	*Cardiosoma armatum*
Grapsidae	*Goniopsis pelii*
	Grapsus grapsus
	Sesarma angolense
Ocypodidae	*Ocypode africana*
	Ocypode cursor
	Uca tangeri
Portunidae	*Callinectes amnicola*
	C. marginatus
	C. pallidus
Xanthidae	*Panopeus africanus*

Table 5: Molluscs found on mangrove plant, mudflats and bottom of river channels of the Nigerian mangrove ecosystem. January - December 1984-1987 and 1992.

MOLLUSCS	
Bivalves	
Family	**Species**
Arcidae	*Senilia senilis*
Cardiidae	*Cardium sp*
Donacidae	*Donax rugosus*
	D. pulcherrimus
	Iphigenia delesserti
	Iphigenia sp.
	Galatea poradoxa
Mactridae	*Mactra glabrata*
	M. nitida
	Mactra sp
Ostreidae	*Crassostrea gasar*
Veneridae	*Venus sp.*
Gastropods	
Muricidae	*Thais coronata*
Melaniidae	Pachymelania aurita
Potamididae	Tympanotonus fuscatus
	Tympanotonus fuscatus var. *radula*

normal vegetational succession is disrupted to form a subclimax which is continuous by denudation, erosion, accretion, sand mining, urbanisation and oil and gas exploitation and other coastal developments. Under optimum condition the gross primary productivity of the mangrove forest can be higher than 20,000 kcal/m^2/year compared with most other marine or terrestrial communities. The productivity of the live Oyster *Crassostrea gasar* has been estimated at 28 metric tons/ha/year in Buguma or 5 metric tons/ha/year of oyster meat (Afinowi, 1983). The Littorina or supratidal zone are exposed and suffer splashes during high tide. The submerged barnacle zone rely on suspended particles since most of them are filter feeders. The supratidal zone organisms feed by rasping on the bark of the mangrove plants, utilizing both atmospheric and dissolved oxygen during low and high tide respectively, while the barnacles depend only on dissolved oxygen (Oyenekan, 1975).

2.5 Epifauna

In the mangrove area, the stilt root and branches of the *Rhizophora* harbour different organisms. There are distinct zonations. On a submerged stilt root are cemented barnacle mainly *Chthamalus estuarii* intermingled with the serpulid - *Mercierella enigmatica* which preys on the Oyster - *Crassostrea gasar* and also another polychaete *Hydroides uncinata*. Higher up on the mangrove root are *Thais callifera* var. *coronata* and *T. haemastoma*. Above *Thais* are *Littorina punctata* mixed with *Thais* and *Neritina labrata* because they are mobile.

2.6 Benthic community

Different benthic communities are found within the Nigerian mangrove ecosystem which depends on the sediment type; Longhurst (1958), identified four main communities based on Jones (1950) classification with no distinct zonation but some members dominating and also overlapping with other communities as shown below:

The mud flat zone is exposed during low tide, it is composed of fine unconsolidated soil, free of plant cover with a distinctive faunal community. These animals are typical inhabitants of soft mangrove mud. They are mostly detritus feeders, either burrowers, or living on the surface mud. Those living in burrows are crabs, others which live on the surface mud are periwinkles and some bivalves. The infauna are the serpulid and polychaete worms even though there are no coral reefs in Nigerian mangrove ecosystem.

2.7 Pelagic community

The most important family in the mangrove brackish water ecosystem is the Clupeidae. They migrate into the estuary feeding, breeding and also using it as nursery ground with some staying back to become permanent residents. The pelagic families in the mangrove ecosystem are as follows:

Clupeidae	*Ethmalosafimbriata* (Bonga) *Pellonulaleonensis* *Ilishaafricana* *Sardinellamaderensis*
Belonnidae	*Ablennes hians* *Strongulura senegalensis*
Megalopidae	*Tarpon atlanticus*
Hemiramphidae	*Hyporhamphuspicarti*
Elopidae	*Elops lacerta* *E. senegalensis*
Albulidae	*Albula vulpes*

2.8 *Ethmalosa fimbriata* (Bonga)

Adult *E. fimbriata* start migration into the estuary at the end of October but the peak of migration occurs in November and December when large schools are sighted both day and night. In the calm creeks, under the root of the mangroves they congregate to spawn. After spawning they migrate back into the sea. The salinity during October to December is between 26-33‰. Juveniles (5-8cm) appear around December near muddy sand bottoms in large schools usually near the edge of the mangrove. They grow rapidly to attain the size of 13-16cm around April - May when they migrate back to the sea. *E. fimbriata* can tolerate reduced salinities and may stay till the end of June before moving back to the sea. Some fishermen claim that some adults become permanent resident and grow to very large sizes which they call "Hangar" at Ajegunle on Andoni river. The fishery of *E. fimbriata* is the mainstay of the small scale fishermen in the coastal villages. Intensive bonga fishing occurs in the Lagos lagoon and most river channels in the Niger delta but the most intensive fishery takes place at the Cross River estuary. The quantity of bonga landed per annum by the coastal villages have not been properly estimated. Being seasonal (dry season) and fishing for 14 - 20 days of the 30 days, the fishery is dependent on both the lunar phase and the tidal cycle.

Sardinella maderensis. They are salinity sensitive and only come into the estuary when the salinity is as high as 28-33‰ in December. The larval fish drift in with the high tide from the coastal waters at less than 5.0cm total lenght and grow to between 8.0cm - 13.0 cm between March and April. These juveniles are often found mixed with *E. fimbriata* and *Pellonula sp.* in their nursery grounds. *Sardinella* fishery in the channels is also dependent on the lunar and tidal cycles.

Ilisha africana. The juveniles like *E. fimbriata* and *S. maderensis* are mostly found in the estuary and are mixed with other fish species. Hence they are taken as incidental catch but not as a target specie. Adults are fished nearshore with specialised gear.

Pellonula leonensis are also found in estuaries but are not as economically important as the *E. fimbriata* and *S. maderensis.*

2.9 Megalopidae

The adults are not found in the estuary between December and March but the eggs drift into the channels where they get attached to the mud or any floating object. The larvae are collected by the local people and placed in dug ponds and fed with shrimp and fish waste. Once they attain a particular size in the estuary they move back to the sea. Other pelagic communities associated with the mangrove ecosystems are: Elopidae, Belonidae, Hemiramphidae and Albulidae.

3. Uses

The mangrove satisfy important local and traditional needs of coastal dwellers. The varying

Table 6: Members of the different benthic communities found on the Nigerian mangrove ecosystem.

COMMUNITY	SEDIMENT TYPES	MEMBERS OF THE COMMUNITY
Sub-tidal and submerged		
Pachymelania aurita	Muddy-sand	*P. aurita, Neritina labrata aurita* (may be epifauna) *Aloides trigona, Iphigenia truncata, Tympanotonus fuscatus.* *Clibinarius africana* (In empty shells of *Thais*). *Balanus pallidus* (cemented on shells of gastropods)
Mangrove	Silty Clay mixed with sand and organic debris Submerged at high tide and exposed at low tide	*Pachymelania quadriserata, Tympanotonus fuscatus* var. *radula, Sesarma* sp and *Periophthalmus* sp.
Amphioplus	Sandy mud	*Amphioplus congensis* (ophuroid), Polychaete - *Nereis succinea, Lubrinereis* sp, *Glycera convoluta, Owenia fusiformis, Dipatra neapolitanea, Clymene monilis* and *Maldane* sp.
Gastropods		*Nassarius oblique* and *N.* sp are predatory, also *Marginella amygdala, M. rosea.*
Venus	Sandy	*Venus declivis* (bivalve) *Arca* sp, *Aloides sulcata* *Mactra nitida, Donax owenii, Cultellus tenuis* and *Petricola* sp., Gastropods - *Natica* sp, *Turritella biangulata, Clabatula smithi, inella* sp, *Nassarius* sp and *Terebra micans.*

COMMUNITY	SEDIMENT TYPES	MEMBERS OF THE COMMUNITY
Estuarine rock	rock (where ever moles are constructed or rocks used as embankments)	Green algae Echinoderm: *Astropecten irregularis* Cirriped: *Chthamalus dentata* Gastropods: *Thais callifera, T. haemastoma, Nerita sp. Littorina punctata, Siphonaria pectinata* Bivalves: *Fissurella coarctata, Brachyodontes niger* Polychaetes: *Pomatoloe spp.* *Isopods: Ligia gracillipes*

resources in the mangroves and their uses include;

Stem and branches: building, construction works, groins, firewoods, curing fish, fish racks, rackets, skewers, boat building, carving

Bark: Tannin extract for dyeing shrimp nets

Aerial root: Rope for various purposes, fishing for shell fishes.

In the 1960's about 20,000m^3 of mangrove wood were utilized annually by the Nigerian Coal Mining Corporation as pit-props, Adegbehin and Nwaigbo (1990). With the advent of petroleum, the demand by the coal industry reduced drastically. It is estimated that over 200,000 poles and other types of wooden items such as logs and billets (about 4 million m^3) are extracted annually for various purposes.

The cultivation of mangrove soil is handicapped by drainage problems and the perennial flooding. When drained for agriculture it becomes very acidic due to the oxidation of the sulphides. Agricultural practice is hindered by the acidic nature of the soil. Experimental rice farms were not successful because the cost of liming the soil is a major constraint to successful agriculture. Experimental fish farms by the African Regional Aquaculture Center at Aluu near Port Harcourt and Buguma, have shown some success. Experimental shrimp farms include that at Oyorokoto, owned by the Rivers State Agricultural Development project. Mining seems to be the most important industry in the mangrove belt. Oil and gas deposits are found along the mangrove belt (Fig. 3) with many oil wells, tank farms and pipelines criss-crossing the area.

Oil and gas are the main sources of foreign exchange for the country, therefore the need to provide adequate accommodation for the oil workers and their families has led to rapid destruction of the mangrove vegetation. Important towns are located on the mangrove belt such as Lagos island, Koko, Warri, Escravos, Forcados, Bonny, Brass, Port Harcourt, Ikot Abasi and Eket-Ibeno have as result suffered economic and environmental disasters. The causes of deforestation also include the following activities; school to land project, logging or timber exploitation, farming, infrastructural development and grazing. Oil and gas exploitation has led to phenomenal urban growth, with new industrial estates, industrial housing projects and new towns as the consequences of the inevitable urban population growth especially in Lagos and Port Harcourt. Most of the mangrove swamps have been reclaimed by land filling, for construction of infrastructural facilities such as roads, airport, landing jetties, berth, educational establishment, gas and oil pipeline and electricity powerline all of which consume a lot of forest. The ever increasing population has led to over exploitation of mangrove forest, most especially *Rhizophora sp.* and *Avicennia sp.* for fuel wood used for cooking and processing fish and shellfish since only cured products can reach the urban centers. The mangrove areas support about 192,800 full time and 108,614 part time fishermen and their families along the coast with production estimated by the Federal Department of Fisheries (FDF) 1990 at 171,332 metric tonnes of fish. Combined brackish, shore and coastal water yielded 204,977 metric tonnes of fish in 1989. A total of 282 shrimping and 158 fishing vessels were licensed for inshore fishing in 1989 which far exceeds the recommended number for Nigerian waters. In addition about 16,024 powered and 61,131 non-powered canoes compete for these exhaustible resources.

Conservative estimates of the catch form shrimping vessels is about 5,234 metric tonnes of *P. notialis*, *P. atlantica* and *P. kerathurus*. The oil based economy has brought the mangrove ecosystem under stress as a result of conflicts in exploitation.

Fishing which is the main occupation of the community may be under pressure due of huge demand and the persistent sahelian drought. A lot of people are now depending on fish as their main source of protein, thus fishing has become a rewarding venture considering the big demand for fishery products. However, this has led to the modification of the gear used by small-scale fisherman for greater efficiency at the expense of sustainable use and management. In Benin River tabular trap-Ita (about 15 meters long and made of closely matted cane) are placed at the mouth of Benin River at flow tide and raised at ebb tide, all sizes of fish species and crustaceans moving into the estuary are trapped. Since several traps are placed close together side by side, any organism moving into the estuary is trapped. Similar traps are constructed and placed at mud flats which are submerged at high tide. The use of mosquito nets and other mesh sizes of less than 1.0 cm for fry and fingerling of clupaeids and other species are rampant in New Calabar river, Sombriero, Sengana, Brass, Nun and Fish town Rivers in the Niger delta.

Long drift nets with very small mesh sizes are employed in the area for fishing of juveniles of bonga and *Sardinella sp.* in Bonny river, Imo river, Kwa Iboe

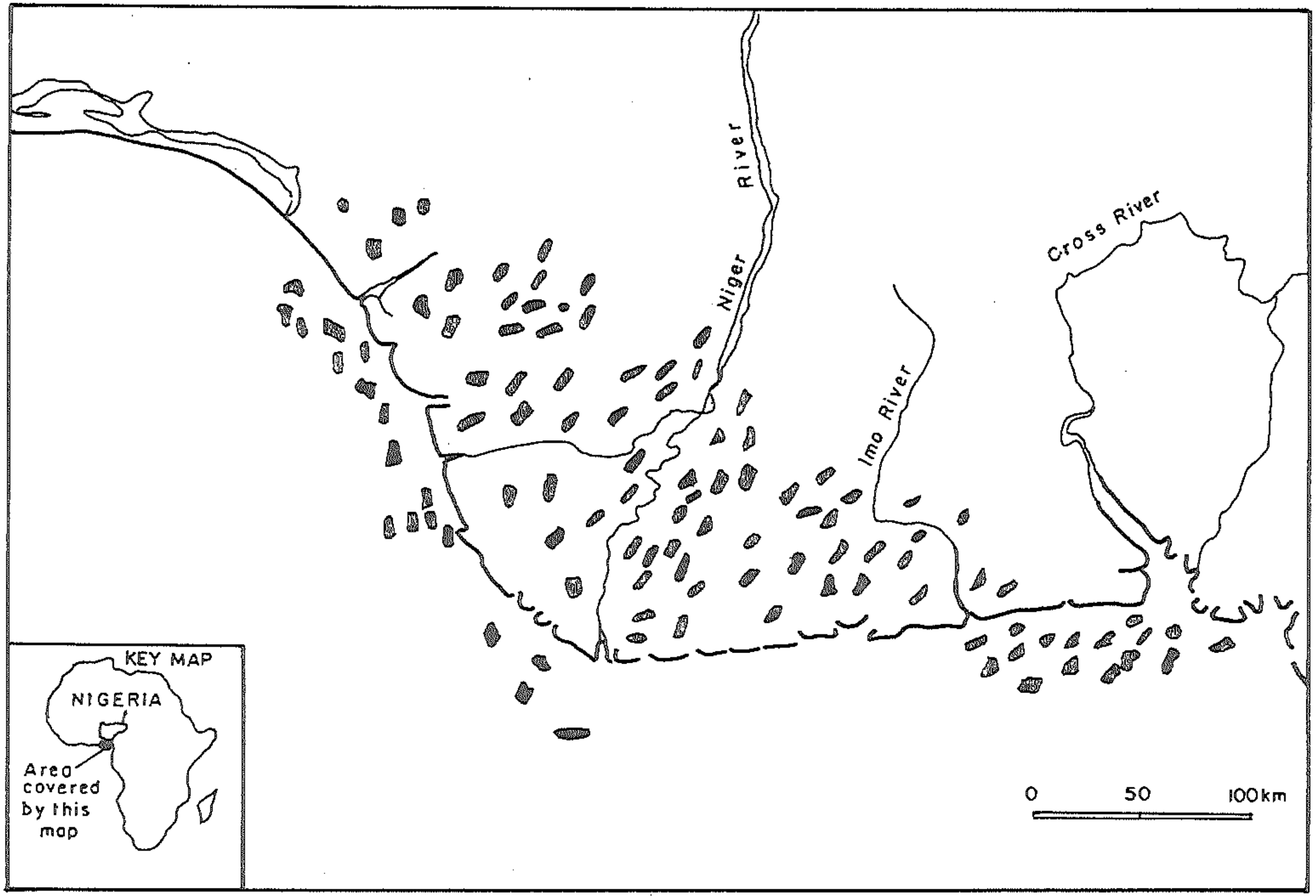

FIG.3 - APPROXIMATE DISTRIBUTION OF MAJOR PRODUCING OIL FIELDS IN COASTAL NIGERIA. 13 MAJOR OIL COMPANIES OWN CONCESSIONS PRESENTLY

(SOURCE: IBE.1988)

and Cross River estuaries. The over fishing of fry, fingerlings and juveniles has led to the depletion of the stock that would have been recruited to the reproductive stock.

Crustaceans, most especially *Nematopaelcomon hastatus* and *Penaeus notialis* are intensively exploited both at sea and in the estuaries when they move in between August - September and back to sea in February - March. Direct communication with local fishermen indicated that the catch has dropped with increase in fishing effort but again that may be due to other factors that could directly or indirectly affect the catch.

Recently, fish production in the river channels, estuaries and creeks area has declined. Less fish are caught due to a combination of factors such as pollution by crude oil, raw sewage, both domestic and industrial effluents, leading to lack of oxygen and over fishing bringing the catch per unit effort to between 0-2kg/canoe/day in some areas. Eniola and al. (1983) also observed that oysters and snails are very rare in some places and over exploitation has led to reduced catches and smaller sizes. The exploited molluscs in the mangrove are, oyster, periwinkles and snails. The sizes found are smaller both in concentration and distribution. But then it might not all be due to over exploitation but other factors such as pollution and destruction of the natural habitat or substrate.

4. Impacts

Tremendous pressure has been put on the mangrove ecosystem due to the various activities of man. Human induced activities impacting negatively on mangrove resources include:

- Oil and gas exploitation
- Fishing using unethical methods like poisonous chemicals, roots and herbs
- Use of dynamite for fishing
- Fishing with small mesh size
- Canalization to ease transportation and communication
- Discharge of raw sewarage into the environment
- Erosion of the Channel fringes due to wave generated by the movement of vessels, tankers, boats, barges and dredgers
- Subsidence due to oil extraction
- Sand mining
- Siltation due to sandfilling and other activities
- Deforestation of the mangrove area
- Flaring of gas causing air pollution
- Construction of embankment which affects the establishment of mangrove seedling and the accompanying fauna.
- Increase population pressure on the coast due to establishment of industries
- Construction of moles to keep channels free of sand leading to the erosion of the downdrift side of the coast.
- Discharge of Pollutants.

Most industries discharge their effluents into the rivers, estuaries, lagoon or sea with partial or no treatment. Toxic effluent such as DDT, mercury, cadmium and dyes used in the textile industries are carcinogenic. Industries which generate large amounts of waste include; breweries, a fertilizer plant at Onne Port Harcourt, distilleries, a pulp and paper plant at Oku Iboku in Akwa Ibom state. Sewage dumping distabilizes the ecosystem through the introduction of excess nutrients which lead to eutrophication. Fertilizers and pesticides from farmland run-off, forms another source of nutrient loading and pollution.

Large quantities are discharged into the mangrove area during an oil spill either through leakage of pipeline, ballast discharge or blow out. The Funiwa-5 oil spill of January 1980, released about 200,000 barrels of crude into the sea at the rate of 11,600 barrel/day was carried by tide into Fishtown and Segana river. The area affected by the spill was 57,600 acres and 836 acres of mangroves area Ekekwe (1981). Oil soaked seedlings of *Rhizophora sp* and *Avicennia* suffered heavy mortality, inter-tidal mudflats were soaked and all the communities of oysters, snails, fish, crabs and polychaetes died.

Clearing of the vegetation and excavation of coastal land at construction sites for new settlements and farms for agriculture are making the coastal soil more vulnerable to the impact forces of marine erosion. There is progressive destruction of pristine mangrove forest along the shoreline and overgrazing of the grassland has led to rapid erosion of the transgressive mud coast (Fig. 1). Along the Imo River, the mangrove forest has been replaced by *N. fruticans* either by natural forces or human action. Nypa has no economic value except for making roofing mat.

5. National Mangrove Committee - Management Policies for Mangrove Resources

At present there are no effective management policies for the conservation of mangrove resources (flora, fauna and land). However, if such plans were to be made, the objective must be in the areas of protecting the genetic resources and biodiversity and also as a gene pool. Various uses presently taking place in the mangrove area such as housing, industrial estates, agriculture and aquaculture should be discouraged or monitored and controlled. Efforts must be made at the three tiers of government, local, state and national level for restoration of degraded areas either by government, oil companies or others to avoid erosion. Illegal or accidental discharge of pollutants into the mangrove environment, should be kept at the barest minimum.

Possible management options should be geared towards the division of the mangrove area into section for different uses such as extending the existing acreage of preserved area (Stubb creek in Akwa Ibom) for conservation and creating new areas as wildlife sanctuaries. The estuaries and channels are important for fisheries and the vegetation around the estuaries protect the land against coastal erosion. The present conserved area in Cross River should be extended to cover the mangrove forest, intertidal mudflat and the swamp. This area adjoins the Cameroon Republic who have similar programmes which are under the World Conservation Foundation, as the last rain-forest in Africa, and resources or disasters know no State boundaries. This will form a complete biological entity for tourism, scientific study, and as an international park. Already this area contains wildlife species listed as endangered species in a worldwide scale such as Tubulidentata (manatee), Primates, Reptiles, Psittacidae (Parrots), Ardeidae (herons, egrets, bitterns) and other species of plants and animals.

Other parts of the mangrove should be divided and planned so as to embrace the existing structures in areas such as in (Lagos and Rivers state) as suggested by Saenger and *al.*, (1983). Extensive agricultural pursuit should be discouraged or minimized because of the fragile nature of the soil when exposed to air and the subsequent release of acid sulphates into the aquatic environment. Areas for firewood cutting should be designated, regulated and controlled. Continuous replanting should take place and supervised by the forestry department with a nursery section attached to it. Rotational felling of trees should be practised and the inhabitants educated on the importance of the mangrove and the crippling effect on the ecosystem when distablised.

All the maritime states which contribute to the productivity of commercial fisheries industries in Nigeria, especially the shrimp resources which is a major foreign exchange earner, should designate mangrove swamp areas for preservation and conservation.

The ministry of Agriculture and Water Resources in conjunction with the National Conservation Council should be in charge of management and conservation of mangrove ecosystem. Other departments to be involved are:

1. The Forestry Department for planning, reproduction, protection and management of the mangrove forest.
2. The Livestock Department for the Management of both domestic and wildstock of animals.
3. The State and Federal Department of Fisheries for enforcement of regulation, surveillance and persecution in mangrove brackish and coastal waters.
4. State Departments of Agriculture (involved in converting the mangrove area into rice plantation, fish farms, vegetable plots such as Lagos State and Rivers State).
5. Federal and State Ministries of Works and Housing, Survey Department, Town Planning (involved in housing project).
6. The Nigerian Institute for Oceanography and Marine Research should be mandated to research into the mangrove ecosystem, monitor the actual and potential danger to the mangrove and provide baseline data for firming up or revising the management plan since they have trained personnel.
7. Federal and State Ministries of Youths, Sports and Culture for the establishment of reserve areas for recreation, Nature Parks and for research.

6. Research and Training

Little research has been carried out on the flora, fauna and ecology of the mangrove ecosystem which ought to have been done, to estimate for the whole of Nigerian mangrove. This has led to poor policy formulation. Therefore, biological survey of the whole range of flora and fauna to estimate the biomass for thorough understanding of the ecological structure and dynamics of the mangrove ecosystem, is of paramount importance. It should also involve characteristics of internal energy cycle, algae, detrital cycle, sediment, nutrient and resident time in the system, contribution of the mangrove leaves and inventory of the standing volume. Studies on the qualitative and quantitative nature of the mangroves with relation to fisheries, the contribution of mangrove towards inshore fisheries with the aim of feeding information to policy makers on the ultimate sustainable yield of the mangroves, which could be useful for management, planning and development. A comprehensive and systematic survey should be carried out to ascertain the degree of pressure exerted by traditional and other uses in Lagos, Warri, Bonny, Port Harcourt, Ikot Abasi, Eket and Calabar on the mangrove ecosystem both in short-term and long-term in view of the global warming.

Scientist teams working on mangrove ecology must be multidisciplinary in composition to include ecologists, zoologists, soil scientists, botanists, economists, journalists, sociologists. Also, law makers, policy planners, environmentalist groups and most importantly women (the major users and abusers of mangrove resources) should be included.

Training programmes should include technical manpower development to undertake implementation and management. Personnel should be trained to study, manage and monitor the mangroves, through funding support from government and private organisations. Short term and non-degree courses should include environmental impact assessment, cultural attitude and habits of the coastal rural dwellers. Training should include areas of extension services and dissemination of information through various media. This should be done with the main aim of sensitizing the dwellers to the importance of the mangrove ecosystem and the effective utilisation of mangrove resources.

Finally, there is also a need to increase awareness of the importance of the mangrove ecosystem with emphasis on its biodiversity, in order to stem the rapid depletion of the mangrove resources and other anthropogenic activities taking place in this area.

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Mangroves in Congo

J. F. Makaya; Orstom B.P. 1286; Pointe Noire, Rep. du Congo

There are very few mangrove swamps in Congo, although the country is located in an equatorial zone which seems to be a suitable area for the development of such an ecosystem.

The mangroves generally form a narrow, 10 meter wide strip along the Congolese coast, mainly along the estuaries and the lagoons where there is a greater species variety. There are no mangroves on the sea front.

Congo is located between 4° S lat and 5° S lat. It has a tropical climate with a long dry season from June to September, during which the monthly average temperatures are sometimes as much as 20°C and a rainy season from May to October with very high temperatures (as much as 30°C). The annual average temperatures are around 25°C. Rainfall varies significantly depending on the years: 299 mm in 1958, 2,048 mm in 1961, 1,160 mm in 1990, 863 mm in 1991. Most of the rains occur in the months of November and March. In between (from December to January), there is what is called here the small dry season whose duration varies with the years.

The development of the mangroves in Congo seems to be limited by the presence, not far off the Congolese shores, of the cold Benguela current whose waters contribute to the poor development of the mangroves, at least for some time every year. Further down in the South, the mangroves are much more developed in the estuary of the Congo river located in Zaïre territory because of the particularly favorable conditions created by the river whose relatively high water temperature counter balances the influence of the Benguela current.

The small tidal amplitude in the region may also be an unfavorable condition. Tides enhance the development of the mangrove swamps located in the estuaries in the Northern part of the Congolese coast. But on the rest of the coast, the lagoons and estuaries are often between sand bars which prevent sea water flow and supply sediment deposits. They equally do not allow the development of a sub-horizontal space which would constitute the central layer of the mangroves.

The most developed mangrove swamps along the Congolese coast are located in Malonda (in the South) and Conkouati (in the North) lagoons - Fig. 1.

Malonda lagoon (Fig. 2): is parallel to the coast, and is separated from the sea by a littoral sandy bar, (almost fixed by the vegetation) and which leaves just a small opening where the Loemé river flows into the sea. Although it is very close to the sea, Malonda lagoon does not seem to undergo much marine influence. The vegetation which plays a part in this estuarine environment can be described as follows:

- On the littoral bar: a Phragmites; a few clumps of *Rhizophora* which have just started colonizing the bar; many vast areas with no vegetation; indeed, this sandy bar is undergoing a process of colonization by the newly arrived vegetation.
- On the shore: there is a herbaceous formation which comprises the so called "anthropophile" species (*Elaeïs guineensis, Cocos nucifera, Raphia sp*)
- The actual aquatic vegetation which. includes many associations: *Rhizophora mucronata* mixed with *Phragmites, Nympheacea* and *Cyperaceae.*

However, *Rhizophora mucronata* become more scarce as one proceeds in the channel upstream fowards Loémé.

Conkouati lagoon (Fig. 2): constitutes the most important mass of brackish water in the Congolese coastal region. One permanent access to the sea is located at the South-West through a channel. Thus, the Conkouati lagoon depends on the vertical and longitudinal salinity gradients because of its maximum North-East/South-West main axis .

The mangroves form a belt all around the Conkouati lagoon, they are homogeneous and consist almost exclusively of *Rhizophora mucronata. Nympheaceae* and another non identified aquatic species enrich the lagoon flora which mainly consists of *Rhizophora.*

In the Western part of the lagoon, at about 1,2 kilometers from the coast, three sand bars of very different size which seem to be stretching parallel to the flood and ebb tidal currents. The small islands are occupied by 6-7 meter high trees and other casual

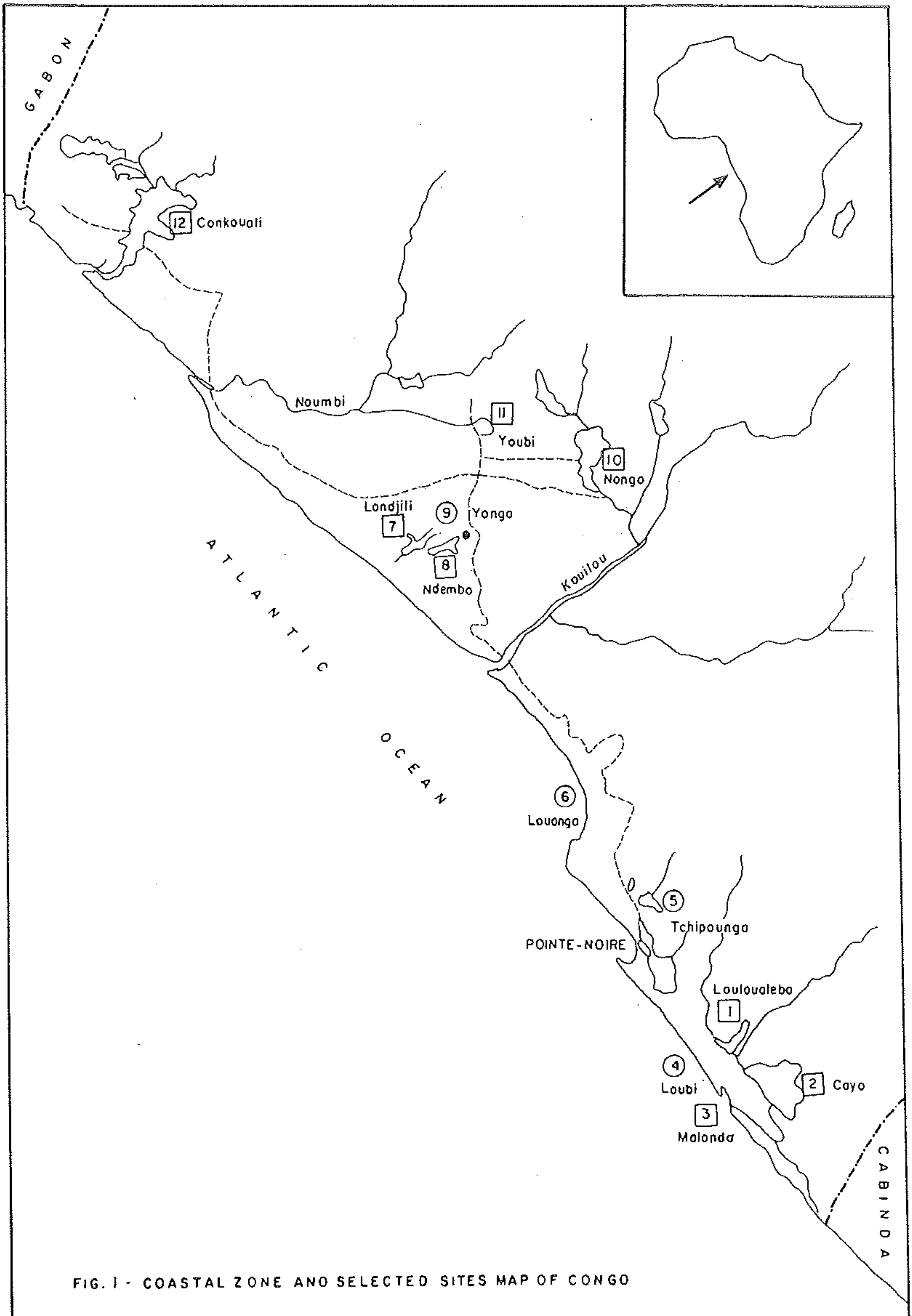

FIG. 1 - COASTAL ZONE AND SELECTED SITES MAP OF CONGO

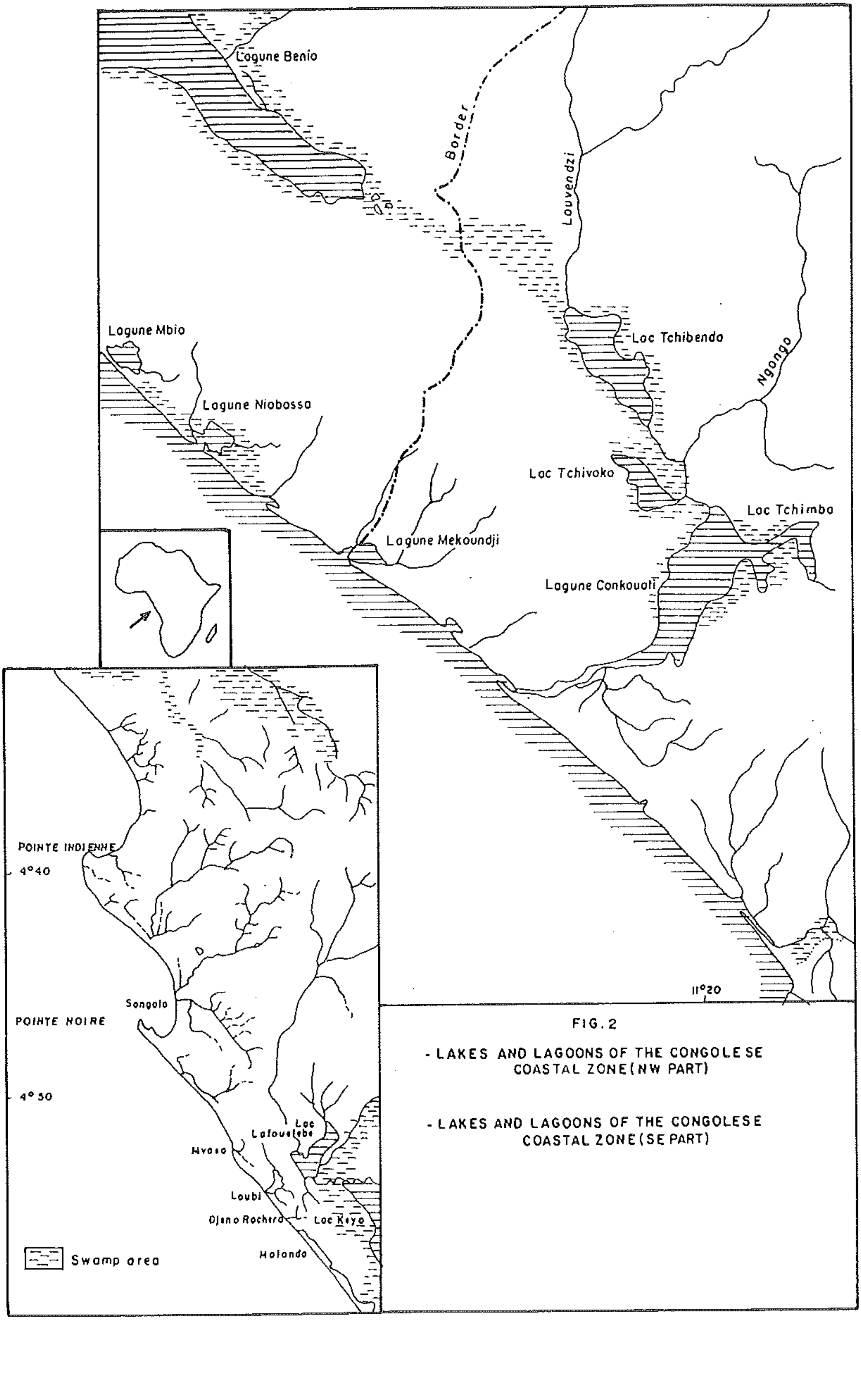

FIG. 2

- LAKES AND LAGOONS OF THE CONGOLESE COASTAL ZONE (NW PART)

- LAKES AND LAGOONS OF THE CONGOLESE COASTAL ZONE (SE PART) species like *Hibiscus tiliaceus*, *Dalbergia ecastaphyllum* Taub, *Ecastaphyllum brownei* Pers (Makany, 1963). Palm tree species also grow there, especially *Phoenix reclinata* Jacq.

Significant areas of the farthest part of the lagoon from the sea are occupied by *Cyperaceae* and a gramineous plant, *Sporobolus robustus* Kunth.

The *Rhizophora* zone is more extended in the estuaries, particularly in those of Kouilou and of Noumbi. The mangrove flora forms vertical zonation layers in the areas where the slikke and the schore are not developed enough to permit different levels of vegetation. The slikke is occupied by *Rhizophora* which forms a thick tree curtain around the water. Right behind the *Rhizophora*, on the schorre, there are *Avicennia* whose roots extend toward the slikke, and whose pneumatophores stretch through the mud toward the roots of the *Rhizophora* (Fig. 3).

1. The Fauna

1.1 Molluscs.

The most frequent is a Gastropod: *Tympanotonus fuscatus varrata* Linné, which is particularly abundant in Malonda lagoon. The individuals are about 40 mm long. However, some of them can be as much as 60 mm long.

There are in the lagoon located in the Northern part of Pointe Noire (Conkouati) *Pachymelania fuscatus* var. *quadriseriata* Gray biocenoses associated with other gastropods: *Pachymelania aurita* Müller and *Tympanotonus fuscatus* L. Empty shells are occupied by hermit crabs.

Most of the lamellibranches identified are *Gryphea gasar* Dantzenberg (= *Ostrea tulipa* Lamarck). The other species are rather rare: *Iphigenia rostrata* Römer, *Tellina nymphalis* Lamarck.

2.2 Crustaceans

a) Crabs:
- *Callinectes latimanus* Rathbun: is the most abundant species, regularly caught.
- *Uca tangeri* Eydeux: lives in groups in the lagoons, digs burrows in the sand, and leaves small piles of chewed stuff and faeces around the entrance to their burroun (P. Giresse and G. Kouyoumontzakis, 1973). The *Pachygrapsus gracilis* Saussure, and *Goniopsis cruentata* Latreille are equally well represented.
- In general, *Callinectes marginatus* A. Milne Edwards, *Menippe nodifrons* Stimpson, *Panopeus africanus* A. Milne Edwards, *Sesarma alberti* Rathbun, *S. africanum*, H. Milne Edwards, *S. büttihoferi* De Man, *S. elegans* Herlotes, *S. angolense* De Britto Capello, *Cylograpsus occidentalis* A. Milne Edwards are scarcer.

b) Paguridae:

The main species of the *Tympanotus* and *Pachymelania* associations are *Clibanarius africanus* Amivillins, *C. cooki* Rathbun.

c) Fishes

Mainly ubiquitous *Periophtalmus papilio* Bl, which lives in abundance among the roots of the mangrove trees.

2. Some Aspects of Pollution and Human Activities

The coastal margin of the Congolese continental shelf and its closely associated environment (lagoons and estuaries) represent only 10% of the marine waters.

The species most exposed to degradation are those which breed and feed in the estuaries and lagoons during their first life stages. The environment and the aquatic life are directly and indirectly affected by a more or less visible pollution due to human activities:
- destruction of the aquatic fauna habitats (reproduction, growth and development sites);
- intoxication by hydrocarbon wastes and chemicals.

Because of the coastal geomorphology, the sea current runs North-West; North-North-West along the coast. The swell originating mostly from the South, between the 201° and 204° directions (the wind directions are between 160° and 204°), creates turbulences. As consequences off shore oil drilling in the Southern part of Congo, results in a quasi-permanent pollution of the coastal section at the South of Pointe-Noire. However oil is the mainstay of the country's exonomy. An assessment of the fauna of the Loubi lagoon (South of Pointe-Noire) conducted in 1968 (Daget and Stauch), revealed that many mangrove species had been undergoing much pollution because of the installation of an oil tanker terminal at Djeno, and significant amount of hydrocarbons frequently poured into the sea.

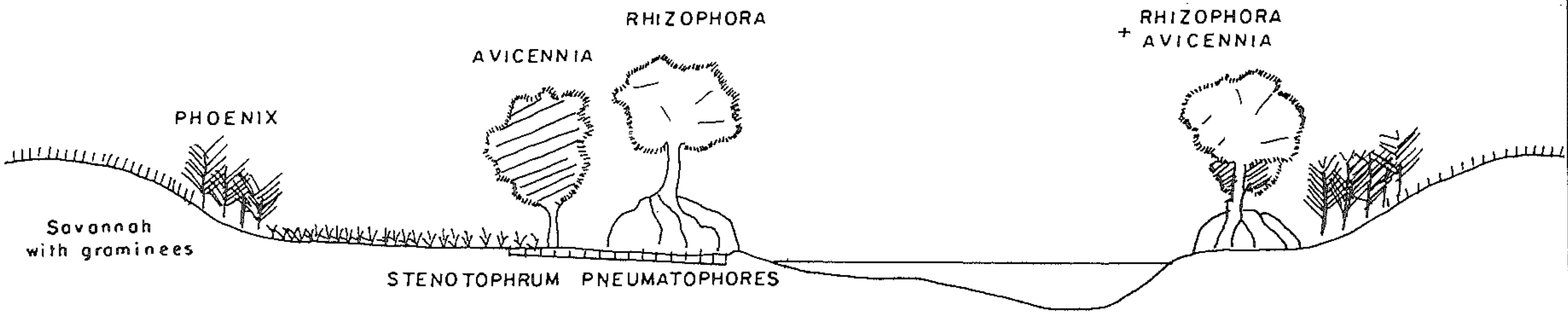

FIG. 3 - TOPOGRAPHY AND VEGETAL COVER OF CONGOLESE LAGOONS AND COASTAL ESTUARIES

(G. MOGUEDET 1980)

All the coast to the South of Pointe-Noire harbour is permanently polluted by hydrocarbons. The lagoons of this part of the region which are connected to the sea are also affected. In general, the mangroves are continuously destroyed by population's activities which use them for fish smoking, vegetable gardening, house building.

Mangroves of Cameroon

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1. The Mangrove Swamp Ecosystem

1.1 Extent and distribution

Situated at the far end of the Guinean Gulf, Cameroon has about 350 km of coastline; more than 30 % of which are occupied by mangrove swamp estuaries. In total, there are around 350,000 ha of mangroves and estuarine waters distributed between two main units : the mangrove of the "Cameroon Mouths" and that of Rio del Rey all situated on either sides of the Cameroon Mount, symmetrically towards the SW-NE axis of the active volcanoes. We have to add to those main units small mangrove pockets of the Nyong mouth, of the Campo river and of the Man O'War bay which cover only a few hectares.

The mangrove swamp of the "Cameroon Mouths", the most important, covers about 60 km of coastline, from the Sanaga mouth to that of the Bimbia river and, around 30 km inland; that is a surface of about 180,000 ha. That of Rio del Rey covers an area of almost the same size: 50 km of coastline and 30 km inland, that is around 150,000 ha.

2. Physical Environment

The physical environment is characterized by warm and humid equatorial climate, by soils varying according to the hinterland geology and by an accumulation of large quantities of continental and sea waters in the Gulf.

2.1 Climate

The climate of the Cameroon littoral is basically characterized by the nearly permanent presence of the Guinean monsoon which causes humidity always almost at the verge of saturation, frequent and abundant rains, a strong nebulosity, a slight evaporation and very little sunshine, high and constant temperatures.

The variety of types of coasts and the general shape of the hinterland relief, the orientation of the coast towards the monsoon fluxes and its spreading in latitude cause some outstanding disparities on the regime of the rainfall and consequently on the other climate parameters as well.

The Mount Cameroon littoral is the spot where it rains most: the rains that fall is a single season (from February/March to November), reach their highest point at Debundsha at the foot of the big mountain with an average of over 11,000 mm a year, thanks to the orographic effect of the imposing coastal volcanic massif and also to the orientation of the coast perpendicular to the main oceanic flows. The rains diminish noticeably westward and eastward, but remain high in general: 4 to 6,000 mm in the mangrove swamps of the Rio del Rey; 4 to 5,000 mm in those of the "Cameroon Mouths".

On the other hand, the rains are less in the South in the Kribian area where they reach 2,400 mm (Kribi), partly because of the equatorial rainfall which has two dry seasons and two rainy seasons and also because of the S-N positioning of the coast which, though very uneven, receives the monsoon flux (SW) at an angle and not directly. The climate is completely different from the northern littoral. Between July and August, while torrential rains fall in Bibundi (3,000 to 4,500 m), in Debundseha (3,000 to 6,000 mm), in Tiko (1,500 to 3,000 mm), in Douala (1,200 to 1,800 mm) for both months, with maxima of 400 to 500 mm/24 h in Debundseha, the Kribian coast is under a dry season sometimes a severe one with minima of 20 to 60 mm at Kribi. This is in fact the repercussion of the dry season from the South characterized by the pressure more or less important of the Ste Hélène Anticyclone up to South Cameroon. This rainfall has an outstanding influence as much over the other parameters of the climate as well as over the quality of the sea waters.

2.2 Waters

Oceanography, hydrology, as well as the mangrove swamps, are still very poorly known, although the main characteristics of the sea movements in the Guinea Gulf provide some basic knowledge.

The Cameroonian littoral is abundantly watered by the rivers Akpa-Yafé, Ndiam, Moko and Mémé which pour into the Rio-del-Rey mangrove ecosystem and by the rivers Wouri, Mungo, Dibamba which nourish the mangroves of the "Cameroon Mouths". To those rivers lesser important ones are, the Sanaga which throws part of its water down to the Cameroon Mouths during the flood period, the Nyong, the Lokungjé and the Ntem which, flow into the Kribian littoral (Fig. 1).

These rivers have a regime that follows that of the equatorial rains with two maxima (April and September) and two minima (February and August). All the other streams of the Cameroonian littoral are subject to the Guinean monsoon regime and have only one maximum in September and only one minimum in February-March.

The highest floods can reach 636 m^3/s for the Mungo; 1,425 m^3/s for the Wouri; 7,570 m^3/s for the Sanaga, 376 m^3/s for the Nyong and 764 m^3/s for the Ntem in coastal stations; low waters can respectively reach: 27,5; 49; 171; 25,7 and 50 m^3/s. These rivers are the main suppliers of fresh water which contribute to dilute the waters of the coasts. According to M. Boye and *al.* 1974; A. Zogning and *al.* 1986; S. Morin and *al.* 1989, we can estimate at 32 billions m^3 the annual volume of waters poured into the Cameroon Mouths by the Wouri, the Mungo, the Dibamba, partly the Sanaga and the vast number of small rivers flowing directly into the Cameroon Mouths. As far as the Rio-del-Rey mangroves are concerned, they receive around 20 billions m^3, of which 4.9 are supplied by the Ndian, 4.6 by the Mémé and 3.6 by the Moko. To these waters we have to add :

- rain waters falling directly in the estuaries: around 5.4 billions of m^3 in the Cameroon Mouths; almost 6 billions in the Rio-del-Rey mangrove swamps;
- stream waters the volume of which is increasing owing to the environmental changes;
- water sheets which reappear under the sea and which can be observed at low tide over the coats, as well rocky (namely Mount Cameroon) as muddy and sandy coasts.

Considering all sources, there are almost 145 billion m^3 of fresh waters which annually pour into the Gulf of Guihea. The convergence towards the far end of the Gulf, the Guinean counter-current and the continuation towards the North of the Benguela current (named Gabonese current) throw considerable quantities of littoral waters towards the coasts. The two convergences of sea and continental waters affect the Guinean Gulf sea, in particular its physical and chemical characteristics. As a result on the physical plan we have:

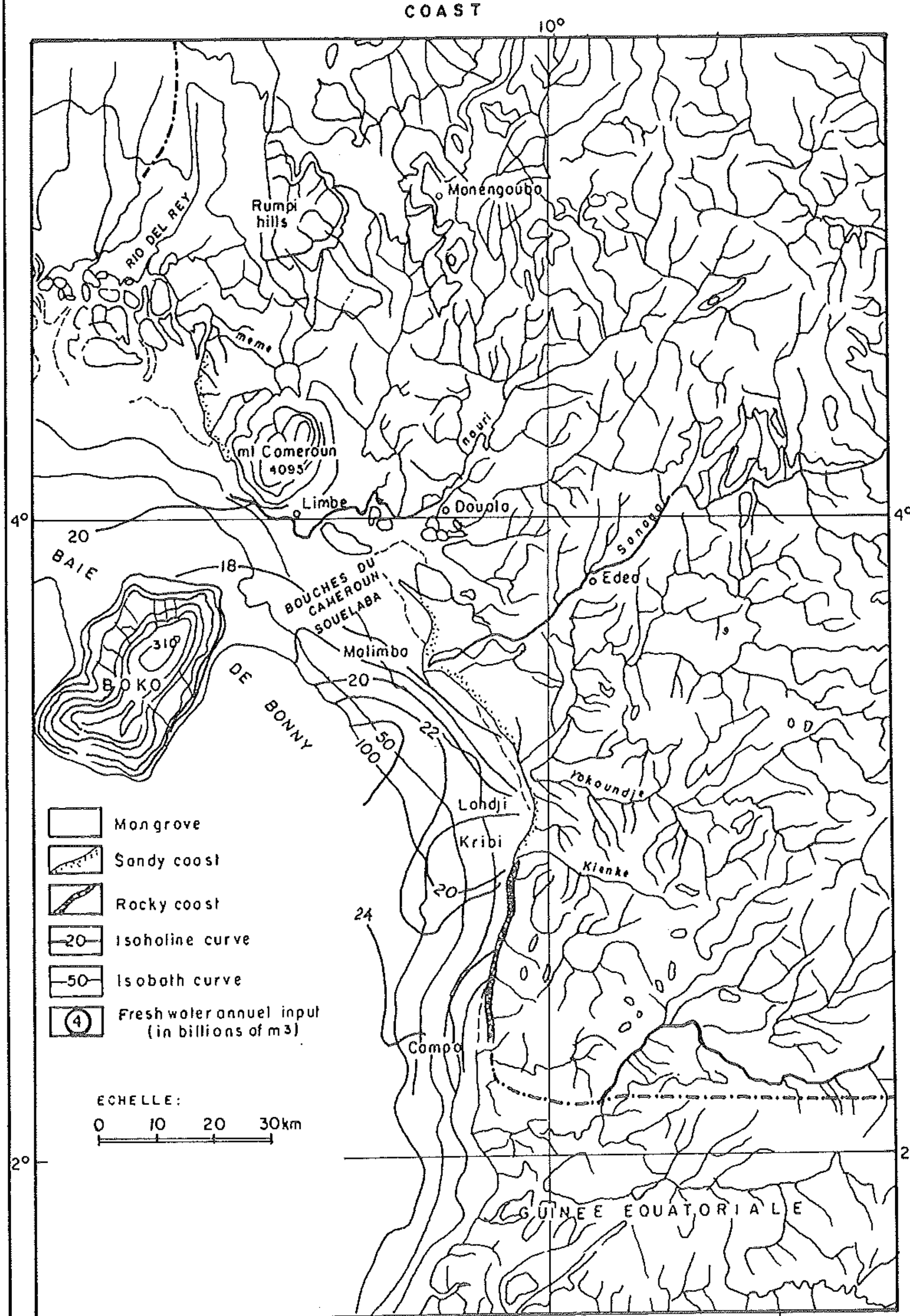
1 - A phenomenon of piling up of water in the Gulf is responsible for the increase of mean sea level, by 1,2 m over that of the Atlantic (J.L. DAVIES, 1977). This swelling mainly noticeable from Equatorial Guinea to Sanaga is also a result of the accumulation - over the shelf- of waters thrust by the equatorial sub-surface current (Lomonosov current) whose horizontal axis, set at about -100 m depth, diverges on the continental shelf; its influences are felt during the boreal winter in the south up to Pointe-Noire and in the West up to Ghana.
2 - Moreover, the piling up of these waters in the Gulf, causes a slow geostrophic current which in a clockwise motion describes a loop between São Tomé and Bioko (A.CROSNIER 1964)
3 - Eventually, the waters of the Guinean Gulf, circulate in unusual manner.
4 - Transparency is low owing to the amount of organic and continental matter dissolved or suspended brought by the rivers. Turbid waters from estuaries, namely from the Cameroon Mouths, penetrating in the sea can be easily identified on satellite imagery.
5 - Temperatures remain high throughout the year, with an average of 25°C in shallow waters. The thermocline is between 25 and 50m depth in the water with pressure gradients of 1°C/m, at places. The temperature regime is under the influence of the southern air masses with maxima in February-March and minima in August.

From the chemical point of view, the main characteristic of the Guinea Gulf waters is their low salinity rate, explained by the dilution caused by continental and climatic waters. LAFOND (1967) finds maxima of 20‰, 15 km away from the Douala port during the dry season and, maxima of less than 12‰ during the rainy season. These rates diminish rapidly close to the port; with an average of 0,26‰ every 100 m (2,6‰ per km). Near Japoma, over the Dibamba it goes up to 0,8‰ despite the tide wedge riding up this river (35 km). Vertically with a depth of 20 to 30m these low saline waters correspond to shallow warm waters. These waters cover the main part of the Gulf continental shelf.

2.3 Movements of the sea: tide, and swells.

Tides are of semi-diurnal type. Generally, amplitude, are not great (1,5 to 4,5 m according to places). Their most spectacular effects are noticeable in complex estuarine mangrove ecosystems where the flood tide penetrates deeply (MORIN and *al. op-cit*). In the Cameroon mouths the tide goes up stream to more than 40 km in the Wouri, 35 km in the Dibamba and

FIG. 1- HYDROGRAPHY AND RELIEF ON THE CAMEROONIAN COAST



around 20 km in the Mungo where the tide penetrates with difficulty owing to the narrow channels of the creeks and their meandering.

Transfers during flood and ebb tides are important but they are still poorly known. OLIVRY (1986), MORIN and *al.* (*op-cit*) estimate them at 10 millions m^3 over the Dibamba and 50 millions over the Wouri. They vary according to the dimensions of the channel. The maze of creeks, the communication between different estuaries or the river (Kwa-Kwa creek between the Wouri and the Sanaga) occasionally become violent currents: 2 to 3 knots during the flood tide and 5 knots during the ebb tide. They periodically reverse, but given the complexity of the channels network, the hour of slack water or the inversion of the current varies from one place to another. The rise in the river water level also occasionally submerges the estuarine complex. The Sanaga river can rise by 8 to 9 m and flow in old beds such as the Kwa-kwa creeks and Ndonga to flood the Cameroon Mouths.

According to CHABERT and *al.* (1977), from November 1974 to November 1976 at the Limboh cape, swells from South-South-West direction are of remote origin. They are caused by the "Westerlies" of the South Atlantic (A.GUILCHER 1954) and they are not influenced by the prevailing winds (of the South-West), weak enough to have no determining effect. This is explained by the double obstacle created by the Bioko island and by the widening continental shelf off the North littoral where it can reach 80 km, against 40 in front of the Kribian coast (Fig. 2). Because of that double obstacle, the swells become generally weaker here than in the West African coasts which are more exposed.

In the Limboh cape, the minimum amplitude can reach 1,91 m and the maximum amplitude only 2,80 m.

Generally the strongest swells (226 m long) are from the South and occur from June to September; the weakest occurring from November to April. They are noticeably stronger over the less sheltered Kribian coasts but they hit the coast at an angle and not directly so that their impact is reduced.

The Guinean Gulf bottom (Bonny Bay) is characterized by a relatively calm sea with warm waters, weakly transparent and strongly desalinized.

3. Biological and Ecological Characteristics

3.1 Flora

Very few studies are carried out at present on the mangrove formations. As far as we know, the only available data are some few limited studies carried out by M. Boye and *al.* (1974) in the area of the "creek of the Doctor"; FOCHO DERECK (1986) and KUETE and *al.* (1990) in the Tiko area. Some general studies based on ground observations and mainly on photo-interpretation : BOPELET and *al.* (1986) on the Cameroon cape area; ZOGNING and *al.* (1986), MORIN and *al.* (1989) on the whole of the Cameroon littoral. The vegetation landscape is dominated by the Cameroon Mouths and the Rio del Rey mangrove formations. Here hydrological and geomorphological data are available. The depth of submersion, the nature of the substratum (sandy or muddy) and salinity rates are favourable for a steady zonation of the plant formations; it can be classed:

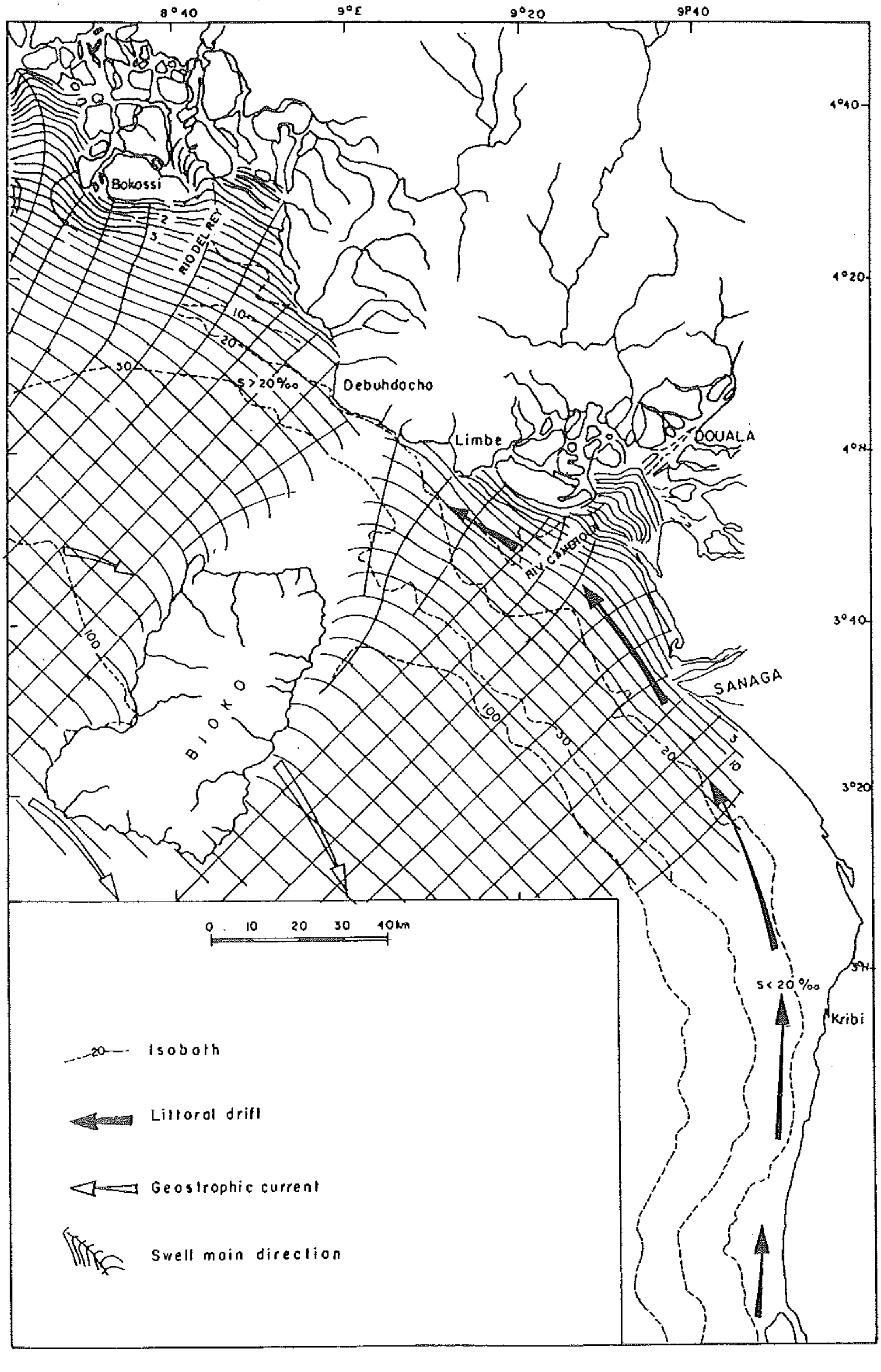
- tidal zone
- middle zone
- mangrove back zone

3.1.1 The tidal zone is composed of *Rhizophora racemosa* formations established in the areas of deeper inundation, mainly over the convex river banks and creek meanders. Under such conditions they develop into a forest with straight trees which can sometimes have an average height of 45 metres. But as the water level decreases; the forest changes and there is an open canopy with low trees (4-8 metres).

Though these formations tend to be monospecific they, sometimes, are mixed with *Avicennia germinans* and with a few epiphytes and parasites such as *Phymapode scolopendria, Rhipsalis cassytha, Bulbophyllum sp.* and different Loranthaceae.

- Formations of *Nypa fruticans* established in the muddy substratum zones submerged only during high tide.
- Formations of *Hibiscus tiliaceus*, mainly limited to the areas of concave river meanders where the muddy substratum is high, ferns such as *Acrostichum aureum* L., some Papilionaceae such us *Drepanocarpus lunatus* and *Dalbergia ecastaphyllum* may be present.
- Formations over the rarely submerged river banks with a clayey substratum there are low arborescent formations with a more complete floristic composition. The main species are : *Raphia nitida, Carapa procera, Chrysobalanus orbicularis, Crudia, Klainei* and *Mamilkara obovata.* In some

FIG. 2 - OCEANOGRAPHICAL FACTORS OFFSHORE CAMEROONIAN COAST



places these are frequent enough : *Cynometra mannii* and *Oxystignia mannii* and they are the only species.

3.2.2 Formations of the middle narrow zone regularly flooded bearing only one association composed of two species : *Rhizophora harrisonii* and *Pandanus candelabrum,* as the upper stratum which is 2 to 6 m high and open. The medium stratum hardly reaches 2 m height; it is discontinuous and is composed of *Conocarpus erectus, Dalbergia ecastaphyllum, Drepanocarpus lunatus* and *Ormocarpum verrucosum.* The herbaceous stratum, rich enough is formed of *Bacopa decumbens, Fimbristylis ferruginea, Eleocaris geniculata, Paspalum vaginatum, Uttricularia sp., Xyris anceps, Acrostichum aureum* and a few young *Rhizophora harrisonii.*

3.2.3 Formations of mangrove back swamp, growing on land never reached by the sea, they are composed of marshy forest species of fresh water such as: *Phoenix reclinata, Allophyllum inophyllum* and *Anthocleista vogelii* and species from mangrove ecosystems which have low salinity requirements such as *Rhizophora harrisonii, Drepanocarpus lunatus, Ormocarpum verrucosum* and *Acrostichum aureum* (Fig. 3).

To these three zones specific environments must be added namely:

- Zones of permanent fresh water flooding in the mangrove back swamp with clumps of *Echinochloa stragnina* frequent in the swamps of the industrial area of Bonaberi.
- Land areas inside the mangrove, corresponding to the islands and to the old offshore bars. Never flooded and often covered with ferralitic soil, these areas like the island of the creek of the Doctor, bear a thick vegetation different from that of the other areas composed mainly of *Acrostichum aureum, Cnestis ferruginea* and *Drepanocarpus lunatus* on the borders, *Bertiera racemosa* and *Carapa procera.* toward the centre.

3.2 Fauna

Because of the extent of the brackish water zone the aquatic fauna is relatively poor off the coasts. It resembles that of the estuaries, pelagic species of the open sea are found far removed from the coast.

An air view of a part of the Cameroon Mouths mangroves between Tiko and the mouth of Mungo. Can be seen:

1- Old offshore bars underlined by the curtain-like parallel tree vegetation.
2- Dense formations of *Rhizophora* over the convex banks of meanders.
3- Several low formations
4- Solid earth with cultivated fields (hazy) and the industrial plantations (geometrical forms)
5- Swampy forest which interposes itself between the zone of cultivations and the mangroves.
6- Capillary network of creeks underlined by "forest galeries" which testify to the outstanding role played by the hydrology in the distribution of the vegetation.

According to J. DAGET and D. DEPIERRE, to whom we owe the essential part of the information about the fauna, around 140 species can be counted. Among these there are Cetaceans such as sperm whales (rare), the Sirenians or dugong. Reptiles, such as turtles (tortoise luth, tortoise "franche"), Selachians such as: sharks, dogfishes (rare), sawfishes (*Pristis,* Peroteti), hammerhead sharks and rays, namely "guitar-ray" (*Rhinobatus vasus*) and the sting-ray (*Dasybatus margarita*).

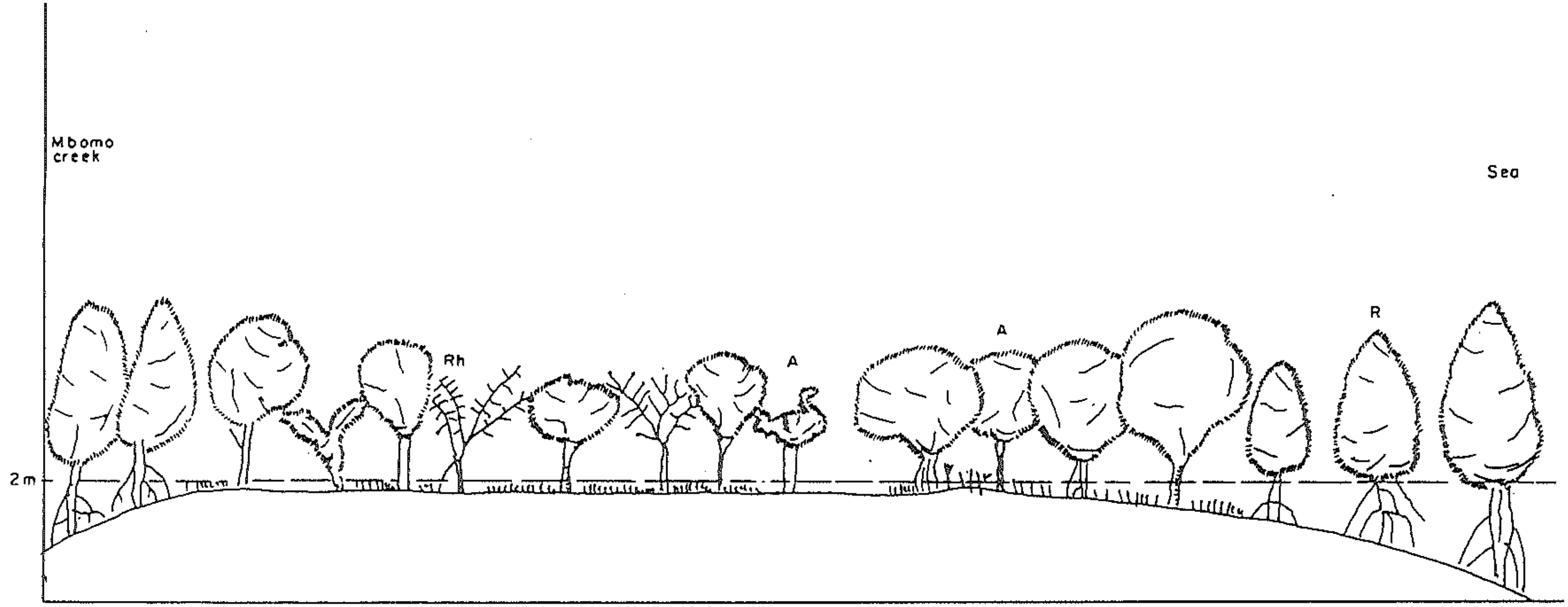
Among fishes:

* Stenohaline species such as the *Balistes forcipatus* (in the Kribi region), the *Cybium tritor* (pimp), bonitos, *Epinephelus nigri, Elops lacerta* and, *Tylosorus choram* mainly and others.
* Euryhaline species are more numerous they and represented by *Polynemus quadrifilis* ("capitaine de mer"), *Galeoïde decadactylus* and *Pentanemus quinquarius.* The Sphyraenidae with *Sphyraena piscatorum* (barracuda or sea pike), the Serranidae family with the pink carps of the *Lutjanus* genus; the Clupaeidae represented by three species: *Pellonula vorax, Ethmalosa fimbriata* and *Ilisha africana,* very well used by the local smoked fish industry.

The Mugilidae family is composed of two well known species: *Liza falcipinnis* and the *Liza grandisquamis* which live in the shallow littoral waters and feed on silt. Fresh water species such as the Chrysichthys and Synodontis, also the Ariidae with *Arius heudeloti,* very abundant in all estuaries; the Sciaenidae *Corvina nigrita* (the hunchback) and the "bar" *Pseudotolithus senegalensis.*

Rare species among the Carangidae such as *Caranx senegalus, Humicaranx bicolor, Lichia glauca* and *Vomer setipinnis; Caranx carangus, Caranx hippos* and *Trachynotus falcatus* are frequent species.

FIG. 3 - THE MBOKO I MANGROVE VEGETATION PROFILE



Acr : Acrostichum aureum

P : Pandanus candelabrum

R : Rhizophora racemosa

A : Avicennia germinans

The Pleuronectidae or flat fishes are represented by *Citharichthys stamplii* a small sole, the *Cynoglossus senegalensis* (or dog tongue); also *Psettus sebae, Tetraodon guttifer, Doryichtys aculeatus* and *Syngnatys kaupi* (two syngnathes), *Caecula cephalopeltis* (kind of very elongated eel) and *Periophthalmus papilio* (big eyes) which are not marketed.

The molluscs (Gastropods) are represented by limpets such as *Siphonaria mouret*, periwinkles of various genera such as: *Melongena, Purpura, Tritonidea, Yetus* and *Purpura callifera*, a predator on oysters; the flat oyster (*Crassostrea rufa*) which hangs over the Kribian coast rocks, the mangrove oyster (*Crassostrea gasar*) which covers *Rhizophora* roots in the mangrove; Cephalopods with *Sepia officinalis* (very rare) and mussels, mainly *Mytilus tennuistriatus*.

Among the Crustaceans mainly shrimps which give their name to Cameroon, derived from the Portuguese expression "Rio dos Camarâos" that is to say the river of shrimps, referring to the Wouri river in which the Portuguese met, in the 15th century, important concentrations of *Callianassa turnerana*.

To that common species we should add the Paleamon genera with *Palaemon jamaïcensis* with big pincers and Atya with *Atya gabonensis* and *A. scabra*. Many species of crabs such as *Eupanopeus africanus*, and *Callinectes latimanus* (a swimmer crab living in brackish waters). Some of them, more numerous, live in the mud of the mangroves, others more or less amphibious such as *Ocypoda ippeus* (a runner crab) dig out their holes in the sandy banks.

Numerous birds live on the coasts: some are pelagic species such as Petrels (*Oceanites oceanicus*), skuas, puffins and seagulls. Others are littoral species such as sandpipers, sanderlings and terns (*Sterna hirundo*) mainly on the Southern part of the Sanaga mouth's banks. Cormorants, herons, egrets, terns, sandpipers (*Tringa*), sanderlings (*Calidris*), barges (*Limosa*), curlews (*Numenius*) and gravelots (*Charadrius*), all live in the mangroves and the lagoons where they feed on invertebrates.

Earth mammals are mainly monkeys around Cameroon Cape.

The interactions between the different environmental factors, both; biotic and abiotic energy fluxes, trophic relationships, productivity and the ecology at large have not yet been a matter of detailed study. The results of the COMARAF seminar held from the 13th to the 19th of December 1987 in Douala on the productivity of the African coastal ecosystems can be considered as one first step; it mainly enables researchers to test and evaluate different methodologies.

4. Ecosystems Adjacent to the Mangroves

Practically we do not have information on the various species of the fauna or the flora of pelagic, benthic or supra-tidal communities, on the seagrass beds or the coral reefs. Different species of the fauna and the flora are submitted to so many changes because of the modifications of factors as mentioned and because of the steadily growing man's impact in the littoral areas since the beginning of the XXth century.

5. Dwelling and Traditional Uses of the Mangroves

The Cameroonian mangroves are generally very densely populated by man. There are more than eighty villages scattered all over the Rio del Rey mangrove swamp (about 45) and the Cameroon Mouths (35). Their size varies: from a few tens to more than a thousand inhabitants.

There are several ways of using the mangroves; for housing, food and medical purposes. In terms of housing, *Rhizophora racemosa* is appreciated for huts construction because of its hardness and resistance; it is used to build the frame of the hut. *Avicennia germinans* is also used, *Pandanus candelabrum* leaves can be used to make mats to separate rooms.

For urban habitats, extented sectors of mangroves are being destroyed for sand and gravel exploitation : that is the case for the quarries of the creek of Doctor. Other main occupations of the inhabitants are focused on fisheries activities: canoe building, net weaving and fishing itself, packaging and selling products. As far as canoe building is concerned, *Avicennia* is mainly used because of its big size (sometimes, over 60 cm in diameter). *Rhizophora* is more resistant but unfortunately it is more dense than water. However, the bark of *Rhizophora* is used to tan fishing nets, ropes and canoe sails. In the Tiko area, FOCHO DEREK mentions that from the medical point of view, *Avicennia* bark powder is a drug to cure bile fits, whereas that of *Rhizophora racemosa* is efficient to stop diarrhea and dysentery. Fishing properly is essentially a commercial activity.

6. Commercial Exploitation and Marketing

There is a difference between industrial and traditional fishing. The latter is practised by using various nets (circling net, beach seine or swivel seine, cast net or hoop net to catch shrimps in estuaries.). This kind of traditional fishing supplies more than 35,000 tons of sea products among which 15,000 tons of shrimps. This represents 60% of the deep sea fishing. Nearly 20,000 fishermen living in camps and in villages scattered all along the coast, from Campo to the Nigerian border, practise this kind of fishing.

Equipped with more than 26 trawlers and 12 shrimp boats, industrial fishing is practised by a few big companies Crecam, Cotonnec, Copemar, Chalutcam. Its logistic means enable that kind of fishing to have a wider area for fishing that extends over the continental shelf of about 8 to 50 meters deep.

The main species caught are hunchback fish, jaw fish, bass, sole, pike, small capitaine, sea carp, ray, grouper, the shrimps, crabs and crayfish. The production which can reach 20,000 t in a year still remains variable because of the inadequacy of a thorough knowledge of the environment and its fauna.

The products are essentially sold throughout the national market, either fresh or prepacked. The main preservation techniques are refrigeration for the industrial fishing and smoking for traditional fishing. The latter technique is related to another use of the mangrove swamp, firewood. In this respect *Rhizophora racemosa* is an excellent wood, cut into bits or turned into charcoal. *Avicennia germinans* is also exploited but in a lesser scale.

Between the fisherman and the consumer, there are intermediaries, wholesalers and retailers who come to get products either in the different fishing ports located on the continent or in the very scattered fishermen villages throughout the mangrove swamp. Most often the fish commerce is coupled with the traffic of other goods fraudulently imported from neighbouring countries, mainly from Nigeria. There are also many Nigerian fishermen living in the Cameroonian mangroves.

7. Conversion to Other Uses

The Cameroonian mangroves are exploited by picking. Very little improvements have been done to enhance the value of their products. Agriculture and aquaculture are almost inexistent. Industrial activities are mainly oil-producing in the Rio del Rey area. As far as urbanization is concerned, we can mention that towns such as Douala and Bonaberi are expanding at the expense of the mangroves. The case of the extended port of Douala is an example which has reduced the Creek of the Doctor's mangrove (SW). The same with the extension of the Bonaberi industrial park which constantly removes the mangrove limits of the creeks of Bombo and Bodjongo (Table 1).

Table 1: Present condition of some mangroves.

Silting in the Wouri estuary, at low tide in an important silt landform, upstream from the obstructed bridge, due to the extension of Douala port.	Some young *Rhizophora* growing in this silt. Their reflection on the water is clear. The mangrove swamp is extending.
Active sea erosion. Man O'WARBAY volcanic cone in the background. Collapsed trees testify to the quick retreat of the cliff.	Partial view of Mabeta, a fishermen village, huts on piling and roofs of braids or corrugated iron (a sign of prosperity!). Parts of the mangrove swamp (*Rhizophora samosa*) on the left.

8. Occupation and Exploitation Impact on the Mangrove Environment

The impacts from the occupation and exploitation of the mangroves are various: Among the most significant are over-exploitation, pollution, erosion, accretion.

8.1 Over-Exploitation

Although over-exploitation is not yet marked, it is mainly striking as tree felling. This occurs mainly around big villages and is seen as openings through the landscape of (mainly *Rhizophora*) formations. On the other hand storage of huge heaps of wood and/or charcoal in villages around huts indicates over-exploitation. These products are sold or used for fish smoking.

The cutting of old trees is one of the natural factors we can add to over-exploitation to complete the image of the mangrove forest degradation around the villages. The amount of dead trees that lay scattered on the soil and some other still standing, although dead and defoliated, are mostly all old *Rhizophora* (20 - 25 m high, 50 - 60 cm in diameter) that stand out clearly from the younger (8 - 12 m high) which are tightly packed and bear dark green leaves.

8.2 Pollution

Beside over-exploitation there are the risks caused by pollution. In Cameroonian mangrove estuaries there are numerous sources of pollution, urban areas, agricultural complexes, harbour, and oil extraction.

8.2.1 Pollution of continental origin

Upstream of many rivers flowing into the Guinean Gulf, there are big plantations of coffee, banana, vegetables, where thousands of tons of chemical fertilizers and other products are sprayed every year. It's quite probable that some residues (nitrates for instance) may reach the sea, however studies should be carried out in order to verify this hypothesis.

Pollution from urban areas is more obvious. It is due to two main sources : household refuse and industry. For many reasons related to uncontrolled growth, the urban communities find that it is impossible to collect household refuse in many districts (mainly the populated ones). Most of the time these household refuse are either heaped up by the road side and burned when necessary or thrown away in the nearby creeks. As soon as the first rainfall comes, it drains them into the estuaries waters. Such is the case of the Cameroon Mouths which are situated downstream from Douala and Bonaberi, a complex with around two million inhabitants that produces millions of tons of refuse the great part of which are carried to the Wouri mangrove swamp estuary.

The pollution of the "Bouches du Cameroon" by Douala, the first industrial city of the country is also caused by many factories: soap factories, dyeing (CICAM-SOLICAM), brewing industries (BRASSERIES DU CAMEROUN, UCB, GUINESS), ciment works (CIMENCAM), among many others. Most of the time, factories dispose of their liquid and solid wastes without any preliminary treating. In Bonaberi (a newly born industrial area), some spots of the mangrove swamp have been turned into a real garbage dump where all sorts of refuse can be found: bits and pieces of bottles, whole containers of spoiled products. At the bottom of Mount Cameroon, the latex factories developed in vast *Hevea* plantations dump their white foul waters in the Tiko mangrove swamp, the soap factories (TIKO SOAP) do likewise (Fig. 4).

8.2.2 Harbour pollution

We can add to this kind of pollution from the continent the one from the ports, mainly in the Douala Port, the most important owing to its trade. Three kinds of pollution can be mentioned: first throwing out into the sea of the refuse by ships in transit at the port. Second is hydrocarbon pollution; according to M. MONO MBOUM (1983) it is "spectacular and revolting". That kind of pollution can be presented in two forms: as accidental and resulting from any kind of leakage during ships refueling, hydrocarbon transport by sea or any kind of ship's operations: fishing boats, tanker freighter, any other harbour machine namely the supply-vessels used as a logistic support for off-shore oil-production or fields containing oil. M. MONO MBOUM mentions three accidents that happened in Cape Limboh oil terminal within four years time. One that occurred on September 2nd, 1981 led to nearly 25 tons of "fuel 3500" pouring into the sea and rapidly covering the littoral.

The "revolting" character of this type of pollution is because it is a "deliberate pollution" characterized by boats pouring out polluting products from oil change within the harbour. This kind of daily pollution is caused by trawlers, cargos or harbour machines. And it can be explained by the lack of a degassing or a dis-ballasting station in the Douala harbour.

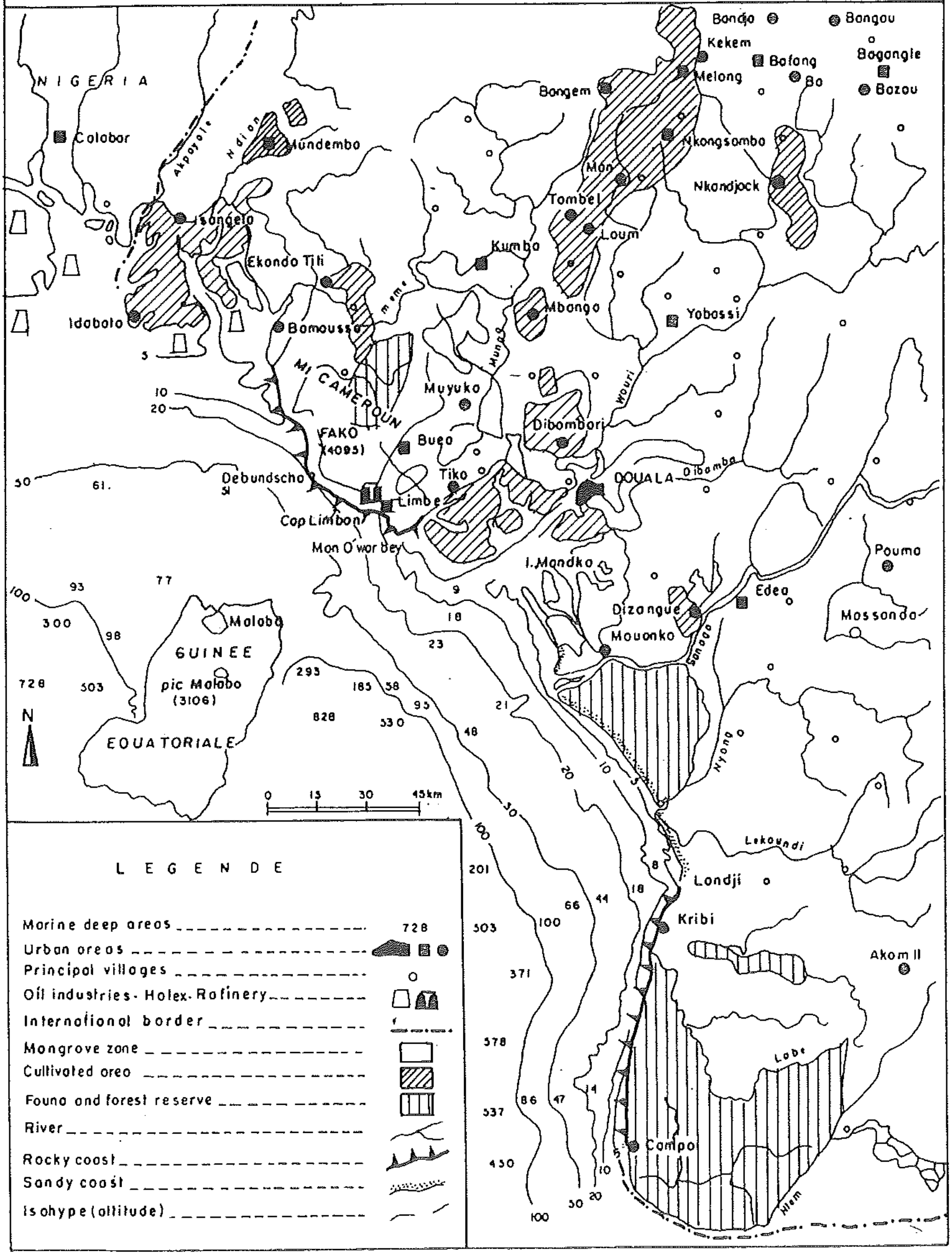
8.2.3. Silts raised by boat propellers

The third kind of harbour pollution is silt being raised by ships' propellers owing to the shallowness of the channel. This increases considerably the turbidity; though waters are naturally unclear by a strong continental erosion.

8.3 Erosion and Accretion

Erosion is also a remarkable and very generalized phenomenon all along the coast. An interesting synthesis of the present morphological evolution has been carried out by S. MORIN and *al. (op. cit)*. In general, the littoral is changing very rapidly. All along the Mont Cameroon coasts, there is a general coastal retreat (HORI, 1977; BATTISTINI and *al.*, 1983; ZOGNING and *al.*, 1986, 1989; MORIN and *al.*, 1989). Also in the Kribi region (HORI, op. cit;

FIG. 4 - SOME DATA ON THE ECOLOGICAL EQUILIBRIUM OF THE CAMEROONIAN COAST



KUETE, 1981, 1990), there is progradation in the mangrove estuarine complexes and some rapid accumulation and erosion phenomena in sandy shores. (GEZE, 1943; BOYE and *al.*, 1975; CROSNIER, 1964; MORIN and *al.* 1984, 1989; BOPELET and *al.*, 1986).

All these papers indicate that the general tendency to erosional phenomena is not new. In 1925 already, Th. MONOD mentioned that the Souelaba spit was threatened to destruction by the spring storms. During periods of strong spring tides, this spit used to be cut off allowing direct communication between the ocean and Malimba bay. In 1939, GEZE noticed that the Sanatorium built by Germans in 1913 and located 30 m from the ocean and 2 km South from the spit was totally submerged. The Buffles island which was navigable until the late XVIII century disappeared and is now shallow and covered with reefs.

Far in the South, in 1964, SEREPCA island was separated from the Malimba spit by channel. Ten years later, the oustide bar of Malimba lagoon was cut into sections by a multiplication of the same process and has become a free bar which still has the same width in the Northern part but is markedly reduced to the South. A channel 500 m wide, separates it from the mangroves. In the North of Sanaga, the Mbenga-Malimba lagoon has almost disappeared filled up by silt and ovegrown by mangroves protected the 1965 bar, the Northern part of which retreated for more than 3 km. Yet, a new free bar appeared 500 m offshore in the same direction than those of the Coconut Kombo (Fig. 5 and 6).

In that island behind the 1965 bars, the lagoon has been silted up. The outside external spit gathered and formed a single bar over 4 m long; the small SW hook detached at the level of the inflexion point disappeared in the mangrove swamp. The shallow parts of Sanaga Southern branch grow seawards and the SEREPCA 7 island is almost linked to the Malimba spit. Judging from the abundance of sand layers sedimentation appears to be intense in Sanaga.

Among the factors responsible for this shoreline evolution, the present general sea-level rise from 1,2 to 1,5 mm per year (PASKOFF, 1985) seems to be the most important factor as this tendency need to be related with the apparent tectonic variations over the littoral.

The Cameroonian big rivers supply great quantities of suspended matter, much silt (Kaolinite clays) and small grain sands. The Sanaga river brings about 6 million tons of materials in suspension to its mouth; but these vary a lot depending on the years, the quantity and type of rainfall in the upstream basin. The Landsat imagery of channel 4 shows turbidity of the waters over 14 km in the ocean and is then deflected towards the North West parallel to the Souelaba strip of land for 15 km, toward the Cameroon Mouths. Such turbid waters are recognized all over the Nyong and the Lokoundje mouths although they are only 1 to 2 km wide.

Important turbidity also characterizes the big mangrove outlets. These series of discharges are detectable in the ocean as far as about 30 km. That's the case in Bakassi peninsula open-sea and mainly in the Cross-River estuary. The Andokat creek creates a lot of sedimentation since it flows into the ocean between a double clayey-sandy submarine level 6 km long. All the Western area of the Rio del Rey is also full of large silt and sand layers which progress southwards, mainly in either part of the Mémé estuary.

The Cameroon mouths do not show an intense tendency of alluvial building save in their western part. There, filling is now happening in the medium and upstream parts of the estuaries. The Wouri river for instance is no longer navigable up to Yabassi, which served during the slave trade period as a port for the Western Highlands. Landings in the inner mangrove swamps cause the floods which inundate seasonally some areas which formerly were only exceptionally flooded. The Wouri river bed, its slope and its current speed, thus its competence are dwindling since the Bonaberi bridge was built in 1956; the situation worsens with the recent extension of Douala port.

The evolution of the littoral also depends on the quantity and quality of river discharge in relation to the frequency and the regularity of the littoral drifts. During flood periods, when the discharge is important, they can destroy littoral constructions, cut off beaches and spits; they can inundate or empty out the mudflats and the high mangrove swamps and flow into other new or old channels. Then the littoral drift is broken and the shore becomes eroded by the waves.

When a discharge is important but not violent, turbid waters are simply brought against the coast

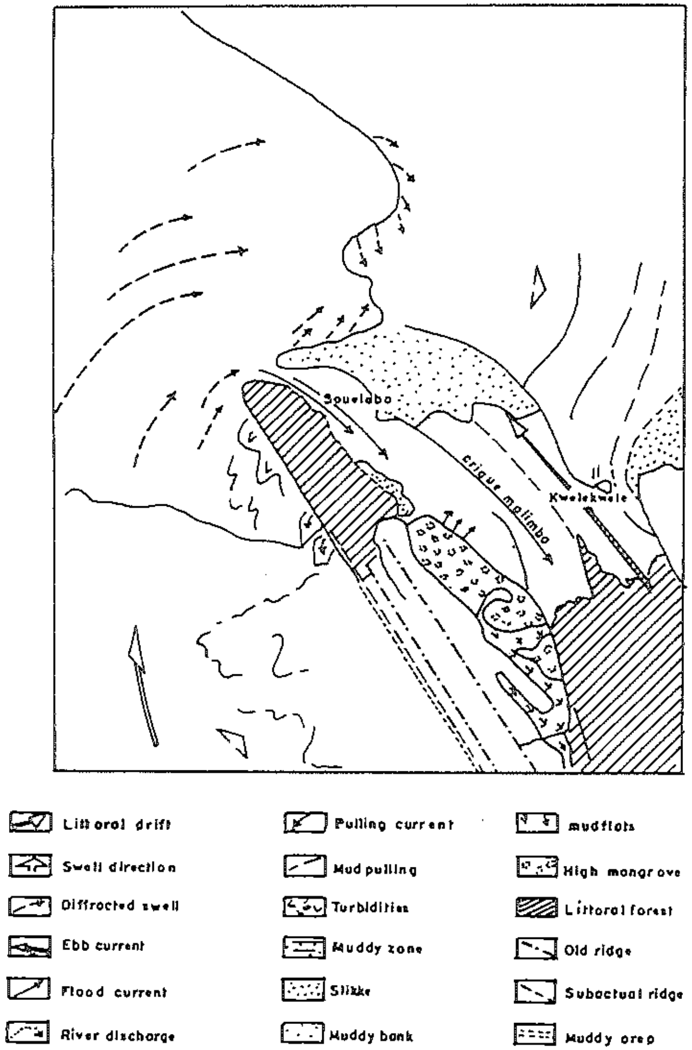


FIG.5 - SOUELABA POINT

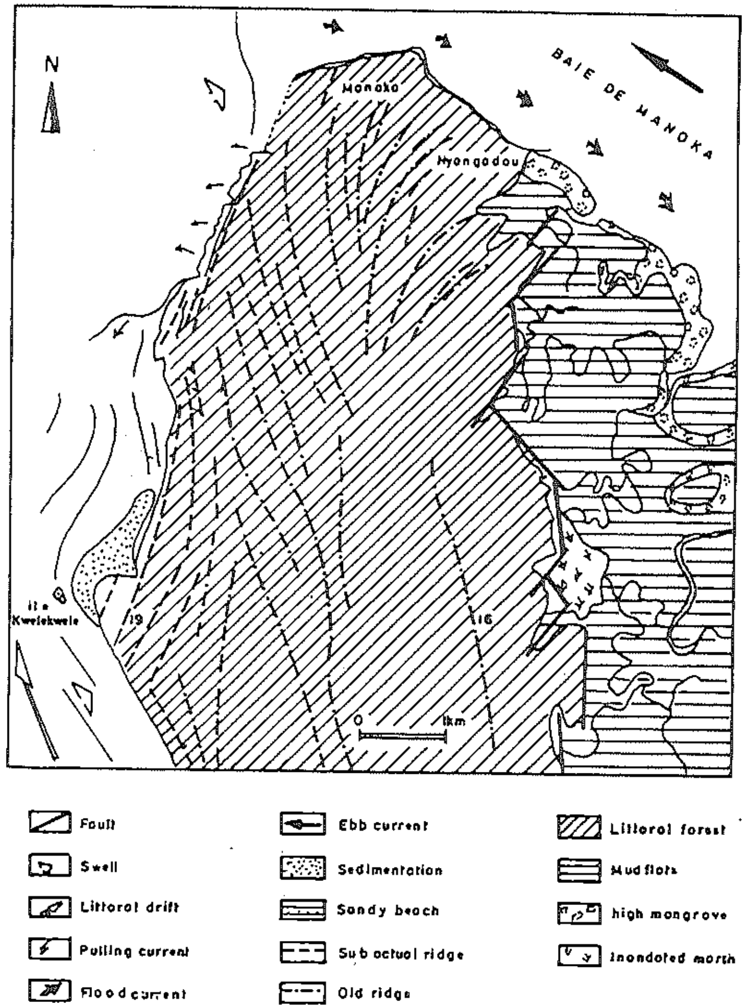


FIG.6 - MANOKA ISLAND

which accretes. Thus, the spits progradation of the Rio del Rey mangrove can be explained first because of materials brought by the Cross and the Akpa-Yafe rivers that are then swept away up to the Mont Cameroon base by the West-East litloral drift.

In the area between the Nigerian border and Bimbia creek, littoral currents can reverse, and depending on the case, they can be responsible for a sedimentation or erosion process over the concerned beaches as noticed around Bamusso. In the estuaries, the process of floodtide and ebbtide combined with the swells in the channels abutts to the same phenomena. Recently, Souelaba spit barred up the Southern part of the Sanaga delta which flows into the Cameroon Mouths. In the past, this river stopped flowing into the Mbenga creek from the South of Moulem island, where it would flow in the Mbenga-Malimba lagoon and then reach the Boungo branch in the deep South. As a consequence the Souelaba sandy spit no longer progresses because of a lack of feeding materials and the Mbenga lagoon has been silted in (Fig. 7 and 8).

Finally, water accumulation on the coast owing to the open sea swells and currents, often causes rip currents which run on the opposite direction of the drift and bring along enormous quantities of sand and silt.

9. National Committee and Management Policy

In Cameroon, marine sciences research in general, and that oriented towards the mangroves in particular are not yet well developed. As an explanation there is the inland location of the Yaounde University and almost no specialized research organism on the littoral area. Only recently organisms such as SRHL/IRZ, (Station des Recherches Halieutiques de Limbé/Institut des Recherches Zootechniques) and its Antenna located at Kribi which has to deal specifically with fishing problems were created. The necessity to set up a pluridisciplinary team for the study of the coastal ecosystems has been fulfilled in 1988 through the creation of EPEEC/Cameroon (Equipe Pluridisciplinaire d'Etudes des Ecosystèmes Côtiers). That team has different specialists (geographers, biologists, hydrologists, geologists) and it has set some research programmes focused mainly on mangrove swamp estuaries, especially those of the Cameroon mouths.

Encouraging results have been obtained so far with different scientific groups. But these efforts need to be maintained in order to extend observations in time and space and to give answers to all the questions raised so that anything related to the Cameroon mangrove area should be thoroughly known.

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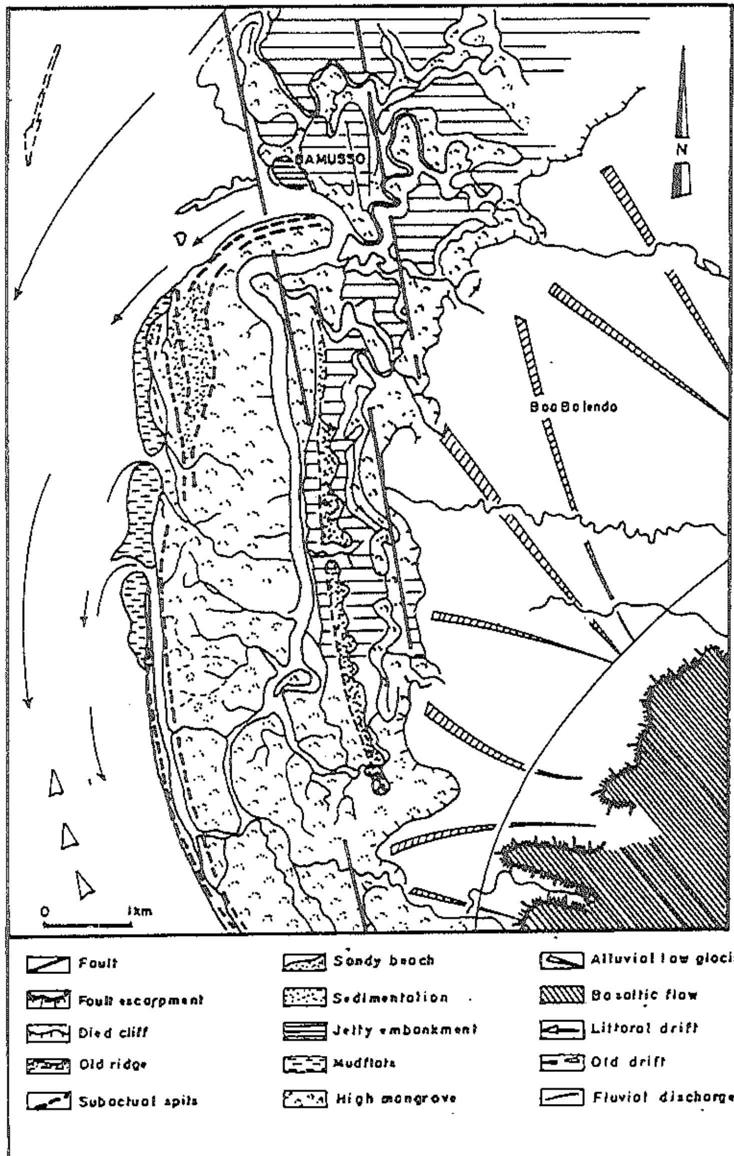

FIG.7 - -BAMUSSO SPIT

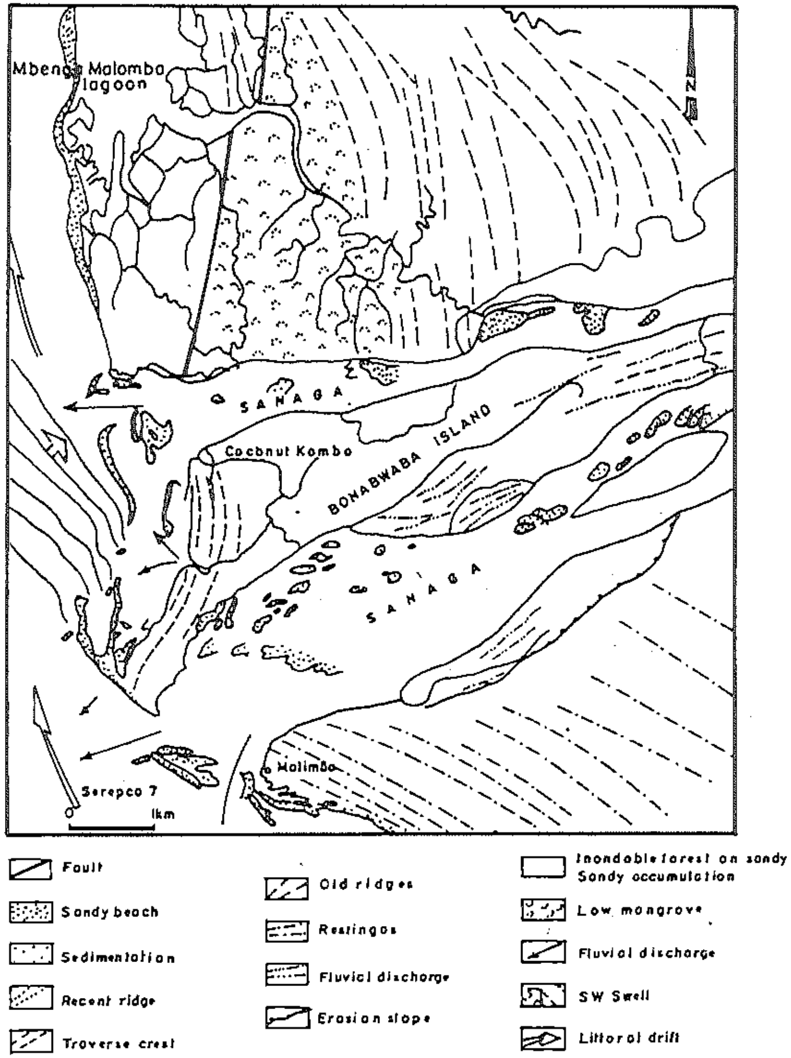

FIG. 8- THE SANAGA DELTA (From S. MORIN 1987)

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Mangrove Ecosystems of Tanzania

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1. Historical Background

So far very few published data are available on the mangroves of the Eastern Africa region. In tropical eastern Africa, mangroves have been described by Graham (1929), Grant (1938), Walter and Steiner (1936), Griffith (1950), MacNae and Kalk (1962), MacNae (1968), Isaac and Isaac (1968), McCusker (1971, 1975), Chapman (1977), Mwaiseje (1982), Semesi (1986, 1988, 1991), Cauto and Hatton (1990), Semesi and Howell (1992) and many others who have been listed in the UNESCO Bibliography on Mangrove research in the period 1600-1975 (Rollet, 1981) or those whose writings are not accessible to most of the people in the region. In 1986, a Proceedings of a Workshop on "Save the Mangrove Ecosystems in Tanzania" was published by the Faculty of Science, University of Dar es Salaam.

Records indicate that along with slaves and ivory, mangrove poles made up a major regional trade by the 9th century. The tree-less towns of Southeastern Arabia and the Persian Gulf, but especially Oman, Siraf, and Basra, all needed mangrove poles for construction. Somalia, Arab, Persian and Indian traders exploited mangroves, and it was not until 1898 in Tanzania (by then Tanganyika) when the colonial German administration established an ordinance dealing with mangroves, that a measure of control was effected over the forests, especially those of the Rufiji Delta. Under this legislation, merchants purchased wood directly from the forest administration. About 70-80 dhows from various ports called in to load mangroves from the Rufiji Delta in the Northeast monsoons of the late 1890's and early 1900's.

In the past, mangrove bark was also an important export and was used as a source of tannin. Mangrove bark has now been replaced by wattle bark as source of tannin in the country (Mbwana, 1986).

After the end of the German colonial era, the British expanded the mangrove reserves and after independence, the Tanganyikan and then Tanzanian governments maintained the reserves. However, the latter government did little to encourage the management and control of the utilization of the mangroves, and as a result, overutilization by commercial pole traders and use by a burgeoning coastal population as well as a number of other factors resulted in a serious threat to the long-term well-being of the mangroves.

Legislation governing Mangroves Forest Reserves is included under Forest Ordinance of 1957, published in 1958, FORESTS CHAPTER 389 OF THE LAWS (PRINCIPAL LEGISLATION) - Supplement 57, Part V. In the part dealing with the Protection of Forests and Forest Produce in Forest Reserves, the restrictions and prohibitions within the forest reserves are outlined as follows:

"Any person who in any forest reserve without a licence or other lawful authority:-

(a) Cuts, removes, has in his possession, sets fire to or damages any forest produce; or
(b) Clears, cultivates or breaks up for cultivation or any other purpose, any land; or
(c) Constructs or re-opens any saw-pit or work place; or
(d) Occupies or resides on any land; or
(e) Erects any building, shelter or livestock enclosure; or
(f) Grazes or depastures livestock, or permits livestock to enter therein; or
(g) Collects any honey, or beeswax, or hangs or places on any tree or elsewhere any honey barrel, hive or other receptacle for the purpose of collecting honey or beeswax; or
(h) Constructs any road, path, water course, tramway, or fence, or obstructs any existing road, path, tramway or water course; or
(i) Covers any tree stump with brushwood or earth or by any other means whatsoever conceals, destroys or removes such tree stump or any part thereof; or
(j) Damages, defaces, alters, shifts, removes, or in any way whatsoever interferes with, any beacon, fence, notice or notice board shall be guilty of an offence against this Ordinance."

Therefore the Forest and Beekeeping Division (FBD) of the Ministry of Tourism, Natural Resources and Environment is the institution empowered to manage the Mangrove Forest Reserves of Tanzania. The legislation imposes many restrictions on access to and utilization of these areas but it is rarely implemented. For many years the mangrove reserves received insufficient attention with respect to both biological investigation and management. As a result, there was little appreciation for the complexity and importance of this resource. Emphasis was placed largely on the harvesting of mangrove trees for poles and barks and not on the essential role of mangroves in supplying the basic needs of coastal communities or their important value to fisheries.

Ecological changes, uncontrolled exploitation by man, uncoordinated and insufficient institutional measures, inadequate policies and an unclear legal situation have all contributed to the present situation in which the survival of the mangrove ecosystem in Tanzania is in danger.

In order to halt this negative trend the University of Dar es Salaam organised a workshop titled "Save the Mangroves of Tanzania" in 1986. In 1987 the FBD took up the Workshop recommendations and initiated an inventory of all the mangroves of Tanzania which was completed in 1989 and a National Management Plan was prepared in 1991 (Semesi 1991). A Project for implementation of the management plan was prepared in 1992 and now the implementation has just started. All these activities have been carried out with the financial support of the Norwegian Agency for Development Cooperation (NORAD).

2. Mangrove Ecosystems: Extent and Distribution

According to the 1989 inventory, the mangroves of mainland Tanzania cover a total area of about 115 500 ha (Table 1). The largest area of mangroves is found in the Rufiji delta. Fairly large areas are also found in Tanga, Kilwa and at the estuaries of Ruvu, Wami, Pangani and Ruvuma rivers.

There are eight common species of mangrove trees which occur in mainland Tanzania (Table 3) and vegetation types of the mangrove forests are summarized in Table 2.

3. Physical Environment

The climate is hot and humid with an average temperature of 25°C to 30°C. Humidity is high throughout the year, up to 90% during the rainy season. It is influenced by two monsoon winds, one of which, the Northeast monsoon blows from October to March and the other, the Southeast monsoon from April to October.

The coast is washed by a Northward flowing current known as the East African Coastal Current. The water is poor in nutrients, especially nitrates and phosphates, and has a salinity of 34.5‰.

The soils of the coastal areas and of the islands are predominantly sandy and coralline with poor moisture-holding capacity, extreme alkalinity and a hard subsoil which results in poor drainage. The natural vegetation of the coast and islands was thicket and forest, but this has been greatly reduced by man.

In the Mangroves the soils are mainly alluvial, incoherent, superficial material mainly of sand, silt and clay resulting from the suspended sediment (Anderson, 1963). They are poorly or imperfectly drained and contain areas of saline or potentially acid sulphate soils. In the saline soils, irrigation development is only possible if extensive drainage works and leaching is carried out and in the potential acid sulphate soils, no drying-out can be tolerated without expensive chemical treatment. The muddy soils in the mangroves vary in salinity levels depending on the location. Some mangroves are also found growing on rocky areas having lots of crevices and ragged surfaces.

Deposition of sediments at the mid parts of the channels is increasing in both Rufiji and Ruvuma delta and these are colonized by pure stands of either *Avicennia marina* or *Sonneratia alba*. The sediments are blocking some channels and this has an impact on transport because bigger vessels can no longer pass through most channels in these deltas or passage is only possible during high tides.

The coastal area is valuable for its fishery, salts, limestone, and natural gas. Prospecting for petroleum is actively under way.

4. Biological and Ecological Characteristics

4.1 Flora and vegetation

The mangroves occur in more or less pure stands and whenever there is a mixed vegetation one species always dominates. The zonation is quite sharp and the species composition can change within little

Table 1: Mangrove areas in the administrative blocks in mainland Tanzania

BLOCK	Forested Area (ha)	Non-Forested areas (creeks, salt pans, bare saline areas) (ha)
1. Tanga and Muheza D.	9,403	3,528
2. Pangani D.	1,756	1,279
3. Bagamoyo D.	5,636	3,548
4. Dar es Salaam R.	2,168	1,045
5. Kisarawe D.	3,858	2,193
6. Mafia D.	3,473	892
7. Rufiji D.	53,255	14,357
8. Kilwa D.	22,429	14,308
9. Lindi D.	4,547	2,754
10 Mtwara D.	8,942	4,408
TOTAL	115,467	48,312

(D = District, R = Region).

distance. The list of plant species present is summarized in Semesi (1991). The dominant tree species are: *Rhizophora mucronata, Avicennia marina, Sonneratia alba, Ceriops tagal, Xylocarpus granatum* and *Heritiera littoralis. Bruguiera gymnorhiza* does not cover large areas while *Lumnitzera racemosa* is very rare and grows on the landward margin. *Derris trifoliata* and *Acrostichum aureum* are widespread in riverine mangroves.

The mangrove trees are under uneven pressure; the small-medium sized, well formed trees of the members of Rhizophoraceae are overexploited in the accessible areas, mainly close to channels and riverbanks, while the larger trees and deformed ones are left behind. This selective and incomplete removal results in the retention of over-mature residuals.

In areas where less water reaches, the vegetation becomes shorter, open and is dominated by stunted *Avicennia marina* or *Ceriops tagal*. The driest parts do not support tree growth only some halophytes such as *Suaeda monoica, Salicornia paclystichya* and *Arthrocnemum indicum* (Banyikwa and Semesi, 1986).

The vegetation close to villages is mainly composed of *Avicennia marina* and *Ceriops tagal* and most have a stand density of less than 50% and a stand height of less than 5 m. This is due to two main factors: the mangroves close to villages are flooded only twice a month because of the elevation and these areas are the main source of fuelwood.

The vegetation found in the intertidal zone close to the mangroves is mainly composed of seagrasses (Horril and Ngoile 1991) and some algae (Jaasund 1976). On the mud flats, mats of cyanobacteria (blue green algae) and of bacteria are common. Exactly which species of these micro-organisms are present is yet to be determined.

4.2 Fauna

The information on wild animals in the mangrove of Tanzania is limited. Crocodiles, alligators, hippopotami, snakes, monkeys, many birds like kingfishers, herons, eagles are reported. The area between the Rufiji delta and Mafia island for example contains large numbers of waders and terns during the winter in Northern Europe (Danish-Tanzania ICBP expedition to Tanzania from January-March 1988). The most numerous species counted were Curlew sandpiper, Little Stint, Crab plover, Roseate Tern, Lesser Black-backed Gull, Herring Gull and Caspian Tern.

There are many mosquitoes in certain mangrove habitats such as in the Rufiji delta. Sand flies, fire flies and many types of insects are also seen in the mangroves. Unfortunately it is not possible at present time to discuss the ecological role of animals in the mangroves of Tanzania because we know very little about them. Thus, there is an urgent need for improving the knowledge on small and big animals.

The studies on finfish of the area are few (Dorsey, 1979, Euroconsult, 1980, Atkins, 1981).

Table 2: The species composition and area occupied by mangrove trees in mainland Tanzania

Classification	Area (ha)	% of the total area
Rhizophora dominant, with *Avicennia, Ceriops, Sonneratia, Bruguiera, Heritiera* and/or *Xylocarpus*	55,549.9	49
Sonneratia - almost pure stands	1,223.3	1
Sonneratia dominant, with *Avicennia, Bruguiera* and/or *Rhizophora*	6,123.2	5
Heritiera - almost pure stands	91.2	0
Heritiera dominant, with *Avicennia, Bruguiera* and/or *Rhizophora*	8,188.4	7
Avicennia dominant, with *Rhizophora, Bruguiera, Heritiera, Ceriops* and/or *Xylocarpus*	17,141.6	15
Avicennia - almost pure stands	1,687.4	1
Mixture of *Avicennia* and *Ceriops*	17,432.7	15
Ceriops dominant, with *Rhizophora, Avicennia* and/or *Bruguiera*	8,037.9	7
Total Mangrove	115,475.6	100
Water in creeks	24,076.0	
Clear-cut areas	4,435.0	
Bare, Saline areas	20,740.0	
Salt Pans	3,093.0	
Non-Mangrove Forest inside the reserve	5,069.3	
Total Reserve Area	172,888.9	

Several species of molluscs and crustaceans are found such as the edible snail (*Terebralia* sp.), the crabs *Sesarma* sp., *Scylla serrata, Uca* spp., *Ocypode* sp; other common molluscs are *Cerithidea decollota,* and *Nerita* sp. It is however, believed that the molluscs and crabs are similar to those reported by MacNae, 1963 and 1968.

4.3 Community stability properties: zonation, succession, accretion, erosion

Community description of the mangroves of Tanzania have been provided by Walter and Steiner (1936), Grant (1939), McCusker (1971) and Semesi (1986).

4.4 Interactions between biotic and abiotic ecological factors

Studies on the interaction between biotic and abiotic ecological factors have been carried out especially in conjunction with the over ten year trial plantation of *Rhizophora* and *Bruguiera* in the Rufiji delta during the German and British rule. It was found that *Rhizophora* could not grow well in *Avicennia* zone but also hippos, monkeys and crabs destroyed seedlings (Grant 1938, 1939).

Natural regeneration of mangroves is not taking place in most abandoned rice farms which were former mangrove areas in the Rufiji delta. Such farms are overgrown by grasses, sedges, *Acrostichum* which hinder natural regeneration.

A red polychaete worm, important to fishermen as bait, is found in the mangroves. These worms are dug from the soil at the bases of mangrove roots in such a way that the latter are cut and damaged, thus creating holes and changing the drainage patterns. At sites where digging is intense, both old and young trees are destroyed, because when the holes are filled with standing water, conditions are unsuitable for mangrove growth and survival.

4.5 Productivity, energy flow; trophic relationship, nutrient cycling.

There are no reported studies which assess the productivity or nutrient recycling of the mangroves of Tanzania. Preliminary work is now underway to monitor leaf litter fall and the rate of degradation of these at selected sites in Zanzibar.

5. Mangrove Related Ecosystems

Mangroves, coral reefs and seagrass beds are among the most productive of coastal habitats, and provide the majority of the fish caught by many local people. There is a close inter-relationship between mangroves, coral reefs and sea-grass beds in terms of fauna, nutrients, and environmental protection (Hamilton and Brakel, 1984).

5.1 Coral reefs

Coral reefs grow where the marine waters are clear, warm, and free from suspended sediments, excessive freshwater runoff and pollutants (Talbot 1965, IUCN/UNEP 1985, Wells 1988). Hence they are not found adjacent the main river mouths which apparently are the areas with extensive mangrove vegetation. For example in Tanzania, Rufiji river delta has 53,254 ha, Ruvu river 2,123 ha, Wami river, 862 ha, Ruvuma river 6,207 ha, Pangani river 753 ha i.e 55 % of all the mangrove area in the country. However, in other coastal areas such as around island coral reefs are found quite close to the mangroves and in certain sites coral heads can be found in between mangrove roots. But the most common arrangement is that mangroves are separated by seagrass beds from coral reefs.

5.2 Seagrass beds

Unlike the coral reefs which have an intrinsic aesthetic value, seagrass beds are not usually regarded as needing protection and may even be considered as a nuisance to swimmers and boat users. Seagrass beds like mangroves are highly productive ecosystems which provide substantial support grounds for marine fauna and are heavily utilized by artisanal fishermen. They also are sediment traps, preventing organic matter and nutrients from being washed out into the deep ocean by tidal currents. Seagrass habitats are important feeding grounds for dugongs (*Dugong dugong*) and sea turtles - all species considered threatened or endangered in the Eastern African region.

The sediment trapped by seagrasses and mangroves ensures the survival of coral reefs which cannot withstand turbid waters and high levels of sediments. The coral reefs in turn reduce the severity of wave action and hence protect the mangroves from being uprooted.

5.3 Mudflats

There is no information on the extent of mudflats in Tanzania but the aerial photographs taken in 1988/1989 used for the inventory of mangrove forests can be used to map the extent of the mud flats adjacent to the mangroves as they were taken at spring low tides. This is an area which needs immediate attention. The organisms which reside in the mud flats are also not well recorded and studied. Birds, crabs, molluscs, bacteria and filamentous algae are common in such habitats.

On intertidal mud flats and the low sublittoral in front of the mangroves of Bagamoyo for example, there are rich seagrass beds with numerous small fishes, sea cucumbers and other invertebrates. Many fishermen dive to collect sea cucumbers for the export market. Others collect algae, mainly *Laurencia papillosa* and *Acanthophora spicifera*, for use as bait in fish traps.

5.4 Pelagic Community

The pelagic community is the one which benefits most form all the related mangrove habitats. The animals of reef, seagrass beds, mud flats and mangroves may use one or more of these at one time or stage of their lives, either for resting, feeding or reproduction. The biomass of the algae and bacteria together with the detritus produced by mangroves and seagrasses supports a wide variety of animals.

5.5 Supratidal community

Many oysters and barnacles are attached to the stems of the mangroves growing on the seaward side especially in areas where freshwater influence is small. Besides insects such as fire flies, mangrove snails, birds, small mammals such as bats, monkeys and lichens form part of the supralittoral community.

6. Human Habitation and Traditional Mangrove Usage

The economy of the coastal people combines fishing, agriculture, trade and handicrafts. Most women and men are farmers, and the main food crops are rice, sorghum and cassava. Since colonial times cashewnuts have been an important, and sometimes the only, cash crop. Due to fungus disease and low government prices, the neglect of the cashew plantations has resulted in a considerable decline in production. Coconuts are slowly becoming an alternative cash crop.

Most men in the coastal areas are fishermen. Apart from intertidal molluscs which are collected by women and children, fish is the main source of protein. Fish and prawns are also an important source of income not only for fishermen but also for many people engaged in their processing and trading (Von Mitzalaff 1989).

Opportunities for employment and other income generating activities not related to fishing are few. Of these the more important and more lucrative are occupations such as cutting mangrove poles, making salt, burning of lime and the skilled trades of house- and boat-builders, all of which are associated directly or indirectly with mangroves.

The direct uses of different mangrove species in Tanzania are summarized in Table 3.

Coastal communities use mangroves on a small scale to supply local needs for fuelwood, fences, house construction, boat building, for fish traps and medicine. A herb, *Sesuvium portulacastrum*, grows on sandy portions in the mangroves and is eaten as a vegetable.

7. Commercial Exploitation and Marketing

Most coastal village communities use mangroves in a sustainable manner for local needs and it is mainly commercial activities which over-exploit the mangrove resource.

At a commercial level, mangroves are an important item of trade and a source of employment and income for the coastal communities. Mangrove poles are cut for both the export and local markets. Poles are sold in quantities called scores; one score is equivalent to twenty poles. Prices and royalty paid to the government vary according to the quality and size which are expressed as classes ranked I to V (Table 4).

Currently most pole cutting is done illegally and the royalty fees collected in 1988, about 10 million Tsh, are less than half of the actual amount of revenue due to government. It is estimated that royalty fees are not paid on more than 50% of the poles harvested.

Mangroves are cut for the domestic fuelwood market, and there is a demand for commercial fuelwood for the production of salt, lime and processing of fish and coconut oil.

Mangroves are the source of raw material for artisans and boat-builders. Fishermen use mangroves to make traps and floats for fish nets. Some species are used as animal fodder, others for local medicine.

Table 3: Direct uses of the mangrove tree species in Tanzania and their names in Kiswahili (shown in brackets)

Species	Uses
Avicennia marina (*mchu*)	Inferior firewood, but used for boiling of brine, fish smoking and production of lime, building dugout canoes and beehives; leaves used as goat and cattle fodder; branches support beehives
Bruguiera gymnorrhiza (*msinzi* or *mshinzi*)	Good firewood; used for fish smoking; fishing stakes; poles.
Ceriops tagal (*mkandaa*)	Good firewood; poles; fishing stakes; fence posts.
Heritiera littoralis	Good firewood; timber for boat-*msikundazi* or *mkungu*) building; furniture; dhow masts.
Lumnitzera racemosa (*mkandaa dume*)	Good firewood
Rhizophora mucronata (*mkoko* or *mkaka*)	Good firewood; poles; fence posts; fish traps; fishing stakes.
Sonneratia alba (*mlilana* or *mpira*)	Inferior firewood; commonly used in boat-building; pneumatophores used as fish net floats.
Xylocarpus granatum (*mkomafi*)	Good firewood; used for fish smoking; boat-building; making furniture. The seeds are used to treat stomach problems and the fruit pulp to cure rashes.

Only rarely, however, are bees kept in the mangroves (Semesi 1991, 1992).

Aside from these direct uses, mangroves have many other indirect uses and values. The mangrove ecosystem includes a unique flora and fauna. Fisheries, and the prawn fishery in particular, depend on the mangroves, which are important in providing nutrient-rich waters as well as suitable breeding and nursery grounds, it stabilizes the coastline by preventing erosion; it prevents siltation of coral reefs by trapping sediments; it builds land through accumulation of silt and detritus; it preserves the purity of the coastal water by absorbing pollutants and it acts as a windbreak for the agricultural hinterland.

7.1 Potentials of mangroves

In 1989, 15.9 million Tsh were collected as royalty fees from the export of prawns worth 929.2 million Tsh obtained in areas near the mangroves. In terms of revenue, but also in terms of income and employment, this particular resource has not yet been sufficiently evaluated and developed.

Similarly the potential of the mangroves for tourism, for commercial honey and beeswax production and for aquaculture has not yet been realized in Tanzania.

8. Conversion to other Uses

8.1 Agriculture

Clearing of mangroves for rice farms takes place only in the Rufiji delta. Clearing started in late 1960s and is still going on despite the issuing of a directive to stop all activities in the mangroves in 1987 by the FBD. Most farms occupy former mangrove forests which had either *Heritiera littoralis* or *Avicennia marina* or *Rhizophora mucronata* forests. The farms are located near river channels and most have no marginal trees left, thus erosion is prominent. Farms cleared from mangroves show an increase on yield from year 1 to 3 and then show a decline. At the 7th year the yields are so low and the farm is so much invaded by grasses, phragmites and sedges that working the farm becomes a problem. The farmers therefore abandon the farm and move to another site.

The villagers staying in the Northern delta now prefer to cultivate in the mangroves because they believe the area is fertile, is less visited by wild animals, has got fewer weeds in the initial five years and it is the nearest land for agricultural expansion. They are now all out to pressurize the government to allow them to cultivate in the mangrove area. Mangroves being forest reserves, are protected from human encroachment, however, in this situation we find that the laxity of the law reinforcement has changed the attitude of the villagers towards the resource. Now they believe that they have the right to clear and cultivate in the mangrove reserves although quite a number of villagers do not support clearing the mangroves for rice cultivation.

There are serious doubts concerning the long term viability of converting the mangrove areas of Rufiji for agriculture. Good agricultural lands reclaimed from mangrove areas through- out the world are rare (Bacon 1975, Blasco 1983), mostly failures have dominated the scene. Abandoned farms in the Rufiji confirm this.

Another problem related to the farms in the mangroves is the presence of a *Sesarma* crab (locally known as Koe) which cut the young rice seedlings and to kill these farmers use D.D.T. Since the dosage used is high due to regular flooding of the farms, the effect of D.D.T. on other aquatic organisms such as fish and prawns is therefore assumed to be bad. This could also be one of the causes of the observed reduction in both fish and prawn catches in the Northern delta.

The farms in the delta are also expected to face other problems in the future because of development programmes upstream. The building of planned dams, increased diversion of fresh water for rice irrigation and the natural changing of river courses all will have a negative impact on the area.

8.2 Salt and brackish water ponds

Records show that salt ponds were started in the early 1930s (Sutton, 1973) but these did not significantly reduce the mangrove vegetation even as late as the 1970s. In the past 10 years, salt works have expanded and in 1989 there were 3,100 ha of solar salt pans in the mangrove areas. Majority of the pans are not properly sited or constructed due to lack of capital and knowledge. The mangroves most affected in this respect are those of Bagamoyo, Dar es Salaam, Tanga, Mtwara and Lindi areas.

The efficiency of salt production by solar evaporation in the mangrove areas is low and could be much higher if properly sited and expanded on the bare saline areas. An evaporation pan of about 30 m

Table 4: Royalty charged per score for different classes of mangrove poles in 1991 (Source FBD)

Class	Description and royalty
I	Poles over 20 cm diameter at butt and not more than 30 cm diameter at 1.3 m above ground - 600 Tsh/score or pro rata
II	Over 15 cm and not more than 20 cm at butt - 400 Tsh/score or pro rata
III	Over 10 cm and not more than 15 cm diameter at butt - 320 Tsh/score or pro rata
IV	Over 5 cm and not more than 10 cm diameter at butt - 180 Tsh/score or pro rata
V	Not more than 4 cm diameter - 80 Tsh/score or pro rata (Logs, including all poles over 30 cm diameter at 1.3 m above ground, were charged 60 Tsh/ m^3).
	(Logs, including all poles over 30 cm diameter at 1.3 m above ground, were charged 60 Tsh/ m^3).

x 30 m can yield about 2.5 tons of salt during one evaporation cycle which lasts for about three weeks in the dry months. In some places mangrove wood is used for fuel, for the production of salt by the boiling method. This latter method is undesirable, because it uses large amounts of fuelwood (Semesi 1988).

8.3 Aquaculture

Although certain individuals have already submitted proposals for the establishment of prawn aquaculture ponds in selected estuaries within or close to the mangroves there are not yet aquaculture ponds in Tanzania because the government is hesitant to lease the area for the purpose. However, a possibility of using solar evaporation ponds for the aquaculture of fish and algae needs to be explored especially considering that salt production is a seasonal undertaking.

8.4 Mining

So far no mining for minerals or drilling for oil takes place in the mangroves of Tanzania.

8.5 Coastal development

Only the mangroves found near Dar es Salaam town, the largest town in the country are being filled for house construction. Near most towns mangroves are used as dumping places by neighbouring residents and that of Msimbazi river in Dar es Salaam receives most of the untreated industrial wastes. A small mangrove stand which used to be on the Southern part of the entry to the harbour no longer exists because of oil pollution. In Tanga town a small stand of mangroves has also been killed by wastes originating from a fertiliser factory.

9. Impacts on the Mangrove Environment

9.1 Human induced stresses

The destruction of large areas of mangrove forests is caused by businessmen and women who usually come from inland. They pay local people to cut mangroves to be used as fuel for boiling brine to produce salt (e.g. Tanga), to produce lime (Bagamoyo, Lindi, Mtwara) and for the drying of fish (Pangani). They exploit the resource without regard for its survival or reproduction and communities most affected are not remunerated for loss of their resource. Almost none of the profit gained from these business enterprises remains in the villages.

This is similarly true for construction of salt pans for solar evaporation. Pans are often constructed within mangrove areas involving the total clearing of the forest. But in many cases, it would be possible to construct them behind vegetated mangrove areas on bare saline patches. For reasons related to the procurement of loans with which to fund salt pan construction, entrepreneurs are often encouraged to construct much larger pans than they would actually ever expect to have in operation. Local District or other regulations may also require a rectangular shape for the pans, thus causing mangrove trees to be needlessly felled, when simply by permitting a triangular or other shape, the pans could be constructed behind the mangrove vegetation on bare, saline areas.

The demand for domestic fuelwood endangers mangroves in areas near large villages and towns. If the inland fuelwood source, often coastal forest, is already exhausted, people turn to mangroves as a second choice. What was originally a small scale domestic use at a village level grows with increasing village size and proximity to towns, into a commercial or semi-commercial cutting pressure on the mangroves.

Cutting of poles, if done on a large scale and in an unplanned manner, can reduce the genetic pool by removing all trees with straight trunks, leaving behind only badly-formed stems unsuitable for regeneration of mangroves harvestable as poles in the future.

Agricultural activities within Mangrove Forest Reserves take place in the Rufiji Delta, where shifting cultivation for rice growing is a serious threat to the mangroves.

Mangroves are also endangered by oil and industrial pollution, by excessive siltation due to man's degradation of catchment areas, by herbicides and insecticides coming from inland via rivers and construction of dams or major irrigation schemes. The close linkage between mangroves and upland watersheds through river systems means that activities even 100 km upstream can affect the mangrove ecosystem. Such activities as petroleum prospecting, oil pollution from ships, the dumping of garbage and sewage and various types of industrial chemical pollution in the estuarine environment also have direct negative effects on mangroves.

Currently the fishermen block most of the small channels with wooden stakes (uzio) so that fish are stranded during low tides. This practice should be regulated because it is known to have a negative effect on fish productivity.

Speeding boats cause river bank erosion and kill mangroves.

Excessive lime production and shell collection is detrimental to the reef and related ecosystems.

9.2 Impact of natural stresses

Though the main threat to mangroves comes from human activities, there are also natural factors which can affect this dynamic and constantly changing ecosystem. These include:

- River floods which may cause considerable areas of mangroves to die as a result of alteration of water level, bank erosion and diversion of water courses. Mangroves cannot tolerate prolonged inundation by fresh or salt water and will die. Such flooding occurs regularly in some parts of the Rufiji delta.
- Sand deposition from sea and land which can cut off portions of mangroves from salt water causing them to die. This problem is pronounced in most parts of Bagamoyo District.
- The predicted sea level rise due to global warming may flood present mangrove areas. They would, however, be expected to colonize new land, the extent of which would depend on local topography.

10. Socio-Economic Implications

The consequences of the mangrove destruction are:

a) decreased production of firewood poles and timber which leads to less revenue paid to government from royalties
b) decrease of fauna and flora associated with and/or dependent upon mangroves with an observed decrease in fish and prawn catches
c) increased coastal erosion which may have very negative effects on buildings such as dwellings in villages as well as hotels
d) increase of siltation of coral reefs, with resultant reduction in productivity of fish, and reduced tourism.

All these will affect local people because their income will be reduced. Their economic security and "pension" in the form of wood products as well as other values of mangroves will be lost or greatly reduced.

Women are the most affected when the nearby mangrove resource no longer suffices for the needs of the community. It is they who must cover longer distances in search of firewood and who must spend more time searching for molluscs, crabs and mangrove plants upon which they and their families depend. Less labour and monetary assistance will be available to them from husbands and sons, who themselves will tend to travel further from home in search of fish, building poles, other employment opportunities.

11. Research and Training Programmes

All the management activities are carried by the FBD and hardly any training on mangroves is offered to the foresters who are given the duties to manage the resource. Most of the research conducted on the mangroves of Tanzania have been by University staff and the colonial foresters. Research programmes on mangroves never existed as such the choice of the problem was always governed by individuals' interests and as a consequence research had been on an ad hoc basis and with very limited funding. Plans are however under way to establish a mangrove Research and Training Centre which is hoped to be able to carter for the region as well.

12. National Mangrove Committees - National Policies for Mangrove Management

12.1 Policy Issues

There are no National Mangrove committees in the country.

The major obstacle which has hitherto prevented rational use and conservation of mangroves in Tanzania has been a management policy which consists of controls and prohibitions without having the means and capability to carry these out. It has not considered the traditional interests of people in their resource or their involvement in its management. In addition, the policy does not reflect the complex nature of the dynamic ecosystem and the need to involve several governmental and non-governmental bodies in decisions concerning its management. No overall authority exists which effectively coordinates conflicting issues such as salt licenses and land titles which concern the Division of Forestry, the Division of Lands and the Ministry of Water, Energy and Minerals simultaneously.

12.2 Institutional Issues

The mangrove ecosystem is dynamic and extremely complex. Biologically, it is linked with terrestrial and aquatic ecosystems often distant from it. Policy and legislation related to the mangroves have largely been an attempt to manage and control the resource as if it were similar to that of a terrestrial forest reserve. Detailed ecological and managerial knowledge of the mangrove ecosystem and technologies relevant to it are often inadequate, widely dispersed and of difficult access. In some cases where specialised knowledge exists, for example, in fisheries, forestry or wildlife, there are no effective institutionalised channels of communication established to convey this information as it relates to mangroves.

Because there has been little appreciation of the specialised nature of mangroves and their management, there is a lack of adequately trained field and management personnel. Furthermore, the lack of transport and general infrastructure greatly hampers patrol and management efforts.

12.3 Legal Issues

Despite the terms of the Forest Ordinance, the present legislation and level of enforcement does little to manage or conserve mangroves. Licenses for the cutting of poles and for the construction of salt pans continue to be issued by local Authorities without the knowledge of the Forest Division. Not surprisingly, the users of the mangrove resource, especially villagers, are confused about the actual legal status and their rights. The situation is aggravated when villagers who are denied their traditional rights of access to mangroves for small local uses see wealthy merchants and middlemen issued licenses to cut large quantities of mangroves and operate salt pans.

Villagers are also not happy with the current approach of issuing licenses because only those with big capital qualify as the minimum requirement is stipulated at 10,000 scores which is done at the district level.

12.4 Rehabilitation

Mangrove species fruit and seed abundantly and germinate readily. The great majority of seedlings seen in most mangrove communities do not survive to be recruited to the tree layer but are eliminated by competition after one or two years' growth (Haig *et al*, 1958; McCusker, 1975). In spite of the impediments due to environmental factors such as tidal currents, nature of the substrate, inundation class, and water salinities, seedling establishment is an obviously successful process in the majority of mangrove forests in Tanzania. In other mangrove areas, natural regeneration is deficient due to variable known and unknown causes. Of the factors known to affect regeneration are:

1) Clear-felling of large areas which leads to poor regeneration possibly due to alteration of soil and microclimate and also due to few seed bearing trees being left in the plot to act as seed source.
2) Weed competition e.g. *Acrostichum aureum, Derris trifoliata* might overgrow the area and prevent seedlings establishment.
3) The slash (wood left behind after felling an area) if it is too much, can interfere with the dispersal of seeds; natural regeneration can effectively take place only after the slash and most of the stilt roots of the felled trees have decayed .

4) Monkeys remove seedlings and crabs feed on seedlings.
6) Poor drainage due to deep flooding or to poor tidal flushing also prevents mangrove regeneration.
7) If the site is overwashed by strong tides, seedling establishment is poor.
8) Insect attack such as borers and caterpillars are known to interfere with regeneration.

Natural regeneration has been the practice in the country and selective tree cutting is done. Only illegal cutters do clear felling. In Tanzania, mangrove planting was carried out in the Rufiji delta (Grant, 1938) with the aim of expanding the area covered by *Rhizophora* trees but most of the trial experiments were not successful after the tenth year because of wrong site selection. Currently regeneration of heavily cut areas is being practiced in Pangani District.

12.5 The National mangrove management plan

In 1991, a mangrove management plan was prepared (Semesi 1991) whose purpose was to identify a programme with objectives and strategies in order to assist the government in its endeavour to rationally use and conserve the mangrove resource of Tanzania. The plan is based on extensive field work in the mangroves and the surrounding communities dependent on them. Aerial photography especially commissioned as part of the study enabled assessment of their status on mainland Tanzania. Discussions with many individuals and representatives of organizations led to the recommendations presented. An outstanding contribution was made by participants of a Mangrove Workshop held in August 1989 at Dar es Salaam; composed of policy makers, scientists and coastal Regional Development Directors.

Long Term Objective of this management plan is to enhance the contribution of mangrove ecosystems to the economy of the country by rational utilization of mangrove ecosystems on a sustainable basis.

12.6 The Short term objectives are:

- Conservation of mangrove areas which serve protective functions such as windbreaks and barriers to erosion.
- To maintain a habitat for the fauna and flora of this unique ecosystem.
- The optimization of a combination of direct and indirect uses of mangrove areas
- Recognition of the needs of communities living in and depending on mangrove environment.
- Management of representative areas for biodiversity, tourism, research and education.
- Improvement of institutional capabilities of the body responsible for mangrove management.
- Identification and planning of research activities.

12.7 Management strategies

The strategies to achieve the above mentioned objectives are geared towards the institutional as well as the operational level. A multidisciplinary approach was adopted and the mangroves are zoned for various uses rather than emphasising wood products alone, as was done in the past. The plan provides background information on the coastal areas of Tanzania, social and economic aspects of the coastal residents and users, and coastal land use problems.

12.8 Institutional Strengthening

First and foremost the capabilities of the FBD will be strengthened and enlarged. A new section within the Division will have the overall authority for the management of the mangrove resource. The number of field staff will be drastically increased, mostly to be recruited from coastal villages and will be provided with appropriate training in matters concerning mangroves, such as management, extension work, harvesting. Their equipment, transport and other infrastructure will be improved. Specialized training in management of mangroves for senior staff will also be provided.

12.9 Increasing inter-sectoral coordination

The governmental institutions directly or indirectly involved in issues concerning mangroves will be coordinated as a special team within the FBD.

12.10 Involvement of the Coastal Communities

The beneficiaries of commercialized exploitation e.g. of the mangrove poles as was seen by Von Mitzlaff (1989) or prawn fishery are often outsiders, not the local people whose habitat is being destroyed. Therefore people participation in decision making should be encouraged in the future.

The participation of the coastal villagers is of paramount importance for the success of the management of the mangrove resource. Only if it is an asset to them they will defend it against illegal exploiters. A combination of approaches will be used to encourage their participation. The first need will be a public awareness campaign concerning the new approach to management of mangroves in selected pilot areas. Such a campaign will involve presentation of general knowledge about the need to conserve mangroves and the methods which will be adopted, as well as the supply of information about specific issues, not only forestry, but wildlife, fisheries, beekeeping. It is crucial that the members of the local communities have a clear understanding of their rights as well as their responsibilities under the pilot scheme.

12.11 Limitations for Village Participation

Although the present management plan recommends that villagers be given direct access to certain defined mangrove areas, under the present legal system, this would not be possible. Rather, licences or permits would be issued for the use of the resources in selected areas. However, the entire Forest Ordinance is now under review by the government, and it is possible that the new legislation will permit more direct community participation in forestry.

12.12 Zoning as a Management Strategy

The mangrove forests under discussion are vast in area, scattered along 800 km of coastline and of very different qualities. For the purpose of management they have been categorized into four zones:

Zone I Forests which will receive total protection.

Zone II Forests which will be put under production. These are ecologically stable areas with sufficient regeneration potential to permit controlled harvesting.

Zone III Degraded areas which will be closed from cutting for periods of varying lengths to allow recovery and rehabilitation.

Zone IV Areas which will be set aside for development of different types.

Functions and uses permitted in the four zones are summarized in Table 5

Table 5: The four mangrove management zones and their functions and uses

Zone	Function	Use Permitted	Users/Beneficiaries
Zone I	Windbreaks	Research	Scientists/students
Totally Protected	Prevent erosion	Training	FBD Personnel
Forests			Fishermen, from nursery function;
			Villagers, from erosion protection
Zone II	Supply mangrove	Poles	Villagers/Outsiders
Productive	products	Fuelwood	Villagers
Forests		Beekeeping	Villagers/Outsiders
		Timber	Villagers/Outsiders
			Fishing Fishermen/Women
			mollusc gatherers
	Other local Villagers uses		
	(crafts, medicine)		
Zone III	Future supply of	Beekeeping	Villagers
Forests	wood products	Research	Scientists/Students
Requiring		Training/	Personnel
Covery		Demonstration	
Zone IV	Aquaculture	Research	Scientists/Students
Development	Salt	Training	FBD Personnel
Areas	Production	Fishing	Fishermen
	Recreation	Beekeeping	Villagers/outsiders
		Tourism	Tourists
		Fuelwood	Villagers
		other local uses (crafts	Vilaggers
		medicine)	
In defined areas:		Solar salt	Villagers/Outside
		Production	Investors
		Aquaculture	Villagers/Outside
			Investors

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Mangroves of Kenya

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1. Historical Background

Mangroves are plants of significant value to the coastal communities on the semi-arid Kenya coastline (Fig. 1). They stand against a background of semi-desert steppe, or sand dunes, but rarely they border tropical savanna forests. Their presence is conspicuous because their canopy is outstanding against the dominant low scrub vegetation. The communities living in the vicinity of the mangrove forests have a long history of being known as non-farming communities that have depended mostly on fishing and cutting of mangroves for sale. Other activities are boat building and making fishing gear for sale. These age-old activities are clear manifestations of the mastery that the communities have developed to exploit the aquatic resources around them. However, historical evidence of the methods used to avoid over-exploitation are not known except for portions of mangrove forests that are used as shrines or sacred forests where exploitation is forbidden.

Around all major mangrove forests are big fishing villages. In a semi-arid coastline like that of Kenya, the success of such settlements is due to adequate availability of freshwater even in shallow wells or boreholes around mangrove forests. Due to the good organizational structures of the fishing villages, the latter became trading centres, then urban centres and administrative centres thereby attracting higher numbers of immigrants which come in search for employment. Urbanization has contributed to degradation of the mangroves due to poor sewage and solid waste disposal besides pollution from industrial wastes, increased sediment load deposition from rivers resulting from poor farming methods in the catchment areas, dredging of harbours and dumping such sediments in mangrove forests, salt and prawn farming which are associated with clear-felling of mangroves and damming of rivers causing salinity stresses in estuaries and threaten the mangrove ecosystems.

2. Mangrove Ecosystems: Extent and Distribution

The semi-arid Kenya coastline (Fig. 1) has a total of about 53,000 ha of mangrove forest cover (Doute and al. 1981) occurring mostly in creeks, bays and estuaries. The geographical distribution of the mangroves and their floral structures are related to the shoreline configuration, the geomorphology and hydrology, specially the submarine groundwater discharges (SGD) which create the brackishwater conditions required for successful development of their seeds. SGD explains the occurrence of mangrove forests away from the estuaries of the only two permanent rivers, River Tana and River Sabaki.

3. Physical Environment

3.1 Climate

There are two major climatic zones along the Kenyan coast (Fig. 2). The zone South of Malindi is described as humid tropical region and that in the North called Sahelian. The climate along the entire coastal belt is under the influence of two distinct monsoon wind patterns called the South East Monsoon (SEM) and the North East Monsoon (NEM) (Isaac and Isaac 1968). The longest season is SEM whose winds predominantly blow from the South Easterly direction towards the mainland from April to October. The NEM whose winds blow towards the mainland from the North Easterly direction begin from November to March. Wind and wave action are stronger in SEM than in NEM (Turyahikayo 1987).

The rainfall generally decreases towards the hinterland and the rainfall zones are as indicated in Fig. 3. During SEM, when the rainfall is heavier, the average rainfall range along the coastline is 55 - 272 mm whereas in NEM it is 8 - 84 mm. The long rains usually begin in April and extend to June, with the heaviest rainfall occurring during May. The short rains which may occur in NEM come in November and December. The average annual rainfall ranges 500 - 1,750 mm. The average air temperature range in SEM is 20°C - 31°C whereas in NEM it is 23°C - 32°C.

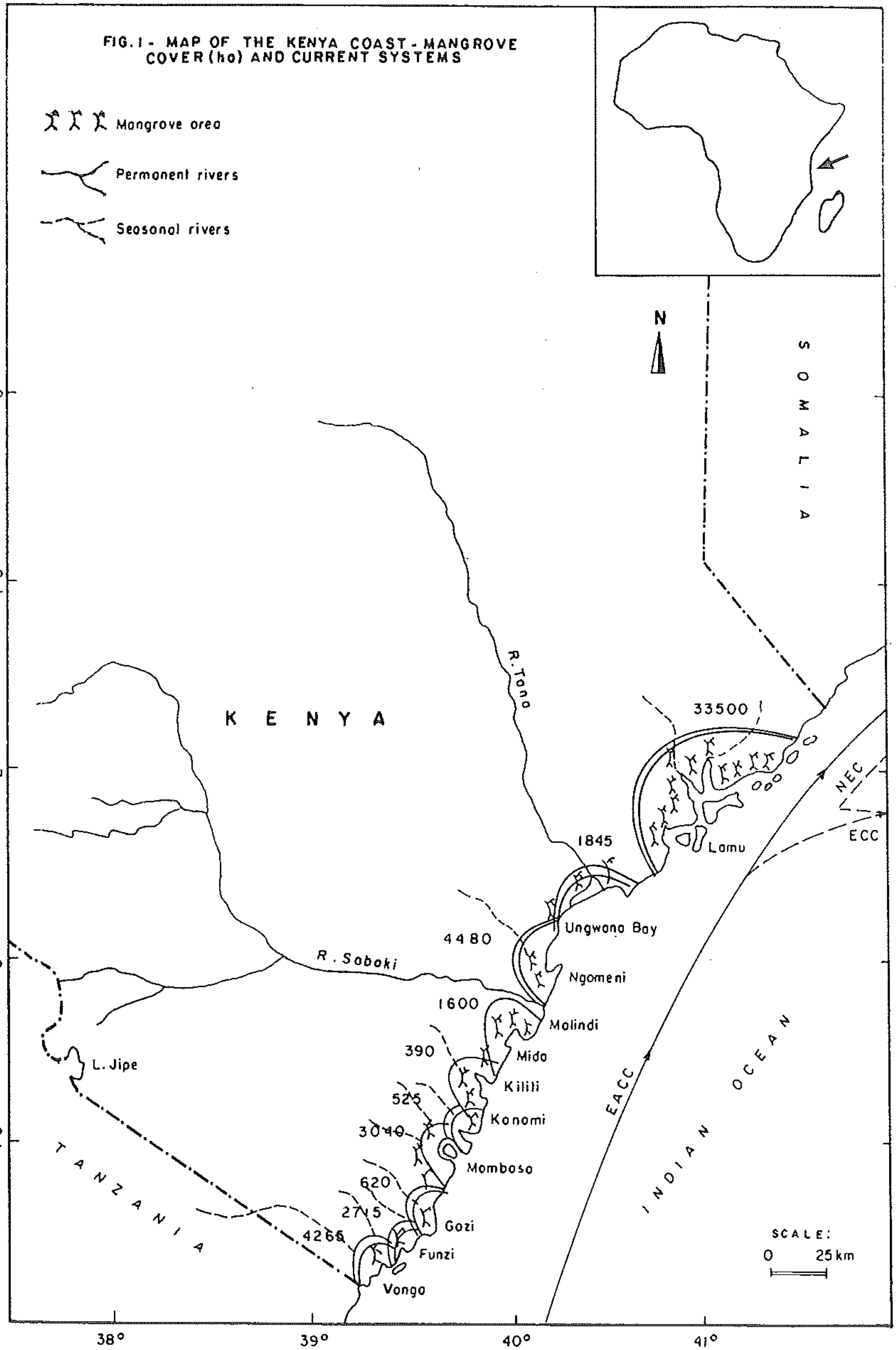
FIG. I - MAP OF THE KENYA COAST - MANGROVE COVER (ha) AND CURRENT SYSTEMS
Mangrove area
Permanent rivers
Seasonal rivers
N
SOMALIA
KENYA
R. Tana
R. Sabaki
L. Jipe
TANZANIA
33500
Lamu
1845
Ungwana Bay
4480
Ngomeni
1600
Malindi
390
Mida
Kilifi
525
Kanami
3040
Mombasa
620
2715
Gazi
4265
Funzi
Vanga
NEC
ECC
EACC
INDIAN OCEAN
SCALE:
0 25 km
0°
1°S
2°
3°
4°S
38°
39°
40°
41°

3.2 Soils

The soil structure depends on the geology, hydrography and hydrology of the area through which rivers or currents pass. Thus, the soil may be of terrestrial or marine origin.

The general geological features of the Kenyan coast are illustrated in Fig. 4. Along the coastline, the coastal belt consists of rocks of Pleistocene coral limestone especially South of Malindi and North of Lamu. Between Malindi and Lamu the coastline consists mostly of sand dune formations. Further inland the coastal belt consist of rocks of lagoonal deposits, Jurassic shales, and alluvial deposits in floodplains (Sombroek and *al.* 1982).

The soils along the Kenyan coastline are a product of deposition of both marine and continental sediments since the Permo-Triassic to the present day. The area around Ungwama bay and Malindi bay are principally depositional shallow water environments which receive most of their sediments from the hinterland through the permanent River Sabaki and Tana (Dubois and *al.* 1985). The metamorphic rocks tend to weather into quartz-rich sandy soils and are easily eroded whereas the Karoo sedimentary rocks (fine grained sandstones) weather slowly. Significant inputs of sediments come from the coastal belt (up to 60m altitude) where the main sediment load is carried by seasonal rivers and from upcountry through the permanent rivers (Rivers Tana and Sabaki).

According to Sombroek and *al.* (1982), the coastal belt has:

(a) soils developed in lagoonal deposits which are complex deep soils of varying drainage termed, albic and ferractic arenosols, orltric ferrosols, gleyic luvisols, solodic planosols and pellic vertisols;
(b) soils developed in the Jurassic shales which may be imperfectly drained dark grey clay termed eutric and vertic cambisols, verto luvic phaeozems;
(c) soils developed in the floodplain which are termed thionic fluviosols, pellic vertisols and chromic luvisols;
(d) soils developed on Pleistocene coral reef limestone which are termed rhodic ferrasols.

The soils in the mangrove swamps are very poorly drained, deep, olive to greenish and grey, soft, excessively saline, and moderately to strongly sodic, loam to clay, often with sulfidic material (thionic fluviols and gleyic solonchaks).

3.3 Waters

The sources of freshwater that create the brackishwater conditions required by mangroves are two permanent rivers, several seasonal rivers (Fig. 1) and submarine groundwater discharges from the underground aquifers. The Kenyan coast is semi-arid and is not particularly endowed with adequate freshwater to satisfy the demand.

In creeks, with river discharge, the salinity may be as low as 2‰ in the inner areas but increase towards the open water to oceanic salinity i.e 36‰ (Kazungu and *al.* in press). During the dry season in NEM when the surface water temperatures are higher with an average of 29°C, the salinities are higher, 33‰ - 34‰, especially in seasonal creeks. During the rainy season in SEM, the mean temperature of the surface waters is 25°C. In the back reef where submarine groundwater discharges occur, lower salinities from 24‰ to 30‰ have been recorded at low tide in pools when it is not raining (Ruwa and Polk, 1986).

The tidal range at the Kenyan coast is about 4m at highest spring high tides and 1.4m at highest neap high tides. According to Brakel (1982), the values of the conventional tide levels above the Kilindini tide are:- Mean high water spring (MHWS), 3.5m; mean high water neap (MHWN), 2.5m; mean low water neap (MLWN), 1.4m; mean low water spring (MLWS), 0.3m. The tides are semi-diural and in a daily tidal cycle there are 2 high and 2 low tides.

The hydrography of the Kenyan coastal waters is described by Newell (1957, 1959), and Johnson and *al.* (1982); it is under the influence of the Northward flowing East African Coastal Current (EACC) throughout SEM (Fig. 1). However, during NEM, whereas the waters South of Lamu continue to be under the influence of the EACC, the waters North of Lamu are under the influence of the Southward flowing North Equatorial Current which is also known as the reversed Somalia Current. The latter meet with the EACC around Lamu to form the Equatorial Counter Current (ECC) which flows eastward and only during NEM when it is formed.

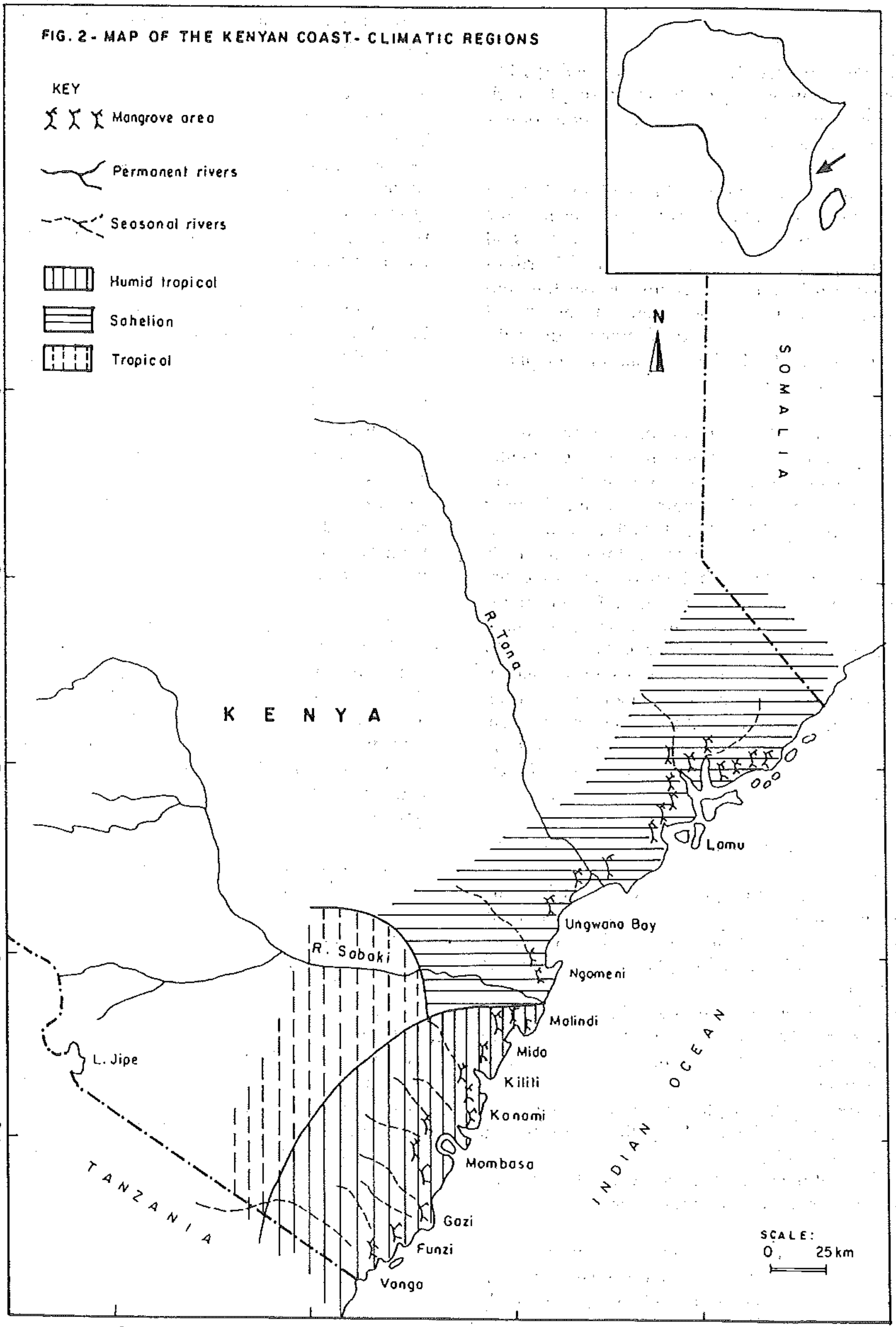

FIG. 2 - MAP OF THE KENYAN COAST - CLIMATIC REGIONS

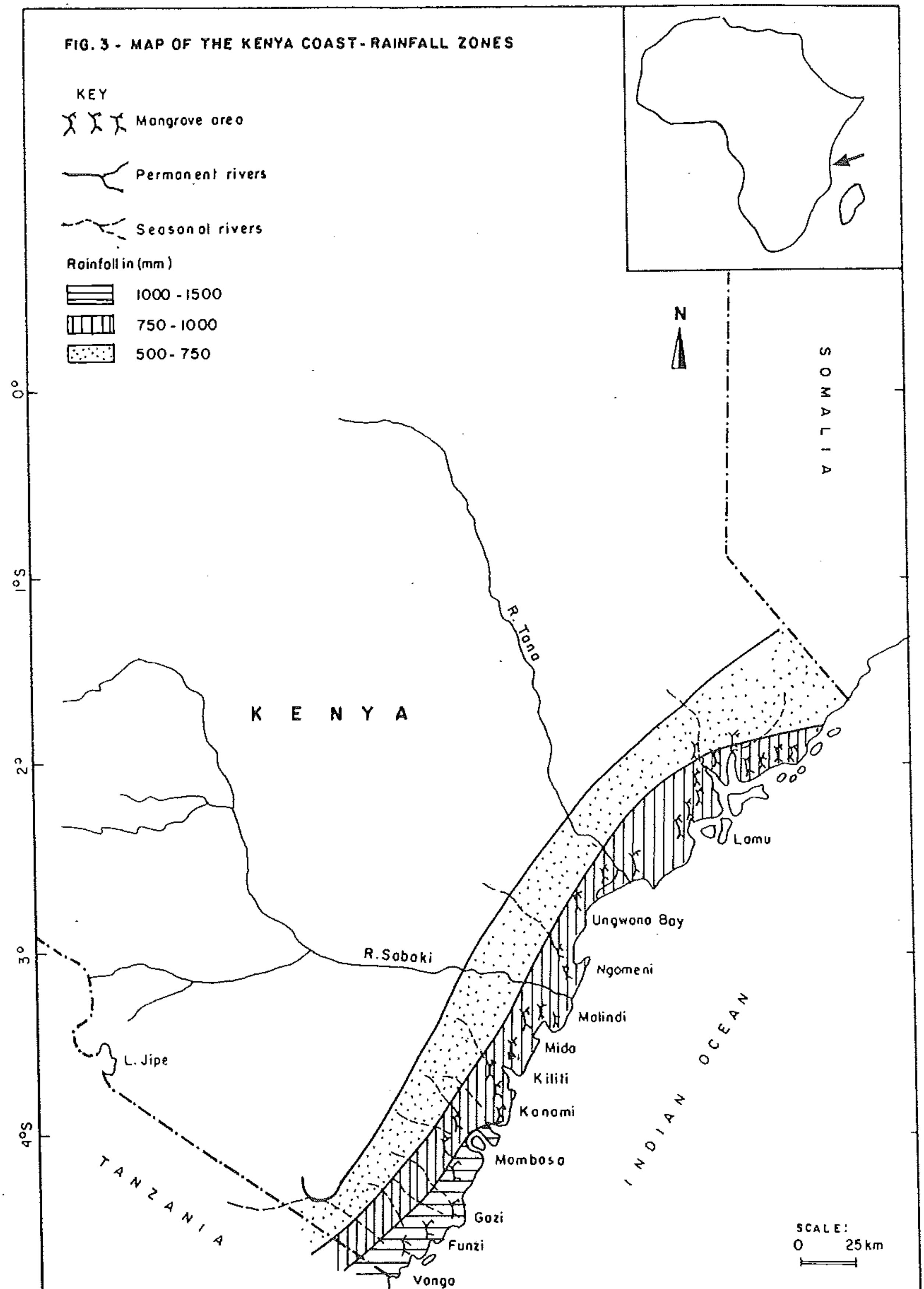

FIG. 3 - MAP OF THE KENYA COAST - RAINFALL ZONES

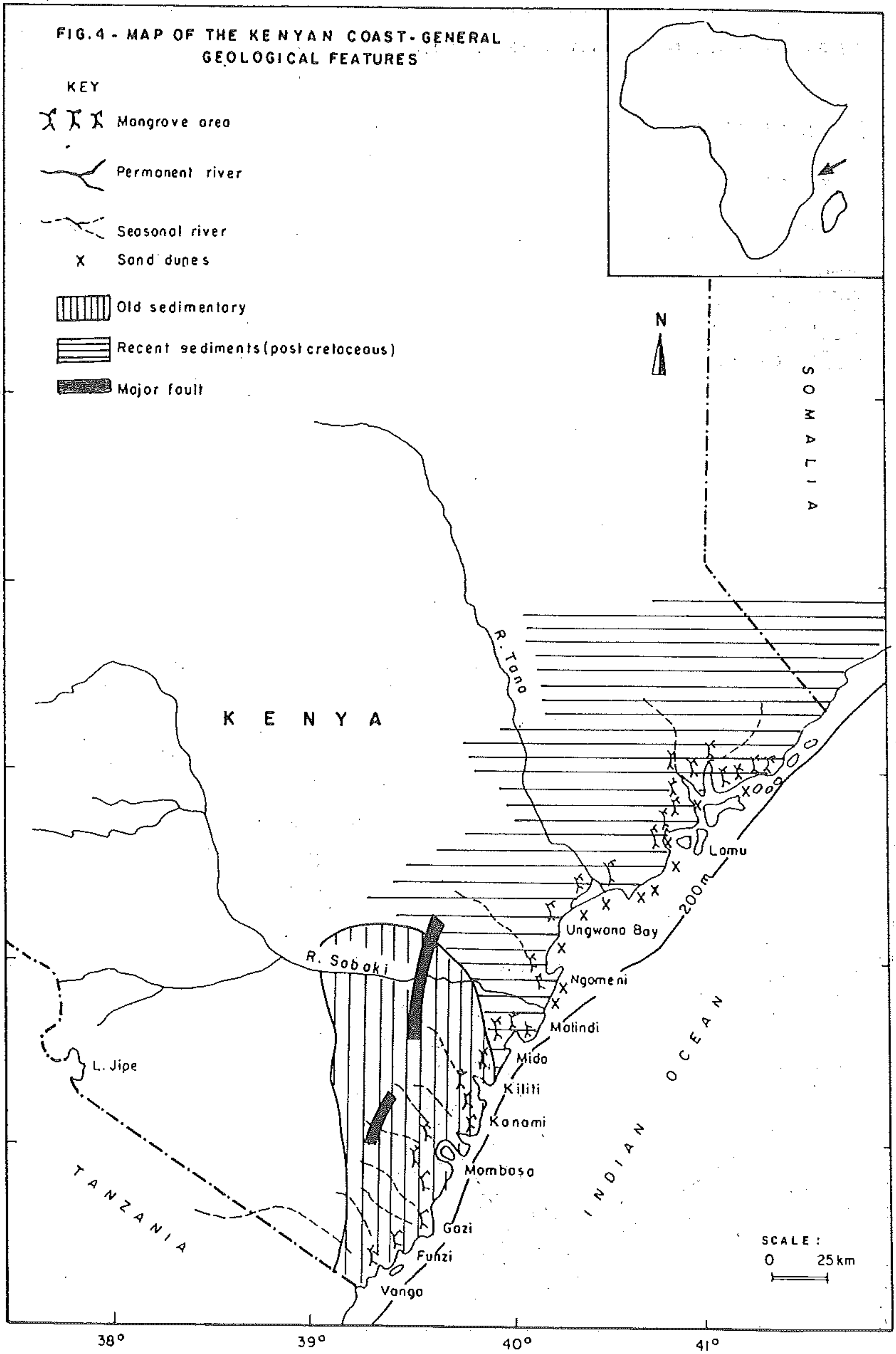
FIG. 4 - MAP OF THE KENYAN COAST - GENERAL GEOLOGICAL FEATURES
KEY
Mangrove area
Permanent river
Seasonal river
X Sand dunes
Old sedimentary
Recent sediments (post cretaceous)
Major fault
N
SOMALIA
KENYA
R. Tana
R. Sabaki
L. Jipe
TANZANIA
Lamu
Ungwana Bay
200m
Ngomeni
Malindi
Mida
Kilifi
Kanami
Mombasa
Gazi
Funzi
Vanga
INDIAN OCEAN
SCALE:
0 25 km
0°
1°S
2°
3°
4°S
38°
39°
40°
41°

4. Biological and Ecological Characteristics

4.1 Mangrove tree species

The species of mangroves found in Kenya are as follows: (i) *Rhizophora mucronata* Lam.; (ii) *Bruguiera gymnorhiza* (L.) Lamarck.; (iii) *Ceriops tagal* (perr.) C.B. Robinson; (iv) *Sonneratia alba* J.Sm.; (v) *Avicennia marina* (Forks.) Yeirch.; (vi) *Lumnitzera racemosa* Willd.; (vii) *Xylocarpus granatum* Koen; (viii) *Heritiera littoralis* (Dryand.) Ait. (Isaac and Isaac 1968).

4.2 Mangrove formations

There are two types of mangrove formations along the Kenya coastline which are determined by the hydrology and geomorphology of the shoreline. These are:

(a) the creek mangrove formations which are well developed mangrove forests in sheltered low gradient shores in creeks or bays and even show zonation by species;

(b) fringe mangroves which occur in high energy shores in front of high rising cliffs, even facing the open sea and do not show zonation.

It is common along the Kenyan coast to find lone trees of fringe mangroves of *Sonneratia alba* in front of high rising cliffs where submarine groundwater discharges occur (Fig. 5) and in other places mixed species of a few trees of mangroves occur in less exposed conditions (Ruwa and Polk 1968).

4.3 Ecology and biology of mangrove ecosystems

Published studies on the ecology and biology of the mangrove plants in Kenya are still scanty and the published ones deal with species composition (Isaac and Isaac 1968), distribution and relationship with submarine groundwater discharges (Doute and *al.* 1981, Ruwa and Polk 1986) and zonation (Ruwa 1992). Based on the principal species, the zonation in an upward shore direction in a creek mangrove formation is: *Sonneratia alba, Rhizophora mucronata, Ceriops tagal, Avicennia marina* and *Lumnitzera racemosa.*

Coppejans and Gallin (1989) recorded various species of algae found on mangroves but those species occurred on rocky shore as well (Oyieke and Ruwa, 1987). This may imply that the mangroves act as a hard substrate like the rock and secondly seepage that provides brackishwater conditions both in the mangroves and rocky shore biotopes allow the two contrasting biotopes to support similar species composition (Ruwa 1990).

5. Mangrove Related Ecosystems

The types of littoral biotopes linked with mangrove ecosystems are shown in Fig. 6. Estuarine or brackishwater biotopes are usually referred in terms of the principal vegetation cover i.e where the dominant vegetation is mangrove, it will be termed mangrove ecosystem, and likewise where the dominant vegetation is sea grass it will be termed seagrass ecosystem. Where there is no vegetation, such biotopes are commonly referred to as mudflats. In East Africa where the shoreline consists of a raised Pleistocene coral reef (Fig. 6) the living coral reef is subtidal and non-estuarine.

The mangrove forests, seagrass beds and littoral mudflats are linked in three ways to the living coral beds: (a) physically by the tidal currents; (b) chemically due to chemical exchanges resulting from chemical materials that are leached and released from the various flora and fauna residing in the different biotopes; (c) biologically by movement of organisms e.g plankton drifting with the currents or freely swimming nektonic organisms which move to feed, breed or take refuge in the various biotopes. Along the Kenya coast, there are various combinations of types of littoral biotopes (Fig. 7), whose species composition shows that mangroves favour increased benthic fauna biodiversity (Ruwa 1990). However for similar shore levels, the benthic floral biodiversity is richer on 'rocky cliffs than on mangrove trees as shown by records of the species composition of algae on rocky shores by Oyieke and Ruwa (1987) and on mangroves by Coppejans and Gallin (1989).

Going in a downward shore direction in a mangrove biotope, there usually are open mudflats which lead to seagrass beds. The mudflats are characterised by green algae mostly *Ulva sp., Enteromorpha sp.*, and *Caulerpa* sp. and the marine angiosperms *Halophila ovalis* and *Halophila stipulacea* (Isaac and Isaac, 1968). Where the sediments are firm or a film of sediment is present over the bedrock, seagrass may be found on the erosional platform and extend to subtidal levels (Isaac and Isaac, 1968). In firm fine sediments *Halodule* sp. and *Cymodocea* sp. may dominate but generally *Thallasia hemprichi* dominates over the platform in most places of the Kenyan shores even in areas where the bedrock is covered only by a thin film of sediment. *Thallasodendron ciliatum* and *Syringodium isoetifolium* dominate in deep pools and subtidally. In areas with adequate submarine groundwater discharges *Enhalus acoroides* may be

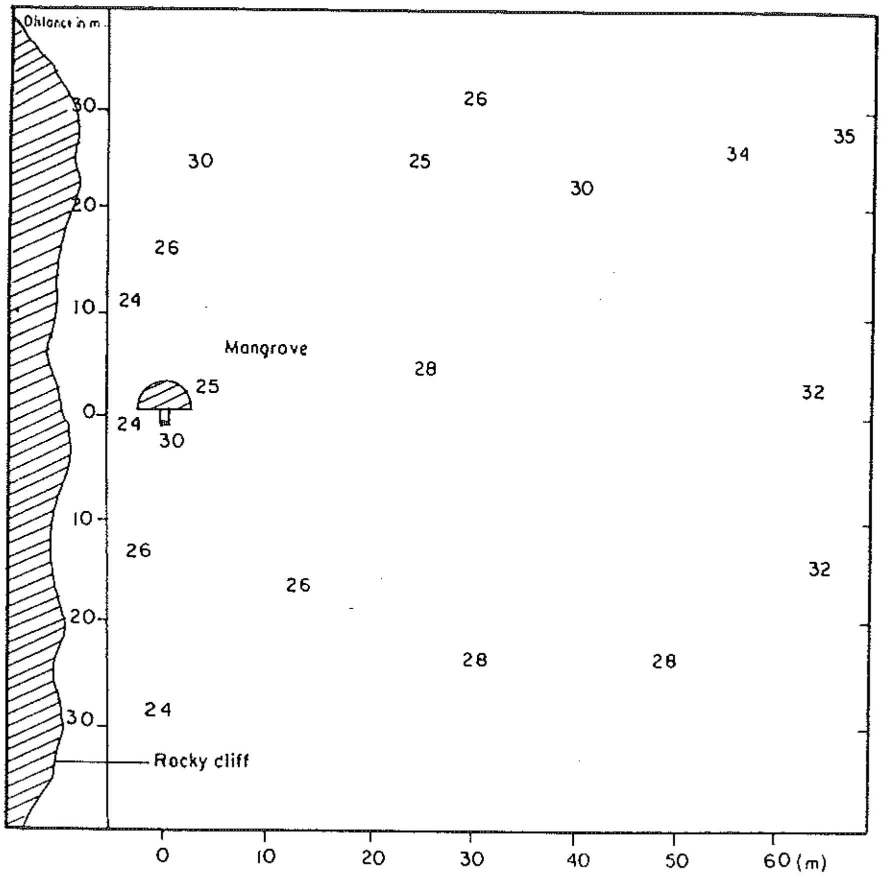

FIG. 5 - SALINITY MEASUREMENTS AROUND SONNERATIA ALBA
A LONE MANGROVE AT KANAMAI

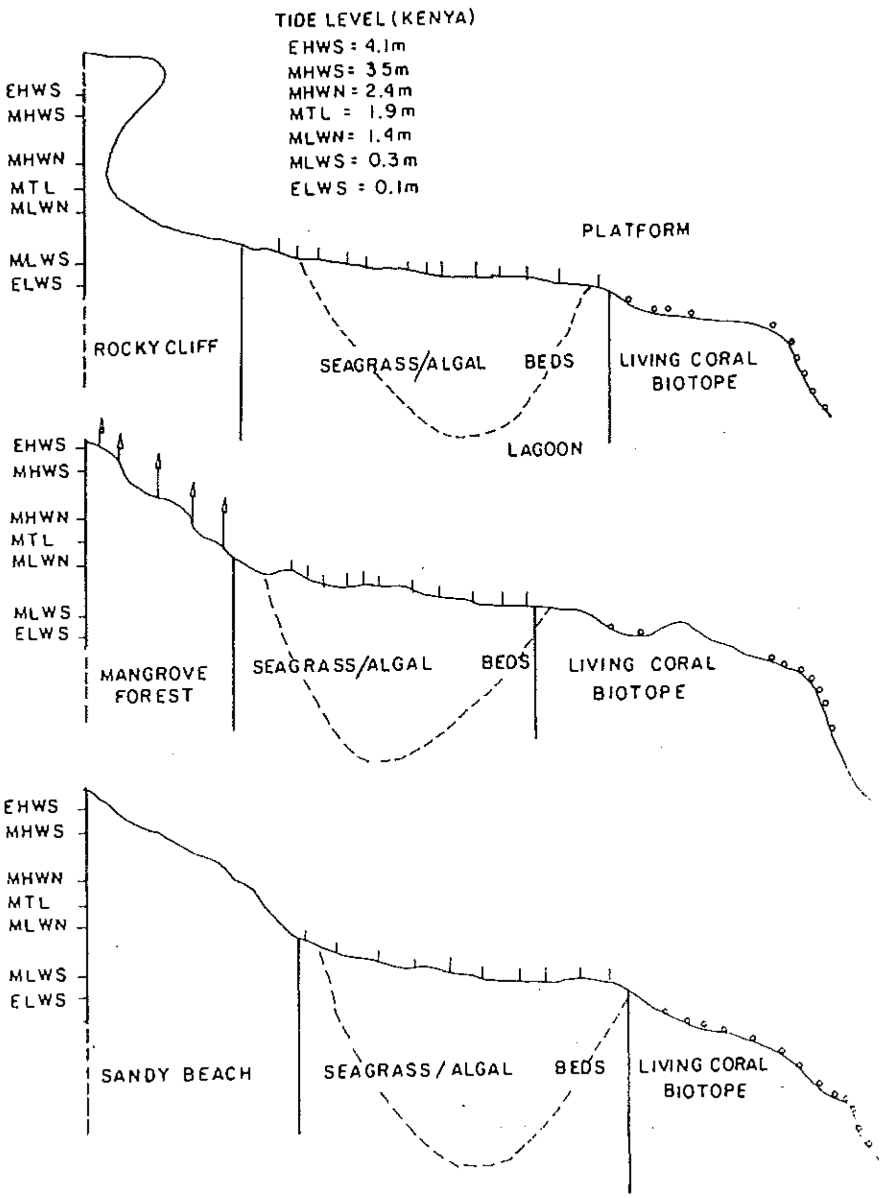

FIG. 6 - HABITAT LINKAGES IN SHALLOW INSHORE WATERS

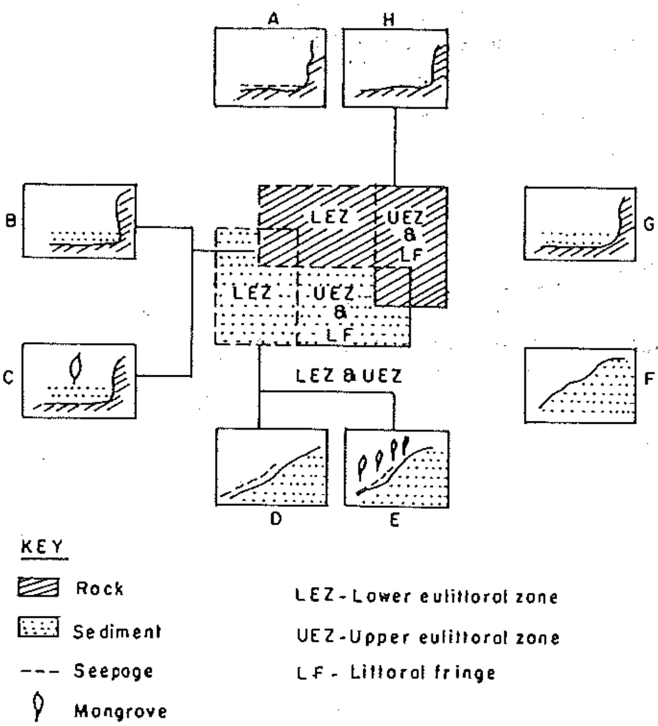

FIG. 7- TYPES OF LITTORAL HABITAT ALONG THE KENYA COASTLINE

found growing luxuriantly and in most cases this marine angiosperm is found abundantly in the vicinity of mangrove biotopes. The seagrasses carry various types of epiphytic algae. Among the seagrass beds there is a variety of epifauna like echinoderms, molluscs and crustaceans whose ecology and biology is scantly known.

The living coral reef is predominantly formed of living surfaces of coral polyp colonies devoid of algae and seagrasses except on the dead surfaces or sandy depressions. The coral fauna has been documented by Hamilton and Brakel (1984). Impacts due to exploitation of coral reef were documented by Bock (1978), Muthiga and McClanahan (1987) and McClanahan and Muthiga (1988). The studies on the coral zone were however, not done with a specific objective to find or describe interlinkages with other biotopes such as mangrove or seagrasses. Comparison of fishes on coral zones documented by Bock (1978) and in mangrove creeks as documented by Litte and *al.* (1988 a, b) clearly show biological interlinkages between living coral zones and the mangrove ecosystem where many young stages find refuge. Besides the chemical interlinkages as described in UNESCO (1987), the biological interlinkages, provide evidence of the importance of the mangrove interaction with other ecosystems. Besides the latter, offshore fisheries of prawns depend on mangrove ecosystems where the young prawns grow to sub-adults and then migrate offshore (Brusher, 1974). Various other planktonic and pelagic communities were described in Kenyan mangrove creeks (Reay and Kimaro, 1984; Okemwa and Revis, 1986; Okemwa, 1989) and these studies reaffirm the importance of the mangrove ecosystems for the oceanic ecosystems. The contributory role of mangrove litter in the detritus based food chain which forms the foundation of higher trophic levels provides the key support mechanism (Odum and Heald 1972).

The supratidal communities are characterised by high salinity tolerant flora such as: *Ipomea pes-caprae, Vigna marina, Casuarina equisetifolia, Juncus sp., Sporobolus* sp. The fauna includes land crabs, *Ocypode sp., Coenobita sp., Sesarma sp., Cardisoma carnifex,* isopods, and insects like crickets. The terrestrial fauna found in mangrove forests includes various types such as: wild pigs, monkeys, monitor lizards, snakes, spiders, bees, wasps, mosquitoes and various types of insects which are yet to be studied in Kenya.

6. Human Habitation and Traditional Mangrove Usage

Along the Kenyan coast, the groundwater table is highest in mangrove valleys and it is common to see people drawing potable water from very shallow wells, 3 - 5m deep, without having to bore holes through rocks in most cases. In other places far away from mangroves forests, water is available at a depth 10 - 15m and is found under layers of rock. Thus, historically the successful habitation around the mangroves is due to the availability of freshwater. Once settled the communities devoted into marine resource utilization activities centered on mangroves rather than landbased occupations e.g. farming. The mainstay activity of such communities was fishing and staying near the sea had other advantages, they could: a) time the tides to fish efficiently: (b) guard their fishing crafts and gears from theft; (c) save spoilage of catch by avoiding to travel long distances in the absence of cold storage facilities. The fishing villages have boat builders and fishing gear makers thus fishing is a mainstay activity. Presently, however, many fishing villages are loosing their humble status as fishing villages due to urbanisation caused by activities not even related to fishing e.g. where the village have become administrative centers, sites of industries, harbours, hotels for tourists, or have attracted immigrants from the hinterland who came for employment and became residents (Ruwa 1985).

In Kenya, the most important traditional uses of mangrove wood is for building houses, making furniture, fuel and construction of boats (Kokwaro 1986). Other lesser uses are for example, provision of fodder especially from *Avicennia marina,* making of net floats from spongy pneumatophores and other uses e.g. honey production using beehives that are placed in the mangrove forests, fishing of mangrove crabs e.g. *Scylla serrata,* collection of oysters e.g. *Crassostrea cucullata* which occurs mainly in mangrove forests.

7. Commercial Exploitation and Marketing

With a total of only 530 km² of mangrove forest cover, Kenya does not have adequate mangrove wood for commercial exploitation. The wood from the mangrove forests around Lamu used to be exported to the Arabian gulf countries since a long time but the Kenya Government banned the export of mangrove wood about a decade ago when over-exploitation was clearly evident. Exploitation for internal use in the country is allowed and this is regulated by the Forest Department. The categories of wood for commercial exploitation and costs are shown in Table 1.

In each village there are licensed cutters from whom middlemen buy and the latter are responsible to sell to the public. Where there is proper organization of mangrove cutters, there may be a mangrove cutter's cooperative society which is responsible for marketing the wood to avoid being exploited by middlemen.

Table 1: Categories of commercial size classes of mangroves in Kenya

Categories (Local name)	Diameter in cm		
Fito	2.5	-	3.5
Pau	4.0	-	7.5
Mazio	8.0	-	11.0
Boriti	11.5	-	13.5
Nguzo 1	14.0	-	16.5
Nguzo 2	17.0	-	20.0
Nguzo 3	20.5	-	30.0
Timber - Banaa	Over 30.0		

Source: Kenya Natio Environment Secretariat 1985

8. Mangroves Conversion to Other Uses

The most important forms of conversion of mangrove forests and wetlands in Kenya are:

(a) Conversion for creating salt pans for salt farming;

(b) Conversion for creating aquaculture ponds for prawn farming.

The area around Ngomeni (Ungwana Bay) is the salt producing area. The firms producing salt at industrial scales are Kensalt works and Fundisha salt works. There are also some small scale producers who sell their unrefined salt to salt manufactures in Mombasa. The salt pans are now also used for production of *Artemia salina* in addition to salt.

In 1978, the Fisheries department in collaboration with FAO started a prawn culture farm at Ngomeni. Currently there are 10 ponds of total area of 14.25 ha under production and there is approximately 45ha for further development. The area cleared had about 60% coverage of mangrove trees. The species of prawn being cultured is *Penaeus indicus* whose seed is readily available and is tolerant of salinity fluctuations which are prevalent because of the aridity and high temperatures encountered in the area.

9. Impacts on the Mangrove Environment

The important environmental impacts on mangroves in Kenya arise from anthropogenic activities associated with:

(a) Bad fishing methods in river catchment areas that lead to increased soil erosion and sediment input in estuaries causing shore accretion leading to high gradient shore profile that end up supporting fringe mangrove.

(b) Damming of rivers causing increase in salinity in estuaries especially during the dry season and salinity stress on mangroves. This may specially affect low salinity preferring species e.g. *Heritiera littoralis*. Similarly, release of brine from the salt farms into estuaries causes salinity stress to mangrove plants and animals.

(c) Clearing of mangroves to create ponds causes hydrodynamic changes which may result into increased erosion of shorelines in creeks.

(d) Dumping of solid organic waste and non-biodegradable materials such as bottles, polythenes, plastics, tins etc. from urban areas has increased tremendously. Substances leached from these wastes may be harmful to mangrove organisms in the ecosystem. Sewage and industrial toxic wastes threaten mangroves. It is known that mangroves can not tolerate large amounts of organic matter. (Clough and *al.* 1983).

(e) Mangroves around Mombasa are threatened by oil spills because Mombasa is a harbour area where oil tankers call to deliver oil. In the vicinity of the creeks there are oil storage tanks. In 1988, an oil spill in the creek occurred when one of the tankers got accidentally punctured. The oil spill killed a considerable area of the mangrove vegetation.

(f) Natural environmental impacts that may kill mangroves are not common in Kenya. There are only isolated cases of individual trees dying from the dieback phenomenon caused by fungi.

When the mangroves are threatened, all the species that depend on mangroves for their survival (Ruwa, 1990) and species that use mangrove area as nursery grounds (Little and al. 1988a, b) will loose their habitat which may be followed by a decline in the adult stocks offshore for those whose young stages are nurtured in mangrove areas.

10. Socio-Economic Implications

Due to the immigration of various communities to mangrove forest areas in search of employment in the urban areas which humbly began as fishing villages (Ruwa 1985), the present day socio-economic implications on use and misuse of mangroves are mostly due to the benefit of the national economic activities practiced by the communities that first established their settlement around the mangrove forests.

Deep, sheltered creeks which are good sites for harbours have been dredged for construction of harbour facilities. Mombasa harbour which has developed to be the largest harbour in East Africa with various harbour facilities including dry docking and repairing facilities for ships is a significant income generating establishment of the country. The harbour has also tremendously contributed to the rapid growth of the Mombasa town. Creeks in Lamu have also been dredged for harbour development to allow large ships to anchor. Again, increased income from vessels that will anchor in the harbour is expected. Other activities undertaken to enhance the national economy are the damming of rivers to produce electricity and to provide water for irrigation.

Although the salt farming activities are also significant income generating activities of national importance, pans need not be in the mangrove forest areas. The potential for prawn farming is also appreciable but destruction of the mangrove forests for ponds is not necessary either, the ponds can be sited outside the mangrove forests.

In the background of the present threats on mangrove forests due to harbour developments, damming of rivers, salt and prawn farming, sewage and solid waste disposal from urban areas, forests, the age old cutting of mangroves from natural forests for sale needs to be augmented with agroforestry of mangrove species. Agroforestry offers other advantages e.g. increase in fisheries production (Martosubroto and Naamin, 1977) and inhibit shoreline erosion.

Non-consumptive economic uses of the mangroves e.g. honey production, eco-tourism using traditional boats made by the fishing communities should be encouraged to improve their economic status.

11. Research and Training Programmes

The national research programmes are undertaken by Kenya Marine and Fisheries Research Institute and the National Universities, University of Nairobi and Kenyatta University. Other organisations that have shown interest to undertake research in mangroves are Moi University, Egerton University College and Kenya Forestry Research Institute.

Research has also been undertaken through international bilateral programmes e.g. Kenyan-Belgian Project in Marine Sciences with participants from Free University of Brussels, University of Ghent and University of Limburg (Belgium), University of Florence (Italy) and Delta Institute of Hydrobiological Research (Netherlands) and through regional projects by UNESCO.

As regards training, the University of Nairobi and Kenyatta University undertake training courses in aquatic sciences which include aspects of mangrove biology and ecology. Through bilateral programmes links with Universities abroad have been made for researchers and students to undertake postgraduate training abroad but collect their data in Kenya where possible. Such links exist within the Kenyan-Belgian Project in Marine Sciences, University of Florence (Italy) and some institutions in Netherlands. Training is also undertaken through regional projects by UNESCO.

12. National Mangrove Committees: National Policies for Mangrove Management

There is no national mangrove committee in Kenya. However, there are environmental groups that are interested in mangrove conservation e.g. Kenya Energy and Environmental Organisation (KENGO), Society for Protection of Environment in Kenya (SPEK), East African Wildlife Society (EALS), Kenya wetland. The Presidential Commission for Soil Conservation and Reafforestation and the Kenya Wildlife Service.

The Forest Department which is responsible for the management of the gazetted forests in Kenya has

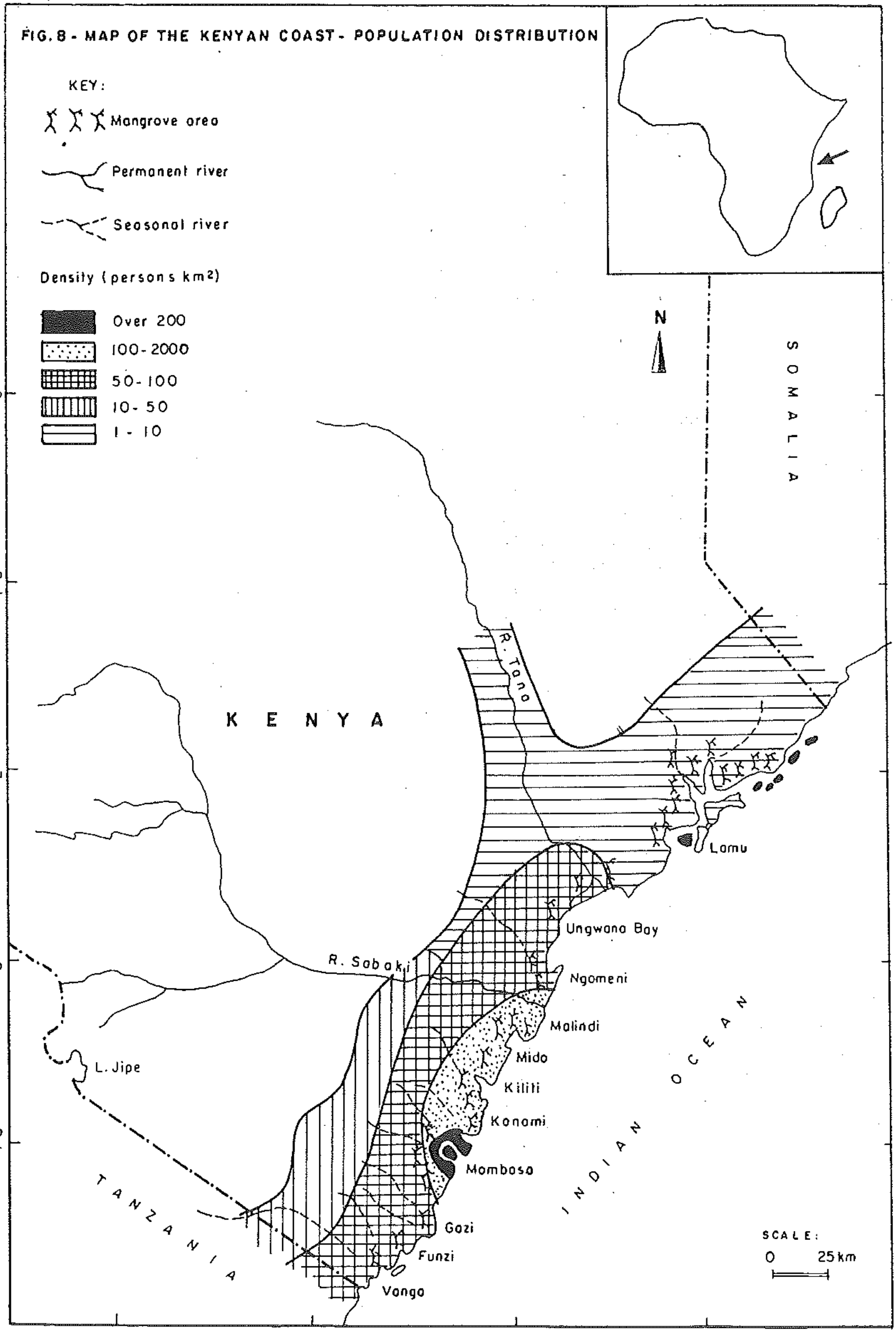
FIG. 8 - MAP OF THE KENYAN COAST - POPULATION DISTRIBUTION
KEY:
Mangrove area
Permanent river
Seasonal river
Density (persons km2)
Over 200
100-2000
50-100
10-50
1-10
N
SOMALIA
KENYA
R. Tana
R. Sabaki
Lamu
Ungwana Bay
Ngomeni
Malindi
Mida
Kilifi
Kanami
Mombasa
Gazi
Funzi
Vanga
L. Jipe
TANZANIA
INDIAN OCEAN
SCALE:
0
25 km
0°
1°S
2°
3°
4°S
38°
39°
40°
41°

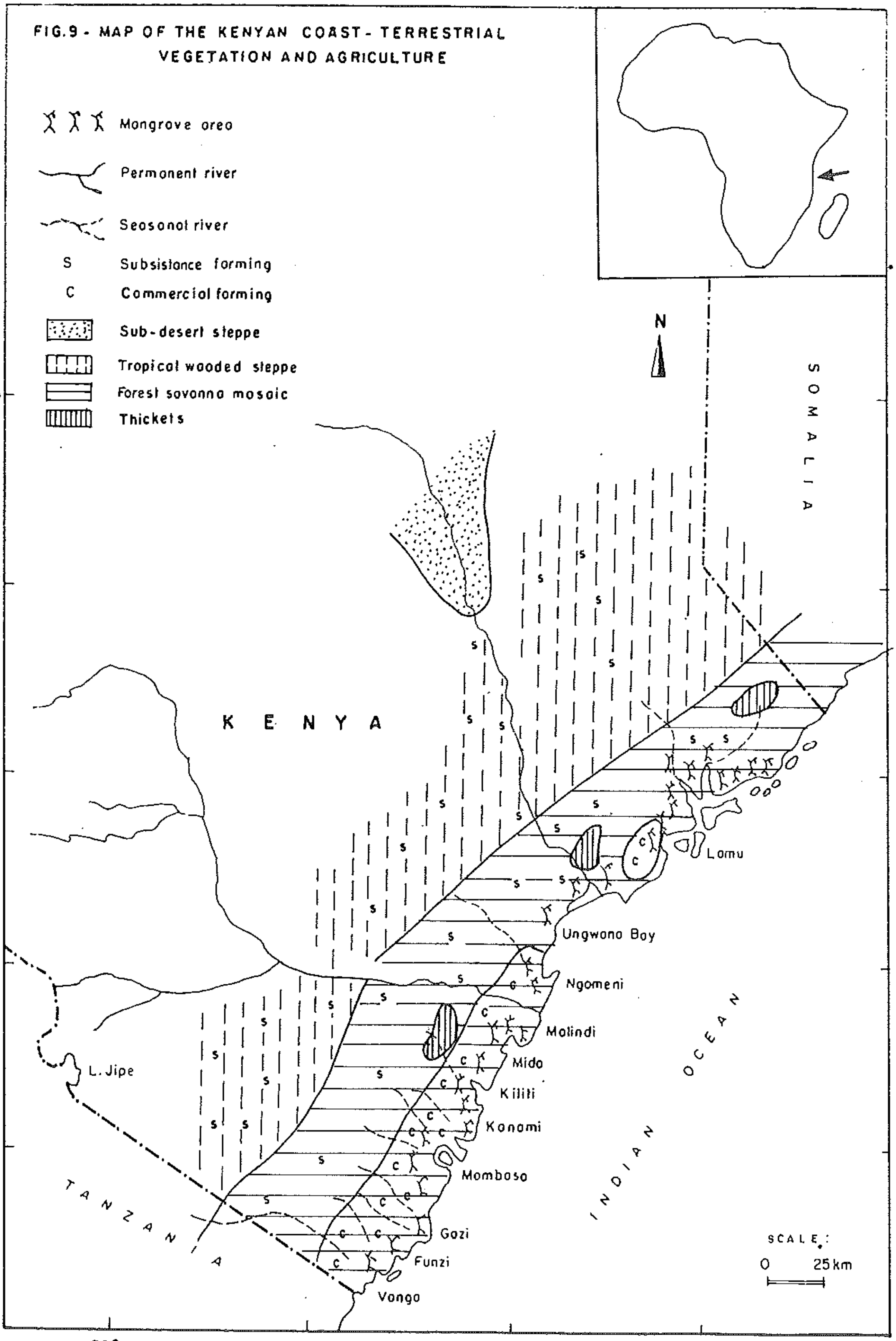
FIG.9 - MAP OF THE KENYAN COAST - TERRESTRIAL VEGETATION AND AGRICULTURE
Mongrove oreo
Permonent river
Seosonol river
S Subsistonce forming
C Commerciol forming
Sub-desert steppe
Tropicol wooded steppe
Forest sovonna mosaic
Thickets
N
SOMALIA
KENYA
Lomu
Ungwono Boy
Ngomeni
Molindi
Mido
Kiliti
Konomi
Momboso
Gozi
Funzi
Vongo
L. Jipe
TANZANIA
INDIAN OCEAN
SCALE :
0 25km
0°
1°S
2°
3°
4°S
38°
39°
40°
41°

no specific policies for mangrove management. All the mangrove cutters have to be licensed but there are no restrictions to the amount of wood to be harvested in the different forests along the coastline. Its Forests Guards have no boats and can not therefore effectively guard against illegal wood cutters or locate the areas that are threatened with overcutting in time. The Kenya Wildlife Service which manages parks, intends to establish mangrove parks for total protection and use them for eco-tourism. Attempts are also being made to form a National Mangrove Committee with membership from researchers, managers and users of the mangrove resources.

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Mangroves of Madagascar

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1. Historical Background

The Madagascar mangrove swamps belong to the Indo-Pacific region and rank among the low mangroves (MACNAE, 1963). Their distribution and typological differences derive from the climatic conditions and the geomorphologic peculiarities of Madagascar. They are essentially located along the Western coast of the island.

Very poor as far as the floristic diversity is concerned (5 mangrove families). They serve as habitat for a great number of animal species (land, aquatic and aerial).

The coastal population uses resources from the mangrove for their daily needs: (timber, firewood or charcoal). People use it also to extract tan-bearing substances and traditional medicinal ingredients. It is mainly near the towns that these coastal formations become more and more threatened. Traditional fishing is beginning to intensify and if no steps are taken to protect the littoral zone, over-exploitation may result before long.

Other dangers are threatening the coastal ecosystem of Madagascar; particularly the intense erosion of the sloping basins caused by tree felling on the highlands. One can witness a process of destabilization, such as estuary sedimentation which in the long run may cause erosion or accretion of the sediments. In fact, tree felling, which is aggravated by the demographic increase, will lead to the decay of mangroves and their resources. Although the Madagascar mangrove swamps are not yet very much affected, it is time to take the necessary steps to realize conservation and management plans in order to safeguard this heritage.

Sylviculture is possible, but the protection of the sites must be a matter of priority, because the Madagascar fauna is characterized by a marked endemism. Among the protection steps, there is first, the knowledge of the mangrove swamps. We must also determine and co-ordinate their contributions to development through an integrated research programme.

2. Extent and Distribution

In Madagascar there are no available recent data on the surface occupied by the mangroves. Estimates vary from one author to another:

400,000 ha by Perrier de la Bathie (1921); 217,000 ha by Gachet (1959); 327,000 ha by Kiener (1966).

Kiener's estimation seems to be closer to the real area of the mangroves: 327,000 ha. These coastal formations have a dissymetrical layout to the benefit of the Western coast, (5,000 ha on the Eastern coast against 322,000 ha on the West). On the western coast sedimentation conditions are far more favourable; low coastal platform; high tidal range (average 3.20 m), allowing for, the supply of large quantities of marine coastal water; constant supply of fresh water deriving from land runoff.

The front parts of the mangroves are sometimes occupied by flat zones called "tannes" (sirasira), the limits of which are not very well defined on the maps. These zones can be very extensive. The surface of the littoral swamps added to that of the tannes is about 400,000 ha. It widens in some estuaries, because the mangrove swamps colonize areas where large quantities of sediments are carried and deposited by the rivers.

Fig. 1 shows that most of the mangroves are located in the sedimentary basins of the Western littoral. They grow on the fluvial sediments deposited at the mouths of many rivers that flow into the Mozambique channel. In many places, the mangrove swamp can be continuous along the coast: these are the linear mangroves (Mahavavy, Ambanja, Besanlampy, Maintirano). Sometimes, the mangrove is interrupted by sand bar lagoons (Mangroves of Belo-sur-Mer). Some mangroves are located on the borderlines of volcanic formations (the Northern mangroves) or crystalline formations in the North-East, and other small mangrove swamps, called littoral that owe their existence to the reappearance of Karst formations. Some mangrove swamps are of estuarine type (the case of Betsiboka, Tsiribihina, Mangoky); they are more widespread and more dense, the following list, gives the surfaces of mangroves as recorded by Kiener (1966).

- The large mangrove of the North Mahavavy	11,200 ha
- The large mangrove of Ifasy	14,000 ha
- Many small mangrove of Nosy-Bé	1,195 ha
- The mangrove of Radama Bay	8,000 ha
- The mangrove of Loza	18,000 ha
- The very large mangroves of Mahajamba bay	39,000 ha
- The very large mangroves of Bombetoka(Betsiboka)	46,000 ha
- The very large mangroves of the South Mahavavy and Soalala	34,000 ha
- The very large mangrove swamps of Besalampy (North and South)	45,700 ha
- The very large mangroves of Maintirano	25,450 ha
- The mangrove of Manambolo	9,000 ha
- The very big mangroves of the river Tsiribihina	28,000 ha
- The small mangroves of Morondava	900 ha
- The mangroves of Belo-sur-Mer	1,600 ha
- The mangroves of Morombe (North and South)	3,500 ha
- The small mangroves of Fiherenana	300 ha

3. Physical & Chemical Conditions of the Environment

3.1 Climate

In Madagascar there is a great variety of climates owing to the combination of several conditions: two maritime fronts, topography, and geographic situation of the island. The rainfall is a determining factor of the climate, it varies from the humid subequatorial in the North to the dry subtropical in the South (Fig 2). Generally the temperature, of tropical type and of low thermic ranges, is homogeneous along the Western coast.

The rainfall regime is strongly influenced by the abundance of monsoon rains from the South-East. The rainfall determines the climate successions on the Western coast, and in this way, conditions the settlement of the mangrove swamps. The rivers have a tropical regime characterized by two seasons : the dry and cold season that extends from May to October and the humid warm season from November to April. The combination of fresh water supply deriving from the rainfall and the diverse climates, differentiates the very varied typological structure of the Madasgascar mangroves.

3.2 Soils

The knowledge of the mangrove soils derives from recent studies. Much research is underway and is concerned with preliminary studies (mainly sedimentology). Elsewhere, as far as the tannes are concerned, pedological studies revealed that these soils have some acid sulphate characteristics.

3.3 Hydrological conditions

3.3.1 Swell

The coast of the Southern and eastern regions of the islands are exposed to intensive swell characterized by a great range and a great wavelength. This swell is subject to general meteorological conditions. The littoral of the West coast is generally protected against the swell, thanks to the coral formations that edges it.

3.3.2 Tides

The tides of the western coast are semi-diurnal with an alternance of neap and spring tides. The tidal range is about 3.2 m and may reach 4 m during the equinoctial periods.

3.3.3 Main marine currents

Marine currents are shown on Fig. 3.

Current measurements in the estuarine zones have not yet been done in detail; however, some investigations have been carried out on the coasts of Nosy-Bé region (North West of Madagascar).

Analysis of the data has shown (MAGAZZU, 1985):

- The tide has an important influence on the coastal currents and on part of the continental waters. The wind influences the surface current .
- The surface current speed is increased when the wind and the tide have the same direction. Wind influence during the neap period deflects the surface current giving it a movement contrary to that of the bottom current which is influenced by the tidal currents.

3.3.4 Sea hydrology

Surface waters offshore from the Western Coasts of Madagascar are the Surface Water of the Mozambique Channel. These waters are protected from the Eastern influences by the relief of the island (Piton

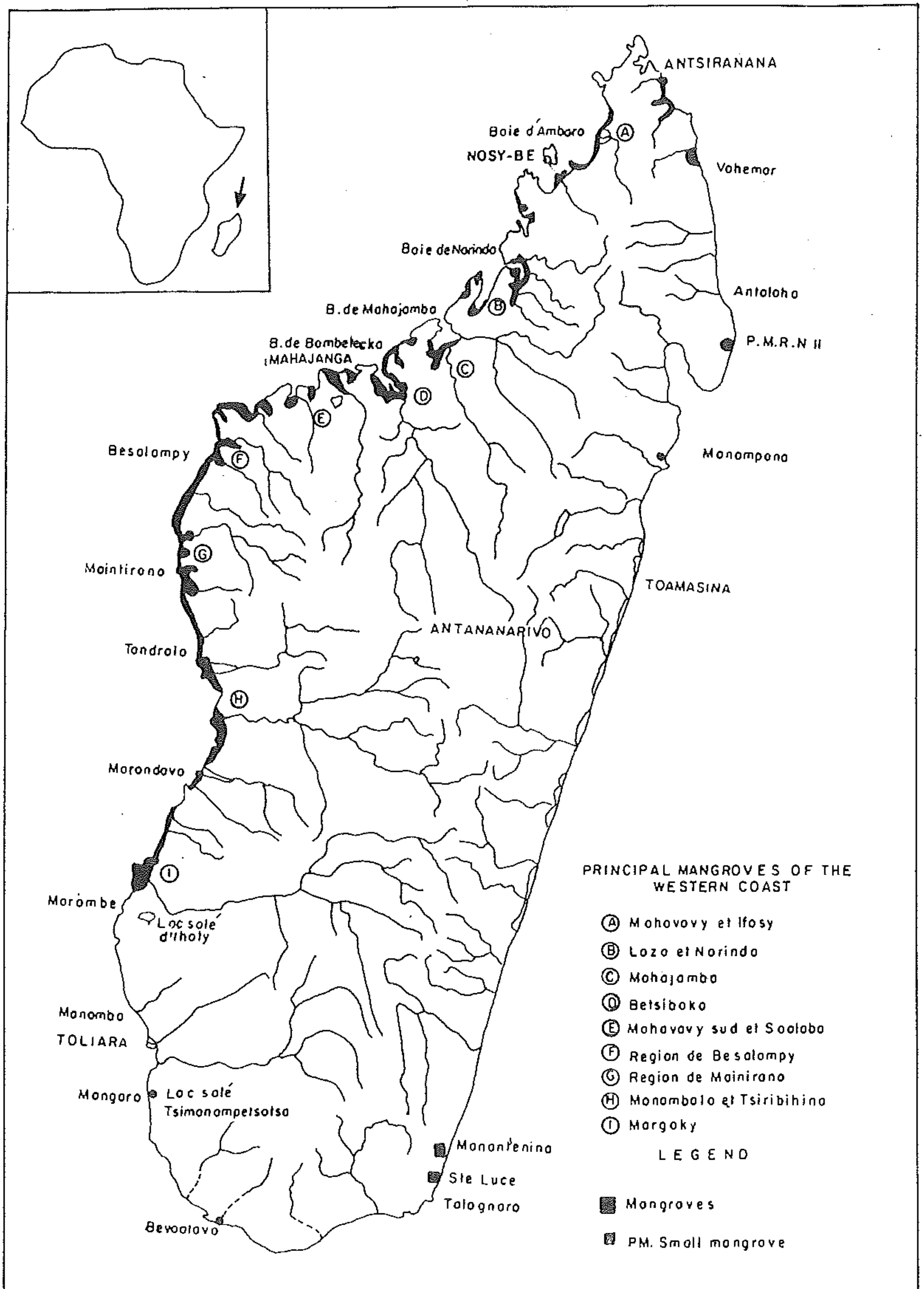

FIG. I- THE MANGROVES IN MADAGASCAR
(FROM KIENER 1966)

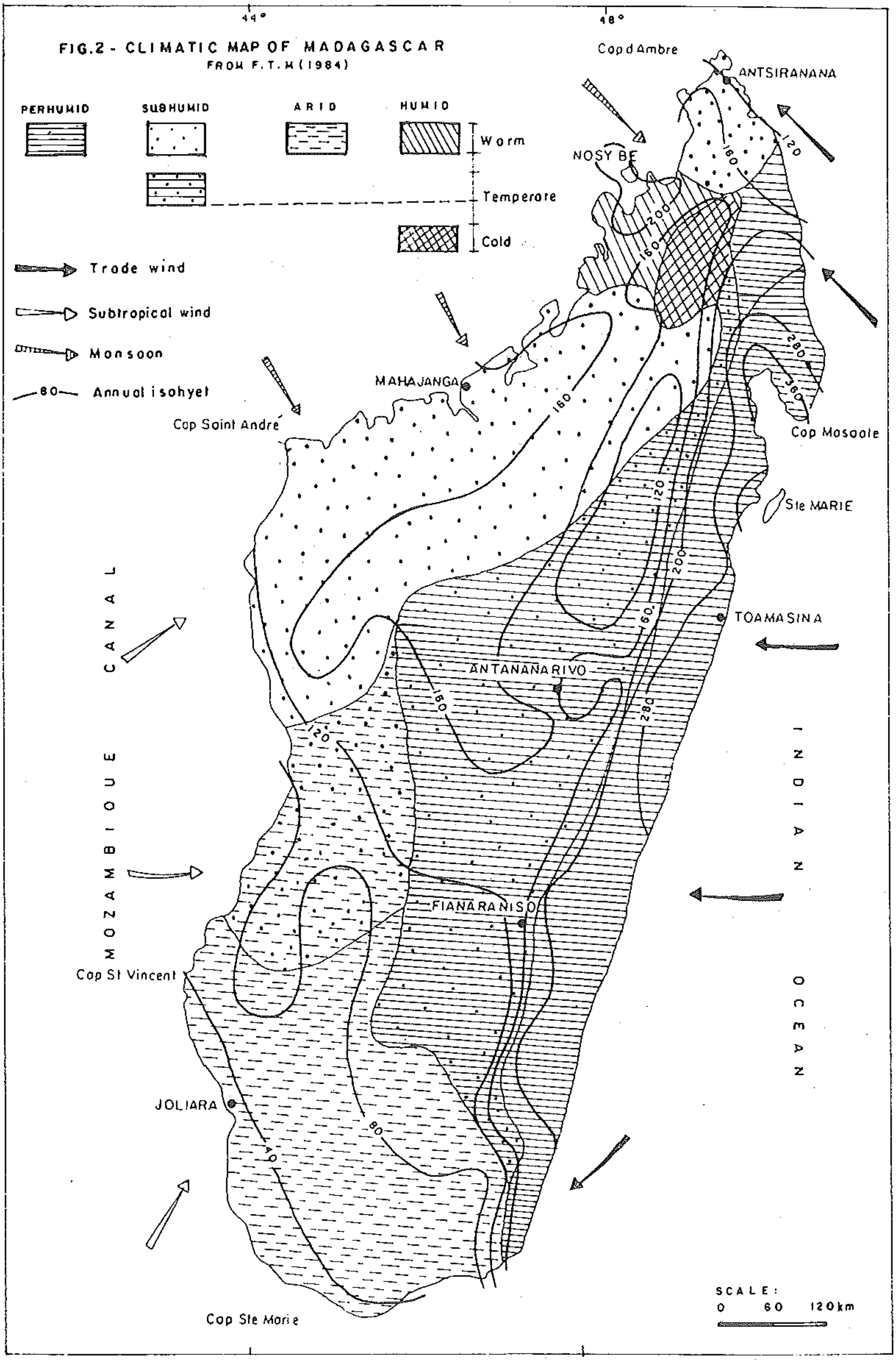
FIG.2 - CLIMATIC MAP OF MADAGASCAR
FROM F.T.M (1984)
PERHUMID
SUBHUMID
ARID
HUMID
Warm
Temperate
Cold
Trade wind
Subtropical wind
Monsoon
80 Annual isohyet
Cap d Ambre
ANTSIRANANA
NOSY BE
MAHAJANGA
Cap Saint Andre
Cap Masoala
Ste MARIE
TOAMASINA
ANTANANARIVO
FIANARANISO
Cap St Vincent
JOLIARA
Cap Ste Marie
MOZAMBIQUE CANAL
INDIAN OCEAN
SCALE:
0 60 120km

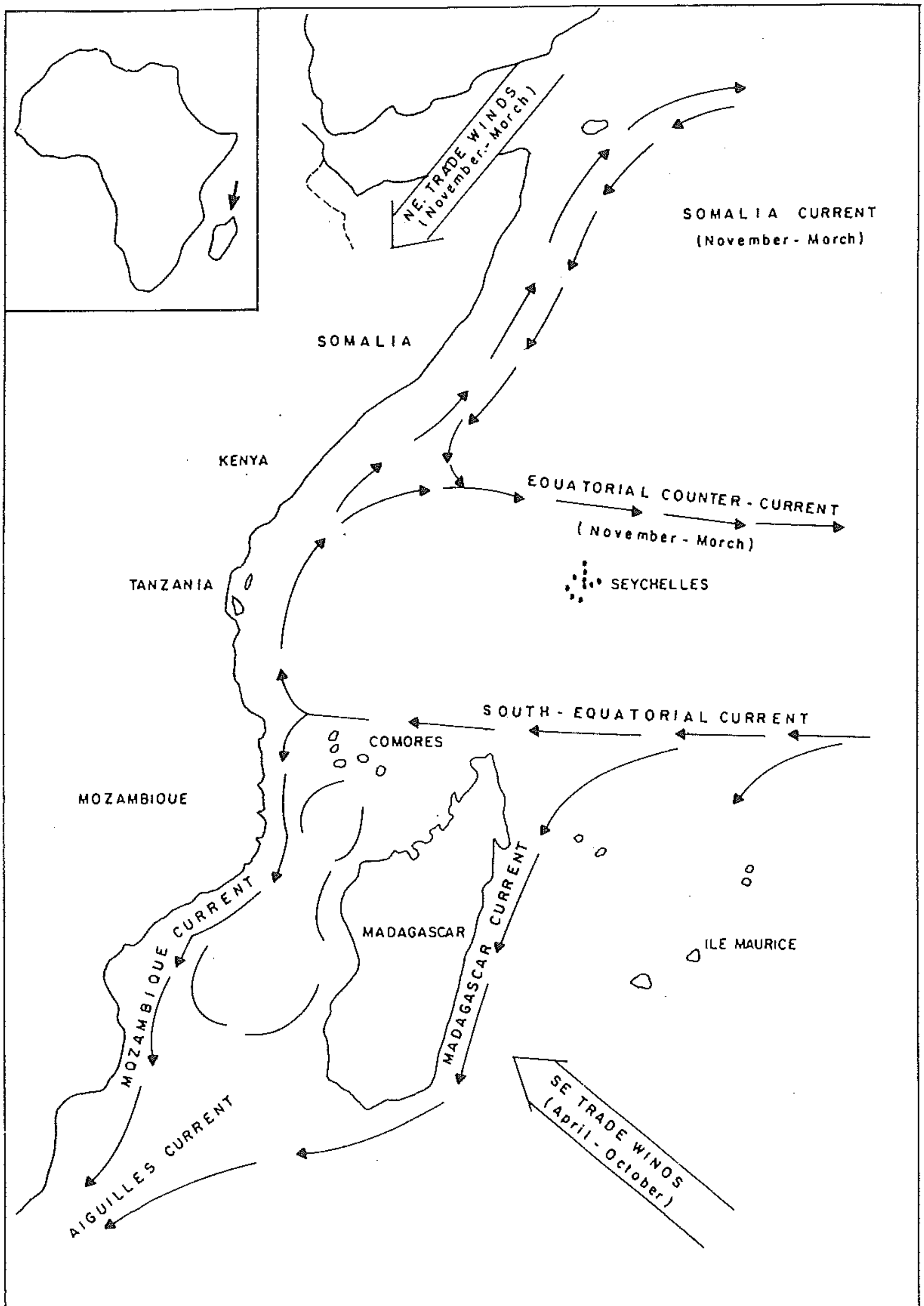

Fig. 3. South-Western currents in the Indian Ocean

and Magnier 1975). The water is in closed circuit circulation is influenced only locally by the alternation of the rainy and dry seasons.

In November (end of the dry season), the salinity in the North of the channel is high (35‰ - 35,2‰). After the rainy season, the salinity of the surface waters varies between 31,8‰ and 34.5‰ on the North Western Coasts (MAGAZZU 1985). In the South, the seasonal variations are less important, because the rainfall is poorer. Beyond 24°S lat, the Mozambique channel waters mix with the tropical surface water which has higher salinity (35.5‰) and comes from the South.

In the Northern part, the water surface temperature is 27°C near the coasts. Temperature decreases perceptibly towards the south.

Generally, the surface waters of the open sea are over-saturated with dissolved oxygen. Dissolved oxygen concentration can reach 4.4 ml/l. In the coastal zone, oxygen concentration is lower in the mudflat areas.

The surface waters of the Mozambique Channel are known to be very poor as far as nutritional salts are concerned. For primary production, the reef areas represent a very precise frontier of the photosynthetic activity (MAGAZZU, 1985).

4. Biological and Ecological Characters

4.1 Vegetation

The conditions of the silty zones determine several types of mangroves:

* The vegetal formations of the coastal mangroves are marked by an incomplete succession of sandy-silty heaps; the vegetation is generally limited to the infra-littoral level;
* The linear formations spread along the coast in the sea front, surrounding sometimes the channels of the isolated lagoons ;
* The estuarine formations and those of the bays; these littoral formations are more extended. The vegetation spreads from the infra-littoral level to the land halophile vegetation.

4.2 Composition of the flora

The floristic composition of the Madagascar mangroves is related to that of all the coastal regions of East Africa. The main species belong to four families :

- The family of Rhizophoracae with the species *Rhizophora mucronata, Bruguiera gymnorhyza* and *Ceriops boiviniana;*
- The family of Avicenniacae, *Avicennia marina;*
- The family of Sonneratiaceae, *Sonneriatia alba;*
- The family of Combretaceae with *Lumnitziera racemosa,* which is not frequent.

Other common plant species are marine algae that grow on the tree roots, the filamentous algae *Lyngbia sp.* and *Vaucheria.*

Behind the mangrove swamps are found other common plants:

- *Acrostichum aureum* (Polypodiacea);
- *Heritiera littoralis* (Sterculiaceae);
- *Thespesia populnea* (Malvaceae);
- *Sesuvium portulacastrum;*
- Land species including *Paspalum vaginatum; Phoenix reclinata; Terminalia catappa.*

4.3 Vegetation zonation

The mangrove trees present a classical zonation, with in the sea front, *Sonneratia alba;* further, there are *Avicennia marina, Rhizophora mucronata* and *Bruguiera gymnorhyza,* in a mixed formation. *Ceriops tagal* and *Lumnitzera racemosa* are on the land side. Near the channels again *Rhizophora mucronata* and *Avicennia marina.* Zonations may be incomplete and interpenetrations are frequent. This zonation (Fig. 4) was illustrated by a study carried out by RAJAOBELINA V. (1987) in one of the small mangrove swamps of Nosy-Bé.

4.4 Fauna

The fishes of the mangroves have been described by KIENER (1961), FOURMANOIR (1953). Species of order Selachii, and the families: Carangidae, Mugilidae, Sparidae, Lutjianidae, Mullidae are abundant in the channels and estuarine waters.

Among the crustaceans: fresh water crayfish (*Macrobrachium sp.*) and shrimps such as *Penaeus* and *Metapenaeus* in their juvenile or subadult stages; *Acetes* (Tsivakiny); crabs (*Scylla serrata, Uca, Sesarma*), which colonize the mangrove swamps soils and channels. Among the Cirripeds, *Balanus* and *Chtamalus.*

Molluscs show a great diversity; among the Bivalves, oysters (*Crassostrea cucullata*) fixed on the trunks and the roots of mangroves is important. On the fringe of the littoral mangrove, large populations of bivalves: *Anadara natalensis* (Arcidae). Among the

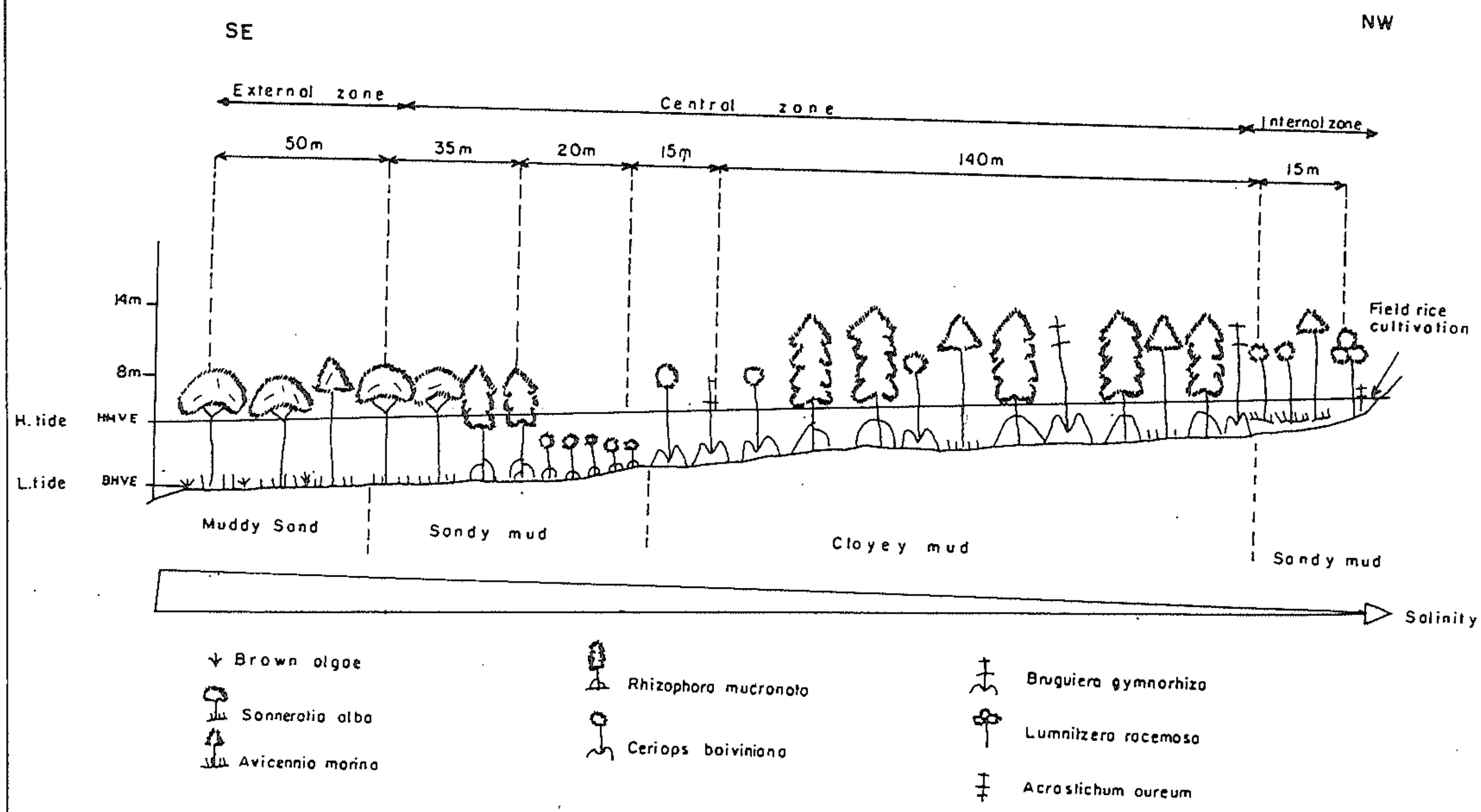

FIG. 4 - TRANSECT ALONG THE AMBANORO MANGROVE (NOSY-BE)
From RAJAOBELINA V. (1987)

Gastropods: *Pyrazus palustris* (Tsakodia) litter the soils of the mangrove swamps and are consumed by villagers on the coast; the small *Littorina scabra*, fixed on the mangrove trees, numerous *Terebralia*, fixed on the stilt roots of mangrove trees.

In a detailed ecological study, RAJAOBELINA V., 1987 described the distribution of animals in the mangrove swamp zones (Fig. 5).

The mudflats that are uncovered at low tide, and the edges of the channels are the favourite place of numerous species of limnivorous and piscivorous birds. The avifauna of the mangroves is markedly endemic (SECA; 1986), such as *Egretta garzetta, Ardea cinerea, Alcedo cristata, Vintsoides, and* the prey bird (*Haliatus vociferoides*). The flying foxes *Pteropus rufus* sleep hung on the branches. Reptiles such as crocodiles and sea turtles have been almost completely exterminated.

5. Associated Ecosystems

All along the Western coast of Madagascar, the littoral extends over a large space and has a lot of biocenos that form diverse ecosystems. The geomorphology of the coast and the environmental conditions contribute to the coexistence of different ecosystems. According to the extent and the morphology of the littoral, we generally have, from the infra-littoral level, the different systems.

5.1 Coral Reefs

The total length of the coasts occupied by the coral reefs is estimated at 1,000 km (RABESANDRATANA, 1985). The reefs are generally distributed on the Western coast where the conditions of the environment favour the growth of reef constituents. There are several types of reefs: the isolated ones and the continuous ones such as those that form barriers or fringes. The coral reefs are essentially very productive ecosystems and are nursery zones for many sea organisms.

Also many plant species are found on the reefs mainly on their dead part. Algae (*Turbinaria, Cystoseira* and *Sargassum*) are very frequent. Among the fauna, a large diversity of animal groups are dependent on the reef systems. *Acropora, Millepora, Stylophora* and other Madreporia are the main constituents of the reefs. Many animals are associated to them:

- fish: morays, scorpion fish;
- crustaceans: lobsters and crabs;
- Echinoderms: urchins, crinoids, ophiuroids, holothurians and seastars
- molluscs: *Cypraea, Murex, Conus, Turbo, Terebra* and many others

The reef corals provide the riverside residents with important resources; through excessive exploitation (fishing, picking) as well as pollution, man has contributed to the degradation of reefs. In addition, the ecological condition of the reef environment has notably changed. This aspect is characterized by sedimentation of colloids in the coastal waters, an invasion of algae on the living parts of the reefs and decrease of the fish stocks.

5.2 Sea-grasses

The marine phanerogams called sea-grasses, generally succeed to the reefs in the lower parts of the silty and sandy shallows. Ten monocotyledon species partake in the constitution of coastal sea-grasses. These include several species: *Cymodocea rotundata, C. ciliata, Syringodium isoetifolium, S. halophila*. The sea-grasses provide reproduction space for several marine animals. They are also threatened by the sedimentation of colloids brought by the rivers.

5.3 Mudflats

Behind the sea-grasses, are small mounts of colloidal silt (called mudflats). Their extension can vary according to the hydrological and sedimentological dynamics of the coastal zones.

5.4 Mangrove creeks and channels

The mangrove area is criss crossed by channels and creeks which constitute an important biocenosis in the ecology of the mangroves. In fact, these waterways sustain a very rich fauna composed of diverse species, pelagic and benthic. Young animals are mostly living there. However a thick stock of adult brackish animals also lives there (mainly fishes and crustaceans).

5.5 The Rear-mangrove swamps

In the rear of the mangroves, a sandy or silty beach may extend, populated by benthic animals (*Sesarma sp., Uca* and *Pyrazus palustris*) and some medio and supralittoral vegetation.

Lastly, in the external zone, rarely inundated by the tides, there are bare or grassy surfaces (tannes) or transition toward the halophile forest.

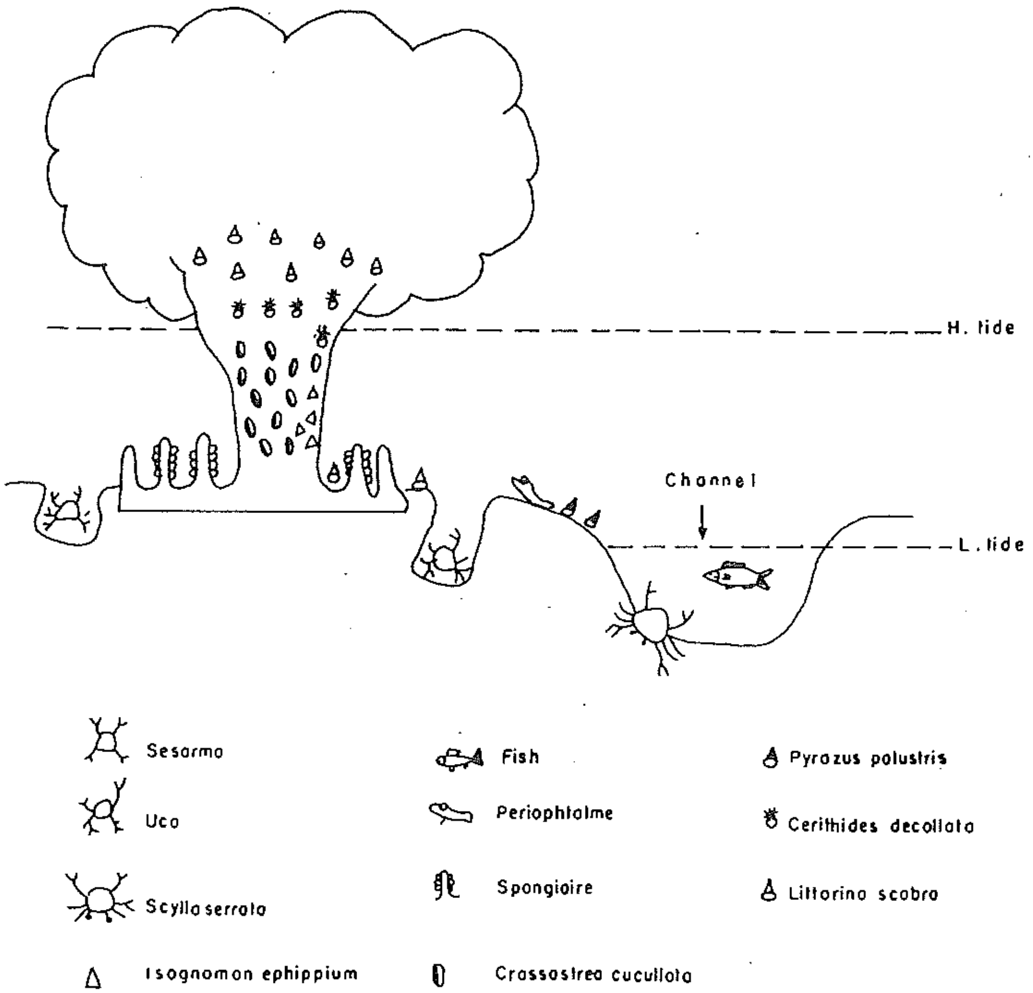

FIG. 5 - VERTICAL ORGANISATION OF THE FAUNA
(Mangrove of Ambanoro-Nosy Be)
FROM RAJAOBELINA V. (1987)

6. Human Population and Traditional Uses

There are no concrete data on the uses of the mangroves in Madagascar. However a few studies revealed man's intense activities in the mangroves.

6.1 Forest exploitation: the mangroves are very little used as far as forestry is concerned. However, some exploitation has developed locally (regions of Mahajanga and Tulear), where the mangrove ecosystem has suffered considerable damages.

6.1.1 Wood production

Most of the mangroves are exposed to anarchic methods of exploitation oriented towards:

a - **Timber**: The mangrove wood and mainly that of *Rhizophora* is excellent. It is appreciated for its resistance to putrefaction and termites. In fact, each species has its own qualities : *Bruguiera gymnorhyza* and *Rhizophora mucronata* with a straight bole are used for masts and 5m standard poles, used for roofing. *Heritiera littoralis* is used for frameworks while *Ceriops* serves in the construction of huts and fences.

b- **Charcoal and firewood** : *Avicennia marina* offers a better quality domestic firewood. However, with the exception of the mangroves in the region of Tulear (North Fiherenana) which are almost entirely destroyed by charcoal and firewood exploitation (VASSEUR, 1987), the practice is not so intense in other mangrove swamps.

6.1.2 Tan bark

The bark of *Rhizophora mucronata* or *Ceriops* was used to dye clothes, mohair carpet, wooden parquets, houses, canoes. Like those of Eastern Africa, the mangrove barks of Madagascar have a record yield of 40% to 50% against 10% to 20% only for those coming from South East Asia.

The exploitation of barks for tannin is at present abandoned. About 200,000 tons of bark have been collected and exported (Guillaumin, 1928). This corresponds in accordance with the average figure of 10t/ha, to the destruction of 20.000 ha of *Rhizophora* mangrove swamps.

For the time being, no sylviculture of mangroves is planned in Madagascar. For an ever increasing forestry exploitation, owing to the demographic pressure, some management practices are advisable. The exploitation must be methodical in order to avoid erosion and bad spontaneous regeneration. Tree planting is also recommended to favour mangrove trees whose pioneer species are in use.

6.2 Fishing

In the mangrove swamp zones, fishing is very active. It is practiced traditionally in diverse different ways. In the mudflat zones the mangroves, coastal dams (Valakira) are set to capture shrimps and fishes. Fishing with nets is practised in the channels and seines are spread out on the sandy banks.

6.2.1 Shrimps

The extension of mangrove zones along the Western coasts allow for a high shrimp production in Madagascar. In the mangrove zones, traditional fishing with valakira and nets aims at the small shrimps. The annual yield of traditional fishing reaches 3.000 tons. The industrial annual capture is 7.000 tons (Anonymous, 1991).

6.2.2 Crabs

Scylla serrata is actively captured. The stock is estimated at about 7,500 tons in steady maximal production. Crab fishing has always been a traditional activity in the Western coast and is mainly developed between Antsiranana and Toliara. They are captured with Taiwan nets, manually and with basquets; they are very much in demand on the national and international markets.

6.2.3 Fish

All along the coast, fish of many families (Carangidae, Mugilidae, Clupeidae) are caught. Fishing is practised traditionally with nets, rod, canoes. Collection networks are organized for the marketing of these products.

6.2.4 Other resources

Holothuria are collected in the mudflats of the mangroves, it is anarchically exploited for export; bivalve and gastropod molluscs are collected for the local market. They are also used for bait for fishing.

6.3 Aquaculture

The aquaculture of the "Tambak" kind that is very developed in mangrove areas of other countries (South East Asia) is still unknown in Madagascar. Shell culture has a certain development in the South West (Region of Tulear).

7. Commercialisation and Market

The commercialisation of the mangrove wood resources has not yet reached a scale that could threaten the management of these patrimonies; on the other side trading of the sea products, representing a large part of the resources exploited in the mangrove swamps is very developed and has been well studied.

ANDRIANAIVOJAONA, C. and *al.*, 1992 presented several characteristic points for the trade of the products coming from coastal fishing in Madagascar. The products from the traditional coastal fishing are, mostly, sold locally or autoconsummed.

Traditional fishermen are the main suppliers of animal proteins to the Malagashy population. Of the total annual production, the fisherman is responsible for 20 % to 80 %. The zones of production are far from the zones of consumption. This situation raises some problems as far as supply is concerned. The sale of sea products is in accordance with the type of product and follows three avenues:

- To a structured circuit (entreprises for collecting and sale)
- to the market place
- or directly to the consummers

These figures show that a large part of the products pass through the structured circuit. However, 50% of the fish are sold in the market place or directly to the consumers.

In this circuit, fishermen generally sell their products to the same wholesale merchants. This situation engenders, on one hand a dependance of fishermen on the wholesalesmen, and on the other hand, a possible competition or destabilization of the circuit. However, fishermen always manage to sell their product through different methods: 70 % are sold fresh and 30 % are preserved and dispatched smoked, grilled, or salted and dried.

The importance of the benefits shows the high profitability of fishing as an activity. Shellfish are more profitable, owing to the prices on the international markets. All shrimps are exported, as for the crabs, the possibilities of export conditions their production. The crab marketing is at present challenged by a product named "SURIMI" which is fish product perfumed with crab. Before long, this product may cause a serious threat to the crab production.

8. Other Uses

8.1 Agriculture

Mangrove swamp rice-growing was very much developed, notably in the delta of Tsiribihina. The rear mangrove swamp zones are used for agricultural exploitation in many coastal regions. Ricefields are filled up with fresh water pushed back by the tidal flood. Small dikes isolate the rice fields. Nowadays, this method has been abandoned because of the soils salinization: consequences of the temperature increase and rainfall decrease.

8.2 Oil and mine prospections

Much research has been carried out in the sedimentary basins of Madagascar, mainly in the marine areas of the Morondava basin and off shore from the coasts of the Belo region on Tsiribihina. Companies have started geophysical research to find structural forms liable to be oil-bearing. For the time being, there is no further serious exploitation. Indeed, several tons of hydrocarbons have been detected in the sedimentary formations of these zones, but their extraction rises serious difficulties (LEBIGRE, 1984).

8.3 Salt marshes

The tannes to the rear of the mangroves have been converted into salt marshes for salt exploitation. These salty surfaces are sometimes made at the expense of the external zone of the mangrove swamps. Elsewhere, soils have been transformed into pasture zones.

Table 1 : Sale circuit of the main sea products in the mangrove swamps zones

Products	to the wholesale fish merchants	to the market	Directly to the consumers	Delivered to the entreprises
Fish	46%	16%	30%	--
Shrimps	47%	27%	--	27%
Crabs	41%	15%	17%	27%

8.4 Polders

Zones that were formerly covered by *Ceriops boiviniana* or *Avicennia marina* in the Analalava and Ambanja (North West) regions have been transformed into polders (Durand, 1964). The polders are used for rice-growing but the aim was to create coconut palm plantations.

8.5 Aquacultural basins

The potentiality of the shrimp zones on the North Western coasts of the island, is evaluated at 55,000 ha by AUTRAND (1990). These sites are tannes (sirasira) and present favourable conditions for setting up aquacultural basins for shrimp breeding, mainly Peneides. Those flat spaces are located on the upper limit of the intertidal zones. Their soil is clayey and slightly acid sulphated. After an experimental phase which was very positive, shrimp breeding started for industrial exploitation phase. Many entreprises want to invest in that domain and the Malagashy government is encouraging these exploitations. But there is a need for an adequate management policy in order to protect the natural patrimony and the environment and so, permit a reasonable use of the mangroves, at the same time as the development of the industrial and commercial shrimp aquaculture.

9. Impact on the Mangrove Environment

9.1 Human factors

The coastal zone has experienced a noticeable demographic increase during recent years. This fact contributes to an over-exploitation of the coastal resources. The immediate impact on the mangrove ecosystems is the local impoverishment of resources.

9.1.1 Forestry

Forest exploitation of the mangroves, is not yet alarming despite increasing and anarchic cutting that alters the natural zonation. In Toliara, the mangrove swamp is being destroyed by wood cutters for domestic uses (timber, charcoal, firewood; ANONYMOUS, 1985).

9.1.2 Fishing

Fishing is practised all along the coasts mainly in the estuaries. There is also competition in shrimp exploitation between the traditional craft fishing and the industrial fishing. The stock is threatened by the capture of younger individuals and excessive maximal catch.

9.1.3 Aquaculture

The development of aquaculture in the mangroves zones is beginning to develop. Aquaculture exploitations can change water quality. For the time being only rear-mangrove zones are converted to shrimp ponds but in the future, expansion of this type of exploitation may seriously jeopardize the ecological balance of the mangroves.

9.2 The impact of urbanization and industrialisation

Pollution is the main impact of urbanization on the coastal systems. Development of the urban and rural zones has not been followed by adequate sanitation of the coastal towns. Household refuse and faecal matter are thrown into the sea; sewers are not maintained if present. This causes decrease of oxygen due to the decay of residues and an increase of nutrients, resulting in eutrophication. Elsewhere, bacteriological contamination of the environment may spread widely.

The industrial development of the coastal zones is a threat to the coastal systems due to toxic effluents discharged into the waters. Concerning chemical pollution, among other things, accidental or deliberate pouring of hydrocarbon products into the waters is a serious hazard.

The impact on the ecosystems can be translated into the suffocation and death of the mangrove swamp plants and animals.

9.3 Natural physical factors

Deforestation is a widespread phenomenon; rapid and continuous destruction of the vegetation, on the soft substrata (laterite, sandy and clayey crust), that compose the superficial part of the soil, is due to intense erosion; the heavy rains add to the damages on the vegetation. Huge quantities of the alluvia are deposited at river mouths. Consequently there is a progression of the marshes on the sea and the land, at the expense of maritime marshes. This is characterized by a regression of mangrove swamps that are changed into tannes (LEBIGRE, 1983). Elsewhere, the granulometry in the silty sediments becomes thicker, causing the erosion of the mangroves. Rapid modifications can also threaten the areas that are under the influence of big swells. Siltation is accompanied by an increase of terrigenous supplies that leads to suffocation of the coral reef communities, and a reduction of their productivity.

Table 2 : Catches and estimative values of the production in 1990.

REGION	ANTSIRANANA		MAHAJANGA		TOLIARA	
Species	C	V	C	V	C	V
Mulets	1,310.6	622.5	1,153.8	654.2	--	--
Cluplides	755.7	395.2	5,320.2	1,213.0	283.6	129.9
Lutjianus	648.8	545.1	320.5	179.9	268.7	116.6
Lethrines	614.0	403.4	--	--	2,030.0	1,029.2
Sphyraenidae	566.8	387.7	--	--	--	--
Carangidae	--	--	341.9	169.9	1,134.4	551.3

C = Catches in tons
V = Values in millions malagasy Francs.

10. Economical Implications

Coastal ecosystems have always played an important role in the social and economical activities of the coastal population in Madagascar.

10.1 Coastal population

There is no reliable census of the inhabitants who depend on the coastal ecosystems. A high percentage of this population considers the coastal systems as the basis of their activities.

The coastal zone population has lately experienced a considerable demographic increase. These populations, mainly composed of fishermen or peasants, live in small communities in villages localized near mangrove areas. These villages are generally small and sparse because of poor roads infrastructure. A large portion of immigrants or visitors is now coming there to partake in the commercial activity.

10.2 Social organization

Coastal inhabitants become fishermen, because it is the most rewarding job (high yield against the effort). Beside fishing with canoes, women participate actively in the picking, the fishing, the transformation of the products (drying, smoking) and selling it in the local market.

Statistics show that 88% of the fishermen have school education, and only 12% an informal education (BELLEMANS M.S., 1989). Many villages in the area have no medical infrastructure. However, with few exceptions, all the villages are endowed with a school. The level of education is low adding to a certain percentage of illiterates.

10.3 Economical activities

10.3.1 Fishing

Fishing is the main activity of people living in these areas. This contributes to the supply of animal protein and to commerce as well. In the majority of cases, fishing is practised in parallel with agriculture and aquaculture.

The fishing and aquaculture direction recorded the following figures from a survey:

- 63% of fishermen are considered as full time fishermen;
- 34% are half time fishermen;
- 3% are occasional fishermen;

These figures show the high participation of the population in fishing. Elsewhere, most of the fishermen say that fishing is a lucrative activity allowing immediate profits. The investments in fisheries (purchase of canoes and fishing instruments) indicate the hope of continuous profit from this activity.

a) Shrimp fishing is the most developed activity in the mangroves. The traditional shrimp fishing increases in yield from 800 tons (late 1970) to more than 1,000 tons (1984-1986) and to 1,237 tons in 1985 (RALISON and RAZAFINDRALAMBO, 1985). However there is a relatively high percentage of small shrimps (about 40 % of the catch; BELLEMANS, 1990). We can estimate the total shrimp production from the artisanal fisheries at 2,000 tons/year (ANONYMOUS, 1991).

Coastal shrimps are good earners of foreign currency for the national economy. The mangrove areas fishermen sell the shrimps from 1,500 Fmg to 2,000 Fmg (1992) according to the seasons and the region. Shrimp exports, including the industrial products represent a total value of nearly 70,000 millions Fmg (ANONYMOUS, 1991).

b) The exploitation of the crab *Scylla serrata* is widespread. The national production in 1990 reached 1,200 tons from which 1,050 tons were aimed at export and 150 tons for the home market. According to ROULLOT'S calculations, the daily catch per fisherman varies from 5 to 50 kg with a profit of 200 Fmg/kg; the export is valued at 1,440 millions Fmg.

c) Fish have always been traditionally exploited in the mangrove areas. The average production per village is 60 kg/day/canoe (RASOARIMIADANA L., 1985). The major part of the fishes from the mangrove areas belong to the Clupeidae, Mullidae and Carangidae families. The following table shows the value of the catches per family in the three coastal provinces of Western Madagascar (RAFALIMANANA T.,1991).

10.3.2 Forest exploitation

The mangrove swamp ecosystems are not much used as far as forestry is concerned because there still are land forest reserves. However there are a few exploitation timber yards. The mangrove wood, sold in the form of poles and bundles is not a very profitable activity. But charcoal is in increasing demand in towns.

10.3.3 Salt exploitation

This activity is very widespread on the tannes (sirasira) in the region of Antsiranana and Belo/Tsiribihina and Tulear. Modernization for a large scale exploitation has been undertaken in Antsiranana.

11. Research And Training Programmes

The first studies carried out on the Madagascar mangrove swamps were achieved by various researchers. The studies were then essentially descriptive in ecology, in faunistic and floristic inventories (KIENER, 1966), (DERIJARD, 1963), (WEISS, 1972, 1973). These studies were isolated and did not show the real bio-diversity and the ecological realities of the mangrove swamps. Today, with the participation of many international and national organizations and institutions, more detailed studies were programmed and realized, with the view of a better knowledge of the mangrove ecosystems. Researches would also allow for a management and preservation policy of resources. Many programmes were elaborated and priority was given to research for development. The aim of these studies are centred on:

- Inventory of the mangrove resources (cartography, biodiversity)
- Long term coastal researches (on the parameters of the environment)
- Ecological and biological researches applied to the mangrove ecosystems
- Integrated studies dealing with mangrove ecosystems (socio-economical, sylviculture, preservation).

Many scientific groups are executing the research programmes:

- In oceanography: researchers of the National Oceanographic Research Centre (CNRO) at Nosy-Bé and those of the Marine station of Tuléar, work on the inventories and the environmental parameters of the mangrove ecosystems for a better use and conservation.
- Geographers of the university and those of "Foibe Taosaritany Madagasikara" (F.T.M) partake in cartographical, biogeographical and sedimentological studies.
- Research teams of the "Natural Ecosystem Department" of the "Centre National de Recherches sur l'Environnement" (C.N.R.E.) at Antananarivo are carrying out pluridisciplinary research in relation to the mangroves ecosystems.
- The Forestry and Water Direction is carrying out in collaboration with the World Bank, programmes on the inventory of the areas to be protected in the mangrove swamp ecosystems and the determination of the strategies for conservation.

In the regional plan, Madagascar is member of the COMARAF regional project: "Research and Training on Coastal Marine Systems in Africa" UNDP/UNESCO; RAF/87/038. This project has contributed to the training of Malagashy researchers, either through the access to various scientific documents which are published by the project (technical reports, occasional series); or through fieldwork with the participation of young scientists from Madagascar. Elsewhere, according to bilateral conventions, researchers from the C.N.R.E (Centre National de Recherche sur l'Environnement) succeeded in deepening their knowledge on the mangrove swamps ecosystems in the domains of cartography and sedimentology of the mangrove swamps.

There are no specialists on mangrove ecosystems in Madagascar, because this discipline is not yet considered a priority. For a reasonable management policy of these mangrove ecosystems, the various institutes should co-ordinate their efforts in the achievement of research programmes by creating pluridisciplinary teams. As far as environmental education is concerned, mangrove ecosystem studies must be included in the different school programmes at an early stage.

12. Management Policies

The legislation of the mangrove swamps in Madagascar comes under the responsibility of the Water and Forestry services. However there is no text mentioning the mangrove swamps.

In the present context of utilization of the mangrove resources, the management policy must consider the natural characteristics of the environment where are located the mangrove swamps. The elaboration of a conservation strategy is vital for a sustainable development; protection measures must be taken, in particular, for the establishment of parks and reserves in definite areas.

Mangrove areas must not be encroached upon by agriculture or aquaculture. Large flat areas (tannes) located behind the mangrove swamps are available for these purposes. For the rice-growing and other products, they should be practised in heavy rain zones.

At present mangrove swamps are not much exploited as far as forestry is concerned. Their development requires preexisting knowledge and a complete inventory of the mangrove ecosystem's natural resources. Areas to be protected should be recorded as reserve sites. Sylviculture should be developed where forestry exploitation threatens large areas.

Before anything else, basic research and training must be elaborated. Priority will be given to research projects for development. The participation of Malagashy researchers in regional or international research projects (COMARAF, ISME projects, international symposia) should be encouraged.

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General Conclusion

At the end of the ISME/ITTO project on "Conservation and sustainable utilization of mangrove forests in Latin America and in Africa regions", the final results including the proceedings of the Rio (May 1992) and Dakar (January 1993) meetings and the final technical reports of Latin America and Africa have been presented in Okinawa, Japan in June 1993.

The present document dealing with the African component, recapitulates in an exhaustive manner the country-reports of the sixteen (16) countries which have taken part to the project.

Most country-reports followed the definite format proposed during the first meeting of the project at Niteroi (Brazil, May 1992). Thus, for the first time, with a coherent approach, number of important informations have been gathered in one and unique document related to the historical perspectives of the mangrove ecosystems in Africa, their extent and distribution, their bio-physico-chemical conditions, their traditional uses and other conversions, the natural and anthropogenic impacts on their environments, the socio-economical implications, the research and training programmes presently initiated and the multidisciplinary national committees set up as well as the scientific investigations on these ecosystems developed during the two last decades (refer to the exhaustive bibliography in each country-report).

This first project has made a general survey, with sometimes detailed descriptions of the mangrove ecosystems in Africa. Now that this first step has been accomplished, it is time to go further (taking into account the principal recommendations of the Dakar January 1993 workshop). For this purpose and for concrete actions, more precise investigation themes need to be tackled. Thus, at the end of the concluding workshop of this project held in Okinawa in June 1993, two major projects have been proposed as far as the mangroves of Africa are concerned:

- the first one should be based in East Africa. It will deal with the particular experiences of Tanzania concerning the evaluation and the cartography of the mangrove resources. Under this framework, two sub-regional workshops could be organised, one oriented towards the decisions makers, the other towards the scientists and the managers through specific site visits along the Tanzanian coast.

- the second one should be based in West Africa and will deal principally with the over-exploited and degraded mangroves of the region through reforestation and afforestation and aquatic resources rehabilitation.

For the research priorities on the African mangrove ecosystems, a few guidelines have been discussed:

- Traditional practices and uses in the mangrove environments of the Gulf of Benin (including Togo, Benin, Ghana and Nigeria);

- Reforestation and afforestation of the mangrove ecosystems and consequences on the aquatic resources rehabilitation (Guinea, Guinea-Bissao, Gambia and Senegal);

- Documentation on the traditional knowledge, multiple uses and management of the African mangroves, including socio-economical aspects, in the Western side of the continent as well as in the Eastern part;

- Updating of the mangrove areas mapping, production of an inventory of the flora and their relative abundance (in terms of surfaces and available timber volume). A certain number of sites rigourosly selected in West and East Africa could be the first test-areas to be considered.

As far as training priorities are concerned, the following recommendations have been made:

Field training courses should be organized to increase the capacity of several African coastal countries in terms of research. For the first stage, the following field areas could be selected:

- Productivity measurements with particular emphazis on soil-water-plant (mangrove) exchange.

- Regeneration and planting technics, including laboratory experiments in particular for the arid areas where mangroves are disappearing because of degradation.

Several projects are now initiated by IUCN, UNEP, UNESCO, ADB (African Development Bank), ORSTOM and recently by ISME. These projects are mainly focused on the rehabilitation and the management of the mangrove ecosystems, their socio-economical aspects, their traditional rights and uses, the legislative aspects of their uses; they need to be well coordinated for a better efficiency. Let us hope that the mapping and the mangrove atlas project as well as the data base mangrove project recently initiated by ISME will consecrate an important part to the mangroves of Africa.

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