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

ITTO/ISME Project PD114/90 (F)

Project Coordinator
L.D. Lacerda

Part I - Latin America

International Tropical Timber Organization

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International Society for Mangrove Ecosystems

ITTO/ISME Project PD114/90(F)

Technical Report of the Project

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

Part I: Latin America

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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 present volume includes the results of the Latin America component of the ISME/ITTO project, PD 114/90(F), "Workshops on Conservation and Sustainable Utilization of Mangrove Forests in Latin America and Africa Regions". It summarizes the available knowledge on the mangroves of Latin American and Caribbean countries and states as far as we have been able to assemble during the short period of time of this project. As Coordinator of the project I tried to make the reports as uniform and concise as possible without loss of information and local flavor. Most reports were written in the national language and had to be translated into English. Due to the shortness of time available it was not possible to show galley proofs to the to authors. Therefore, any mistake or misunderstanding are the sole responsibility of the Editors.

Luiz Drude de Lacerda
Project Coordinator

Acknowledgements

ISME wishes to acknowledge gratefully the unfailing support received from ITTO, the Government of Japan and the Prefectural Government of Okinawa. Supporters and collaborators are too many to single out by name, but their individual and collective effort is much appreciated and is of the type and magnitude needed to carry out ISME's ideals.

Introduction

An ambitious project for updating our knowledge of the mangrove forests of Latin America, the Caribbean and Africa was funded by ITTO and was started in May 1992. It lasted for 18 months. The present publication is the technical report of the project: it is divided in two parts: Part I, Latin America and Part II: Africa. The African Report is Volume 3 of this Series, a French version of which has been published and is also numbered Volume 3 of this Series. A Spanish version of the Latin America version is under preparation. Dr. Luiz Drude de Lacerda of the Federal University of Niteroi, Brazil was the overall coordinator of the project and Dr. E. Salif Diop was the coordinator for Africa.

Meteorological and oceanographic data acquisition, processing and analysis systems know no national boundaries. The output of these global networks finds an application, among others, for making weather predictions: these are highly significant for short and long term rational use and management of the coastal zone. The forces that operate on the coastal zone also ignore national boundaries.

The importance of the mangrove forests and of the role they play world wide in all aspects of coastal management is closely interwoven with oceanographic, meteorological and climatological phenomena. The need for a close cooperation among coastal countries in general and specially those that are part of the same meteorological and oceanographic systems, is obvious and its significance cannot be over-emphasized.

One of the most important points brought up by the technical report of this ITTO/ISME project, is the need to envisage management of the coastal areas in a comprehensive and transnational manner. Examples are numerous, two of the most striking in the context of mangrove research and application of research results to sustainable use and management, come from Latin America and Africa.

Along the Pacific coast of South America, three countries with mangroves are strongly affected by the same meteoro-oceanographic systems, including the El-Niño: they are Peru, Ecuador, Colombia and to some extent Panama. The usefulness of networking for mutual assistance in analysis and prediction of normal cycles as well of episodic events like typhoons and hurricanes, or the El-Niño, is obvious. This is specially true when talking of mangroves, since we are usually dealing with nations with limited resources for field, laboratory and organized predictive capability. Planning for rational sustainable management is based on all these factors and on the establishment of a workable infrastructure.

The same applies for groups of countries in Africa. Most striking is the case of Togo, Benin and parts of Ghana and Nigeria where coastal dwellers because of environmental and ecological realities, have more affinities among themselves across international boundaries than with the people living inland in their own countries. Coastal dwellers of these countries speak the same language and are exposed to the same climatological regimes that spread on the coast along a west-east gradient. Their socio-economic-cultural-environmental problems are similar or comparable, hence the need to develop programmes and projects that will encompass the whole of the northern coast of the Gulf of Guinea. A networking approach will increase efficiency and effectiveness on a cost-benefit basis to achieve rational sustainable use of whatever mangroves are left and to obtain restoration of mangroves where feasible and convenient from environmental and socio-cultural-economic points of view.

The estimates of the magnitude and timing of global climate change and expected mean sea level rise vary widely, however there is no doubt that changes will take place in the next decades. Mangrove ecosystems are important formations of the tropical and occasionally sub-tropical belt; they will be affected positively or negatively by environmental changes whether induced by global warming or other oceanographic, meteorological or geophysical events of regional or global magnitude.

Mangroves are well known to render many indirect benefits in addition to the direct quantifiable benefits. Indirect benefits are most often the outcome of slow processes difficult to gauge or measure though they may be determinant factors for long-term rational use and management. It is obvious that special care must be given to recognize and record both short term and long term changes in the coastal zone as accurately as possible. It is equally important to assess whether changes are episodic, one time events or continuing forces stressing on the physical, chemical and biological environment. The adaptability and evolution of biological components of any ecosystem is superimposed on the evolution and changes of the physical and chemical environment; the interrelations must be understood to forecast the results of changing ecologic conditions. The work done for this project has gone a long way towards building a solid foundation and drawing a baseline of information for the functioning of an efficient network capable of contributing to the immense task of building preparedness to face all types of natural and man made changes. The mangroves are at the forefront of hazards and changes and these reports are particularly useful to register what we know and what we do not know.

Spadework in this direction is Asia and the Pacific and in Africa and the Caribbean had been done by several programmes of the UN, NGOs and individual countries, specially COMAR, COMARAF and CARICOM programmes of UNESCO, ITTO/ISME and others. Central and South America, or Latin America in general had not yet developed major multinational projects covering the coastal zone with the participation of most countries having mangroves. This ITTO/ISME project gives the opportunity to take a few steps in this direction.

This project has satisfactorily set the baseline on which to build a constructive programme of monitoring, assessing and advising for rational use and management of mangrove forest for sustainable use.

The task ahead is immense and requires understanding of its significance, support by scientists, managers, decision makers, governments and other NGOs. The work is multi-faceted and therefore calls for a multi-pronged attack and diversified support at all levels. It involves many efforts, from training and education to scientific research and law enforcement.

ISME has now in the pipeline for ITTO's support and funding a project proposal for the establishment of a Global Information System - MRIS - (Mangrove Resources Information System). It will be computer compatible with the GSI and it has already been planned in detail. MRIS will be based in Okinawa at ISME's Secretariat and will avail itself of the information obtained through this and other projects and it will pursue the work that this project has set in motion. Some countries have already organized, or are in the process of organizing, national mangrove information systems: these will be linked to MRIS and the effort should be encouraged by all means.

The mangroves are varied and speak many languages as coastal dwelling people themselves do. Only an International Society like ISME could dare tackle such a task. But ISME is still an infant, it requires powerful support from Governments, NGOs, all thinking persons, societies, agencies and entities in general.

ISME is extremely grateful to Government of Japan and ITTO for having placed confidence in the Society even before it had a chance to show its worth. The Prefectural Government of Okinawa gave the infrastructure and moral support needed to see ISME through its birth and infancy. I believe that we may confidently say that ISME has now graduated from infancy to childhood. With ISME's acknowledgments we wish to consign here also the hope that we will continue to enjoy the steady support and confidence that we badly need to carry out work firmly and wisely.

In conclusion: the project has achieved full success along five important lines:

1- establishing a network that covers about 90% of the mangrove area of the regions;
2- pinpointing geographic and subject wise areas in need of special attention;
3- generating awareness at national level of the important role of mangroves;
4- showing the need to improve training at all levels for sustainable use and management of mangroves, including developing and enforcing adequate legislation;
5- encouraging international cooperation

Dr. Marta Vannucci
Vice-President
ISME
October 1993

Contents

Mangrove Ecosystems of Latin America and the Caribbean: a Summary

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1. Mangroves and Man in Pre-Columbian and Colonial America

In various countries of the American continent, there is strong archeological evidence of mangrove utilization by Pre-Columbian and even Pre-historical human groups. Pre-Columbian inhabitants traditionally used mangroves for many purposes, including wood and energy production. The use of mangroves varied from site to site, depending on the particular characteristics of the population who started mangrove utilization during the transition period from nomad to fixed habits, between 9,000 to 3,000 years BP; however, several common features are evident (Alvarez-León, 1993).

In tropical coastal areas, the expansion of mangrove forests probably triggered, 6,000 years ago, important social changes among itinerant human groups, especially inducing an initial settling process of gatherer, fisher, and hunter communities. In Venezuela 6,000 or 5,000 years ago, human populations possibly coming from the inner lands of Venezuela, occupied the mouths of the rivers that descend from the Paria Sierra, and other coastal areas, many of them covered by mangroves (Sanoja, 1992), in a process similar to the one hypothesized by Widmer (1988) for the South coast of Florida, USA. Mangroves, as a resource, including wood, resins, fibers and dyes, and also proteins of animal origin, provided a spectrum of resources for diverse types of extraction and encouraged some incipient forms of cultivation of native edible plants. Extraction of mangrove oysters by the indigenous populations of the coastal areas could have induced a kind of seminomad exploitation, which can be compared to the use of soil by slash-and-burn farmers (Veloz Maggiolo & Pantel, 1976, cited in Sanoja, 1992).

The nomadic human groups frequently formed semi-permanent settlements along the coast, close to lagoons and bays, where an abundant and easy to collect protein-rich diet was provided by molluscs (Reichel-Dolmatoff, 1965). In these areas, they left large amounts of shells and organic and "cultural" debris, called "conchales" or "concheros" in Spanish speaking countries and "sambaquis" in Brazil. These remains provide important information on the characteristics of these populations including food habits and utilization of natural resources (Perdomo-Rojas, 1978; Prahl *et al.*, 1990).

Castaño-Uribe (1989) suggests that in Colombia the process of colonization by the human population was a continuous chronological sequence, with great implications for the cultural development of the entire continent. An example of this was the finding in mangroves and adjacent areas along the Atlantic coast of Colombia, of the most ancient ceramics of the American continent (*c.a.* 2,400 years BP) a discovery of pivotal cultural importance (Reichel-Dolmatoff, 1985). Along the extensive mangrove fringes of the Pacific and the Caribbean coasts of northern South America, the development of human groups resulted in distinct patterns of cultural adaptation which can still be recognized today. Their technology was continuously being changed and optimized for the exploitation of these resource-rich, non-seasonal wetlands, to provide the necessary infrastructure for the establishment of large human groups, whose economy was based on the collection of molluscs and on fisheries. The experience diversified and expanded through the continent (Castaño-Uribe, 1989).

In Panamá there is evidence of human settlements in mangrove areas about 5,000 years BP; these people made tools out of mangrove wood (D'Croz, 1993). The importance of fishing of euryhaline species from mangrove-bordered estuaries and channels for pre-Columbian human settlements located in the central coast of Panamá at that time has also been noted (Cook & Ranere, 1992). Utilizing fences, harpoons, fishhooks and other primitive tools, many of them made of mangrove wood, people from these settlements caught estuarine and coastal species belonging to the Carangidae, Batrachoididae, Ariidae, and Clupeidae.

In Brazil the pre-Columbian record extends from 3,500 to 2,000 years BP, when deposits of shells and fish bones from mangrove species were accumulated in mounds by nomad populations of fisherman and collectors (Beltrão, 1976).

In Peru, the Tumpis Culture, which settled in the Tumbes region, had an important role in Pre-Columbian America. They formed a large coastal population dedicated to agriculture, fishing and commerce, and are considered the best navigators of the Peruvian coast. They developed to a high degree the art of carving several mangrove bivalves, including *Spondius* sp., *Ostraea* sp., and *Anadara grandis*. To the *Spondius* shell, known to the Andean people as "Mullu", they attributed magical powers and after carving zoomorph or phytomorph figures they were offered during certain religious rituals (Echevarría & Sarabia, 1993).

The migration of human populations to the coastal areas is also testified, in Venezuela, by the presence of archaeological preceramic places of shellfish pickers and fishers in the Tucacas area, Falcón State, where nowadays there is a large extension of mangroves (Cruxent and Rouse, 1958). In the southern Pacific coast of Costa Rica huge "concheros", testify to the early settlements of indigenous communities. The indians of Puerto Rico (probably the Arawaks) occasionally ingested the red mangrove seedlings; this is a custom actually observed among the fishermen, who sustain that it helps them to quench their thirst during their prolonged fishing journeys (Carrera, 1975). In the Los Roques Archipelago, 100 km north of the Venezuelan coast, indians used mangroves intensively. As a consequence of this exploitation, some of these mangroves disappeared almost totally on some of the islands of the archipelago (Antczak & Antczak, 1987). Almost five centuries later, mangrove products still occupy a very important rank in the Venezuelan indian economy. In the Delta Amacuro State, indian populations use mangrove wood in the construction of poles and pilings for houses and jetties (Flores, 1977).

Archeological evidences suggest that mangroves were used intensively by the Arawak indians in Puerto Rico (Carrera, 1975). Many of the "concheros" are found in the coastal zone of this island (Carrera, 1975). Among the molluscs consumed by the indians are two mangrove species commonly found on the red mangrove: *Crassostrea rhizophorae* and *Isognomon alatus* (Carrera, 1975).

In Latin America, mangroves were the subject of curiosity since the discovery. Spanish colonizers were much attracted by mangroves, as can be inferred from the words of the historian Gonzalo Fernandez de Oviedo y Valdés, who wrote that the mangrove is " ... a tree of the best that in these places exists, and it is common in these islands ... rare and admirable trees to sight, because of its forms it is not known another being similar". This author is allegedly the first to mention, at the beginning of the XVI century, American mangroves (Rodríguez, 1984; Schaeffer-Novelli & Cintrón, 1990.). He added an inventory of mangrove uses. In 1595, Sir Walter Raleigh, in relation to some trees surrounding the channels at the mouth of the Orinoco Delta, mentions that these trees are capable of living in salty water. Tejera (1977) has catalogued other historical references on mangroves in the Americanist literature.

During the colonization, the indian opposition lead to the virtual extinction of native populations along the coasts of the entire continent. By the time of the European conquest, mangroves represented such a nuisance to troops and horses that Cristobal de Molina, for example, described the mangroves in 1552 in Peru as the "most difficult land of these kingdoms". However, this did not hamper the discovery of the quality of mangrove timber for construction, and the exploitation was immediately started, mostly for poles and boat construction, and later for tannin. From the 16^{th} century on mangrove timber was exported from Colombia to Peru and reached an amount of 6,000 poles a year in the 17^{th} century. In 1677 for instance, thousands of mangrove poles were exported to Cuba from the Pacific coast Colombia (Prahl *et al., 1990*) Commerce of bark was also very intense. Ecuador for example exported to neighboring countries nearly 600 tons of bark per year from 1879 to 1906 (Bodero, 1993).

During the colonial period the commerce of mangrove products was so important that the colonial authorities produced specific legislation to protect and manage the use of this resource. In 1760, the King of Portugal and Brazil, D. José issued one of the first, if not the very first, law to protect and adequately manage mangrove resources in Brazil. The law included specific penalties to be applied to people who cut the trees that had not been previously debarked. This is an example of environmentally sound lobbing by leather merchants who wanted to guarantee abundant high quality material for their tanneries, an important product of which was parchment for manuscripts, books and diplomas. In fact, as early as the XVII century, the Portuguese made methodical studies of the properties of the tannin from the bark of different species of *Rhizophora*, *Avicennia*, *Sonneratia* and *Xylocarpus* from many places in South India, Molucca, and Sri Lanka. These studies enabled them to select the best sources of raw materials for their tanneries, usually located in Portugal. The interest in the Brazilian mangroves grows only after the Portuguese supremacy in Asia was on a downward trend; the bark of the tree species of the mangroves bordering the Atlantic Ocean had been recognized as producing tannin of a lesser quality.

The Edict of the King of Portugal also indicates concern with sustainability of production, hence the banning of the practice of "ringing" the trunks to extract the bark. The Edict also reflects the accurate observation concerning the growth and regeneration pattern of mangroves South of Cabo de São Roque, since the species of that coastal area grow slowly and do not reach the height and importance of the species of the Northern Atlantic coast of South America or of the Indian Ocean and Southeast Asia. Other examples of sound management legislation occurred in other parts of the Colonial Americas.

The exploitation of mangroves in Puerto Rico was so intense, that in 1839 a Royal Edict set up a "Junta" with the duty to protect, among others, *Rhizophora mangle* and *Conocarpus erectus*; their wood could not be used in the naval industry (Carrera 1975).

During the second half of the XIX Century, the Curazao's people exploited the mangroves especially *Rhizophora mangle* of the Roques Archipelago, off the coast of Venezuela, using it as firewood for the furnaces of steamships; as a residual product, tannins were extracted from the crust (Amend, 1992).

Resources derived from mangroves have been utilized from pre-colombian times to the present. Presently, some forest products from mangroves are widely utilized in rural constructions, also as sticks in horticultural crops and they are still used for the extraction of tannin. However, only recently they have been considered as an ecosystem. This change in attitude in evaluating mangroves has been in many cases due to the negative experiences in attempting to manage single resources in isolatiton.

2. Extent and Distribution of Mangrove forests in Latin America and the Caribbean

In Latin America and the Caribbean, mangroves occur in all maritime countries except the three Southernmost nations Chile, Argentina and Uruguay. Only recently, however, efforts have been developed to survey the mangrove cover in these countries. Table 1 shows the most recent, and probably reliable, available estimates of mangrove area in Latin American and the Caribbean.

The major comprehensive estimate of mangrove areas in this region was published by Saenger *et al.* (1983), based on available information given by forest and environmental authorities and from scientific reports from the countries. This estimate shows that the total mangrove area is approximately 6.7 million ha, with 70% (4.8 million ha) occurring along the Atlantic Ocean and the Caribbean and only 30% (1.9 million ha) distributed along the Pacific coast. The largest forests are located in Brazil, Mexico, Cuba and Colombia.

Although this estimate has been widely accepted as representative, recent surveys suggest that it is an overestimate. The data presented in Table 1, include figures from Saenger *et al. (1983)*, for countries where no other information is available. According to recent estimates, mangrove cover in Latin America and the Caribbean is approximately 4.1 million ha, which is only about 60% of the total given in Saenger *et al.* (1983). For example, in Brazil, during the late 80's, a complete survey by satellite imagery and aerial photography of all coastal states, showed that mangrove cover is approximately 1.01 million ha with nearly 85% of the total forests in the northern coast of the country (Hertz, 1991). Considering that this is possibly underestimated by 20% to 30% (Kjerfve and Lacerda, 1993), the final figure is less than half of the 2.5 million ha proposed by Saenger *et al.* (1983).

In Venezuela mangroves occur along nearly 35% of the coastline. Saenger *et al.* (1983) estimated that mangrove cover reaches 673,600 ha, while the most recent figure is only 250,000 ha (MARNR, 1986), which is only 37% of the previous estimate. For several countries however, the estimates by Saenger *et al.* (1983) are in accordance with the most recent ones and in some cases even lower.

In Ecuador, a detailed study by remote sensing techniques covering the evolution of mangrove areas during the last two decades (CLIRSEN, 1984; MAG, 1991), showed the mangrove cover to be 161,770 ha, with nearly 70% of total mangrove area (110.000 ha) located in Guayas Province. This number is approximately the same of that proposed by Saenger *et al.* (1983) of 160,100 ha. For other countries like Cuba, where mangrove forests cover approximately 4.8% of the country's surface, a recent estimate from the Ministry of Agriculture gives a total mangrove area of 529,700, which is nearly 25% larger than the estimate proposed by Saenger *et al.* (1983).

The relative importance of mangroves for each country is illustrated by comparing the ratio between total mangrove area and total surface area of each country and the ratio between mangrove surface and coastline length (Table 1). Among the continental countries the percentage of the total surface covered by mangroves ranges from 0.01% in Peru to 3.1% in Belize. Mangrove area/coastline length ratios ranges from 2 in Peru to 326 in Guyana. For insular countries the percentage of total mangrove area can be as high as 27.6% in the Cayman Islands and 10.2% in the Bahamas, to less than 0.01% in Bermuda, while mangrove/coastline ratios range from less than 1 for Bermuda to 142 in Cuba. This rough representation shows that mangroves are the most important forest formation in certain countries and they should have a priority place in management and conservation.

Notwithstanding differences, recent data confirm Saenger's *et al.* (1983) relative distribution of mangroves of Pacific and Atlantic coasts of Latin America and Caribbean. The Pacific coast with approximately 1.16 million ha, has 28.5% of the total mangrove cover, while the Atlantic coast has approximately 2.14 million ha (52.8% of the total) and the Caribbean insular countries approximately 0.76 million ha or 18.7% of the total (Table 2).

Recent estimates of world mangrove cover vary and range from 15 to 30 million ha, with an average of 21.8 million ha (Saenger *et al.*, 1983; Lugo *et al.*, 1990; Twilley *et al.*, 1992) . Latin American and Caribbean mangroves represent approximately 18% of this total. However, considering the figures on Table 2 we conclude that they represent approximately 28.6% of the World total mangrove cover; African mangroves cover about the same area whereas mangrove cover in the Indo-Pacific region, represents nearly half of the world's mangroves.

Nearly all countries of the region are now mapping their mangroves to estimate area and density distribution. There is growing concern with the importance of these forests and with their health and survival in the coastal region. In several countries, mangroves are being cut and replaced by other biological or engineered structures, such as large scale mariculture in Ecuador, tourism in southeastern Brazil and harbor and industrial complexes almost everywhere. On the other hand, replanting and recuperation programs are being carried out in degraded mangrove areas such as those presently occurring in Cuba and Brazil. Therefore, although the data given Table 1 are, to our knowledge, the most recent, they are not final, and will certainly be changing in the near future.

3. Biogeographical Considerations

The New World mangrove flora is believed to have evolved later than the more diversified mangrove flora of the Indo-Pacific. The genera *Rhizophora* and *Avicennia* are believed to have evolved earlier and therefore they were able to spread through the Tethys Sea into what is presently the Mediterranean and thence to the East coast of the Americas and the West coast of Africa. They may have reached the Caribbean by the early Eocene (some 55-50 million years BP), when the distance from the Tethys Sea was considerably smaller.

Mangrove pollen of *Rhizophora, Avicennia* and *Pelliciera* has been reported from the Gatuncillo Formation, Panamá, of the middle to late Eocene (c.a. 40Ma BP) (Graham, 1989). Around the same time extensive *Rhizophora* and *Avicennia* forests covered the North of the South America coast. However they disappeared from the palynological record of

Table 1. Recent estimates of mangrove cover and the respective percentage of total countries' area and length of the coastline in the Latin American Continent.

	Area (ha)	% country surface	mangrove area/coastline	Author
Continental countries				
USA	190,000	0.02	10	Odum *et al.* (1982)
Mexico	524,600	0.27	56	Yàñez-Arancibia *et al.* (1993)
Belize	73,000	3.10	189	Saenger *et al.* (1983)
Guatemala	16,040	0.15	40	Jimenez (1992)
Nicaragua	60,000	0.50	66	Saenger *et al.* (1983)
Honduras	121,340	1.08	148	Jimenez (1992)
Costa Rica	41,330	0.08	32	Jimenez (1992)
El Salvador	35,235	1.65	45	Jimenez (1992)
Panamá	171,000	2.22	69	D'Croz (1993)
Colombia	358,000	0.31	148	Alvarez-León (1993)
Ecuador	161,770	0.60	72	MAG (1991)
Peru	4,791	0.01	2	Echevarria & Sarabia (1993)
Venezuela	250,000	0.27	76	MARNR (1986)
Guiana Françesa	5,500	0.06	15	Saenger *et al.* (1983)
Guyana	150,000	0.70	326	Saenger *et al.* (1983)
Suriname	115,000	0.70	298	Saenger *et al.* (1983)
Brazil	1,012,376	0.12	134	Hertz (1991)
Insular countries				
Trinidad & Tobago	7,150	1.40	20	Bacon (1993)
Jamaica	10,624	1.02	7	Bacon (1993)
Cuba	529,700	4.80	142	Padron (1992)
Haiti	18,000	0.65	10	Saenger *et al.* (1983)
Republica Dominicana	9,000	0.20	7	Saenger *et al.* (1983)
Puerto Rico	6,500	0.71	-	Saenger *et al.* (1983)
Bahamas	141,957	10.18	40	Bacon (1993)
Bermuda	20	<0.01	<1	Ellison (1993)
Guadelope	8,000	4.49	20	Saenger *et al.* (1983)
Martinique	1,900	1.73	7	Saenger *et al.* (1983)
Cayman Islands	7,268	27.60	45	Bacon (1993)
Antilles*	24,571	----	-	Bacon (1993)

* Includes only the islands from where reliable mangrove surveys have been reported (Anguilla, Antigua, Aruba, Barbados, Barbuda, Bonaire, Curaçao, Dominica, Grenada & Grenadines, Montserrat, Nevis, St. Kitts, St. Lucia, St. Vincent, Turks & Caicos).

Table 2. Mangrove forest cover in the Atlantic and Pacific coasts of Latin America, including the Caribbean Islands, compared to World mangrove forest areas.

	Mangrove area (ha)	(% of the total)	Author
Atlantic Coast	2.143.356	(52.8)	This study
Pacific Coast	1.154.289	(28.5)	This study
Caribbean Islands	764.690	(18.7)	This study
Total	4.062.335	(100)(28.6)	This study
Africa	3.257.700	(22.9)	Diop (1993)
Southeast Asia	6.877.600	(48.5)	Saenger *et al.* (1983)
World total	14.197.635	(100)	This study

this area by the Paleocene (Wijmstra, 1969). Later palynological registers along the Americas show abundant mangroves (Graham, 1989; 1992), that confirm the early Eocene as the probable date of mangrove arrival to the New World.

By the time of the arrival of the first mangrove genera to the American continent, the Panamá isthmus was still open, allowing for the colonization of the western coast of the Americas. The closure of the Tethys Sea route and the lowering of the temperature of the South African coast by the Benguela Current would have prevented the migration of more recent mangrove genera. This hypothesis was supported by Chapman (1974) and others, and has been well accepted by most mangrove scientists.

Mepham (1983) argued against the hypothesis of the origin of mangrove flora in southeast Asia and their distribution by radiative dispersal from a single hypothetical source in this area. He proposed a broader Tethyan region as the place where angiosperms first acquired the mangrove habit, and where most contemporary mangrove genera originated. However, he also agrees that migration through Tethyan distribution routes by the early-middle Tertiary was probably the major route of colonization of North and South America, the Caribbean and the West coast of Africa by the early mangrove genera *Rhizophora* and *Avicennia*. This route is believed to be confirmed by the widespread pollen of *Nypa* in late Eocene deposits (*ca.* 40 million years BP) along the present Mediterranean coast, England, North America, West Africa and Northeastern Brazil (Dolianiti, 1955; Muller, 1961; Macnae, 1968). It is interesting to note that the distribution of fossils, which is widely used as an argument in favor of a single centre of dispersion, may also be interpreted as indicating that mangroves arrived in this region from a Tethyan origin as proposed by Mepham (1983), rather than originating there. But the fossil evidence for Pleistocene mangroves is so scarce, that reconstructions of mangrove distributions are merely speculative (Woodroffe & Grindrod, 1991).

A contrasting view on the origins of New World mangroves is provided by Hou (1960); van Steenis (1962) and Muller and Caratini (1977). These authors proposed that at least for the Rhizophoraceae, the family originated in the Eocene in Southeast Asia together with inland relatives (e.g. *Carallia* and *Anisophylla*). This agrees with the most accepted views of mangrove origin. From southeast Asia, the Rhizophoraceae would have extended their distribution eastward, and not westward, through trans-Pacific land bridges to tropical South America, reaching the Caribbean before the rise of the Panamá Isthmus and therefore being able to cross to the Atlantic and colonize North and South America and West Africa. However several Pacific islands do not have mangroves, an unexpected situation if the migratory route to the New World had crossed this ocean. Woodroffe & Grindrod (1991) suggested that idiosyncrasies of mangrove distribution, nonetheless, could be understood in the light of sea-level and other environmental fluctuations during the Quaternary.

Fig. 1 shows different views on the origin of mangroves and the proposed routes to the New World, it gives major fossil sites and possible origin. The configuration of the continents is as far as possible that believed to have occurred at the end of the Cretaceous (100 to 70 million years BP) after Mepham (1983) and Degens (1990).

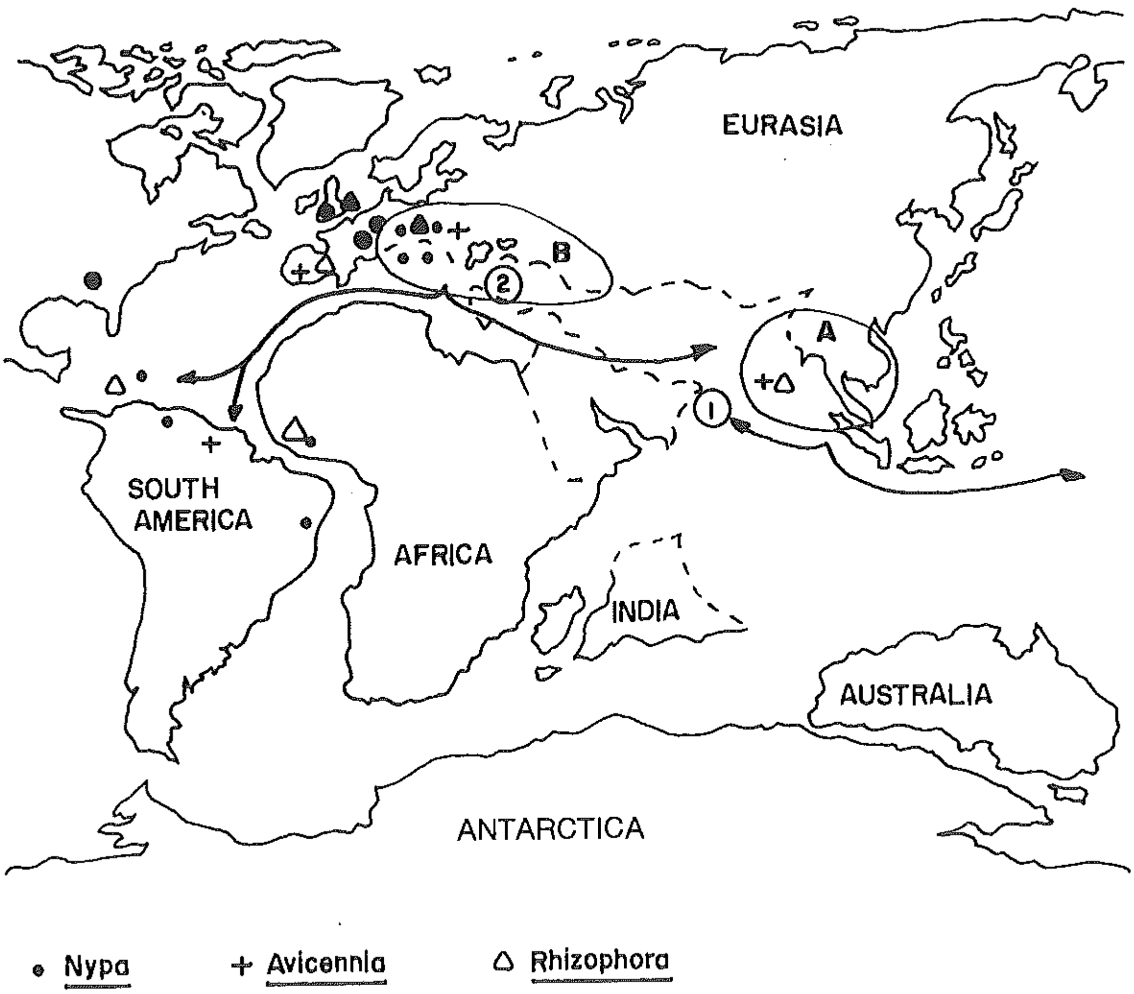

Fig. 1. Palynological record and proposed origin centers and migration routes of New World mangroves. A- Southeast Asia origin center. B- Thethian Sea origin center. 1- Migration through the Thethys Sea to the Atlantic and trans-Pacific migration. 2- Migration from the Thethys Sea to SE Asia and the Atlantic and through the Panamá Isthmus.

It seems quite clear that the view of Chapman (1975), on a migration route through the Tethyan Sea and then to the New World, is supported by the fossil record and is more readily acceptable than a trans-Pacific migration. However, different centres of dispersion and speciation along the Tethys Sea proposed by Mepham (1983), must be considered.

The distribution of mangroves along the American continent prior to the full development of glaciations in the Pleistocene, seems to reflect the climatic conditions of that time (Wijmstra, 1969). During the Eocene period, the mangrove flora extended to higher latitudes. *Nypa* for example was very common along the Caribbean basin from Northeastern Brazil to Southeastern USA (Muller, 1961; Dolianiti, 1955; Thanikaimoni, 1987), as well as *Pelliciera rhizophorae;* the distribution of both species was drastically reduced later, probably as a result of more pronounced seasonal rainfall, longer dry periods probably higher salinities (Germeraad *et al.*, 1968; Muller, 1980; Jimenez, 1984), and sea-level and coastline geomorphological changes (Woodroffe & Grindrod, 1991). *Nypa* disappeared from the Americas and the West coast of Africa while *P. rhizophora* presents a scattered and very restricted distribution, from the Pleistocene to present. Along the coast of what is today Suriname, mangrove forests spread over large areas of the continental shelf following regressions of the sea, and colonized large plains landward during transgressive periods (Wijmstra, 1969).

Presently, mangrove forests are unevenly distributed along the American continent's coastline, with the Atlantic and Caribbean coasts harboring nearly 70% of the total mangrove area. While along the Atlantic coast they form a nearly continuous belt from South United States to South Brazil, along the Pacific coast they have a more restricted distribution due to climatic constraints generated by the oceanographic conditions along the Peruvian and California coasts, where the upwelling of cold waters of the Humboldt Current waters suppresses convective activity and results in extremely arid climates, high soil salinity and almost totally absent freshwater input, restricting the extension of mangrove forests (Lacerda & Schaeffer-Novelli, 1992). Along the Pacific coast of South America mangroves extend only to lat. 5°32'S, at the Piúra River estuary, in northern Peru. Their Northern Pacific limit however, reaches lat. 30°15', in Puerto de Lobos, Mexico. On the Atlantic coast mangroves extend northward to Bermuda (lat. 32°20'N) and St Augustine, Florida (28°50'N); and southward to Laguna, Santa Catarina, in South Brazil (lat. 28°30'S). With the exception of the South Pacific coast, the latitudinal limits of mangroves are determined by the frequency, duration, and intensity of cold winter temperatures, rainfall and/or frost. The western limit of mangroves in the American continent are the Galápagos Islands, off the coast of Ecuador (long. 91°W, lat. 0°) from where *A. germinans, L. racemosa, C. erectus* and *R. mangle* have been reported (Chapman, 1975; West, 1977). The eastern limit are Fernando de Noronha Islands, off the coast of Pernambuco, Brazil (long. 32°24'W; lat. 3°50'S), where a small forest of *L. racemosa* covers approximately 0.15 ha at the estuary of Maceio River, Sueste Bay, which drains the most important watershed of these islands (Hertz, 1991).

4. Flora Composition and Distribution

4.1 Mangrove trees

Contrary to southeast Asia, which has nearly one hundred taxa of mangrove plant species (Mepham & Mepham, 1985; Rao, 1987) Latin America and Caribbean mangroves have a reduced number of tree species. Further taxonomic research is needed, because of the high population variability among species of each genus and because of the length of the Latin American and Caribbean coasts. Basic biological surveys have yet to be done for areas of northern South America and some Caribbean Islands.

Latin American and Caribbean mangroves include only 11 tree species and one variety. The *Rhizophora* (Rhizophoraceae) and *Avicennia* (Avicenniaceae) are dominant with 4 species each. Other genera are *Laguncularia* and *Conocarpus* (Combretaceae) and *Pelliciera* (Pelliceriaceae), all with only one species each. *Conocarpus* seems to have an endemic variety (Bacon, 1993) in the Northern Caribbean islands (Table 3).

The genus *Rhizophora* (Fig. 2) is represented by *R. mangle* L.; *R. harrisonii* Leechman, *R. racemosa* G.F.W. Meyer and *R. samoensis* (Hochr.) Salvosa. *R. mangle* is the most widespread, it occurs along all the tropical and sub-tropical Atlantic Coast from Bermuda to Santa Catarina, South Brazil, and although restricted by extreme climatic conditions, it is present from Baja California, Mexico to North Peru, at the Tumbes River estuary (Breteler, 1969; Savage, 1972; Cintrón & Schaeffer-Novelli, 1992). *R. racemosa* and *R. harrisonii* have more restricted distribution. Along the Atlantic coast, both species occur from Central America, Guyanas and Trinidad to northern Brazil (Bacon, 1970). The southern limit of these two species had been established by Prance *et al.* (1975) at the equator, and extended to Maranhão (2°40'S) by Santos (1986). In this area, large (up to 20m tall) fringes of both species occur generally landward of *R. mangle* belts. Along the Pacific coast these two species occur from South Mexico to Ecuador (Flores-Verdugo et al. 1992; Jimenez, 1992). The fourth species of *Rhizophora* is *R. samoensis*, which was first reported for the Pacific coast of Colombia, c.a. 5°N (West, 1956; Hueck, 1972). Later Horna *et al.* (1980) and Twilley (1990) recorded *R. samoensis* for the coast of Ecuador (lat. 1°N to 3°20'S). A recent survey of the mangroves of Ecuador (MAG, 1991) however, does not include this species. *R. samoensis* may be a variety of *R. mangle* (Hou, 1960). However, Mepham (1983) does consider it as a true species. The occurrence of *R. samoensis* along the Pacific coast of South America is far from established and still requires more systematic work.

The geographical distribution of the genus *Avicennia* (Fig. 3) is similar to that of *Rhizophora*. One species, *A. germinans* L., has a pan-continental distribution, from Bermuda, lat. 32°20'N to Atafona, lat. 21°37'S, in southeastern Brazil on the Atlantic and from Puerto de Lobos, Mexico, lat. 30°15'N to Piúra River estuary, Peru, lat. 5°32'S on the Pacific (West, 1977; Cintrón & Schaeffer-Novelli, 1992; Echevarria & Sarabia, 1993; Ellison, 1993; Lacerda & Rezende, 1993). *Avicennia schaueriana* Stapf. & Leech. is also widely distributed, endemic in the Atlantic coast,

Fig. 2. New World distribution of the genus *Rhizophora*

and spreads from the Caribbean Island of St. Kitts, lat. 17°30'N to Laguna, Brazil, lat. 28°30'S (Bacon, 1993; Cintrón & Schaeffer-Novelli, 1992). The other two species *A. bicolor* Standl. and *A. tonduzii* Moldenke, have been recorded only on the Pacific coast of Central America from Costa Rica to Panamá (Cintrón & Schaeffer-Novelli, 1983; D'Croz, 1993; Jimenez, 1992).

The family Combretaceae (Fig. 4) has two widely distributed species: *Laguncularia racemosa* Gaertn. and *Conocarpus erectus* L. The first has a distribution similar to that of *A. germinans,* although it does not extend as far north as Bermuda, its northern limit along on the Atlantic coast is Florida, USA, lat. 30°N) (Savage, 1972). *C. erectus* has a smaller range of distribution, in the Atlantic coast where it extends from Florida, lat. 28°5'N, to the coast of Rio de Janeiro, Brazil, lat. 22°55' (Araújo & Maciel, 1979). A variety of this species *C. e. sericeus* has been recorded in the northern Caribbean islands (Bacon, 1993).

The family Pelliceriaceae (Fig. 5), is represented by *Pelliciera rhizophorae* Pl. & Tr., which was widely distributed in the Caribbean, Central America and northern South America during the Miocene (Graham, 1977). Today it is restricted to sites of the coasts of Central America and the Pacific coast of South America (Winograd, 1983; Roth & Grijalva, 1991; Roth, 1992). Significant stands of the species are found only in the very wet Pacific coast of Costa Rica, where annual rainfall may be as high as 6,000mm (Jimenez, 1984). These forests are probably relicts of a wide distribution of *P. rhizophorae*, and could be due to low tolerance of high water salinity caused by dry climatic conditions (Jimenez, 1984).

4.2 Associated flora

Many plant species occur associated with mangrove forests in Latin America and the Caribbean. The diversity could be due to climatic conditions and proximity of other pristine ecosystems. A complete list of such flora however, is a mere curiosity, since it varies from region to region and even from forest to forest in a given region. Some of these species appear to be associated with mangrove forests throughout their distribution range in Latin America and the Caribbean. Among them the fern *Acrostichum aureum* L. and the Malvaceae *Hibiscus tiliaceus* L. are the most widespread, they occur in most mangroves of the World. These species frequently form dense belts along the landward edge of mangroves, on more elevated sites and around dry and saline areas inside mangroves. *A. aureum* biology has been studied by Lamberti (1969) in Brazil and by Medina *et al.* (1990) in Puerto Rico. Notwithstanding this, the biology and ecology of these two species are insufficiently known.

In the very humid Pacific coast of Central America, many tropical forest species "invade" mangrove forests, such as the Leguminosae vine *Dalbergia brownei* (Jacq) Urban, and the Apocynaceae liana *Rhabdadenia biflora* (Jacq) Hull (Jimenez, 1992). In Venezuela, mangroves are frequently invaded by the Lorantaceae *Phthirusa marina*. This liana has also been reported as a typical component of mangrove forests in French Guyana (Lescure, 1977). From the Amazon estuarine region to the coast of Maranhão State, North Brazil, where mangroves are seldom exposed to high or even moderate salinity, various typically freshwater macrophytes occur among true mangrove species, such as the Araceae *Montrichardia arboresens* Schott and the Leguminosae *Mora oleifera* (Triana) Duke (Mochel, 1993; Pantoja, 1993). Many palm species e.g. *Euterpe oleraceae* Mart., are common in these mangrove forests.

The glicophytes that occur in association with mangroves of Venezuela are evergreen communities of *Symphonia globulifera* L. (Clusiaceae); *Virola surinamense* (Myristicaceae); *Pterocarpus officinalis* Jacq. (Papilionaceae); *Mora excelsa* (Caesalpiniaceae) and *Pachira aquatica* (SW) Aubl. (Bombacaceae) and the endemic *Tabebuia aquatilis*. Among the palms, *Mauritia flexuosa* L.; *E. oleracea* and *Phenankospermum guyanense* are frequent (Huber & Alarcon, 1988).

From Rio de Janeiro to Santa Catarina State, SE Brazil, mangroves occur adjacent to mountain rain forests, and are host to a great diversity of epiphytes of the families Bromeliaceae and Orchidaceae in particular *Tillandsia usneoides* L., *T. stricta* Solander and *Vrizia* spp. (Lacerda, 1984). High diversity of epiphytes is also common in *R. harrisonii* forests of southern Ecuador (MAG, 1991). In the Pacific coast of Mexico and in the coast of Venezuela, *Pachira aquatica* typically occurs as a member of the mangrove community (Flores-Verdugo *et al.*, 1992).

Typical salt marsh species also occur in New World mangroves, though they are in general restricted to pioneer formations at the seaward fringe of the mangrove forest, to natural gaps under the canopy and occasionally as fringes of tidal creeks and channels. They occupy large areas of landward margins of mangroves in drier Caribbean islands such as British Virgin Islands and Turks & Caicos (Bacon, 1993). This marginal distribution is due to light attenuation by the mangrove canopy (Reitz, 1961; West, 1977; Santos, 1989; Costa & Davy, 1992; Bacon, 1993).

The most common grass along the mangroves of the Atlantic coast of Latin America and the mainland Caribbean coast is *Spartina alterniflora* Loisel, a world wide distributed salt marsh species. It has been recorded from almost all mangroves of the continent typically at the seaward fringe along the forests. This species may play an important role in the dynamics and environmental conditions of mangroves (Lacerda & Abrão, 1984; Costa & Davy, 1992), it promotes sediment fixation and trapping of chemical elements in the mangrove environment. In Insular Caribbean *Sporobolus virginicus* substitutes *S. alterniflora* in these habitats (Bacon, 1993). In the Pacific, saltmarsh-mangrove association has not been reported (D'Croz, 1993).

Other salt marsh species specialize in colonizing areas disturbed by hurricanes or anthropogenic activities. *Sesuvium portulacastrum* L. (Aizoaceae) and *Blutaparon vermiculare* L. Mears (Amaranthaceae), have been reported as typical of such areas forming very dense communities that may permanently occupy disturbed mangrove areas (Lacerda & Hay, 1982). In many saline areas of the Venezuelan coast these species occur generally associated with *C.*

Fig. 3. New World distribution of the genus *Avicennia*

erectus and other halophytes such as *Atriplex pentandra, Salicornia fruticora* and *Batis maritima* (Huber & Alarcon, 1988).

Common salt marsh species associated with mangroves include the Batidaceae, *Batis maritima* L., widely distributed throughout the Americas and the Caribbean; the Chenopodiaceae *Salicornia ambigua* Michx., along with *B. vermiculare, Portulaca pilosa L., Cakile lanceolata, Ipomea pes-caprae* and *S. portulacastrum* occupy high salinity areas inside mangroves; and the Gramineae *Sporobolus virginicus* L. Kunth and *Paspalum vaginatum* Swartz, frequently occur in more sandy areas (Pannier & Pannier, 1985; Huber & Alarcon, 1988).

Other typical mangrove associates are submersed macrophytes, seagrasses and macroalgae and fungi. Among the seagrasses, *Holodule wrightii* Aschers, *Halophila baillonis,* Potamogetonaceae, *Thalassia testudinum* Konig, Hydrocharitaceae and *Ruppia maritima* L., Zannicheliaceae, are recorded throughout the Atlantic and Caribbean mangroves (Acosta-Fabelo, 1974; Phillips, 1992;). Seagrass bed are not common in the Pacific coast (D'Croz, 1993).

Macroalgae and fungi have recently been studied by mangrove scientists throughout the Americas. Cordeiro-Marino *et al.* (1992) listed over 150 taxa from the mangroves of Latin America and the Caribbean. The highest diversity occurs among the

L. racemosa —●— ; C. erectus - - - - - ; C. erectus sericeus ———

Fig. 4. New World distribution of the genera *Laguncularia* and *Conocarpus*.

Rhodophyta with 78 species and the lowest among the Phaeophyta, less than 15 species. In the Caribbean due to high water transparency and association with coral reefs, algae diversity is maximum, with 109 species and a high degree of endemism, nearly 70% among the Rhodophyta.

Low water transparency and salinity variation typical of most continental mangroves, is probably the cause of the small number of species compared to the Caribbean (Oliveira Filho, 1984). The North Pacific region, including Central America, presents the lowest algal diversity with only 10 species, however, this region is the poorest studied of all coasts of the American continent. Therefore, this low diversity may just represent a lack of taxonomic work in the region.

Mangrove macroalgae are mostly found on the roots of mangrove trees (over 50% of the species). Other hard substrates like rocks, stones and large shell fragments, account for nearly 30% of the species, while soft mud and sandy substrates account for the other 20% of the species (Cordeiro-Marino *et al.*, 1992).

In most mangroves, the macroalgal community of trunks and aerial roots, is dominated by the Bostrichietum association, which includes the genera *Bostrichia*, *Caloglossa* and *Catenella*. These include 12

Fig. 5. New World distribution of the genus *Pelliciera*

typical species with year round reproduction (Braga *et al.*, 1990). Another typical association is in the sediment, the so called Rhizoclonietum association, formed mostly by over 10 species of green algae of the genera *Rhizoclonium, Enteromorpha* and *Cladophora* (Pedrini, 1980). Typical tropical species of *Caulerpa, Acetabularia, Halimeda, Sargassum* and *Penicillus* are frequent in the clear-water mangroves of the Caribbean (Pannier & Pannier, 1989)

Marine fungi of mangroves belong to all groups of higher fungi of warm waters. They infest submersed roots, stems and twigs, as well as sessile animals and algae. Over 30 species of marine fungi occur in New World mangroves. However, only a few seem to be host-specific (Kohlmeyer & Kohlmeyer, 1979).

The distribution and species composition of the mycoflora is determined by the duration of submergence of the parts of the tree infested by the fungus and of its physiology. Submersed parts have a different mycoflora from the non-submersed parts. However, at high tide level, marine and terrestrial fungi overlap. Host-specific species generally have a restricted distribution while more omnivorous species tend to have a wider one (Kohlmeyer, 1969).

Among the New World mangrove marine fungi, typical host-specific species reported are the Ascomycetes; *Didymosphaeria rhizophorae* J. & E. Kohlm.;

Table 3. Updated list of species of "true mangrove" trees in Latin America and the Caribbean and their distribution limits.

	Atlantic Ocean		Pacific Ocean	
	North	South	North	South
Family Rhizophoraceae				
Rhizophora mangle L.	Bermuda, 32°20'	Praia do Sonho, Brazil, 27°53'	Puerto de Lobos, Mexico, 30°15'	Tumbes River, Peru, 3°34'
R. harrisonii Leechman	Estero Real, Nicaragua, 13°	Rio Preguiças, Brazil, 2°40'	Chantuto, Mexico, 15°15'	Guayas R., Ecuador, 2°20'
R. racemosa G.F.W. Meyer	Estero Real, Nicaragua, 13°	Rio Preguiças, Brazil, 2°40'	Chiquirí River, Panamá, 10°	Guayas R., Ecuador,2°20'
R. samoensis (Hochr.) Salvosa	No ocurrence		Restricted to the Pacific Coast from Ecuador (3ºS) to Panamá (10ºN)	
Family Avicenniaceae				
Avicennia germinans L.	Bermuda, 32°20'	Atafona, Brazil, 21°37'	Puerto de Lobos, Mexico, 30°15'	Piúra R., Peru, 5°32'
A. schaueriana Stapf. & Leech	St. Kitts Is., Carib., 17°30'	Laguna, Brazil, 28°30'	No occurrence	
A. bicolor Standl.	No occurrence		Restricted to the Pacific coast of Central America	
A. tonduzii Moldenke	No occurrence		Restricted to the Pacific coast of Central America	
Family Combretaceae				
Laguncularia racemosa Gaertn.	Florida, USA 28°50'	Laguna, Brazil, 28°30'	Estero Sargento, Mexico, 29°17'	Piúra R., Peru, 5°32'
Conocarpus erectus L.	Florida, USA 28°50'	Lagoa de Araruama, Brazil, 22°55'	Estero Sargento, Mexico, 29°17'	Tumbes R., Peru, 3°34'
Conocarpus e. sericeus	Endemic to Northern Caribbean Islands 20ºN to 25ºN		No occurrence	
Family Pellicieriaceae				
Pelliciera rhizophorae	Prinzapolca R., Nicaragua,13°	Cartagena Bay, Colombia, 9°	Gulf of Nicoya, Costa Rica, 9°30'	Esmeralda R. Pl. & Tr. Ecuador, 1°

Sources: Araújo & Maciel (1979); Bacon (1970, 1993); Breteler, (1969); Calderon (1983); Chapman (1975); Cintrón & Schaeffer-Novelli (1983; 1992); Flores-Verdugo *et al.* (1992); Horna *et al.* (1980); Hueck (1972); Jimenez (1984, 1992); Prance *et al.* (1975); Rincón & Mendoza, 1984); Roth (1992); Roth & Grijalva (1991); Santos (1986); Savage (1972); Stoffers (1956); West (1956, 1977); Winograd (1983).

Keissleriella blepharospora J. & E. Kohlm.; and the Deuteromycetes, *Cytospora* sp., on *R. mangle*. On *A. germinans*, host-specific species of marine fungi are *Leptosphaeria avicenniae* J. & E. Kohlm. and *Mycosphaerella pneumatophorae* Kohlm. (Kohlmeyer, 1968; 1969).

Most terrestrial fungi described from New World mangroves occur as parasites of living leaves, only a few were described as wood-inhabiting. Most frequent host-specific terrestrial fungi on *R. mangle* are the Ascomycetes *Anthostomella rhizophorae* Visioli, *A. rhizomorphae* Berl ex Voge; *Physalospora rhizophorae* Bat. & Maia and *P. rhizophoricola* Bat. & Maia (Batista *et al.*, 1955; Stevens, 1920; Vizioli, 1923). Among the Deuteromycetes, the genus *Pestalotia* (Guba, 1961) and *Cercospora* (Craeger, 1962), show the highest species diversity. Host-specific terrestrial fungi were also reported for *L. racemosa* and included the Ascomycetes *Irene laguncularie* (Earle) Toro, *Micropeltis laguncularie* Wint and *Physalospora laguncularie* Rehm (Kohlmeyer, 1969). Among the Deuteromycetes, *Helminthosporium glabroides* F.L. Stevens has been reported (Seymour, 1929).

Marine fungi play a key role in litter decomposition processes and nutrient cycling. Important species such as *Pestalotia*, *Nigrospora* and *Gliocidium*, which show marked succession during the different phases of the decomposition process (Fell & Master, 1973). Studies in the Laguna de Tacarigua (Venezuela) showed that Deuteromycetes and Phycomycetes, in particular *Aspergillus* and *Penicillum* were the dominant fungi involved in the litter decomposition process of mangrove organic matter (Barreto, 1988)

5. Mangrove Fauna

The fauna of mangrove forests includes elements from marine and terrestrial habitats. Few animal species, however, are exclusive inhabitants of mangroves, hence the difficulty of characterizing a "true" mangrove fauna. In most species their presence depends on season, tides, life cycle stage and other factors. Of the 358 macroinvertebrates and vertebrates found in a 4,000 ha mangrove swamps in Trinidad, only the Cirripede *Chthamalus rhizophorae* was strictly confined to this habitat; although many of the other species were most commonly found associated with mangroves, and it is only in this sense that they can be called mangrove fauna. Most of the animals to be found in mangroves also occur elsewhere in other coastal habitats, and even in areas hundreds of km apart from the coastal strip, as in the case of the scarlet ibis, *Eudocimus ruber* (Conde & Alarcón, 1993).

Whether transient or permanent, the mangrove fauna is large and diversified. Over 140 species of birds and 220 species of fish and hundreds of species of terrestrial and marine invertebrates, create high diversity assemblages along otherwise low biodiversity mudflats.

Due to the accelerated destruction of inland forests, in some Latin American and Caribbean countries, many mangrove areas have become important sanctuaries and stepping stones in the migratory routes of various species, which otherwise would be threatened with extinction. For example, the monkey *Chipodes satanas* finds refugee in the extensive mangrove forests of Maranhão, northern Brazil, as well as the manatee *Trichechus manatus* and the scarlet ibis *Eudocimus ruber*. A small population of the American crocodile, *Crocodilus acutus*, inhabits the mangroves of Tumbes River, Peru. In Venezuela and many Caribbean islands, small populations of the endangered *C. acutus* inhabit mangrove lagoons, which have become their main remaining shelters. In Ecuador, at the Churute Mangrove Ecological Reserve, the only population west of the Andes of the "Canclón", *Anhima cornuta*, finds shelter.

In some localities, where waters are extremely transparent, the red mangrove (*Rhizophora*) roots provide settling space for the attachment of many invertebrate species, which in some areas, in particular in the Caribbean, can be highly diversified. This colorful community, where many species and taxa are represented - where sponges, bivalves, and algae predominate - can grow into a huge biomass on some roots.

Among the more common species of this community is the mangrove oyster *Crassostrea rhizophorae*, which can be a very important staple in the economies of the mangrove forests villagers. In Jamaica, 17 species of sponges and 17 of tunicates are commonly found in this habitat that can support also dense masses of the commercially important mangrove oyster *Crassostrea rhizophorae*, *Isognomon bicolor* and the mussels *Brachidontes exustus* and *B. citrinus*. In Venezuela, 33 species of sponges and 12 of tunicates have been cited from mangrove roots (Sutherland, 1980; Díaz *et al.*, 1985; Orihuela *et al.*, 1991). Among the sponges of the sessile community the more common are: *Tedania ignis, Haliclona viridis, Spongia zimocca, Halichondria magniconulosa, Desmacellia jania,* and *Lissodendoryx isodictyalis.* The algae include *Acanthophora spicifera, Bryopsis plumosa, Caulerpa verticillata, C. racemosa, Cladophora fascicularis, Dyctyota bartayresii, Spermothamnion investiens* and *Ulva lactuca.* The tunicates are: *Botrylloides nigrum, Botryllus niger, Didemnum* sp., *Diplosoma listerianus, Ecteinascidia conklini., E. turbinata, Microcosmus exasperatus, Phallusia nigra, Polyclinum constellatum, Pyura momus, Styela canopus* and *Symplegma viridae.* Other organisms present are the octocoral *Telesto riisei;* the bivalves *Brachydontes* sp., Crassostrea *rhizophorae* and *Isognomon alatus;* the cirriped *Balanus eburneus;* the annelid *Spirorbis* sp; the bryozoans *Schizoporella* sp., and *Bugula* sp.; the polychaete *Sabellastarte magnifica;* and the actinid *Aiptasia pallida* (Sutherland, 1980; Díaz *et al.*, 1985; Orihuela *et al.*, 1991). Species lists are also provided for Florida, USA, (Bingham, 1992); Quintana Roo, Mexico (Inclón-Rivadeneyra, 1989); Puerto Rico (Rodríguez & Stoner, 1990); and Belize (Ellison & Farnsworth, 1992).

In some localities (for example, Cocinetas Lagoon, Venezuela), the mangrove oyster present is *Crassostrea virginica*, a larger species than *C. rhizophorae* and apparently more tolerant of salinity extremes (MARNR, 1991c). At some place in Venezuela, as Boca de Caño Lagoon and Tacarigua Lagoon, where great amounts of sediments are in suspension, the sessile community on the mangrove roots is very poor, represented by a few specimens of *Crassostrea rhizophorae* and other bivalves, algae with scant cover, and isolated and poorly developed sponges. Prop root communities are typically zoned in relation to tidal levels and tolerance to desiccation during tidal emersion. Sessile community distribution in Trinidad showed an upper *Chthamalus* zone, a mid-tidal *Balanus* zone and a lower tunicate/sponge zone (Bacon, 1970). The sessile community of the mangrove roots has been considered very stable (Sutherland, 1980); however, it can be removed almost entirely by resuspension and salinity changes produced by hurricanes or unusual torrential rains. Recuperation of biodiversity in such community was slow; after twenty months it had not reached the original structure and only 45% of species originally attached to the red mangrove roots had recolonized the habitat (Orihuela *et al.*, 1991). Variability of water temperature, wave exposure, root type, proximity of roots to the barrier reef affect epibiont distribution and richness in Belizean mangroves (Ellison & Farnsworth, 1992). Biological factors also play a role in the structuring of this community; the spatial heterogeneity probably results from differential larval recruitment (Sutherland, 1980; Bingham, 1992). The biomass of epibionts can be so large that it can affect root growth and production (Perry 1988; Ellison & Farnsworth, 1990).

The complex habitat that results from the imbrication of numerous red mangrove prop roots, provides refuge and nursery ground for many species of fishes. The number of species, density and biomass of fishes found in that environment can be up to several orders of magnitude larger than nearby ecosystems, such as beds of *Thalassia* and other species of seagrasses (Thayer *et al.*, 1987). In a fringe mangrove in south Florida, 36 species were collected exclusively in the mangrove prop root system, while 24 species were sampled solely in the adjacent ecosystems (Thayer *et al.*, 1987). Furthermore, juveniles of commercially important fishes, as the gray snapper *Lutjanus griseus,* feed exclusively in the prop root habitat (Thayer *et al.*, 1987).

Benthic epifauna and infauna in mangroves frequently show patterns of zonation related to sediment type, depth of tidal flooding, and mangrove forest type. In Port Royal, Jamaica, the crabs *Panopeus herbstii, Uca thayeri, Pachygrapsus gracilis,* and *Goniopsis cruentata* showed reduction in numbers along transects from the sea landwards in relation to the mangrove vegetation zones (Warner, 1969).

The fauna associated with mangroves along the Pacific coast of Latin America is composed of numerous species living in the mangrove trees, the ground and the brackish waters of the tidal channels. Crustaceans are among the most noteworthy taxa related to the mangrove swamps; this group has been very well described by Abele (1972). The most common arboreal crab is *Aratus pisonii,* although other species such as *Goniopsis pulchra* can be observed occasionally in mangrove trees. The soil of the mangroves is the habitat for other crabs, such as *Cardisoma crassum, Ucides occidentalis,* and several species of *Uca.* The tidal channels hold large populations of hermit crabs of the genus *Clibanarius,* the portunids *Callinectes arcuatus* and *C. toxotes,* and xanthidae *Panopeus purpureus,* among others. Some of these decapods feed on detrital material from the mangrove's litterfall, as reported for *Uca, Sesarma, Cardisoma* and *Ucides* (Abele, 1972). Other species are filter feeders (*Petrolisthes*), predators and scavengers (*Callinectes*) and some include mangrove leaves in their diet.

Many of the aforementioned genera are also found in the Caribbean and the Atlantic coast of Latin America. Likewise, *Aratus pisonii* is one of the most common crustacean in the New World mangroves, and perhaps the only true marine arboreal crab in that region. This species is found in mangroves that grow in marine, estuarine, hypersaline and freshwater habitats (Conde & Díaz, 1989a,b; Conde *et al.*, 1989; Conde & Díaz, 1992ab; Díaz & Conde, 1989), where it shows size and life history traits gradation closely related to mangrove productivity (Conde & Díaz, 1992a; Conde & Díaz, 1989b; Conde *et al.*, 1989,1993). Population dynamics of *Aratus pisonii* are related to rainfall and tide regime (Conde & Díaz, 1989a; Conde, 1990; Díaz & Conde, 1989). *Goniopsis cruentata*, apparently a predator of *A. pisonii* (Warner, 1967), can be observed occasionally on mangrove trees; although most of the time, it can be sighted on the mangrove ground. In the same habitat and in the sand flats close to mangrove forest, many species of *Uca* are present; among them, *U. mordax* and *U. rapax* are very common (Conde & Díaz, 1985). *Ucides cordatus* is very abundant in some mangrove forests. Several species of the blue crab *Callinectes* are caught the fishermen in mangrove lagoons. Another species usually associated to the most terrestrial zone of mangrove forests of the Caribbean is *Cardisoma guanhumi*, a commercial species which has been severely depleted in some localiities and a very important staple in the economies of some mangrove forest villagers.

The importance of coastal lagoons including those fringed by mangroves to penaeid fisheries has been repeatedly highlighted (Edwards, 1978). Several species of penaeid shrimps are related to the Pacific coast mangroves, most important *Penaeus occidentalis, P. vannamei, P. stylirostris* and *P. californiensis.*; although, as much as nine species have been reported to use the mangrove swamps as nursery area (D'Croz and Kwiecinski, 1980). Some of these shrimps enter the mangrove swamps as small postlarvae seeking the protection and food available in this brackish habitat; later, they move offshore as juveniles. These penaeids are the major component of the coastal shrimp fishery in the Pacific coast of Latin America. A similar pattern is found in the Caribbean. Mangrove lagoons are instrumental in the life cycle of the four species of *Penaeus*: *P. brasiliensis, P. notialis, P. schmitti* and *P. subtilis* found in the Caribbean. They enter the lagoons as juveniles, where they find a highly productive and almost predator-free environment (Stoner, 1988). In Laguna Joyuda, Puerto Rico, as much as 955 kg wet weight of shrimp can be produced yearly per hectare (Stoner, 1985). Recruitment of juvenile shrimps to the lagoon is discontinuous through the year, but highly correlated to the rainfall pattern (Stoner, 1988).

Molluscs are found attached to the mangrove trees, example are some scavenger snails such as *Littorina, Nerita,* and filter feeders such as the oysters *Ostrea cortezensis* and *O. columbiensis*. The muddy bottoms of the mangrove swamps are inhabited by bivalves: *Chione subrugosa, Tellina ecuatoriana, Tagelus spp., Anadara spp.*, and *Mytella guyanensis*. In the Caribbean coast, the mangrove oyster *Crassostrea rhizophorae* is ubiquitous. Another species of bivalve is *Isognomon alatus*.

Besides providing nursery grounds and refuge for many species of shrimps, mangrove lagoons play the same role for many species of fishes. In their waters large predators are not common, hence, the predation pressure over juveniles, including those of species whose adults live in deeper waters, is reduced. Although many species can be found in these lagoons, a small number of species-up to six or seven-represent most of the total catch. In the western Atlantic mangroves, three groups of fishes have been identified by Stoner (1986): resident small flatfish; several species of transient juveniles; and small planktivores. In some localities, a fourth group-marine catfishes-appears (Phillips, 1981; Yáñez-Arancibia *et al.*, 1980). A high percentage of juveniles belongs to species that are not resident in the lagoons and that live offshore as adults; up to 55% (Stoner, 1986) or 46% (Yáñez-Arancibia *et al.*, 1980). Among the most common fishes in mangrove swamps of the Pacific coast are: the mullet *Mugil curema*, the "mojarra" *Eucinostomus californiensis*, and several snooks: *Centropomus armatus, C. robalito, C. nigrescens* and *C. unionensis*. All of these fishes are found as juveniles in the mangrove channels.

In coastal lagoons of the Caribbean coast of Venezuela the most common species are the catfish *Arius herzbergii* and *Cathorops spixii*; the snooks *Centropomus undecimalis, C. ensiferus, C. pectinatus*, and *C. parallelus*; the mullets *Mugil liza, M. brasiliensis*, and *M. curema*; the mojarras *Eugerres plumieri, Diapterus rhombeus* and *Gerres cinereus* (Ginés *et al.*, 1972; Pagavino, 1983; Cervigón & Gómez, 1986). Less abundant, but present are the Atlantic tarpon (*Tarpon atlanticus*), juveniles of the horse jack *Caranx hippos*, the ladyfish *Elops saurus*, and the hogchoker *Trinectes maculatus brownii* (Pagavino, 1983). In the Caribbean, a great diversity of typical coral reef fishes are frequently found in mangroves (Alvarez-León, 1993).

Species lists and analysis of community structure are provided by Austin (1971), Phillips (1981), Stoner (1986) and Yáñez-Arancibia *et al.* (1980).

In addition to the aquatic fauna, some birds, reptiles and mammals inhabit mangrove forests. Many of them are resident or, in one or other stage of their life cycles, visit mangrove forests, as part of any of their daily activities or during their migrations. More than 150 species of birds have been listed for mangroves in Venezuela. Among the birds that have been reported as typical of Venezuelan mangroves are the yellow warbler (*Dendroica petechia*), the bicolored conebill (*Conirostrum bicolor*), the clapper rail (*Rallus longirostris*), the great-tailed grackle (*Cassidix mexicanus*), the spotted tody-flycatcher (*Todirostrum maculatum*), and the rufous crab-hawk (*Buteogallus aequinoctialis*). Common to all the seven places where inventories have been carried out are the common egret (*Casmerodius albus*), the black vulture (*Coragyps atratus*), the scarlet ibis (*Eudocimus ruber*), and the brown pelican (*Pelecanus occidentalis*) (MARNR, 1986). *E. ruber*, an endangered species in many places of the world, is very common in Venezuelan mangroves. This seems to be the only country where there are still considerable reproductive colonies of this bird (Gremone *et al.*, undated). Other common species are *Pelecanus occidentalis*, the magnificent frigatebird (*Fregata magnificens*), the great-tailed grackle (*Cassidix mexicanus*), the tricolored or Louisiana heron (*Hidranassa tricolor*), the great or common egret (*Casmerodius albus*), the white ibis (*Eudocimus albus*), *Ardea cocoi, Bubulcus ibis, Egretta tricolor, E. caerulea, Egretta alba*, the anhinga (*Anhinga anhinga*), the american wood ibis (*Mycteria americana*), the glossy ibis (*Plegadis falcinellus*), the limpkin (*Aramus guarauna*), the wattled jacanã (*Jacana jacana*), the collared plover (*Charadrius collaris*) and the common stilt (*Himantópus himantopus*) (Figueroa & Seijas, 1986). Non-reproductive visitors are: *Egretta rufescens*, the great blue heron (*Ardea herodias*), the flamingo (*Phoenicopterus ruber*), the blue winged teal (*Anas discors*), numerous species of Nearctic Limicolae, the laughing gull (*Larus atricilla*), the gull billed tern (*Gelochelidon nilotica*) and the Caspian tern (*Hydroprogne caspia*) (Figueroa & Seijas, 1986).

Among the species that hibernate in the Venezuelan mangroves are *Calidris mauri* and *Micropalama himantopus*; the osprey (*Pandion haliaetus*) has also been pointed as a winter visitor (Figueroa & Seijas, 1986). The Neartic migratory species include *Egretta rufescens, Butorides virescens virescens, Anas discors, Pluvialis squatarola, Numenius phaeopus, Tringa melanoleuca, T. flavipes, Actitis macularia, Catoptrophorus semipalmatus, Arenaria interpres, Limnodromus griseus, Calidris canutus, C. alba, C. mauri, C. minutilla, Larus atricilla*, and several species of *Gelochelidon, Hydroprogne* and *Sterna*, among them *Hydroprogne caspia* and *Sterna maxima* (Figueroa & Seijas, 1986). Non aquatic common species are the orange-winged parrot (*Amazona amazonica*), which forms great groups, the yellow-headed parrot (*Amazona ochrocephala*), the pale-vented pigeon (*Columba cayennensis*), and dense populations of the macaws *Ara chloroptera* and *A. severa* (Figueroa & Seijas, 1986). Venezuelan mangroves and flats are very important as feeding grounds for thousands of flamingos (*Phoenicopterus ruber*) that reproduce in the islands close to the Venezuelan coast. Besides, flamingos nest in a mangrove complex in western Venezuela, being this only one the four locations in the Caribbean where this species reproduces. In the Pacific coast, many of these genera, and in some cases the same species, are present, such as the pelicans *Pelecanus erythrorhinchus* and *P. occidentalis*, the spoonbill *Ajaia ajaja*, the kingfisher *Chloroceryle americana*, and the egret *Bubulcus ibis*.

Among the reptiles are: *Iguana iguana*, the spectacled caiman *Caiman crocodylus fuscus*, the American crocodile *Crocodylus acutus*, the arboreal snake *Corallus hortulanus* (Figueroa & Seijas, 1986). Marine turtles, among them *Chelonia mydas* are very common in the Caribbean, mainly in those places where *Thalassia* beds are associated with mangroves. Other turtles sighted in the waterways of the huge riverine mangroves of eastern Venezuela are *Podocnemis unifilis* and *Phrynus gibbus*.

Mammals are represented by the opossum *Didelphis marsupialis*, the crab-eating raccoons *Procyon lotor* on the Pacific coast and *P. cancrivorus* on the Atlantic; the otters *Lutra annectens* on the Pacific coast and *L. longicaudis* on the Atlantic, and the weasel *Mustela frenata* (Aveline, 1980; Figueroa & Seijas, 1986; MARNR, 1986; Alvarez-León, 1993), the reeds *Odocoileus virginicus* and *Mazama mazama* and many monkey species. Other mammals reported for Venezuelan mangrove forests are the crab-eating fox (*Cerdocyon thous*), the cottontail rabbit (*Sylvilagus floridanus*); the jaguar, *Panthera onca*, and the South American tapir, *Tapirus terrestris*, the ocelot (*Felis pardalis*), the giant anteater (*Myrmecophaga tridactyla*), the howler monkey (*Alouatta seniculus*), the capuchin or ring-tail monkey (*Cebus* sp.), the paca (*Agouti paca*), the kinkajou (*Potos flavus*), agoutis (*Dasyprocta guamara*) and several species of bats; many of those species are intermittent or regular visitors

(Salvatierra, 1983; Figueroa & Seijas, 1986; MARNR, 1986; Bisbal, 1989). Among the aquatic mammals that have been observed in the pristine mangroves of the Orinoco Delta are several endangered species, including the manatee *Trichechus manatus*, the river dolphin, *Sotalia guianensis*, and the Amazon dolphin, *Ina geoffrensis*.

6. Mangrove Forest Structure and Development

6.1 Physiognomy of mangrove forests

Mangrove forests are best developed in a tropical climate, where the coldest winter temperature is above 20°C and temperatures are fairly constant throughout the year (< 5°C of variation). Highly developed forests are also associated with low wave energy, protected shorelines, abundant freshwater supply, allowing for the deposition and accumulation of fine, organic muds, and water salinity range between 5 and 30 ppt. Under such conditions, a large tidal amplitude will also allow the extension of mangrove forests farther inland, forming large forest belts which can extend over 60 km landward from the sea (Lugo & Snedaker, 1974; Walsh, 1974).

Under these optimal environmental conditions in the dynamic and humid regions, mangrove forests attain their maximum growth. Red mangrove (*Rhizophora*) forests 40 to 50m in height and more than 1.0m in diameter have been reported in Ecuador and Colombia (West, 1956; Hueck, 1972; Lacerda & Schaeffer-Novelli, 1992). At the Southern coast of Costa Rica and several areas of the Panamanian coast, where seasonality is less pronounced and annual rainfall ranges from 2,100 to 6,400mm, mangrove trees exceed 35m in height and a biomass of 280 $tons.ha^{-1}$ (Jimenez, 1992). Well developed black mangrove forests, with trees up to 30m in height and 0.7 m in diameter, occur on the coasts of Suriname, French Guyana and Northern Brazil, frequently with biomass over 200 $ton.ha^{-1}$ (Lacerda & Schaeffer-Novelli, 1992).

The structure of mangrove forests along the American continent has been categorized by Lngo & Snedaker (1974). These authors recognized 6 different forest types: Fringe, Riverine, Basin, Overwash, Dwarf and Hammock forests. The last three types are supposed to be specific cases of the first three types (Cintrón *et al.*, 1985). Briefly the major characteristics of these forest types are:

Basin forests occur inland in drainage depressions channelling terrestrial runoff toward the coast. Water flow velocities are slow and extensive areas with a low profile are flooded. They are particularly sensitive to inundation, and export of mangrove litterfall to coastal areas is minimal. They export Carbon mostly in dissolved form (Twilley, 1985).

Fringe forests occur along the borders of protected shorelines and islands and are periodically flooded by tides. Due to their greater exposure to waves and tides and their great developed root system, they are particularly sensitive to erosion and marine contamination. Nutrient cycling and litterfall dynamics are highly dependent on episodical climatic events rather than the ecophysiology of the forest itself. Variable and important amounts of nutrients and Carbon from marine origin participate in nutrient cycling processes of these forests (Lacerda *et al.*, 1988a; Ovalle *et al.*, 1990; Rezende *et al.*, 1990; Silva *et al.*, 1991).

Riverine forests occur along rivers and creeks and are flooded daily by tides. They generally consist of tall straight-bole trees and the low surface waterflow velocity precludes redistribution of ground litter. Fluvial nutrients and constant freshwater frequently support high productivity rates in these forests. However, when freshwater flow dominates over the tidal prism, such as in the Amazon and Orinoco river estuaries, riverine mangrove forests may decrease or even disappear in the strong competition with freshwater macrophytes.

The classification described above, however, in not valid for certain mangrove areas and may change very rapid following changes in coastal geomorphology. For example, in deltaic areas in Tabasco, Mexico, where distributionary diversion is quite common, the sequence of mangrove developments may be drastically altered following a shift in the center of active sedimentation and freshwater discharge (Thom, 1967). Along the Pacific coast of Colombia, high sediment loads brought by rivers, create depositional environments that are rapidly colonized by mangroves and change completly the pattern of forest distribution of previously established mangroves (Alvarez-León, 1993).

Zonation and succession patterns of American mangroves have been described by several authors. However, their omnipresence and suitability of the concept has been questioned (Rodriguez, 1987) and it is our view that these two parameters, although important in certain areas are extremely site specific and no expected pattern can be forecasted safely.

Another important aspect of mangrove forest structure is the variability of major structural parameters according to a latitudinal gradient. Table 4 shows the variability of major structural parameters along the spectra of latitudes throughout the American continent where mangrove forests occur.

Apart from latitude, the major factors controlling mangrove forest structure are wave action, rainfall and freshwater runoff which controls important environmental variables such as erosion/sedimentation rates, aridity, salinity, nutrient inputs, and soil quality (Kjerfve *et al.*, 1993).

Although mangroves preferentially occupy tidal fringes along marine coasts, inland mangroves are typical in some arid areas of the Caribbean. These forests occur as far inland as 15 km in Barbuda (Stoddart *et al.* (1973), and 50 km in Inagua Island in the Bahamas (Lugo, 1981). Similar formations were also reported associated to freshwater plants in Lake Izabal in Guatemala (Brinson *et al.*, 1974) and the South coast of Cuba (Lacerda, 1992, *pers. obs.*). In Paraguaná Peninsula, Venezuela, stands of *C. erectus* occur 10 km from the coast.

These formations attracted greater attention, since they seem to have no connection with the ocean. However, in general, they have high water and soil salinity, apparently due to some connection to the sea. In Lake Izabal, a long seawater wedge reaches the lake during the extreme of the dry season (Brinson *et al.*, 1974). At Inagua and Barbuda, kartz formations possibly allow for the instrusion of tidal water very far inland. At Cuba it seems that a salt water lens, underneath the freshwater marshes extends far inland. There is also the possibility that these mangroves are relict forests from the Pleistocene, when connection with the sea would could have been permanent (Stoddart *et al.*, 1973).

The colonization of these inland mangroves, at least where they are definitively relict forests, is still a puzzle. Since mangrove seedlings cannot float underground, the colonization of inland areas depends on episodic flooding events of abnormal sea level rise during hurricanes and strong storms when waves and swells usually reach far inland. This seems to be the case in Cuba and has been hypothesized by Lugo (1981) for other Caribbean mangroves. However, this colonization process has not been described in detail.

6.2 Primary production, biomass distribution and allocation

Net above ground primary productivity of mangroves is the sum of wood growth and total litterfall. While litterfall has been studied by many authors throughout the American continent, wood growth has seldon been monitored. Therefore, estimates of net primary productivity of mangroves are few.

Wood growth seems to be influenced by the availability of freshwater and nutrients. Fringe and riverine mangrove stands in Laguna de Terminos, Mexico, under humid conditions (1,680 mm of rainfall) showed very different values (Day *et al.*, 1988); fringe forest wood growth was significantly smaller (772 $g.m^{-2}.yr^{-1}$) than riverine forest (1,206 $g.m^{-2}.yr^{-1}$). Under more arid conditions found in Puerto Rico (810mm rainfall), Golley *et al.*, (1962), estimated a smaller wood growth rate of 307 $g.m^{-2}.yr^{-1}$.

Based on these values and litterfall rates, net primary productivity for these forests was estimated as 2,457, 1,606 and 781 $g.m^{-2}.yr^{-1}$, for the Mexican riverine, fringe and Puerto Rican forests respectively. Other estimates for mangrove primary productivity were provided through gas exchange experiments in various mature south Florida mangroves (Miller, 1972; Carter *et al.*, 1973; Lugo *et al.*, 1975;). These studies found much higher values ranging from 2,044 to 5,475 $g.m^{-2}.yr^{-1}$ probably due to the method used. To our knowledge no study has focused on the belowground production and even belowground biomass data are scarce.

Table 5 lists various mangrove litterfall data from different sites on the American continent. Leaf litter is the major component of total litterfall of mangrove forests, regardless of forest type, latitude or climate. In general, it sums up to over 70% of the total litterfall. From the available data no clear relationship is found between rainfall and litterfall. The data suggest that a relationship between latitude and annual litterfall is not clear and that local, site specific differences seems to be overwhelming determining litterfall rates, and sites very close together show different litterfall values (Lugo & Cintrón, (1975); e.g. in Puerto Rico Island Musa (1986), Table 5.

Biomass distribution in mangrove forests was one of the most studied aspects of New World mangroves. However most authors had studied aerial biomass and few data exists on underground biomass, also most studies are on *R. mangle; A. germinans* and *A. schaueriana*, and *L. racemosa;* nearly no study has dealt with less widely distributed mangrove tree species such as *R. harrisonii, R. samoensis* or *R. racemosa*, or *A. bicolor*.

Table 6 lists biomass distribution data for various mangrove forests throughout the American continent. Highest aboveground biomass are found roughly between 10° North and 10° South. No assumption can be made regarding belowground biomass, however it is very important in relation to aboveground parts ranging from 20% to 64% of the total forest biomass. The few data available suggest that stressed mangrove communities such as those in arid climates tend to show higher percentages of belowground biomass, but definitive conclusions are hampered by the existence of little information.

7. Physical Environment

7.1 Mangrove soils

Dominant soils in continental mangroves are mostly entisols, but sometimes istosols. Riverine mangroves generally grow on immature clay soils (clay hydraquents). On tidal flats mangrove grow on mineral (sulfaquents) and organic (sulfahemists) soils. Seaward fringe mangroves grow on acid sulfate soils whereas in many Caribbean islands mangroves grow on bioclastic, coralline sands (Alvarez-León, 1993).

A detailed study of mangrove soils was done on the Guianas coast (Brinkman & Pons, 1968; Augustinus, 1978), where extensive mangroves have grown on the young coastal plains. Marine clays of the Comowine phase (later than 1,000 BP) are found in a band along most of the Guianas with their surface at about high tide level. The sediments are saline with brown or reddish-brown mottles when leached at the surface. Original pyrite content is low to medium, but thin layers of pyrite clay occur in places. These clays on which pioneer *Avicennia* forest develops alternate with ridges of coarse or shelly sand. Soils of river and estuary levees in areas dominated by *Rhizophora* show less variation in soil depth and degree of soil formation than marine clays.

In Venezuela, other detailed classification of mangrove forest soils was carried out by MARNR (1986). Mangroves are found mainly in istosols and entisols. In arid zones, however, mangroves grow in aridisols. In the alluvial plains of the Atlantic coast, soils saturated during long periods (hydraquents) prevail, they are associated with superficial tropohemists in the plain basins. In the rest of the landscape, tropofibrists and sulfaquents occur. In the Caribbean coast of Venezuela, mangroves are associated with coastal lagoons, growing in acid soils of sandy texture (tropofibrists) with high concentrations of organic matter (sulfaquents). In the arid zones soils have predominantly a loamy-sand texture to loamy-clay with torripsaments to sulphic hydraquents.

Rapid accretion of mud and sand characterizes the coast of the Guianas, the dominant mud type being a reduced olive gray pelite. In Guadeloupe, mangrove soils were found similarly under reducing conditions, with redox potential of -300 mV indicating strong anaerobiosis (Febvay & Kermarrec, 1978).

Recent studies by Thibodeau & Nickerson (1986); Nickerson & Thibodeau (1985) and Lacerda *et al.* (1993) showed that, at least close to the rizosphere of mangrove plants, mangrove soils are highly influenced by the physiological activity of the roots which is different depending on plant species. For example, consistently lower redox potential have been reported for *Rhizophora* soils when compared to *Avicennia* soils. Also the organic content and composition of mangrove soils are directly related to the above vegetation. Carbon isotopic studies showed that over 95% of the Carbon present in mangrove soils originate in the mangrove litter (Lacerda *et al.*, 1986).

7.2 Hydrology

The hydroperiod of the fringe-overwash mangroves lasts only hours and occurs daily as a result of high tide wash, which is the only water input to this type of wetland. Riverine mangroves present hydroperiods which may last from hours to days. The frequency of the hydroperiods may be daily or seasonal, with deep waters. Water-level fluctuations within riverine mangroves are large and follow stream discharge patterns. Stream flow and tides represent the major water fluxes of this type of mangrove forest. Basin mangroves have hydroperiods of perennial duration, continuous frequency, and shallow waters. Fresh ground-water discharge, overland runoff, and surficial and underground saltwater intrusion are the water inputs to this type of mangroves (Zack, & Roman-Mas, 1988).

In general major transport of water occurs during short periods (1 to 2 hours) of the tidal cycle

Table 4. Structural parameters of New World mangrove forests.

Location	Type	Latitude	rainfall (mm)	height (m)	DBH (cm)	Basal Area ($m^2.ha^{-1}$)	Density ($t.ha^{-1}$)	Author
Estero Pargo (ME)	F	18°30'N	1,680	6.0	5.6	23.3	7,510	Day *et al.* (1988)
La Lechuguila (ME)	F	25°30'N	459	4.5	11.4	-	4,341	Flores-Verdugo (1986)
Marismas (ME)	F	21°45'N	1,200	5.2	16.9	-	1,461	Flores-Verdugo (1986)
Agua Brava (ME)	F	22°45'N	1,200	7.5	14.0	-	3,203	Flores-Verdugo (1986)
Isla Venado (NI)	F	11°55'N		25.0	14.0	14.9	440	Roth (1992)
Ilha Comprida (BR)	F	25°00'S		8.6	9.3	21.2	-	Adaime (987)
Sepetiba Bay (BR)	F	23°00'S	1,500	6.1	7.8	21.6	4,510	Silva *et al.* (1991)
Majana (CU)	F	21°30'N	1,200	10.0	-	20.6	3,527	Padron *et al.* (1993)
Sipacate (ES)	F	13°00'N		9.0	-	9.2	3,400	Oxloj (1987)
Darién (PA)	F	8°00'N	2,200	22.0	>10	35.0	320	Mayo (1965)
Tacarigua (VN)	F	10°50'N	990	9.5	60	2.7	-	MARNR (1986)
Morrocoy (VN)	F	10°40'N	1,065	11.0	-	10.2	440	MARNR (1986)
Cocinetas (VN)	F	11°50'N	277	7.0	-	30.0	4,000	MARNR (1986)
Barra Navidad (ME)	R	19°11'N	750	4.9	-	14.0	2,090	Zamorano (1990)
Mona Island (PR)	R	18°00'N	810	13.0	-	27.3	-	Cintrón *et al.* (1988)
Boca Chica (ME)	B	18°30'N	1,680	20.0	8.6	34.2	3,360	Day *et al.* (1988)
El Verde (ME)	B	25°30'N	627	7.0	-	11.9	1,430	Flores-Verdugo (1987)
Ilha do Cardoso (BR)	B	25°00'S	2,269	8.7	9.5	25.9	3,735	Peria *et al.* (1990)
Tacarigua (VN)	B	10°50'N	990	15.3	10.4	30.1	790	Rodríguez & Alarcón (1982)
Morrocoy (VN)	B	10°40'N	1,065	25.0	-	66.8	1,320	MARNR (1986)
Cocinetas (VN)	B	11°50'N	277	7.5	20.0	16.8	1,280	MARNR (1986)
Orinoco Delta (VN)	R	9°00'N	2,290	28.0	-	65.1	1,000	MARNR (1986)
San Juan (VN)	R	10°10'N	2,055	28.0	-	27.5	350	MARNR (1986)
Paria Gulf (VN)	R	10°25'N	960	28.0	-	13.8	380	MARNR (1986)

Forest types are: F=Fringe; B=Basin; R=Riverine.

immediately after the changing of flow direction (Kjerfve *et al.*, 1993). Major hydrochemical changes also occur during these short periods (Lacerda *et al.*, *1988b*; Ovalle *et al.*, 1990; Rezende *et al.*, 1990).

Mangroves grow most prolifically on deltaic plains that are subject to regular flooding during high tides and have ample supply of freshwater via regular or episodic river flooding or rainfall. The hydro-period of inundation of fringe-overwash mangroves usually only lasts a few hours but occurs daily during high tides. This is the only water input to this type of wetland. Riverine mangroves, on the other hand, usually exhibit longer hydro-periods, which may last from hours to days and depend not only on tidal flooding but also on river regime. Water-level fluctuations within riverine mangroves vary greatly and increase with increasing river and stream discharges. Basin mangroves often have hydro-periods of perennial duration, and are often covered in shallow water on a continuous basis. Ground-water seepage and overland flow, as well as some saltwater intrusion, are the main water sources for this type of mangrove system (Zack & Roman-Mas, 1988).

In general major rates of water transport in mangrove systems occur during short periods (1-2 hours) of the tidal cycle, immediately before and after high water standstill, when the flow direction also changes. Although stream velocities can be substantial, the flow within the mangrove vegetation is slow and sluggish and seldom exceeds 5 cm s^{-1}. Major hydrochemical water and soil changes can occur during these short periods (Lacerda *et al.*, 1988; Ovalle *et al.*, 1990; Rezende *et al.*, 1990; Kjerfve *et al.*, 1993).

A critical factor for the well-being of mangrove ecosystems is the availability of freshwater, usually indicated by the ratio of rainfall to evapotranspiration, R/E. Although mangroves are found in both humid (R/E > 1) and arid climates (R/E < 1) in Latin America and the Caribbean, mangrove structural development and growth rates are by far greater in humid equatorial areas with plentiful rainfall, preferably distributed relatively evenly during the year (Blasco 1984; Snedaker, 1984; Kjerfve, 1990). Most of the Latin American mangrove wetlands, as well as the mangrove wetlands on the larger islands in the Caribbean, are distributed along coasts where R/E > 1. Notable exceptions are the northern coast of Peru, portions of the Caribbean coasts of Colombia and Venezuela, the coast of Ceará in Brazil, and most of the smaller islands in the Caribbean, where R/E < 1. The most extensive and best developed mangrove systems in Latin America and the Caribbean exist in regions with ample freshwater supply and R/E > 1, including the Pacific coast of Colombia, the Caribbean coasts of Panamá and Nicaragua, and the north Brazil coasts of Parã and Maranhão. Whereas mangroves flourish in the Orinoco River delta, this is not the case in the Amazon River where the discharge is so tremendous (average 175,000 m^3 s^{-1}) that the constantly fresh conditions in the mouth region of this world's largest river cause invasion of freshwater glycophytes which successfully out-compete mangroves.

Rainfall by itself apparently does not limit the growth of mangrove wetlands, as these exist in arid as well as wet climates (Galloway, 1982). However, rainfall does serve an important role as a primary control in leaching residual salts from mangrove soils, and thus acts to reduce soil salinity. Salts are deposited by tidal flooding in mangrove wetlands. In arid areas or regions with a strongly seasonal rainfall pattern, a barren salt flat often develops as a rim landward of the mangroves, where soil salinities often exceed 70 ppt and restrict mangrove development (Kjerfve, 1990).

Other factors being equal, coasts with a great tidal range can be expected to have more extensive mangrove wetlands because of a greater potential for tidal flooding. Such conditions are encountered along the humid Pacific coast of Colombia with spring tides reaching 3.9 m at Buenaventura, and also along the humid coasts of Pará and Maranhão in northern Brazil where at places semidiurnal spring tides exceed 7 m. On the other hand, in the inner part of Baja California, México, where the climate is arid, mangroves are poorly developed in spite of daily tides with a range greater than 7 m. In contrast, all of the Gulf of México and the Caribbean Sea is microtidal, sometimes diurnal and sometimes mixed, with a range less than 0.5 m (Kjerfve, 1981; Seim *et al.*, 1987). Here, the tide is of little consequence in terms of affecting mangrove distribution.

The difference in distribution of mangroves along the east and west coasts of South America is easily explained by the distribution of ocean currents. Temperature is the primary control of mangrove distribution (Kjerfve, 1990), and the surface water temperatures, even in relatively nearshore coastal waters, along the west coast of South America can be as low as 12C. The reason is the northward flowing cold-water Humboldt (or Peru) current and the presence of one of the most intensive wind-driven cold-water upwelling systems on earth along the coasts of Peru and Ecuador. As a result, mangroves only begin to appear at latitude 5°32'S in the estuary of Piúra in northern Peru and further north. Along the east coast of South America, the situation is completely different, and water temperatures are usually well above 20° except for the coast along the Cabo Frio upwelling system in the state of Rio de Janeiro. The warm-water Brazil current flows southward along the Brazilian coast, and mangroves are flourishing as far south as 32°20'S at Praia do Sonho, Santa Catarina.

8. Natural and Anthropogenic Impacts

8.1 Herbivory

The role of mangrove leaves in marine coastal food chains has been emphasized repeatedly (Odum & Heald, 1972,1975; Lugo & Snedaker, 1974). In New Guinea up to 20 percent of the leaves are consumed by herbivores (Johnstone, 1981). Insect herbivores remove up to 35% leaf area of Australian mangrove plants; but in general the leaf area losses are smaller than those reported for several terrestrial communities (Robertson & Duke, 1987); although occasionally massive defoliations may occur (Whitten & Damanik, 1986; Lee, 1991). Similar percentages have been indicated for American mangroves (Lacerda *et al.*, 1983; Farnsworth & Ellison, 1991). However, several authors have reported small proportions of damage to mangrove leaves, typically less than 8% of the

Table 5. Litterfall, rainfall and location of New World mangrove forests (g.m-2.yr-1.).

Location	Type	Latitude	Rainfall	Leaf litter (%)	Total litter	Author
Agua Brava, (ME)	F	22°45'N	1,200	821 (81%)	1,015	Flores-Verdugo (1986)
Estero Pargo, (ME)	F	18°30'N	1,680	594 (71%)	834	Day *et al.* (1988)
Itacuruçá, (BR)	F	23°00'S	1,500	697 (73%)	960	Silva (1988)
Bertioga, (BR)	F	23°53'S	2,200	376 (90%)	416	Ponte *et al.* (1984)
Agua Brava, (ME)	R	22°45'N	1,200	749 (59%)	1,263	Flores-Verdugo (1986)
El Verde, (ME)	R	23°25'N	627	980 (89%)	1,100	Flores-Verdugo *et al.* (1987)
Laguna Mancha, (ME)	R	21°30'N	1,250	749 (59%)	1,236	Rico-Gray & Lot (1983)
Boca Chica, (ME)	R	18°30'N	1,680	881 (70%)	1,252	Day *et al.* (1988)
Vacia Talga (PR)	R	18°00'N	890	931 (70%)	1,322	Lugo & Cintrón (1975)
Chame (PA)	R	8°40'N	1,500	- -	900	D'Croz, 1993
Chiriqui River (PA)	R	8°30'N	2,500	- -	2,000	D'Croz, 1993
Barra de Santiago (S)	R	13°40'N	-	- -	993	Ramirez & Nuñez (1988)
Barra Navidad, (ME)	B	19°11'N	750	1,029 (80%)	1,287	Zamorano (1990)
Laguna Joyuda (PR)	B	18°00'N	900	714 (77%)	919	Musa (1986)
Laguna Joyuda (PR)	B	18°00'N	900	415 (81%)	511	Musa (1986)
Majana (CU)	B	21°30'N	1,200	- -	1,060	Cuba (1993)
Florida (USA)	B	25°-27°N	-	404 (75%)	538	Day *et al.* (1988)
Florida (USA)	D	26°00'N	-	88 (72%)	122	Day *et al.* (1988)
Tacaragua (VN)	B	10°50'N	990	1,000 (71%)	1,400	Barreto *et al.* (1989

Forest types are: F=fringe; R=riverine; B=basin; D=dwart

total leaf area (Heald, 1971; 86; Onuf *et al.*, 1971; Beever *et al.*, 1979; Lacerda *et al.*, 1986), but higher defoliation rates (Farnswoth & Ellison, 1991), including mass defoliation, do not seem to be uncommon. In a Belizean mangrove forest, Farnsworth & Ellison (1991) found that herbivores damaged 4.3 to 25.3% of *Rhizophora mangle* leaf area and 7.7 to 36.1% of *Avicennia germinans* leaf area. *R. mangle* was more frequently damaged than *A. germinans* (Farnsworth & Ellison, 1991), even though the second species has a higher content of nitrogen (Ernesto Medina, personal communication). In mangroves of the Sepetiba Bay (Brazil) *Avicennia schaueriana* had less leaf area eaten than *Rhizophora mangle* and *Laguncularia racemosa* (Lacerda *et al.*, 1986).

Herbivory rates vary widely from site to site and are related to several factors, including species, leaf age, branch height, orientation of branches, seedling height and distance to nearest neighbor, presence of a canopy, and chemical composition of leaves, including ash, crude fiber, water content, soluble carbohydrates and phenols (Lacerda *et al.*, 1986; Farnswoth & Ellison, 1991). Herbivores in Belize include the common mangrove tree crab, *Aratus pisonii*; the gastropod *Littorina angulifera*; Lepidoptera larvae, including *Megalopyge opercularis*, *Automeris* sp., *Phocides pygmalion*, and other unidentified species; Coleoptera larvae (mainly Chrysomelidae and Lampyridae); Homoptera (Aphididae, Blattidae, Cicadellidae, Cercopidae and Diaspididae); unidentified leaf miners; and larvae of unknown identity.

Leaf area damaged has shown a great variability (Lacerda *et al.*, 1986). In the Caribbean the rate of direct grazing by crabs and insects on live mangrove leaves is small (Heald, 1971; Onuf *et al.*, 1977; Beever *et al.*, 1979).

The isopod *Sphaeroma terebrans* was cited as the agent that damaged many of the mangroves of southwestern Florida (Rehm & Humm, 1973). This species bores into the tips of aerial roots of the red mangrove tree *Rhizophora mangle*, destroying root apices and, possibly, initiating lateral budding and the proliferation of lateral roots (Gill & Tomlinson, 1977; Simberloff *et al.*, 1978). *Sphaeroma terebrans* can affect up to 83% of the tips in some localities and

Table 6. Biomass allocation, forest type and rainfall in New World mangrove forests (ton.ha^{-1}).

Location	Latitude	Type	Rainfall	Aboveground	Belowgroung	Total	Author
Itacuruçá, (BR)	23°00'S	F	1,500	65	16 (20)	81	Silva *et al.* (1991)
Darien, (PA)	8°00'N	R	2,200	279	190 (41)	469	Golley *et al.* (1975)
Florida (USA)	25°00'N	D	-	8	8 (50)	16	Lugo & Snedaker (1974)
Florida (USA)	25°30'N	Island	-	8	14 (64)	22	Lugo & Snedaker (1974)
Puerto Rico (PR)	18°00'N	F	890	63	50 (44)	113	Golley *et al.* (1962)

Forest types are: F=fringe; R=riverine; B=basin; D=dwarf.

frequently prevents roots from reaching the substrate (Rehm, 1976). This process would stimulate a beneficial action of branching (Simberloff *et al.*, 1978), although Ribi (1981) has not found any evidences to support this effect.

On mangrove cays off the coast of Belize, the isopod *Phycolimnoria clarkae* attacks the submerged roots of the red mangrove *Rhizophora mangle*, reducing root relative growth rate by 55% (Ellison & Farnsworth, 1990). These isopods do not stimulate lateral branching, as was postulated by Simberloff *et al.* (1978) for the isopod *Sphaeroma terebrans* in Florida. The epibionts that grow on submerged roots inhibit isopod colonization and thus facilitate root growth (Ellison & Farnsworth, 1990).

Another species, *Sphaeroma peruvianum*, can cause a 50% decrease in the growth rate of the prop roots of the red mangrove (*Rhizophora mangle*) in the Pacific coast of Costa Rica and a decrease of 52 to 62% in net root production (Perry, 1988). In Cuba, a new species of Pyralidae (Lepidoptera) larvae is a root borer of red mangrove roots (Padron *et al.*, 1993).

The mangrove tree crab *Aratus pisonii*, although omnivorous (Díaz & Conde, 1988), in some localities can have up to 42% of its diet based on mangrove leaves (Lacerda *et al.*, 1991). In Pine Island (Florida, USA), Beever *et al.* (1979) found that *Aratus pisonii* can damage up to 80.6% (mean=46.8%) of the leaves of the red mangrove and up to 7.1% (mean=3.3) of the leaves area; these numbers translate in a mean consumption of 35.3 cm^3 of leaf area per month. *A. pisonii* is an important biomass exporter; Warner (1967) estimated that the average output of *Aratus* is 207 eggs per day per m^2. Most of this effort is consumed by aquatic organisms, given that the survival rate from egg to adult is only 0.041% (Warner, 1967). Another contribution of *Aratus* as a biomass exporter is through frass. Beever et al. (1979) estimated that an adult *Aratus* would introduce 8.8 cm^3 of frass per month into the aquatic system.

In Australian mangroves, Smith (1987ab) found that crabs belonging to the family Grapsidae can shape mangrove species distribution and abundance, through selective predation of propagules. In some Neotropical mangrove forests the results do not support the dominance-predation model (Smith *et al.*, 1989). In Florida, no *Rhizophora mangle* propagules were eaten (Smith *et al.*, 1989). However, in Panamá, more propagules were consumed in the low intertidal, *Rhizophora*-dominated forest than the high intertidal, *Avicennia*-dominated forest, but there seems to be less predation on *Rhizophora* in Florida and Panamá than in Malaysia and Australia (Smith *et al.*, 1989). The predators responsible for consumption of propagules appear to be the grapsids *Aratus pisonii* and *Sesarma curacoense*; unidentified burrowing crabs; unidentified water-borne organisms (probably fishes); and the snails *Melampus coeffus* and *Cerithidea scalariformis* (Smith *et al.*, 1989). The grapsid *Goniopsis cruentata* has also been observed to frolic with *Rhizophora* propagules in Venezuela (J. E. Conde, *personal observation*). Other important herbivores are the Scolitidae (Coleoptera) which attack the seedling of the red mangrove (Padron *et al.*, 1993).

8.2 Hurricanes and tropical storms

The consequences of hurricanes Hugo, Gilbert, and Joan, that struck the Caribbean in 1988-1989, were studied in many terrestrial plant communities and populations (Walker *et al.*, 1991). Nevertheless, mangrove forests were not specifically evaluated in that issue.

Tides and waves, which may cause excessive siltation or erosion, produced by hurricanes and storms are considered natural stressors of mangroves (Lugo, 1980). In the model of Cintrón *et al.* (1978), hurricane cycles are one of the most important external factors in mangrove function. Hurricanes may act as catalysts of succession or may retard or stop it in any of its cyclic stages (Lugo, 1980). Also, they could prevent mangrove forest from reaching structural complexity, as could be the case in Florida (Lugo, 1980). Periodic exposure of Caribbean mangroves to hurricanes and storms has been suggested as one of the mechanisms responsible for the low structural complexity and lack of climax elements in those forests (Roth, 1992).

Although there is an extensive literature where accounts of mangrove damage by hurricanes is included, most of them are descriptions of the immediate consequences, and do not consider the long-term effects and the responses of mangroves to these climatic disruptions (Roth, 1992). The damages can include defoliation, shearing of branches and trunks, and uprooting of trees (Roth, 1992). The process of recuperation is slow (Lugo & Snedaker, 1974), and depends on species and topographic characteristics, sedimentation and drainage patterns, and proximity to the hurricane pathway (review in Roth, 1992). The regeneration of the mangrove forests usually starts immediately thanks to the surviving seedlings and saplings (Alexander, 1967; Wunderle *et al.*, 1992).

Roth (1992) carried out a detailed study of the impact of hurricane Joan and the regeneration of a mangrove forest in Nicaragua. Thirty-six percent of the trees died, representing 68% of the basal area of the pre-hurricane stand. The supression was not random, larger trees were the most affected. As a consequence, the complexity index was lowered. Abundant regeneration by all the original mangrove species appears to have been favored by the hurricane. Seventeen months after Hurricane Joan struck the mangrove stands, seedlings of *Rhizophora mangle*, *Avicennia germinans* and *Laguncularia racemosa* were growing in great numbers throughout the stand, except on those places where the fern *Acrostichum* was present. The responses of *Rhizophora mangle*, *Avicennia germinans* and *Laguncularia racemosa* to the damages produced by the hurricane were dissimilar (Roth, 1992). Sprouting capacity and initial seedling density were the lowest in *R. mangle*. This species, however, showed the highest seedling survival rate and an intermediate seedling growth rate. *L. racemosa* showed the highest sprouting capacity, although its seedling survival rate was the lowest. Initial seedling density was highest in *A. germinans*, but seedlings grew slowly.

Roth (1992) points out that post-hurricane mangrove stands development is relevant to its management. It would appear that periodic, small-scale harvests, could offer a combination of protection and profitable use in those places where hurricanes are frequent.

8.3 Oil contamination

Contamination of mangrove swamps by oil is common place in much of the tropics, and has received much attention from scientists, in particular those working in threatened areas such as the Caribbean and Gulf of Mexico coasts. Mangroves, due to their particular geographic and hydrographic settings, are particularly vulnerable to oil contamination (Gundlach, 1987).

Major causes of oil contamination in mangroves are spills of various sizes following tanker accidents and other shipping incidents, damaged pipelines and blow-outs. Other, generally small-scale contamination events occur during loading and unloading operations in ports and terminals, such as overloading of tanks, tank cleaning, malfunction of valves and carelessness while connecting and disconnecting hoses. Such "small" spills however, can involve up to 5 tons of oil (Baker, 1982). Without doubt accidents involving large tankers cause the most impressive impacts on mangroves, since they involve large quantities of oil up to a hundred thousand barrels, and may affect pristine mangrove forests along extensive coastlines with devastating and long lasting consequences.

New World mangrove forests have witnessed many such accidents, in particular during the 1960-1970's, when regulation and safety procedures were not commonly in use. Between January 1974 and June 1990, 31 oil spills occurred near coastlines in the Caribbean, Florida, the Bahamas and the east coast of Mexico (Burns *et al.*, 1993). Other spills occurred in the open Caribbean and Atlantic, in the Amazon and Orinoco Rivers and unspecified localities in the Caribbean. One of the first accidents to receive attention from mangrove scientists was the spill of nearly 70,000 barrels of crude oil from the "Argea Prima", in Puerto Rico in 1962. Oil accumulated preferentially on mangrove roots and large mortality of invertebrates, fish and turtles were reported (Díaz-Pferrer, 1962). Along the Panamá coast, Rützler & Sterrer (1970), reported reduction of many invertebrate species after the soaking of mangrove sediments with diesel oil from a 15,000 barrel carelessness while connecting and disconnecting spill from the "Witwatter", in 1968. Jernelöv *et al.* (1976) described short-term and long-term effects of a spill of crude oil from the "St Peters", along the Ecuador/Colombian coast. Short-term effects followed a thick oil covering of roots and trunks, resulting in partial defoliation, large mortality of sessile animals and reduction in crab density. After removal of oil by wave action, defoliated parts recuperated as well as invertebrate populations through migration from non-affected areas. Chan (1976; 1977) studying the effects of a small (1,500 to 3,000 barrels) spill of crude oil in Florida Keys, showed that *R. mangle* seedlings were killed when over 50% of their surface was oiled and *A. germinans* trees were also killed when 50% of the pneumatophores were oiled.

More recent accidents involving oil spills and mangroves received better attention and detailed studies. For example, the effects of the 37,000 barrels of crude oil spill from the "Zoe Colocotroni", in a Puerto Rican mangrove were monitored for over 10 years after it occurred, by many authors. A summary of their major findings showed that three years after the spill, *R. mangle* and *A. germinans* trees which were defoliated following the spill had died, and associated fouling communities were reduced to a great extent (Nadeau & Bergvist, 1977). After four years, the oil present in sediments had been highly weathered, even in the most affected areas. Recolonization by seedlings from unaffected adjacent mangrove forests was observed for the first time (Page *et al.* 1979). However, two years later, the remaining oil in the sediments was still affecting the infauna, although colonization processes were already in progress (Gilfillan *et al.*, 1981).

In Venezuela, Bastardo (1991,1993) studied the dynamics of mangrove leaf decomposition under the influence of hydrocarbons in the Tacarigua coastal lagoon. The results suggested that decomposition rates were accelerated by the presence of hydrocarbons. However, after 14 days of exposure there was no traces of hydrocarbons left.

Finally the best studied case of oil spill in American mangroves followed the spill of nearly 8 million liters of medium weight crude oil on April 27th, 1986, from a ruptured storage tank in the Caribbean coast of Panamá (Jackson *et al.*, 1989). After 20 days, the oil spilled over the coral reefs fringe and reached the mangroves.

Upon reaching the mangroves, the oil accumulated on proproots and pneumatophores, immediately killing the fouling communities. When defoliation started, just one month after the spill, branches lacking the weight of leaves flexed upward lifting the roots and thus killing also the subtidal epibiota that had escaped from direct oiling.

A band of defoliated trees was apparent within two months of the spill and it widened thereafter. After 10 months a band of dead mangrove trees (18 to 100 m wide) had been formed and after 19 months dead mangroves occurred along 27km of coastline. After 15 months over 60% of roots were dead, broken or rotting. *Rhizophora mangle* seedlings planted in the area failed to produce leaves, therefore the mangrove fringe habitat was largely destroyed and will not recover until new trees will be able to grow there.

The results of these studies allowed the proposition of a pattern of events occurring in mangroves affected by oil spills. Getter *et al.* (1981), compared the effects of 5 oil spills on mangrove areas of Gulf of Mexico and the Caribbean Sea. Despite the different circumstances of these spills, there were a number of common effect which included a series of stress symptoms and damages. In general at all sites, defoliation immediately follows the spill, resulting in deaths of the three, depending on the proportion of crown defoliated. Leaf deformation was also a common symptom at all al sites. Mortality of seedlings generally occurred later due to availability of internal reserves.

Stress symptoms observed following an oil spill, are leaf necrosis, root malformation and alterations in leaf morphology; these major symptoms correlate well with most others, and always correlate with the degree of stress imposed on the plant. Mangrove leaves become significantly and proportionally shorter and narrower just after the onset of the stress (Getter *et al.*, 1985).

Tree mortality due to oil contamination has been frequently related to the obvious blocking of gas-exchange surfaces by the oil coating. However, the waxy nature of mangrove surfaces, both leaves or seedlings, could minimize the effect of the coating (Getter *et al.*, 1985). Mortality seems to be more likely a result of the toxicity of the oil derivates and/or dispersants which results in the degradation of plant metabolism. Toxic effects on roots decrease transpiration in mangrove plants. Physical damage of stomata is common due to coating affecting gas exchange and photosynthesis, an unbalance of the transpiration/osmotic regulation system will immediately lead to permanent damage to the plant's metabolism (Getter *et al.*, 1985; Getter & Ballou, 1985).

Significant differences in response to oil by different mangrove species have also been reported and have been attributed to the differences in the physiology of the various mangrove species. For example, *R. mangle* seedlings resist better and recuperate faster than *A. germinans*, from chronically exposed sites. This seems to be related to the "filtering" capacity of *R. mangle* roots to cope with the saline environment. This mechanism which has been shown to be effective for salt exclusion and trace metals exclusion (Lacerda *et al.*, 1986), is also probably efficient in avoiding the uptake of toxic substances derived from oil. On the other hand, *A. germinans* that lacks this filtering mechanism and regulates osmotic balance through excretion of salt through glands in the leaves, would more readily absorb toxic oil derivatives (Getter *et al.*, 1985).

Site conditions and type of oil, are the key determinants of mangrove recovery after a spill (Jacobi & Schaeffer-Novelli, 1990). Removal of oil is dependent on the export of sediment particles and litter deposited in the sea. These fluxes are dependent on tidal amplitude and the consequent extension of flooded area during high tide (Ovalle *et al.*, 1990). Removal time will be different along a given forest, resulting in a uneven distribution of the effects. For example Burns *et al.* (1993) demonstrated that up to 20 years are necessary for deep mud coastal habitats to recover from the toxic effects of catastrophic oil spills. Defoliation and mortality are more intense in the inner parts of forests, where oil stays longer and weathering forces such as waves and currents are less effective. The outer fringe generally shows less serious effects, such as partial defoliation, root loss and loss of fouling communities. This difference however, will be smaller at very protected sites, where there is lack of intense waves or currents, the seaward fringe can also be strongly affected. Also, the use of dispersants greatly reduces the retention of petroleum hydrocarbons in mangrove sediments, reducing their availability for plant uptake and accelerating weathering processes, and therefore the forest recuperation.

9. Mangrove Uses

Mangroves play an important role in tropical coastal economies providing many goods and services for the human population. These include: coastline protection and stabilization, nursery for a variety of economically important shellfish and finfish, and source of important products for the coastal human populations in the form of timber, firewood and charcoal, chemicals, medicine and waterways for transport, enrichment of marine coastal waters by nutrients, and an environment for aquaculture, although some of these benefits are at present poorly understood or unrecognized in Latin America countries. Examples of the importance of such direct and indirect benefits provided by mangrove are significant for the rational management of the Latin America coastal belt.

Waterways protection using mangroves are common in Ecuador and Colombia. In Brazil, mangroves have recently been included in the management plans of marinas and coastal condominiums. In Panamá, up to 60% of total shrimp fisheries is based on 5 species which depend on mangroves for completing their development. Along the Maranhão coast, North Brazil, the huge shrimp production includes two species of shrimps which develop in the local mangrove waters. Apart from these indirect benefits, mangrove products themselves are particularly important for many coastal populations. Firewood and charcoal seems to be the major uses of mangroves in Latin America. In countries like Nicaragua, where nearly 80% of households uses wood for cooking, mangroves provide a significant percentage of firewood. In Brazil annual firewood extraction reaches up to 9,000 m^3. In Honduras the use of firewood may range from 80,000 m^3 to 120,000 m^3, while in El Salvador, with only 350 km^2 of mangroves, up to 30,000m^3 of firewood are extracted annually. In Brazil, mangroves are a regular source of firewood for bakeries and potteries, even along the most developed areas of the Southeastern coast (Araújo & Maciel, 1979).

Charcoal production is another major use of mangrove wood, although only a fraction of the total yield is collected due to inefficient extraction techniques. In Costa Rica up to 1,300 m^3 of mangrove charcoal is produced annually in the Terraba-Sierpe forests, while in Panamá this may reach up to 7,400m^3. Mangrove bark is still a source of tannin in most Latin America countries. Bark yields range from 1,840 to 4,490 $kg.ha^{-1}$ in Costa Rica, and bark production in Panamá may reach over 400 tons.yr^{-1}. At the Parnaíba River Estuary, Piauí, Brazil, mangroves support over 10,000 people who depend on artisanal crab fishing.

Despite their importance for most coastal tropical countries in Latin America, mangrove ecosystems have been witnessing an accelerated rush for their resources, most of the time without the necessary care to maintain their integrity and threatening their sustainable utilization. Estimates of deforestation in mangrove areas of Latin America are few. Central America has annual cover losses estimated for Nicaragua (385 ha); for Guatemala (560 ha) and for Costa Rica (45 ha), mostly for conversion into rice fields, salt ponds and mariculture. In Ecuador nearly half of the mangrove area (*ca.* 80,000 ha) has been deforested for various purposes, in particular for shrimp ponds, during the last two decades. In the Ilha Grande Bay, southeastern Brazil, which harbored nearly 600 ha of mangrove forests in the early 80's, nearly 80% of it have been reclaimed to build condominiums and marinas.

Apart from deforestation itself, degradation of large mangrove areas is taking place in many Latin America countries due to misuse of coastal resources. Diversion of freshwater for irrigation and land reclamation purposes has been one of the major actions leading to mangrove degradation (Conde & Alarcón, 1993). The mangroves of Guanabara Bay, Rio de Janeiro, which reached nearly 50km^2 in the beginning of the century, is presently nearly totally degraded with less than 15 km^2 of pristine forests, mostly due to clearcutting of creek and river banks, oil spills, solid wastes dumping and decreased freshwater inputs. In French Guyana over 20,000 ha of mangroves have been cut for rice culture and large amounts of fungicides, pesticides and fertilizers are being used (K. Wood. *pers. comm.*). In the insular Caribbean and the Caribbean coast of Venezuela, tourism development in coastal regions has been the major destroyer of mangrove areas (Aristiguieta, 1980; Hudson, 1983; Bacon, 1987). One of the few mangrove silviculture experiments in Latin America was carried out in Venezuela from 1969 until the mid 80's. In 1969 a vast area was granted to TAMAVENCA (Taninos y Maderas de Venezuela), in concession for 30 years to exploit timber in the Guarapiche Forest Reserve, San Juan River. This mangrove use has been considered a well planned forestry enterprize (Canales, 1983). However the results were not satisfactory. In 1983 only 20% of the proposed area were actually exploited and with a low yield of 150 m^3.ha^{-1} of timber compared to over 500 m^3.ha^{-1} expected. Recovery from this damage is still incomplete (Medina, E. *pers. com.*).

Pressures and menaces on mangrove forests vary from country to country, and even within a country, nearby localities can suffer different consequences. In some places the damage is inflicted slowly, and the degradation rate escapes the eye. In other instances, degradation occurs instantly and can reach dramatic proportions. These deleterious actions have not gone uncontested. A rich legislation has been developed in many countries. Since D. José's Edict, in the XVIII century, in Brazil, up to the 70's, when Carlos Andrés Pèrez, promulgated a presidential decree to specifically protect the Venezuelan mangroves, efforts have been made to face mangrove degradation within a legal frame. The results have varied and were not always successful. Another avenue for mangrove preservation has been that of non-governmental organizations which develop programs in mangrove conservation awareness. The success of this approach however remains to be evaluated and is a long term task. Finally, rational sustainable use and development of mangroves in Latin America and the Caribbean is a task in which scientists play an important, but theirs is not the only role. Politicians, planners, decision makers, engineers, entrepreneurs, villagers should also be involved in the conservation of a resource whose ecological, scenic, medicinal, aquacultural and silvicultural values, among others, are unique and a heritage to be preserved.

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Mangroves of Peru

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1. Historical Background

1.1 Past and present uses of Peruvian mangroves

Tumbes had an important role in Pre-Columbian America when a large coastal population dedicated to agriculture, fishing and commerce, formed the Tumpis Culture. These littoral people were the best navigators of the Peruvian coast. They developed to a high degree the art of carving mangrove bivalve shells of the species: *Spondius* sp., *Ostraea* sp. and *Anadara grandis*. To the *Spondius* shell, known to the Andeans as "Mullu", they attributed magical powers and after carving zoomorph or phytomorph figures they offered them in religious rituals. This is probably one of the first records of mangrove uses in Peru.

Mangrove uses in Peru have been mostly restricted to fuelwood and charcoal production. In small scale, it has also been used for construction in farms, as supporting poles for fishing nets and in banana plantations as poles (Araquistain, 1987). Along the coast, mangrove bark has been used to prepare medicine for stomach problems. In the recent past, mangrove bark was also used to prepare covering for oil drilling wells and more recently for tannin extraction. The expansion of prawn aquaculture has made use of mangrove trees to produce poles for pond construction and canal protection (CDC-Peru, 1986).

Apart from the wood itself, mangroves from northern Peru are important sources of shellfish to the local human population. Many species are presently used in the local diet. The importance of this resource has been recognized since the beginning of this century, when studies dealing with the ecology of these organisms always took into consideration aspects of palatability to humans, taste and nutritional value (Coker, 1910 *In*. Rivadeneira and Doig, 1992). The recognition of the nutritional value of mangrove shellfish induced Schweigger (1947; *In*. Rivadeneira and Doig, 1992) to recommend already at that early date, the establishment of oyster culture in areas other than the mangroves, based on a better growth under permanent flooded conditions.

Permanently artizanal fisheries of mangrove shellfish includes placing traps in creeks and canals of the mangroves. These traps collect from 200 to 300 shells a day. However, they are of low efficiency and, there is no control of the catch (Ministerio de Agricultura, 1989).

1.2 Present interest in the mangrove ecosystem

There is an increasing interest in managing the entire mangrove ecosystem of Peru and to preserve a significant area of the forest. As a consequence, the Peruvian Government created in 1988 the Santuario Nacional Los Manglares de Tumbes (National Sanctuary of Tumbes Mangroves). Public and private institutions coordinate their activities for the management of this sanctuary. Some of the most important are described below as well as the names of the institutions in charge of making them a reality:

- Demarcation and signalization of the area.
- Detailed mapping of the mangroves by the Peruvian Foundation for the Conservation of Nature, the National Office for the Evaluation of Natural Resources (FPCN-ONERN) and the Bilateral Office Canada-Peru.
- Reforestation plans by the Tumbes University, the Zarumilla Municipality and the Peruvian Office of Services.
- Farming the American crocodile *Crocodylus acutus*, by the Tumbes National University.
- Installation of an Experimental Research Station and Data Bank on the Mangroves of Tumbes in the Tumbes National University.
- Characterization of the ecology of the "black cockle" for its management, stock reconstitution and economic use by the Universidad Nacional Agraria La Molina and Tumbes University.

There is no central plan for the management and conservation of the mangroves of Peru. Control policies are not efficient. However, the infrastructure and equipment necessary for the purpose is presently being undertaken (CDC-Peru, 1992).

2. Location, Extension and Distribution

The mangroves of northwestern Peru are located in two distinct areas. The first, closer to the Equator, is located between latitudes 3°24'S (Punta Capones) and 3°34'S (Estero El Chalaco) and between longitudes 80°13'W (Estero Hualtaco) and 80°31'W (Estero La Chepa) (Fig. 1). This area includes the Corrales and Tumbes Districts of the Tumbes Province and the Zarumilla District of the Zarumilla Province, both in the Tumbes Department. Mangrove cover in the area decreased 43% from 1943 to 1983 (CDC-Peru, 1986) (Table 1) and covers at present 4,541 ha.

Table 1. Changes in mangrove cover due to changes in land use at Tumbes, Perú (ONERN, 19902).

Cover type	(ha)
Mangrove surface in 1982	5,961
Mangrove loss to aquaculture	1,294
Mangrove loss to other land uses	497
Increased mangrove cover due to colonization	368
Mangrove surface in 1992	4,541

The second mangrove area is located south of the first at the mouth of Piúra River, lat. 5°32'S, close to the city of Sechura. In this area about 6km of coasts are covered by stands of *Avicennia* sp., with a total area covered by mangroves of 250ha (Fig. 2) (Cintrón & Schaeffer-Novelli, 1985; Peña & Vasquez, 1985; CDC-Peru, 1986).

Although the Tumbes River estuary is widely quoted in the literature as the southern limit of mangroves along the Pacific coast of South America (*e.g.* Lacerda & Schaeffer-Novelli, 1992), the actual limit of well developed *Rhizophora* forests, occurs at Estero Corrales, a canal of the Tumbes River located at 3°40'S. The southern limit of mangroves properly occurs in the Piúra River. There, according to Vasquez (*pers. comm.*) stands of *Avicennia* form narrow fringes along the river and marshes. In these stands the trees are short and reach up to 20cm in diameter. According to Cintrón and Schaeffer-Novelli (1985), *Laguncuria racemosa* is also found in this area.

3. Physical Setting

3.1 Climate

According to Thornthwaite (1928), climate in the Northern Peru coastal region is a semi-arid, hot climate with little rainfall. This climate pattern is only changed during "El Niño" years a phenomenon caused by the invasion of the Peruvian coast by hot northern oceanic currents. As a result there is a rapid increase in rainfall. The phenomenon normally occurs in summer with variable duration and effects. But since it is occasional, it is not enough to change the general climatic pattern (ONERN, 1983). From the Ecuador border to lat. 5°S, the climate is semi-equatorial with rainfall ranging from 100 to 300 mm per year. South of lat. 5°S the climate is subtropical and arid, with nearly zero annual rainfall, due to the Humboldt Current.

Mean annual temperature recorded at the Tumbes Department Meteorological Station at Tumbes is 25.4°C, while at Los Cedros station it is and 24.4°C. Temperature ranges from a maximum mean of 30°C in summer, which lasts for four months from January to April and a minimum mean of 18°C in winter, which lasts for eight months from May to December. Rainfall is not uniform with highest values occurring in consecutive summers but with discontinuities which may last for some years leading to severe droughts with serious impacts upon the socio-economy of the region. Eventually very humid summers may occur, resulting in rainfall much greater than the normal annual mean (Ferreyra, 1979).

The "El Niño" phenomenon occurs as a decrease in the strength of Trade winds and a displacement to the south of the Anti-cyclone of the Austral Pacific, resulting in the displacement of the Intertropical Convergence Zone. During the phenomenon, large air masses saturated with humidity form heavy cloud cover (for example, up to 50% in December, 1982 and up to 70% in March, 1983) and rainfall several orders of magnitude higher than the normal mean. Maximum rainfall was observed in 1925, with 1,524mm. Rainfall at Tumbes was 10 times higher than normal and at Piúra, over 60 times higher than normal.

In 1983, the "El Niño" induced rains, resulted in a significant increase of the Tumbes River flow and its drainage, which is frequently dry. With the increase in river flow there was an increase in the suspended sediment load, which affected the normal

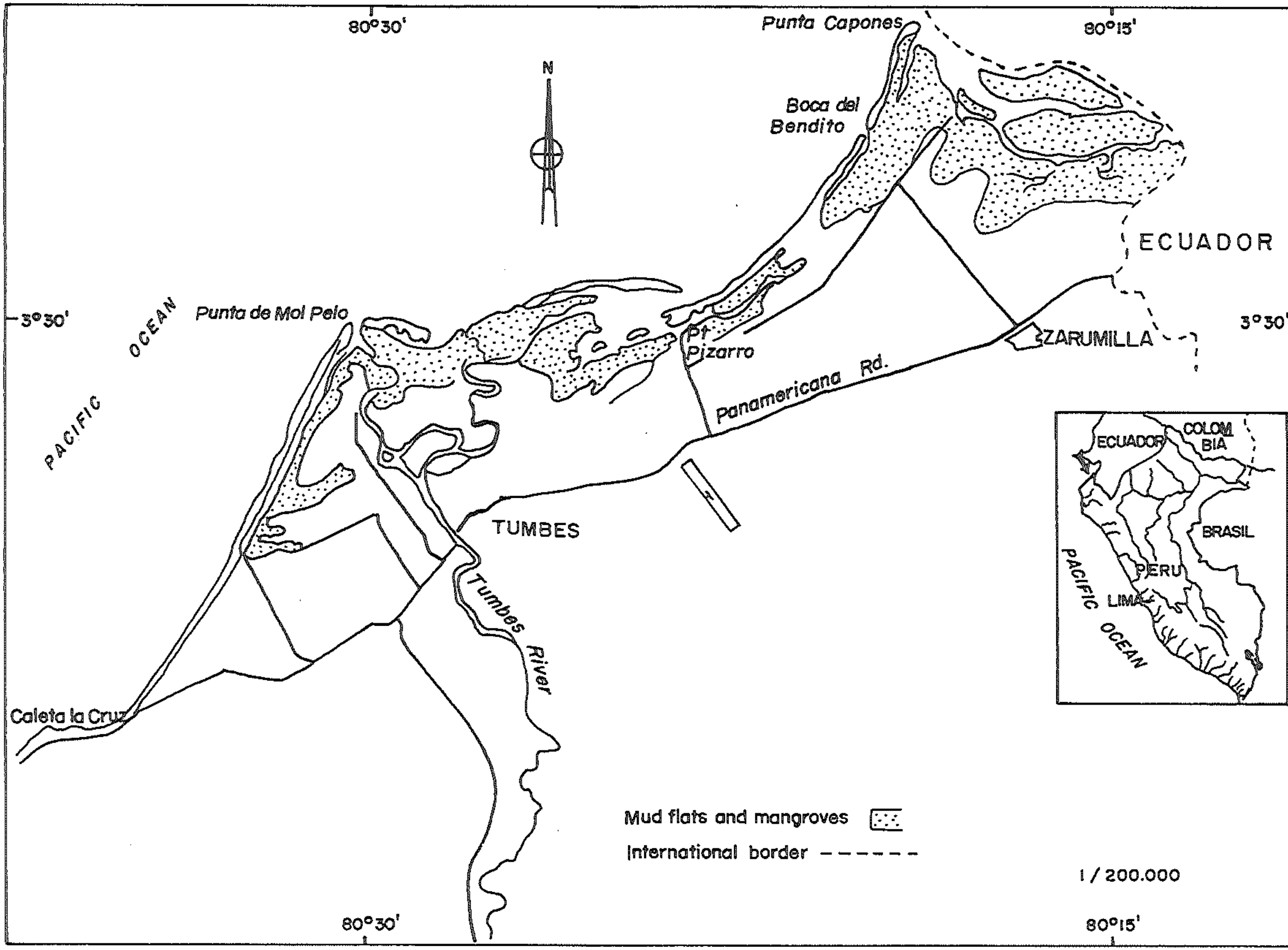

Fig. 1. Map showing the mangrove areas of the Tumbes River Estuary, northern Peru.

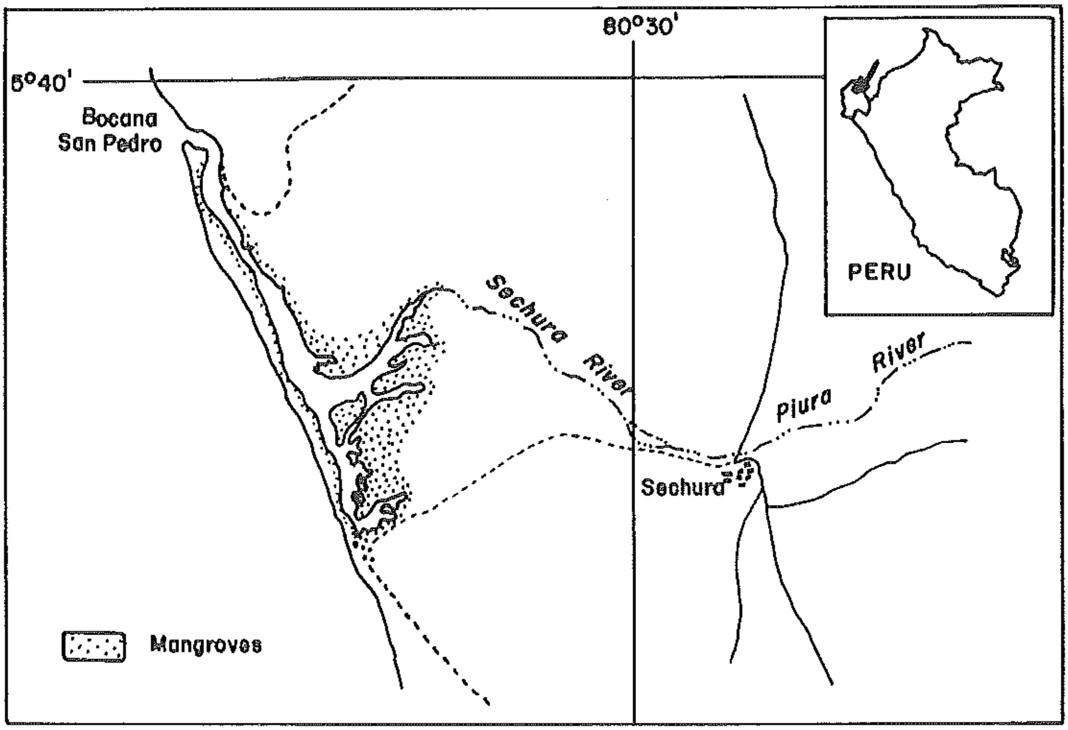

Fig. 2. Mangrove areas of the Piura River Estuary, Peru.

hydroperiod of the local mangroves.

Most significant winds occur between 12:00 to 13:00hrs, with a predominant and nearly permanent north-western direction. Typical wind velocity ranges between 1.0 to 1.5 km.h^{-1}. Evaporation is much higher than the rainfall, with annual mean of 880 mm, over four times the mean rainfall of less than 200mm. Insolation is also high ranging from 4.4 to 6.4 hours per day at Los Cedros Meteorological Station. Cloud cover is relatively constant with a mean of 6/8 per month. Typical cloud types are stratus and stratu-cumulus (ONERN, 1983).

3.2 Geology, geomorphology and soils

Mangrove forests of Tumbes Department are located over recent, quaternary continental deposits (Pleistocene and Holocene). These deposits are constituted by unconsolidated sands, clays, and gravel. Fine sedimentary particles and mud are also present. The following sedimentary stratigraphic formations have been described (CDC-Peru, 1986).

Zarumilla Formation: This is composed by a sand-clay-gravel cover of marine origin, of over 100m of depth. This formation is believed to have been formed by the Pliocene-Pleistocene.

Punta Malpelo Formation: This is composed by sediments of continental origin of sands from spits and mud from sheltered areas, with layers of sand and gravel from aeolic erosion.

The depth of deltaic sediments varies according to the original relief of the coast during the Pliocene. The sediments brought in by the Tumbes River (17 million m^3 per year) are the most important components for the delta development. The quantity of sediments transported by the Tumbes River is higher during summer, when waters are very turbid with high concentration of fine particles with diameter ranging from 0.008 to 0.07 mm. These fine sediments can be transported over 6.5 km in the ocean (CDC-Peru, 1986) and formation of mud flats is frequent. The fine sediments retained in the delta, are constantly redistributed according to tidal flow. When reaching the mangroves they are fixed and consolidated.

The geomorphology of the Tumbes River delta is dependent on three major factors: tidal flow; coastal currents and sediment load brought by the river. Depending on the behavior of one or more of these factors in different years, the delta may suffer accretion or erosion. There is no typical geomorphology of the delta. For example, the main canal of the Tumbes

River at Punta Malpelo, increased over 400m between 1943-1970. Extensive sand spits may form and move rapidly and eventually reach the mangrove areas (CDC-Peru, 1986). While sedimentation processes seem to dominate the local marine environment, strong erosive processes may occur along the river banks, resulting in the decrease of the sandy beaches and even of areas covered by mangroves.

Deltas with strong transport of sediments, but with weak tidal and wave energies, generally turn into lobulated forms. They are characterized by large transport of fine sediments to the sea. When marine erosion acts upon these sediments, sandy ridges and dunes are formed. This occurs at the Tumbes River delta making it a very dynamic coastal areas due to the action of the Tumbes River proper and that of River Guayas, in the Guayaquil Gulf in South Ecuador which also affects the North coast of Peru. The results of such dynamic littoral are the accelerated sedimentation of the waterways between La Cruz and Punta Malpelo resulting in the progressive expansion of Hermosa Beach; the presence of temporary islands in Puerto Pizarro Bay and other areas; constant formation of sandy ridges; and formation of wetlands and mangroves behind these sandy ridges.

Soils are mostly sandy-silts. In Estero Corrales however, Gutierrez *et al.* (1980) reported clay soils. They generally show neutral pH although in some areas acidic and alkaline soils may occur. Organic matter content typically ranges from 6.7% to 11.2%. High organic content is in general associated with pH values around 5.5. Carbonate content is in general low (<1.0%) with the exception of Isla del Amor soils, which due to the presence of large quantities of shell fragments may present carbonate content ranging from 1.3% to 1.8%.

3.3 Hydrology

The Tumbes River has a mean annual discharge of 3,467 x 10^6 m^3, corresponding to a mean flux of 110 $m^3.s^{-1}$ (CDC-Peru, 1986). However, under certain specific meteorological conditions, the Tumbes River can reach a maximum flow of 12,290 $m^3.s^{-1}$ (Berger, 1979). Sediment transport has an average of 1.25 $t.m^{-3}.s^{-1}$ and is composed of silts (65%), sands (30%) and clays (5%) (Berger, 1979). During exceptional rainy seasons they are deposited inside the mangroves and may cause tree death (CDC-Peru; 1986). For example, in 1992 flow discharge increased from 198 $m^3.s^{-1}$ in January, with rainfall of 162 mm, to 2,381 $m^3.s^{-1}$ in March, with rainfall of 462 mm. This was considered a typical "El Niño" year (IND, 1992).

Tidal regime is typically mesotidal, with heights ranging from 2 to 4 m, and subject to intense wave action originated in the South Pacific Ocean. The strong tidal currents are responsible for the modeling of the coastal sediments along the Tumbes River delta. High tidal amplitude and low topographic profile facilitate saline intrusion far inland, considerably increasing the areas with a potential for mangrove development (Cintrón & Schaeffer-Novelli, 1985).

Water salinity of estuaries and tidal creeks ranges from 10 to 30 ppt (Quiroz, 1980), while inside mangroves it shows seasonal variation. Salinity is minimum during the rainy season and may go down to zero during heavy rains in May. From September to November, salinity ranges from 25 to 27 ppt, and reaches 33 ppt from January to March (Quiroz, 1980; Alvarado, 1981). Water temperature is quite high with a minimum of 27°C from May to October and a maximum of 33°C from January to February (Quiroz, 1980; Alvarado, 1981).

4. Biology and Ecology of the Mangroves

4.1 The mangrove flora and vegetation forms

Mangrove flora is dominated by *Rhizophora mangle* L., forming dense stands with *A. germinans, R. harrisonii, C. erectus* and *L. racemosa* as co-dominant species, which extends from the Tumbes River to Punta Capones in front of the Ecuador border (Ferreyra, 1979; CDC-Peru, 1986). Other species present in the mangroves are: *Prosopis chilensis, Acacia macracantha,* and *Scutia spicata,* which form small stands inside the mangroves. In open areas inside and along the mangrove border various grasses and herbs occur. Among the most common species are *Eragrostis amabilis, Bouteloua disticha, Sporobolus piramidatus, Chloris halofila, Ipomoea pes-caprae, Cacabus maritimus, C. prostatus, Batis maritima, Sesuvium portulacastrum* and *Pectis arenaria.*

4.2 Mangrove fauna

The mangroves of Peru are particularly productive in phyto and zooplankton which serve as food for many marine species whose juveniles live in the mangroves before migrating to the sea for completion of their life cycle. Also these planktonic species serve as food for shrimp culture when mangrove waters are pumped into aquaculture ponds. Mangrove plankton in Tumbes includes the larvae of at least 33 species of gastropods and 24 of bivalve molluscs as well as many other larvae of fish, echinoderms, priapulids; sipunculids and crustaceans and typical zooplankton species, in particular (Penã, 1971; Del Solar, 1981).

Molluscs are one the most important components of the mangrove fauna of Peru, over 26 species of gastropods and 21 of bivalves (Penã, 1970; Rivadeneira and Doig, 1992). Regarding the fish fauna, Chirichigno (1963) were described listed 105 species of 43 families occurring in the rivers of Tumbes Department. Among them 42 species have been found in mangroves and nearly 20% of these are typical mangrove inhabitants (Peña, 1986). Typical marine fish which seek mangroves for shelter and food are the Mugilidae, Centropomidae, Sciaenidae and Ariidae (Vasquez and Sarabia, 1989).

There is no extensive survey of mammals and reptiles of the mangroves of Tumbes. However, preliminary data from CDC-Peru (1986) indicates the occurrence of at least 13 species for the two groups; important is the presence of *Crocodylus acutus*, which has its southern limit of distribution in the mangroves of Tumbes. The avifauna is represented by 40 bird species inhabiting the mangroves and areas influenced by the mangroves. Also 37 bird species were reported to occur in adjacent areas and other 13 species occur temporarily in the mangroves during the rainy periods (CDC-Peru, 1986). Some species typical of other inland habitats spend periods of their life cycle in mangroves. The white wing turkey (*Penelope albipennis*) is a typical example and the mangroves may represent an important refuge for these species presently threaten with extinction in their inland habitats.

4.3 Ecological relationships

Very little is known on the ecological properties of the Peruvian mangroves. Some zonation pattern has been described, however, the periodical occurrence of the El Niño phenomenon alters pattern eventually established in the community.

The mangroves of Peru are the most important source of shellfish of economic importance and include many marine species which are found in great numbers in the mangroves (Peña, 1970, 1971; Rivadeneira and Doig, 1992). However, although the link between mangrove productivity and fisheries seems obvious, no research is available on important topics such as energy fluxes, trophic relations and nutrient cycling.

5. Mangrove Related Biocoenosis

5.1 The benthic community

The benthic community is represented by a large number of species occurring under different sediment conditions. In the intertidal sandy flats the bivalves *Donax asper, D. navicula, D. obesus* and *Iphigenia altior* are very abundant. Also typical of this association are the gastropods *Olivella columellaris*, and *Terebra peruviana* (Peña, 1971). Inside the mangroves, sediment dwelling species are the bivalves *Anadara tuberculosa, A. similis* and various oysters, the fish *Talasso phrybe deoressa* and the crustaceans *Ucides occidentalis* and *Uca princeps*. The gastropods *Thais kiosquiformis* and *T. biserialis* are also common on the sediment surface, while the mangrove mussel *Mytella guyanensis* is abundant along the transition zone between the mangroves and mud flats. Between the mangroves and the sandy beaches, the mud flats are colonized by a varied fauna of sea urchins, polychaetes, sipunculids and priapulids. Also molluscs of high economic interest occur in the zone, in particular *Rhynocorine humboldtii, Cerithium stercusmuscarum, Anadara grandis* and oysters. There is no information on other benthic marine communities such as coral reefs and seagrass beds. Along the supra-littoral, *Prosopis chilensis* (Leguminosae) and the salt marsh (*Distichlis spicata*) communities are only seldom flooded and are inhabited by typical terrestrial animals.

6. Social-Economic Considerations

6.1 Human population and traditional uses

Shrimp is by far the most important economic resource of the Tumbes River estuarine region. The city of Tumbes, capital of the Tumbes Department, has witnessed a fast increase in its population which doubled since 1961, due to the migration of people working to capture of shrimp larvae for export to the shrimp farming industry of Ecuador. Presently the city's population is 44,000 inhabitants.

6.2 Commercial exploitation

By 1985 there were 36 industries devoted to shrimp farming in the Tumbes area. They occupy 2,000 ha and produce about $600 t.y^{-1}$. These industries have a productivity ranging from 300 to $800 kg.ha^{-1}.y^{-1}$, which is quite low when compared to other countries.

Apart from shrimp, shellfish is second most important natural resource of the area, in particular clams, oysters and the mangrove mussel. Finfish is most of oceanic origin although some artizanal fisheries involving the trapping of fish in tidal creeks also is practiced.

7. Conversion to Other Uses

7.1 Agriculture

The implantation of rice culture, with nearly 6,000 ha of cultivated land, presently threatens some mangrove areas, and small stands close to Estero Corrales creek have been cut to reclaim land for rice culture (Cintrón and Schaeffer-Novelli, 1985; CDC-Peru, 1986). Presently agriculture covers 7,148 ha (ONERN, 1992).

7.2 Mining

Although mining does not exist in the Tumbes area, at Cuenca Alta, Puyango River, over 10,000 people are involved in prospecting and mining gold and silver. Of environmental relevance is the use of mercury to amalgamate and extract these precious metals. As the amalgam is roasted to extract and purify the gold, Hg is released into the environment. For every kilogram of gold produced, about 0.9 kg of Hg is released into the environment. Cimelco (1991) estimated that over 2.6t of Hg are released annually in the Puyango-Tumbes watershed. Potential accumulation of methylmercury in aquatic organisms of these rivers is expected. Mercury concentrations in water close to mining sites may reach 230 $g.l^{-1}$ and similarly to many other areas of the Amazon where gold mining occurs, concentrations of this order have lead to high levels of Hg in fish species, in particular of high trophic level species (Cimelco, 1991).

7.3 Aquaculture

The first attempts to develop aquaculture in the Tumbes area occurred in 1958, when the basic studies for the cultivation of oysters (*Ostrea columbiensis* and *O. corteziensis*) were started (Quiroz, 1980). Later the traditional methods used and the presence of mollusc predators made these attempts uneconomical. Presently attempts are being made to cultivate the black cockle *Anadara tuberculosa* (CDC-Perú, 1986).

The first attempts to actually use mangrove areas for shrimp cnlture started in 1971. Studies showed the feasibility of collecting the larvae of *Penaeus vannamei* and *P. stylirostris* during their migration and residence from January to October in the local tidal creeks, mangroves and estuaries (Quiroz, 1980). In 1978, the Peruvian Shrimp Association was founded accelerated and the implantation of shrimp culture programs. In 1980, over 10,000 ha of coastal areas were demarcated for shrimp culture, 4,500 ha of which were actual pond area. The development of the industry however was hampered in 1983-1985 by the "El Niño" phenomenon (CEE-ICE, 1988).

7.4 Urbanization

The city of Puerto Pizarro had less than 1,000 inhabitants in 1981. Expansion however is restricted by natural hazards such as inundation and large tidal amplitudes. Therefore it does not seems to threaten the mangroves such as in other Latin American countries (ONERN, 1983).

8. Impacts on the Mangroves

8.1 Anthropogenic stresses

The environmental impact caused by human occupation of mangrove areas for urbanization and other activities, is the strongest environmental impact of the Tumbes mangroves. Among these activities conflicts between mangrove conservation, rice culture and shrimp farms are the most relevant.

Of particular importance are the human activities taking place in the Puyango-Tumbes Rivers watersheds which may result in reduction of the river flow, due to the threat of hypersalinization of the region (Cintrón and Schaeffer-Novelli, 1985). There is a binational project in this watershed to build a dam to divert river water for irrigation, in this case large environmental impacts may be expected (CDC-Perú, 1986).

Contamination of mangrove habitats is due to the release of domestic and industrial wastes. However the situation is still poorly studied.

8.2 Natural stresses

The most important natural environmental impacts in the region are the potential for hypersalinization due to the aridity of the climate, the changes brought by the "El Niño" and changes due to the dynamics of the local geomorphology, such as invasion of mangroves sands due to regression of the coastline. The differential development of the mangrove stands seems to be a reflection of these natural stressors, since the best developed stands occur at the mouth of the Tumbes river were the supply of freshwater and nutrients is highest (Cintrón and Schaeffer-Novelli, 1985).

8.3 Over-exploitation

Mangrove destruction for wood production is unimportant due to the small area of mangrove forests available for timber production. However, extensive areas have been cut for the construction of shrimp culture ponds. It is estimated that nearly 50% of the total mangrove area at Tumbes has been cut between 1945 and 1985 due to this activity. Exploitation of other mangrove resources, in particular of molluscs and crustaceans has been carried in a non-sustainable manner. The over-exploitation of these resources resulted in a significant decrease of the size of captured animals (CDC-Peru, 1986; Vasquez and Sarabia, 1989).

8.4 Erosion and sedimentation

Erosion of the coast is significant along the littoral between the Tumbes River mouth and Punta Capones. The coast here is very dynamic and is due to remobilization of sediments brought by the Tumbes River. The delta of the Tumbes river suffers increasing sedimentation due to the input of sediments, in particular during the rainy period. This sedimentation process results in the formation of sand bars and barrier islands which advance seaward (ONERN, 1983).

9. Research and Training

Various scientific studies have dealt with ecological aspects of the Tumbes River estuarine region (Dall, 1909; Weberbauer, 1929; Petersen, 1935; Koepcke, 1951; Ferreyra, 1957;1979; Vegas, 1971; Ecco, 1980; Horna, 1981; ONERN, 1983; 1951; Clusener, 1987; Peña, 1989; Peña and Sarabia, 1989). Many other studies were done specifically on the shellfish fauna (Koepcke, 1956; Vegas, 1968; 1971; 1989; Peña, 1960;1970; Alamo and Valdivieso, 1987; Robles and Mendez, 1989; Rivadeneira *et al.*, 1989;). Chirichigno (1963) studied the ictiofauna. A plan for mangrove forest management was proposed by Araquistain (1987), while Del Solar (1981) and Giglioli (1978) discussed some anthropogenic impacts on the local mangrove resources. Recently, Berger (1979); Chirichigno (1977) and Gutierrez *et al.*, (1980) have studied the possible effects of damming the River Puyango-Tumbes on the hydrobiological resources of the coastal zone.

10. National Policies and Management Strategies for Mangrove Resources

10.1 Objectives

There is no actual national strategy towards mangroves in Peru. However, there is a national policy to protect and preserve natural biological diversity through the creation of protected natural areas.

In the National System of Protected Areas, there is a protection unit which includes the mangroves of Peru: The Tumbes Mangroves National Sanctuary (Santuario Nacional Los Manglares de Tumbes). Specifically for this area there is a strategy for the conservation of the mangroves of northwest Peru, developed by the Conservation Data Center from the Universidad Nacional Agraria La Molina, with support from the World Wildlife Fund-US. The main objectives of this strategy are: -To establish a conservation plan for the mangroves and adjacent ecosystems; and - To generate the basic knowledge to establish a conservation unit for the area. These two main objectives are to protect the mangroves themselves, the invertebrates of economic importance and species threatened with extinction such as the American crocodile *Crocodylus acutus*.

10.2 Legislation and management policies

The mangroves of Peru have suffered some deterioration due to the action of the State and of private groups. Although the existing conservation law and the regulation of major anthropogenic activities (aquaculture), should fulfill the needs for the system conservation and management. Therefore, we can conclude that the major cause of the present threats to the mangroves are due to lack of political will rather than lack of legislation. The main organizations responsible for the present status of the mangroves of Peru are: the Municipality of Tumbes and of Zarumilla; the Ministry of Fisheries, the Agriculture Unit at Tumbes and the Regional Fisheries Authorities. There is specific legislation on the mangroves and their resources. The General Fisheries Law, which determines areas for aquaculture; regulates larvae exploitation and pond construction. The Supreme Resolution, issued in 1978, specifically states that shrimp farming cannot be installed in mangrove areas and adjacent to mud flats and that these areas are of public domain. Finally, in 1980, the Santuario Nacional los Manglares de Tumbes was officially created, with a total area of 2,972 ha in the Zarumilla Province. Presently, studies are being undertaken to enlarge its present area. Various court actions are being issued since 1989, against those who had responsibility for any damage to the mangroves of Tumbes.

From 1976 to 1986, it was estimated that from 20 to 30% of the total mangrove area had been lost, mostly due to the cutting of trees for the expansion of shrimp farming (CDC-Peru, 1986). Although some studies had been carried on to evaluate the utilization of *R. mangle* for reforestation purposes (Vasquez and Sarabia, 1989), no attempt has been made until now to recuperate mangrove resources. No management plan exists for the mangrove of Peru. However, a pioneer study carried out by the Peruvian Foundation for the Conservation of Nature, the National Office for the Evaluation of Natural Resources, and the Intergovernmental Office Canada-Perú, has already started with the major aim of protecting and managing the mangroves of Tumbes.

11. Acknowledgements

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Mangrove Ecosystems of Ecuador

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1. Extent and Distribution

Mangrove ecosystems of Ecuador cover an area of 162,055 ha (CLIRSEN, 1991b) (Table 1). Major areas are located along the estuaries of rivers Mataje-Santiago-Cayapas, Muisne, Cojimíes, Chone, Guayas and Jubones-Santa Rosa-Arenillas (Fig. 1).

The Motaje-Santiago-Cayapas is located in the north of Esmeraldas Province, in a typical tropical humid zone with annual rainfall of 3,000 to 4,000 mm. Its watershed covers 751,300 ha and mangroves cover 22,863 ha. The most important villages are San Lorenzo, Limones and La Tola and the majority of the population depends on mangrove related economic activities. The Muisne estuarine zone is located south of Esmeraldas Province and includes several small rivers which originate in the coastal mountain chain. Annual rainfall ranges between 2,000 and 3,000 mm and mangroves cover a total surface of 1,105 ha.

The Cojimíes zone is located in the north of Manabí Province bordering the Esmeraldas Province. It is also composed of several small rivers originated in the coastal mountain chain. Rainfall ranges from 2,000 to 3,000 $mm.yr^{-1}$ and mangroves cover 6,088 ha. Both the Cojimíes and Muisne estuaries have a drainage basin of approximately 72,700 ha.

The Chone estuarine zone is located in the central littoral of Manabí Province has a basin of 290,800 ha and annual rainfall ranging from 500 to 700 mm. Mangroves cover 865 ha.

The Guayas River estuary is located in Guayas Province, it receives freshwater from a 3,523,800 ha basin and has an annual rainfall ranging from 200 to 1,300 mm. Mangrove swamps cover a total of 109,927 ha at low tide. Tidal influence goes up to 80 km north of Guayaquil and nearly 40 km during the rainy season through the Daule and Babahoyo rivers.

The Jubones-Santa Rosa-Arenillas estuarine zone is located in El Oro Province and has a drainage area of 725,300 ha. Annual rainfall ranges between 400 and 600 mm and mangrove surface reaches 20,918 ha.

Other mangroves are located in many small rivers throughout the coast such as Calope, Rio Verde, Montalvo, Atacames, Jama, Tochingue, Pedernales and others were mangrove areas are small, between 5 and 200 ha. All these smaller mangroves cover a total area of 488 ha.

2. Physical environment

Ecuador is located on the west coast of South America. Its continental and insular territory is

Table 1. Mangrove extent by hydrographic systems in Ecuador.

Province	Estuarine zone	Mangrove area (ha)
Esmeraldas	Santiago-Guayas-Mataje	22,863.1
Esmeraldas	Muisne	1,105.6
Manabí	Cojimíes	6,088.0
Manabí	Chone	865.1
Guayas	Guayas	109,927.6
El Oro	Jubones-Santa Rosa-Arenillas	20,918.0
Other		488.0
Total		162,055.0

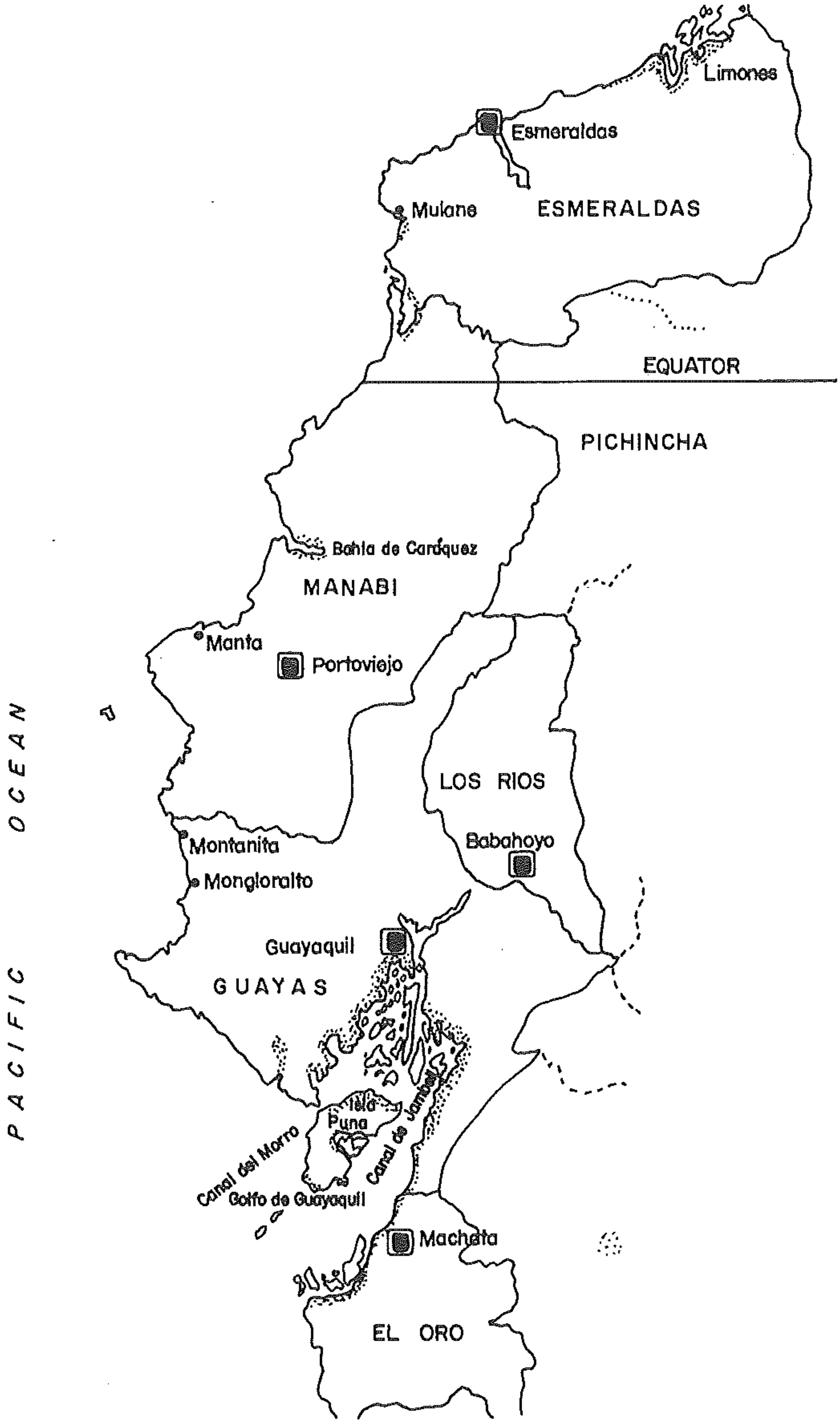

Fig. 1. Location of major mangrove areas (:::) in Ecuador.

distributed on both sides of the Equator. The coastline extends through 950 km and the coastal relief shows mountain chains ranging from 200 to 700 m. Offshore submarine relief presents a narrow shelf and a continental slope, these are limited by a trench of approximately 4,000 m deep (Fig. 2).

Low and steep coasts are the two main littoral types found in Ecuador characterized by sedimentation and erosion respectively. Erosion dominates the steep littoral formed by cliffs with no beach or only narrow, open beaches formed during low tide. This littoral is submitted to intense high energy waves with aeolian action and tidal flow. Sedimentation dominates the low littoral, with wave energy softened by estuaries. Mangroves typically develop in this low energy littoral (Fig. 2).

Total coastal length is 530 km and from 20 to 200 km wide, between the Andes and the Pacific Ocean. The coast includes a mountain chain parallel to the sea running very close to the coastline forming rocky cliffs in several areas. This chain actually divides typical coastal environments from the continent. Major elevations are the Onzole, Muisne, Mache, Chanduy, Convento-el-Carmen, Cuaque, Jama, Balzar, Puca, Colonche and Chongón. The coastal mountains are structured in an arc starting in Esmeraldas in the north and extending to Guayaquil in the south. Major watersheds facing the sea are the Mataje, Santiago and Esmeraldas rivers in the north and Cañar, Naranjal, Balao, Gala, Siete, Jubones, Santa Rosa and Zarumilla rivers in the south. The great Guayas river basin develops between the coastal mountain chain and the Andes mountains and is considered a physiographic sub-unit due to its peculiar characteristics.

The littoral of Ecuador can be divided in 24 different zones according to their major physical characteristics. However two zones are particularly important in relation to mangroves: the Mataje-Las Peñas River Zone and the Posorja-Boca de Capones Zone. The Mataje-Las Peñas Zone extends through 480 km including the San Lorenzo Archipelago. Shell remains, saline, sand marine deposits make up partially flooded littoral strands and old beaches in a typical depositional environment. Small deltas are formed by the estuary outlet. The San Lorenzo Archipelago stretches over 421 km of the coast and is located on the central and northern portions. Heavy sedimentation is detected offshore by sand banks formed several kilometers from the shore. Mangroves in this zone are particularly abundant. The Posorja-Boca de Capones Zone harbours the immense mangrove areas of the Guayaquil Gulf, which stretches from Guayaquil in the north to Jamelí Archipelago in the south along two major estuarine systems the Estero Salado and the Guayas River. Both are connected through various canals between mangrove islands. The Estero Salado is the main maritime access to Guayaquil and suffers sedimentation near Posorja and erosion, due to mangrove felling for shrimp farm construction and the breaking of waves produced by the passage of large ships.

The eroded sediments and those from the Guayas River entering the Gulf through the Cascajal Canal form sand banks in the access canal to Puerto Marítimo. The sedimentation of the Guayas River bed is due to the sediments brought by the River itself due to decrease in sediment transport capacity when the river reaches the wide and shallow estuary. Mangroves grow on muddy sediments in the inner part of the Gulf and on sandy sediments in the middle and outer sections. The breaking of waves and currents cause the formation of sand banks which accrete to islands, whose central parts are ideal places for the colonization by mangroves.

The tidal amplitude in the coast of Ecuador ranges from 2.5 to 3.0 m. In the Guayaquil Gulf however, lateral constriction and resonance extend this range up to 5.29 m. Mangroves dominated by *Rhizophora* are flooded daily (*c.a.* 700 times per year) while those dominated by *Avicennia* and *Conocarpus* are flooded half of this time. Vegetation cover starts at 1.0 m from the low spring tide. Waves have periods ranging from 9 to 40 seconds, while wave height ranges from 0.2 to 2.33 m. Between January and March wave direction is between 310 and 350 degrees while from April to December it is between 240 and 290 degrees (INOCAR, 1980).

Freshwater inputs come from 78 rivers with a total volume of 3,342 $m^3.s^{-1}$; 50% of the total input enters the Esmeraldas Province through 24 rivers; in the Manabí Province 25 rivers are responsible for only 2.6% of the total. In Guayas Province 23 rivers discharge 39% of the total flow and only 7 rivers are responsible for 7.5% of the total freshwater input to the coast of Ecuador. El Oro and Guayas Provinces rivers discharge in the Gulf of Guayaquil.

The continental shelf surface is approximately 24,200 km^2, with 50% of the surface corresponding to the Guayaquil Gulf. The narrowest parts of the continental shelf are located off Galera, San Lorenzo and Santa Elena ranging from 9 to 18 km. Four different

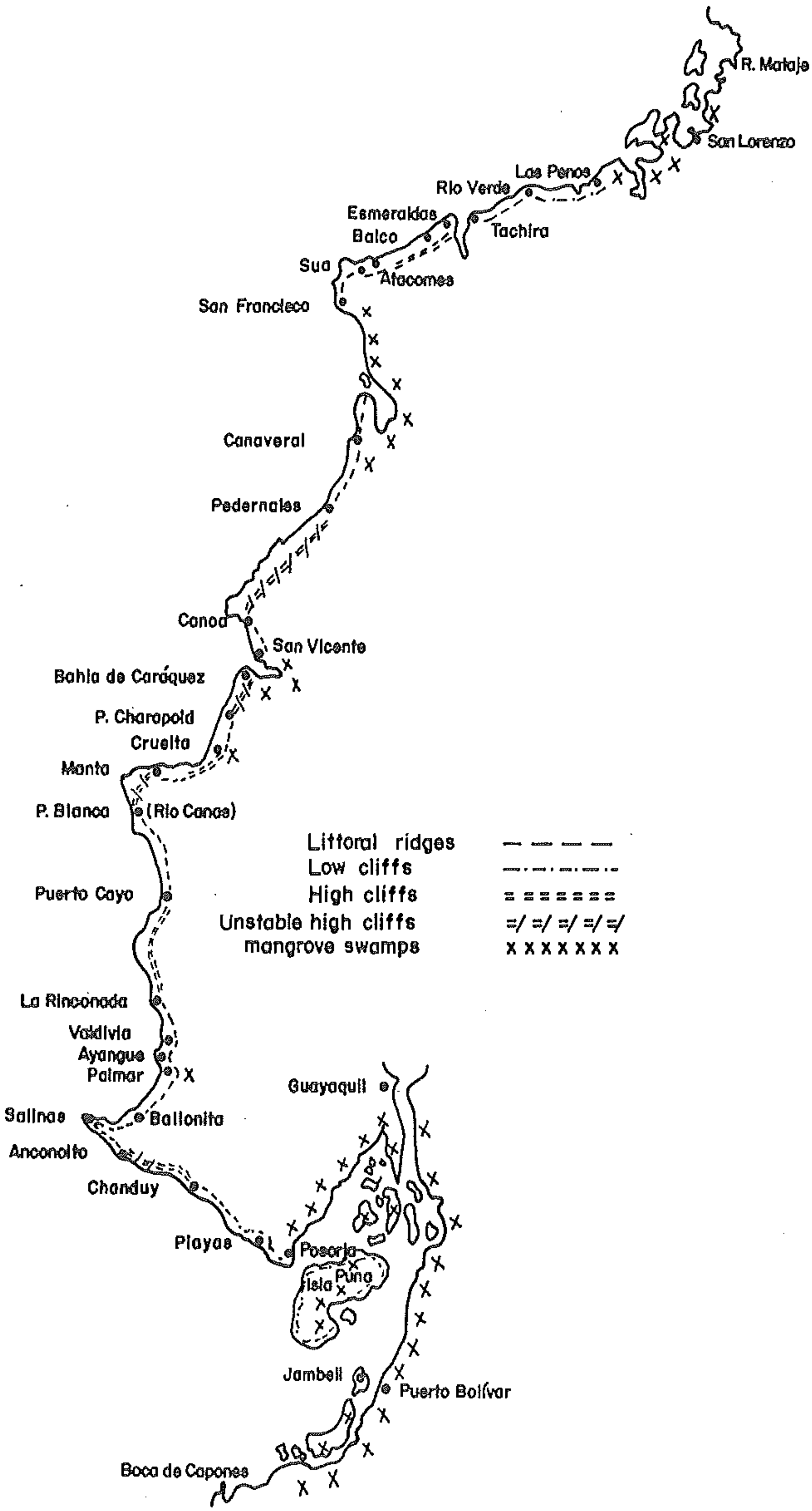

Fig. 2. Major physiographic aspects of the coast of Ecuador.

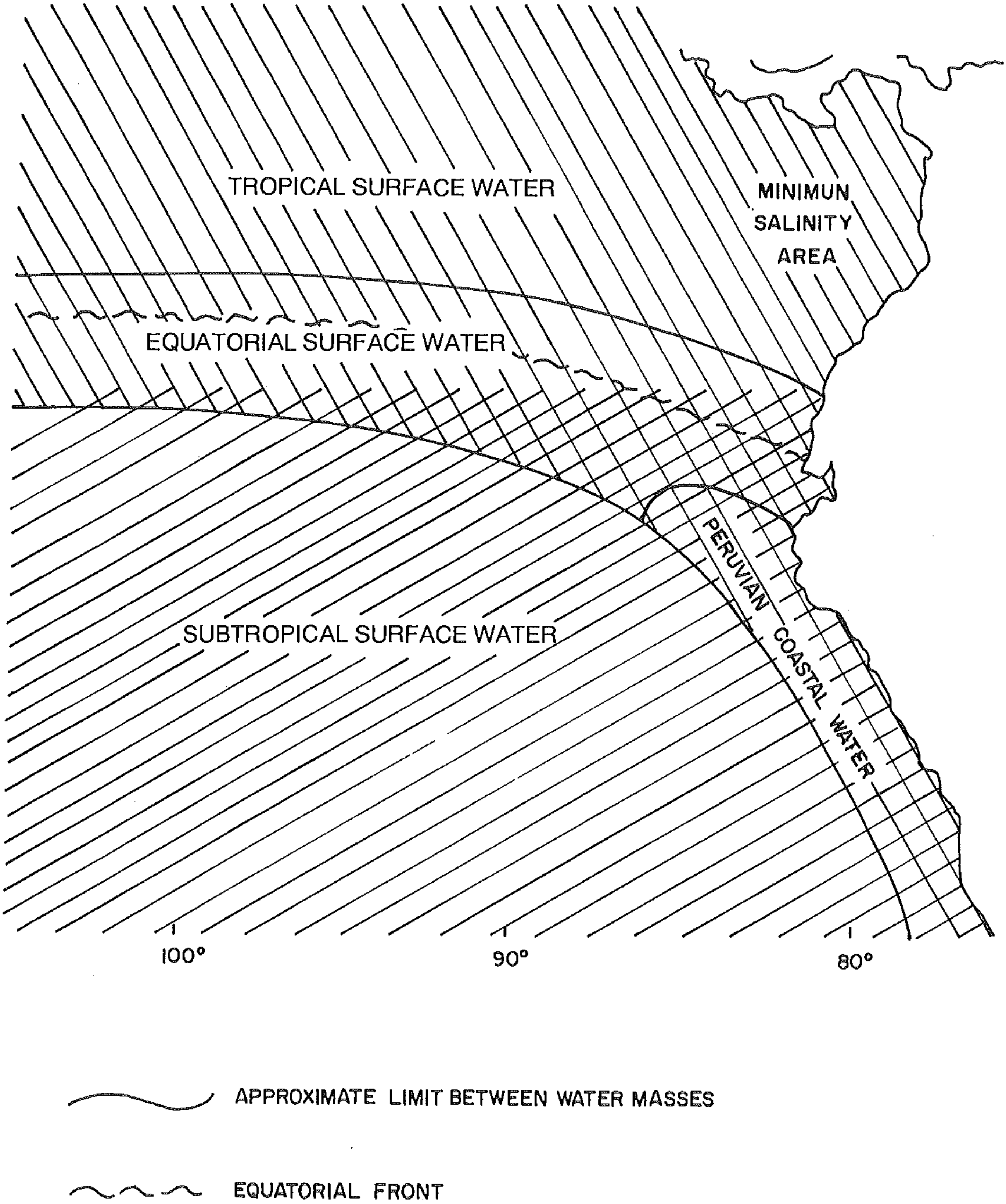

Fig. 3. Major water masses along the coast of Ecuador.

water masses with different temperature and salinity forms the equatorial front which shifts position seasonally (Fig. 3); they are: the Peruvian Coastal Water, the Equatorial Surface Water, the Tropical Surface Water and the Subtropical Surface Water.

The intertropical convergence zone is seasonal spreading from parallel 8° to 10° from July to September and from 0° to 18° in February. The El Niño phenomenon greatly influences the climate and rainfall intensity along the coast of Ecuador. Rainfall, temperature and evapotranspiration in various sectors of the coast of Ecuador are shown on Fig. 4.

Annual rainfall is highest (3,000 to 4,000 mm) in the Mataje zone, Esmeraldas and decreases southward to a minimum of 100 to 300 mm in Santa Elena and Manglaralto. In the Guayas basin annual rainfall ranges from 300 to 400 mm on the coast to 700 to 1,300 mm in Guayaquil city. Insolation (heliophany) is inversely proportional to rainfall and ranges from less than 700 hours per year in Puerto Ila, La Maná and San Carlos to more than 1,200 hours per year in Portoviejo and Guayaquil. Positive evapotranspiration ranges from 1 month (October-November) in Esmeraldas to 7 months in Guayaquil (June-December) and 11 months in Playas (Fig. 4).

3. Biological and Ecological Characteristics.

3.1 Mangrove trees

The mangroves of Ecuador show an arboreal vegetation represented by species of the *Rhizophora, Avicennia, Laguncularia, Conocarpus* and *Pelliciera* genera. The first four are distributed along the entire coast while *Pelliciera* is restricted to the Chone River estuary in Manabí Province on the border between Colombia and Ecuador.

Rhizophora is represented by two species: *R. mangle* L. and *R. harrisonii*. *R. mangle* is locally called red mangrove, mangrove, shoemaker mangrove, reddish mangrove and others. Trees show a variable height and diameter, with a light gray external cortex sometimes smooth others rough with deep fissures. *R. harrisonii* is locally called red mangrove, gentleman mangrove, true mangrove, cholo and others. The two species have different inflorescence but present various dendrological similarities related to the physical, mechanical, chemical and anatomical characteristics and of workability.

Zambrano (1991) studied the phenology of *R. harrisonii* in the Guyaquil Gulf and Churute Mangrove Reserve. The results showed that *R. harrisonii* flowers with intervals of three to four months. Flowers are produced in June, July, October-November, and April-May. Flowers will stay closed for 90 to 120 days prior to opening and pollination. Between 35% and 40% is the fraction of closed flowers able to open. Open flower/fruit ratio is 0.085 whereas closed flower/fruit ratio is 0.031.

Tazán (1990) studied the biomass distribution in *R. harrisonii* and found that aerial roots allocate the highest biomass. A summary of his results is presented in Table 2.

Avicennia is represented by only one species, *A. germinans L.* locally called black mangrove or salado mangrove. Trees are typically 8 to 15 m tall and with diameters between 10 and 30 cm. This species is in general quite tolerant of salinity.

Table 2. Biomass distribution (kg.ha^{-1}) of *Rhizophora harrisoni* in Ecuador according to Tazán (1990).

Component	Wet weight	(%)	Dry weight	(%)
Aerial roots	1,476.4	52.3	888.5	50.8
Trunk	764.3	27.1	509.0	29.1
Branches	470.3	16.6	307.6	15.6
Leaves	97.3	3.4	37.4	2.1
Stipules	5.7	0.2	2.4	0.1
Flowers	8.4	0.3	3.6	0.2
Fruits	0.8	0.02	0.8	0.02
Total	2,823		1,479	

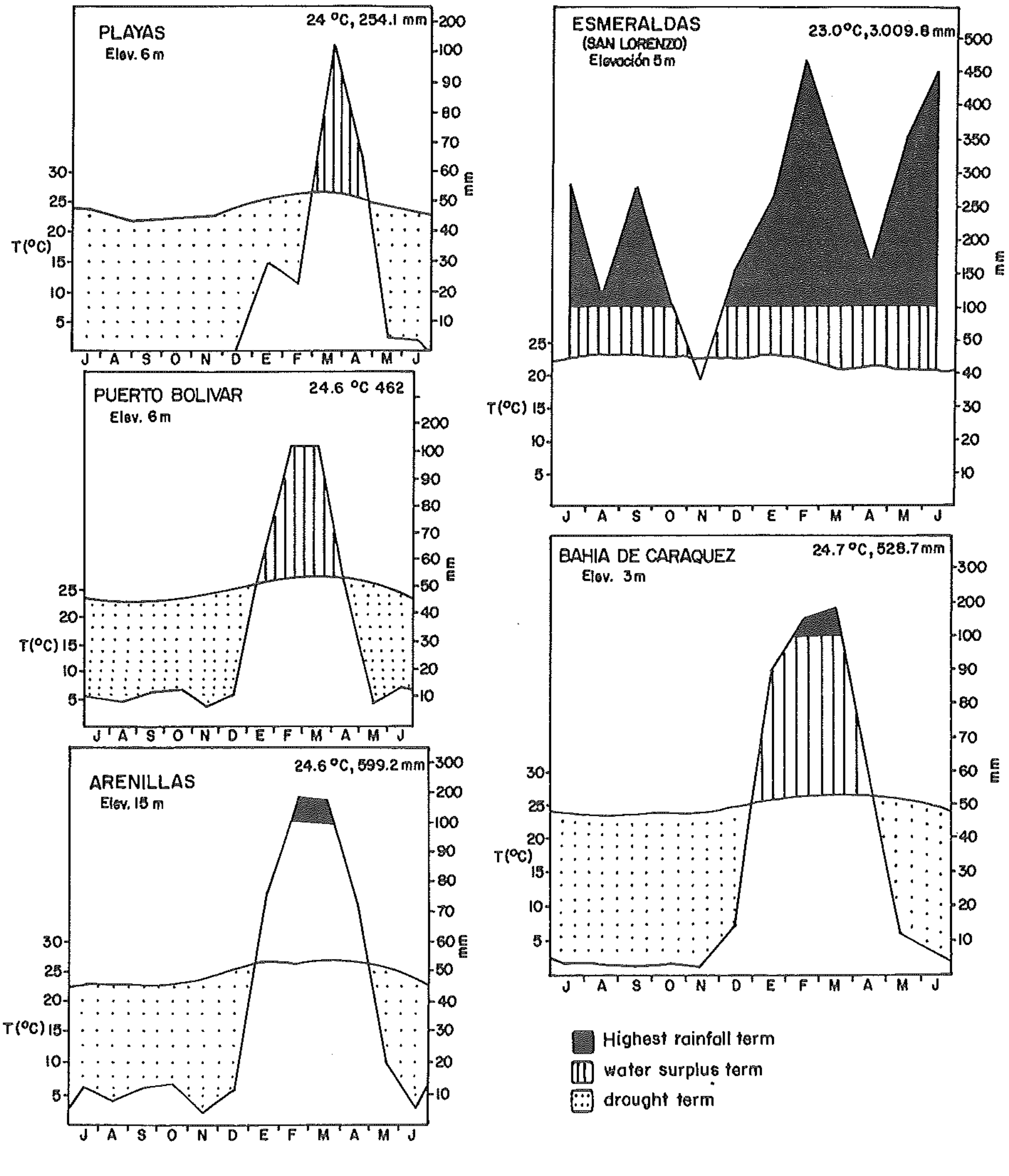

Fig. 4. Major climatological characteristics of the coast of Ecuador.

The family Combretaceae is represented by *Laguncularia racemosa* Gaertn. and *Conocarpus erectus* L.; *L. racemosa* is locally called white mangrove, yellow mangrove, female mangrove or stupid mangrove. Typically, this species is 8 to 15 m tall with 20 cm in diameter. *C. erectus*, locally called Jeli mangrove or male mangrove, typically shows trees 5 to 8 m tall and with 10 to 12 cm in diameter. The Pelliciériaceae *Pelliciera rhizophorae* Planchon & Triana, locally called cypress nut, is 5m tall and has a diameter of 5 to 10 cm.

Typical vegetation associated to the mangroves of Ecuador is composed by herbaceous communities including *Achrostichum aureum, Batis maritima* and *Salicornia fructicosa*. Epiphytes are also abundant and include many orchids (*Catasetum sp., Lockartia sp., Oncidium sp., Aspacia sp., Notislia sp., Epidendrum diforme, Pleurotalis sp., Rodriguezia sp., Scaphyglottis sp.*); bromeliads (*Tillandsia disticha, T. triglochinoides*); cactus (*Cereus triangularis*) and mosses. Rhodophyte algae form a characteristic epiphyte community on the roots and pneumatophores of mangrove trees.

3.2 Types of mangrove forests

The structural development of mangroves is closely related to soil topography, type and quantity of nutrients, volume and frequency of river and tidal inundation, evapotranspiration, temperature and insolation, salinity, etc. Three structural types can be described for the coast of Ecuador: riverine, fringe and basin forests.

a) Riverine forests

Riverine mangrove forests extend along rivers following the intrusion of salt water. In such environments freshwater and nutrient inputs are generally high, resulting in large development of forest structural characteristics. Porewater salinity varies seasonally but is generally less than that found in other forest types. Riverine mangroves cover a total area of 13,034 ha and the largest forests are located in Guayas Province, in particular along the Guayaquil Gulf and Guayas River (Table 3).

The major physical characteristics of riverine mangrove forests along the coast of Ecuador are shown in Table 4.

b) Basin forests

Basin forests occur in interior areas near salinas (salt pan areas), are flooded only by the highest tides and remain inundated for a certain period, drying very slowly. The interstitial salinity is very high but decreases a little during the rainy period. There are some factors for vegetation development which limit the establishment of certain mangrove species. Better adapted species to these areas are *Avicennia* and *Conocarpus*. This forest type covers a total surface of 39,028 ha and the largest areas are located in Esmeraldas Province with a total area of 8,707 ha (Table 5).

The major structural characteristics of basin mangrove forests along the coast of Ecuador are shown in Table 6.

c) Fringe forest

Fringe forests are subjected to daily tidal washing (over 700 times per year). Vegetation development is high due to the daily incoming of nutrients and sediments with the tides. *Rhizophora* is the dominant taxon. This mangrove forest type covers a total surface of 125,388 ha along the coast of Ecuador with the largest forests occurring in Guayas Province (Table 7).

Major structural characteristics of fringe mangrove forests of Ecuador are shown in Table 8.

3.3 Productivity

Of major importance to the coastal zone is the high productivity typical of mangroves. A

Table 3. Distribution of riverine mangrove forests in Ecuador.

Province	Hydrographic Basin	Surface (ha)
Esmeraldas	Mataje-Santiago-Cayapas	2,394.5
Esmeraldas	Muisne	1,501.3
Manabí	Cojimíes	1,970.0
Manabí	Chone	1,263.2
Guayas	Guayas	5,643.5
El Oro	Jubones-Santa Rosa-Arenilla	261.7
Total		13,034.2

Table 4. Structural parameters of riverine mangroves in Ecuador.

Site	Density ($s.ha^{-1}$)	Basal area ($m^2.ha^{-1}$)	Total volume ($m^3.ha^{-1}$)	Volume without bark ($m^3.ha^{-1}$)	Volume with bark($m^3.ha^{-1}$)
Guayas	260.9	8.84	106.2	38.2	44.3
Jubones-Sta Rosa-Arenilla	350.6	12.72	159.3	73.4	85.8
Chone-Muisne-Cojimíes	801.2	7.98	72.5	34.6	39.6
Santiago-Najurango	553.3	12.36	129.6	76.1	86.1

Table 5. Distribution of basin mangrove forests in the coast of Ecuador.

Province	Hydrographic Basin	Surface (ha)
Esmeraldas	Mataje-Santiago-Cayapas	8,220
Esmeraldas	Muisne	487
Manabi	Cojimes	2,282
Manabi	Chone	107
Guayas	Guayas	24,592
El Oro	Jubones-Sta Rosa-Arenillas	3,340

substantial portion of mangrove productivity returns to the environment in the form of leaf litterfall. A relationship between forest structural characteristics (particularly basal area) and litterfall rates has been reported for many mangrove areas (Cintrón, 1981). Litter decomposition and fragmentation processes and further conversion into detritus particles make the mangrove organic matter available for consumers. Bacteria and fungi are the typical organisms involved in these processes transforming mangrove litter carbohydrates, proteins, fats, cellulose and lignin into microbial protoplasm. During the decomposition process, mangrove litter, originally poor in protein, is transformed into high-microbial protein particles, therefore increasing the nutritional value of the mangrove detritus during the process.

The colonization of mangrove leaf litter by fungi and bacteria is associated with the colonization by ciliate and nematode populations and also of larger size organisms such as amphipods, gastropods, bivalves, polychaetes and oligochaetes, which also contribute to the fragmentation process of the litter particles. Triglycerides are also part of the lipid leaf cover, after decomposition they are appropriate food for shrimp post-larvae, in particular of Penaeid shrimps.

The mangrove biocoenoses occupy a variety of habitats showing zonation pattern according to well defined ecological properties. Bivalves such as *Anadara* are buried in the mud as well as the red crab *Ucides occidentalis*. Oysters (*Crassostraea columbiensis*) colonize the aerial roots and trunks of mangrove trees as well as cirripeds (*Balanus* spp.) and Grapsidae crabs. Gastropods (*Littorina* sp.) dwell on mangrove foliage, while mussels colonize tidal flats adjacent to mangroves. Brackish waters are inhabited by many species of fish, in particular mullets (*Mugil* spp.) and juveniles of Penaeid shrimps of great economic importance for the local fisheries.

3.4 Mangrove - estuary relationship

High productivity levels of mangroves are supported by nutrients brought in by fresh water. The organic matter produced is eventually redistributed, dissolved and fragmented, by tides through the estuary and adjacent coastal waters. Mangroves are reported to export from 10 to 14 metric tons of organic matter per ha per year and at least 10% of it is transformed into fish and other organisms biomass. This large food supply is used by many species of estuarine and marine organisms. Many are permanent residents of the estuaries while others use it during parts of their life cycle. Many other freshwater and marine species visit these areas following the seasonal variation of salinity.

Fish species belong to different trophic levels. Some feed directly in the detritus (*e.g. Mugil* spp.), most of them however indirectly consume mangrove organic matter in the form of detritivorous prey such as protozoans, nematodes, rotifers and crustaceans. Detritivorous organisms are the link between detritus particles and higher carnivores.

Although mangrove litterfall occurs throughout the year, it peaks during the rainy season when transportation to the estuarine areas reach its maximum due to increasing river volume. In the Guayaquil estuary in February, river volume reaches a

Table 6. Structural parameters of basin mangroves in Ecuador.

Site	Density ($s.ha^{-1}$)	Basal area ($m^2.ha^{-1}$)	Total volume ($m^3.ha^{-1}$)	Volume without bark ($m^3.ha^{-1}$)	Volume with bark($m^3.ha^{-1}$)
Guayas	349.3	8.11	96.1	33.5	37.6
Jubones-Santa Rosa-Arenilla	522.3	6.81	67.4	24.3	28.5
Chone-Muisne-Cojimíes	784.7	9.52	86.4	40.5	46.4
Santiago-Najurango	554.6	10.12	99.2	57.2	64.8

Table 7. Distribution of fringe mangrove forests in the coast of Ecuador.

Province	Hydrographic Basin	Surface (ha)
Esmeraldas	Mataje-Santiago-Cayapas	12,510
Esmeraldas	Muisne	484
Manabi	Cojimes	4,625
Manabi	Chone	108
Guayas	Guayas	86,679
El Oro	Jubones-Sta Rosa-Arenillas	20,900

maximum, temperature also increases and salinity decreases whereas oxygen levels decrease to very low values.

Phytoplankton production is minimum in January when fluvial contribution is large decreasing water transparency. It reaches its maximum in April when silicates, nitrates and phosphates also peak. Zooplankton productivity follows, reaching a maximum in June. Small herbivorous fish such as herring also follow the phytoplankton peak and are then consumed by large carnivores such as tuna. Changes in primary and secondary production of the estuary will thus affect the productivity of large economically important fish of adjacent coastal waters.

3.5 Associate fauna

Associated fauna of mangrove ecosystems of Ecuador includes many species of mammals, molluscs, crustaceans, birds, insects, reptiles etc. However very few studies have focused on this aspect. Table 9 lists associated fauna species reported in the mangroves of Ecuador.

Ortiz (1990) reported 42 species of birds in the mangroves of Chone River estuary in Manabi Province. Many were resident species while some visit mangroves for shelter and food. In a bird census done in Ecuador in 1986 many migratory neartic birds were recorded (*Pluvialis squatorola, Numewnius phaeopus, Catoprophorus semipalmatus, Tringa sp.*). Others like *Pelecanus occidentalis* are permanent mangrove inhabitants using the swamp for reproduction and food. *Columbina* sp. uses mangroves for nesting while *Fregata magnificens* is another resident species. In Isla de los Pajaros, Chone River estuary, over one thousand juveniles and adults of this species have been reported. *Eudocimus albus, Mycteria americana, Casmerofdius albus, Egretta* sp. and *Nycticorax* sp. are also common species which visit mangroves for food. With the development of shrimp ponds, *Phalacrocorax olivaceus* became a common visitor of the ponds as well as some migratory rapacious birds such as *Pandion haliaetus* and *Rostihamus sociabilis.* Ortiz (1990) reported that various species may be threatened with extinction due to habitat destruction and indiscriminate hunting.

Among the aquatic fauna of mangroves in Ecuador, important components are the molluscs in particular the cockles *Anadara tuberculosa* and *A. similis,* oysters *Crassostraea columbiensis* and the mussel *Mytella guayanensis,* which are intensively harvested by the local population, comprising a significant nutritional and economical resource.

Crustaceans are also important components of the mangrove fauna. Massay (1989) reported several permanent or temporary resident shrimp species found in the mangroves of Ecuador. However only the most economically important species have been studied in detail. Penaeid shrimps lay their eggs in marine waters. After a planktonic stage of 3 to 4 weeks these larvae become demersal. Post-larvae are brought into estuaries by tidal currents and feed on mangrove organic matter. At this stage they are captured by fishermen who sell the post-larvae as seed to shrimp farms. After 3 to 4 months the juvenile shrimp becomes less tolerant to low salinities and migrate back to marine waters where they complete their life cycle. Major spawning season is from

Table 8. Structural parameters of fringe mangroves in Ecuador.

Site	Density ($s.ha^{-1}$)	Basal area ($m^2.ha^{-1}$)	Total volume ($m^3.ha^{-1}$)	Volume without bark ($m^3.ha^{-1}$)	Volume with bark($m^3.ha^{-1}$)
Guayas	379.3	7.32	86.4	28.9	32.6
Jubones-Santa Rosa-Arenilla	535.2	7.91	85.9	35.2	41.1
Chone-Muisne-Cojimíes	657.6	9.00	83.9	40.0	45.7
Santiago-Najurango	618.8	11.08	118.6	69.8	78.9

Table 9. List of most important fauna species associated with the mangroves of Ecuador.

Molluscs	*Cebus capucinus*	*C. inda*
Anadara similis	*Panthera onca*	*Caticussela SP.*
A. tuberculosa	Insects	*Pregato magnificens*
A. grandis	*Melipona sp.*	*Crotophaga sulcirrostris*
Crassotraea columbiensis	*Apis sp.*	*Buteogallus anthacinus*
Mytella guayanensis	Reptiles	*Rhosthranus sociabilis*
Crustacea	*Iguana iguana*	*Numenius phaeopus*
Uca sp.	*Crocodylus acutus*	*Limnodromus griseus*
Ucides occidentalis	Birds	*Bubulcus ibis*
Penaeus californiense	*Nycticoran nycticoran*	*Coragyps atratus*
P. occidentalis	*Nyctibassa violaceus*	*Catharfes aura*
P. stylirostris	*Egretta alba*	*Calidris sp.*
P. vannamei	*E. thula*	*Jacana jacana*
Trachypenaeus byrdi	*E. caerules*	*Cinclus leucocephalus*
T. similis	*Ardea cocoi*	*Hydramas tricolor*
T. fanea	*Phalacrocorax olivaceus*	*Haematopus palliatus*
Goniopsis pulchea	*Pelecanus occidentalis*	*Actitis macularia*
Ucides sp.	*Eudocimus albus*	*Columbina sp.*
Macrobrachium sp.	*Ajaja ajaja*	*Florida caerulea*
Callinectes arcuatus	*Mycteria americana*	*Rigrisonam lineatum*
Cardisoma crassum	*Butorides striatus*	*Rallus longirostris*
Fish	*B. virencens*	*Columba cayenensis*
Dormitador latifons	*Cyclarhis guayanensis*	*Cassidix mexicanus*
D. maculatus	*C. nigrirostris*	*Dendrocyona autumnalis*
Centropomus armatus	*Dendroica peruvianus*	*Sarkidiomis melanotos*
Mugil curema	*Coccyzusmela coryphus*	*Cairina moschata*
Isopisthus remifer	*Pringa solitaria*	*Aramides asillaris*
Lutjanus sp.	*Himantopus mexicanus*	*Pluvialis squatorola*
Mammals	*Pandion halieaetus*	*Catoptrophorus semipalmatus*
Procyon cancrivorus	*Chloroceryle amazona*	*Himanoptus himanoptus*
Aluoatta paliata	*C. americana*	

November to April. The major species are *Penaeus occidentalis, P. stylirostris* and *P. vannamei*.

The most commercially important crab species in the Guayaquil Gulf zone is *Ucides occidentalis*. A study in the mangroves of Churute showed an average density of 7 crabs.m^{-2} (Tazán, 1990). Another important species is *Goniopsis pulchra* which lives in mangrove mud holes and climbs the trees during high tide and is an important prey for fish such as *Lutjanus* sp. and birds such as *Cassidix mexicanus*. Also of significance is the blue crab *Callinectes arcuatus*, which is an important predator in shrimp farms.

The fish fauna of the mangroves of Ecuador is composed of fresh water, marine and typical estuarine species, although the commercially important ones are typical brackish water mullet species *Mugil* spp.

3.6 Zonation patterns of mangroves of Ecuador

Distribution and zonation patterns of mangroves in Ecuador are quite diverse and site specific. On the North Coast, where rainfall exceeds evapotranspiration, there is no salinity gradient and mangroves border the non-halophytic forests. *Rhizophora* is the pioneer tree colonizing the shallow bottom. Behind it a fringe of *Conocarpus* creates a transition zone between the mangroves and the terrestrial forest.

In the Mataje river zone pure stands of *Avicennia* and *Conocarpus* occur, whereas the Atacames islands, where there is an intense accretion process, are colonized exclusively by *Avicennia* and *Laguncularia*. In areas of water deficit, islands are colonized by *Rhizophora* which are substituted by *Avicennia* more inland, saline areas, where tidal frequency is less than 160 times per year and salinity of pore waters is frequently over 60 ppt.

4. Mangrove Uses

Man colonized the littoral of Ecuador about 13,000 years ago. By that time exploitation of mangrove resources in estuaries and lagoons, in particular mangrove wood for construction and fuelwood and aquatic organisms for food, was done by family groups. Commercialization of food and religious products however, was done by specialists.

Bark exploitation began in 1879 with a yield of 90 kg. Yield increased to 349 t in 1901, 316 t in 1904 and reached a maximum of 586 t in 1906. In the 40's due to the World War II demand for mangrove timber and bark increased throughout the coast, in particular in the Gulf of Guayaquil. However there are no statistics for the exploitation during this period.

Table 10. Mangrove products presently exploited in Ecuador.

A. Forest products
Construction wood for houses, ships, bridges, furniture
Wood for use in fishing gear
Charcoal and fuelwood
Tannin for leather and fishing net treatment
Medicine
B. Ecosystem products
Fish and shellfish
Honey and wax
Mammals, reptiles and amphibians

In 1968 Ecuador started intensive shrimp farming with the conversion of extensive mangrove areas into shrimp ponds. Major shrimp species cultivated were *Penaeus stylirostris* and *P. vannamei*. Shellfish and finfish capture is also a major use of mangroves. Principal species captured are *Anadara tuberculosa, A. similis, Crassostraea columbiensis, Mytella guayanensis, Ucides occidentalis, Cardisoma crassum, Mugil sp., Isopisythus* sp. and *Dormitator* sp. Present day mangrove products used in Ecuador are summarized in Table 10.

The major shellfish production zone is along the border with Colombia in the Mataje-Santiago-Cayapas rivers estuary. From this zone from 2.0 to 2.5 million scallops are captured per month. Crabs from mangroves supply the domestic market at a national level. The most accepted species is *Ucides occidentalis*. *Cardisoma crassum* is the most accepted species in Esmeraldas and Manabi Provinces.

5. Conversion to Other Uses

In 1969 the first cartographic register of mangrove and salt marsh areas of Ecuador was prepared (CLIRSEN, 1991a). This register was updated in 1984, 1987, 1991, and included areas converted to aquaculture. The results of these studies are shown in Table 11.

5.1 Agriculture

The conversion of mangrove areas to agriculture started in 1940, when in Esmeraldas Province cultivation of *Cocos nucifera* was established in 15,000 ha, 10,000 of them were converted to mangrove areas. Palm tree plantations need soil preparation and felling of mangrove trees and the construction of drainage canals. This allows better reaction of soil material with air and accelerates the decomposition of soil organic matter. The coconut cultivation starts production in four years and reaches 60 coconuts per hectare. Conversion of mangrove areas into agriculture affects mostly the physiography of riverine mangroves and inner parts of creeks.

5.2 Cattle farming

Basin mangrove forests have been preferred for the conversion into cattle farming. These forests are basically composed of *Avicennia* and *Conocarpus*. Existing farms use extensive farming with 0.8 to 1.2 animals per hectare. The conversion of mangrove forests do not require changes in the soil. The vegetation cover is felled and different types of grasses are planted which are tolerant of a certain degree of salinity. Latter with the continuous use of the area some modification in soil texture and structure occur stabilizing the conversion of the area. It is estimated that over 40,000 ha of mangroves have been converted to cattle farms along the coast of the country.

5.3 Aquaculture

Shrimp culture started in the early 70's and over 146,030 ha of shrimp ponds have been built, first in salt flats then in mangroves and later in highland agriculture areas. Conversion of mangrove and salt flat areas into shrimp farming increased from nearly 22,000 ha of mangroves in 1969 to over 40,000 ha in 1991 and from nearly 30,000 ha of salt flats in 1969 to over 43,000 ha in 1991 (Table 12). Of the total area converted into shrimp farming 29% were mangroves, 29% were salt flats and 42% were agriculture lands. The most affected province was by far the Guyas Province where the Guayaquil Gulf is located.

There is a present trend of using tidal flats for shrimp farming due to the recent prohibition to convert mangroves into shrimp ponds and the fact that the fertility of the backward high lands has made them preferable for cattle farming and/or agriculture practices.

Shrimp ponds vary in size from 5 to 150 ha depending on the place. Shrimps are farmed extensively, semi-extensively and semi-intensively and production is highly dependent on the practice in use. Table 13 shows annual shrimp yield through different systems in use today.

Table 11. Mangrove and "salinas" surface areas (ha) changes from 1969 to 1991 along the coast of Ecuador (CLIRSEN, 1991).

Year	Mangrove area surface	Salinas surface
1969	203,695	51,495
1984	182,108	20,024
1987	175,126	12,398
1991	161,776	8,614

Table 12. Mangrove and salt flat areas (ha) converted into shrimp ponds from 1969 to 1991 in Ecuador.

Period	Mangroves converted	Salt flats converted
1969-1984	21,588	31,471
1984-1987	6,982	7,626
1987-1991	13,350	3,784

The shrimp production pattern in Ecuador is: uncultivated and laboratory-cultivated post-larvae; raising of juveniles in fish ponds up to 2 ha; growing and fattening in development ponds. Typically 90 to 120 days are necessary to complete the cycle. In general shrimp farmers get their crops twice a year, but frequently they get less than this due to shortage of larvae and post-larvae supply. These problems determine an effective use of the installed capacity not greater than between 60% and 70%.

5.4 Urbanization

Many towns and villages have mushroomed along the coast at the expenses of mangroves. Around cities mangrove swamps are felled and houses are built above the high tide mark, later the area is filled in. About 3,000 to 5,000 ha of mangroves have already been converted into urbanized areas.

6. Research on Mangroves of Ecuador

Various major regional programs had been developed to survey mangrove forests in Ecuador. In 1969 and 1972 a physiognomic and taxonomic

Table 13. **Larvae density and annual production of shrimp under different practices presently in use in Ecuador**

Production system	Larvae density/ha	Production (pounds/ha)
extensive	10,000 - 30,000	600 - 1,200
semi-extensive	30,000 - 80,000	1,600 - 2,000
semi-intensive	80,000 - 120,000	over 2,000

survey of the mangroves of the northwestern coast were completed by DEFORNO (Forestry Development of the Northwest) and Forsefor (Strengthening the Forestry Sector) projects. In the middle 70's the PREDESUR Program surveyed the mangrove forests of the south coast in El Oro province.

The country's Universities are also involved in mangrove research, in particular on the biology and taxonomy of the fauna and flora. Polytechnical schools study ecology and distribution of mangrove forests whereas the Technical University of Esmeraldas has a program on forestry inventories in Esmeraldas Province.

With the advent of shrimp farming, CLIRSEN (Remote Sensing of Natural Resources Center) and the National Forestry Office started a periodical survey of the evolution of mangrove areas including the identification of mangrove forests types (CLIRSEN, 1991a,b). In 1988 the Program for Coastal Resources Management (PMRC), organized a mangrove committee aiming at developing a the desirable management plan for the mangroves of Ecuador. A survey of the available knowledge and the identification of present demands were produced in appropriate data basis.

This mangrove committee devoted studies to investigate mangrove primary production, biological components, nutrient cycles and energy flow, and material transfer from mangroves to coastal waters.

With these objectives the research programs listed below were started in 1989.

- Taxonomy of mangrove tree species of the coast of Ecuador
- Multitemporal survey of mangrove, salt pans and shrimp pond areas using remote sensing techniques
- Inventory of mangrove resources of the coast of Ecuador
- Phenological studies of *R. harrisonii*
- Biomass estimates of different mangrove forest types
- Litterfall production, decomposition and export from mangroves to adjacent coastal waters
- Inventory of associated fauna species
- The role of mangrove swamps in controlling water quality in adjacent coastal ecosystems.

7. National Mangrove Committees and Management of Mangroves

In Ecuador coastal resources management is carried out by many institutions such as the Fisheries Resources Undersecretary, Littoral Merchant Navy Direction, Afforestation Undersecretary and the Renewable Natural Resources Office which belongs to the MAG (Ministrerio de Agricultura y Ganaderia) (Pérez, 1989). Other important institutions are the Public Health Ministry, Hydraulic Resources Institute of Ecuador, Tourism Corporation of Ecuador, Ministry of Energy and Mining, Municipalities and regional developmental agencies.

The Afforestation Undersecretary and the Natural Renewable Resources Office, according to the present Forestry Law, are in charge of the protection and management of mangrove swamps and have started special plans for these ecosystems including: exploitation concessions, protection as ecological reserves, forest reserves, mangrove shrimp farming areas and active and passive recreation.

The National Merchant Navy Council and the Economic Development Council of the Merchant Navy are responsible for marine and harbor policies to be implementetd by the Littoral General Merchant Navy Direction. Their major role is in the concession of beach and bay areas, including some mangrove zones, for installation of shrimp farms, fishing, potential contaminant activities in river and estuaries and any other potentially impacting activity.

The Tourism Corporation of Ecuador is in charge of designing a National Tourism Plan for the country including the selection of coastal areas and ecosystems for tourism; these include mangrove swamps, beaches, estuaries etc.

The Public Health Ministry is responsible for the preservation of environmental quality, in particular water and air contamination.

The Institute of Hydraulic Resources of Ecuador promotes the best use and protection of the country's hydric resources. It controls water contamination which may affect human health and the development of the fauna and flora and participates in the planning and management of existing protected forests.

Local municipalities, according to the present Provincial Law, take part in designing and controlling the developmental plan of its jurisdiction. They can also issue regulations and ordinances to ensure the rational use of natural resources.

The Fisheries Resources Undersecretariat controls the use of fisheries resources and aquaculture, including the construction of production facilities, capture, manipulation and commercialization.

The fact that several participant institutions have their own specific views on the management of the resource of their interest, creates certain jurisdictional problems that hamper interinstitutional coordination for integrated management of the coastal resources of Ecuador.

During the seventies the need for proper management of natural resources was recognized and resulted in the review of laws, issuing of new resolutions and pacts to settle a legislation for the proper management of natural resources. Regarding the mangroves there was in 1975 the total prohibition of bark extraction. In 1978 the Ministerial Resolution 2939 prohibited the cutting of mangroves for timber or shrimp pond construction. In 1979 the Churute Mangrove Swamps Ecological Reserve was created. Finally in 1983, a symposium was held in Guayaquil with the aim of divulging the importance of mangrove ecosystems to potential users of their resources and the major impacts caused by the shrimp farming boom to these ecosystems. Also in 1981, UNEP and the Government of Ecuador organized a first seminar on "Ordination and Integral Development of the Coastal Zone".

In March 1986, a technical cooperation agreement created the Coastal Resources Management Program (PMRC) with the aim of creating and implementing a national, integrated program for the management of the coastal resources of the country. The Government Executive Decree 3399 defines the PMRC as an organisms attached to the presidency of the republic with its headquarters in Guayaquil. The Program objective is to promote the conservation, protection, restoration and development of coastal resources in the Esmeraldas, Manabi, Guayas, El Oro and Galápagos Provinces. The basic structure of PMRC is: National Commission, Executive Direction, Zonal Management Organisms and Conservation and Vigilance Units.

The National Commission is the highest authority in the Program and is composed by members of the Public Administration Secretary, the Ministries of National Defense, of Industry, Commerce, Integration and Fisheries, of Agriculture, and of Energy and Mines, the General Secretary of the National Planning Development Council, and the Executive Director of the Tourism Corporation of Ecuador. The National Commission is in charge of approving the annual working plan of PMRC and the development plans for the special management zones, established in each one of the coastal Provinces of the country.

The Zonal Management Organisms promote the cooperation and coordination of public and private institutions, users groups and coastal communities, in order to identify important matters in the corresponding zone, formulate plans, approve and carry them out.

The Conservation and Vigilance Unit promotes the knowledge and fulfillment of the present legislation, as well as administrative regulations and techniques related to the protection, preservation and adequate use of coastal resources.

In 1988, PMRC organized *ad hoc* working groups as specialized advising elements for the major coastal resources. The Mangrove Working Group (GTM) is composed of representatives of all institutions with jurisdiction over the mangroves in the country (forestry, beaches and bay uses, production activities etc.). It also includes all Universities of the coastal provinces, and non-governmental organisms sponsoring the protection and utilization of natural renewable resources. GTM and PMRC objectives are the orientation, coordination, and evaluation of management policies for the mangrove swamps of the country. It is also a task of GTM to develop research work for a better understanding of the role and functioning of mangrove ecosystems in Ecuador.

7.1 Mangrove management zones of Ecuador

The diverse environmental conditions of the coast of Ecuador as well as the peculiarities of mangrove ecosystems throughout the coast such as forest structure, associated fauna and flora, anthropogenic impacts and uses, accessibility to the mangroves etc. determined the necessity to develop specific management procedures for different zones of the coast. Therefore the following zones and specific policies were established:

- Santiago-Cayapas-Mataje Zone

This zone is located in the extreme North of the coast along the border with Colombia. There are 22,859 ha of mangroves in this zone and the estimated converted areas is 3.5% . The mangroves are very diverse with the representatives of *Rhizophora, Avicennia, Laguncularia, Pelliciera* and *Conocarpus* genera. Major forest types are fringe riverine and island. Some of the most developed mangroves of the Pacific coast, with trees over 50m tall occur in this zone.

Major impacts on the mangroves are: Construction of shrimp ponds causing changes in hydrology and sedimentation patterns and leading to changes in the associated fauna. Expansion of urban areas with filling of mangrove areas, sewage and solid waste dumping and contamination of soils, waters and associate biota. Expansion of agriculture draining mangroves and contamination by agro-chemicals. Cattle farming with related changes in soil characteristics. Wood exploitation with loss of largest specimens and genetic pool impoverishment.

- Atacames Zone

The zone is located in Esmeraldas Province and is an important focus for recreation and tourism activities. There are only 52 ha of mangroves and the converted area accounts for 69.5%. The same genera of the Santiago-Cayapas-Mataje zone occur here and major forest types are fringe, riverine and island. Major impacts are shrimp pond construction, expansion of urban areas, cattle farming and wood exploitation for small constructions. In this zone "Eco- and Green Tourism" is being developed to increase recreation in mangrove areas.

- Muisne Zone

This zone is also in Esmeraldas Province and has a total mangrove area of 1,375 ha with nearly 50% of it converted to other uses. All genera are represented with the exception of *Conocarpus* and major forest types are riverine and fringe.

Major anthropogenic impacts are: Selective wood exploitation which changes forest structure. Urban area expansion filling mangrove areas. Road and civil engineering constructions. Palm tree plantations in reclaimed mangrove areas.

- Bolivar Chamanga-Cojimíes Zone

This zone is located between Manabi and Esmeraldas Provinces and has 3,448 ha of mangroves. Conversion of mangroves to other uses is estimated to be 51.3% . *Conocarpus, Rhizophora, Avicennia* and *Laguncularia* are the dominant genera and major forest types are of the fringe or island and riverine types. Major impact on the local mangroves are shrimp pond construction and pasture development.

- Chone Zone

This zone is located in Manabí Province and has 783 ha of mangroves. Converted areas reach 80%. It is in this zone that most mangrove destruction has occurred. Mangrove genera and forest types are similar to the Bolivar Chamanga-Cojimíes Zone. Shrimp farming is the major cause of mangrove destruction and has also significantly altered the hydrology and sedimentology of the coastal zone. River and estuarine sedimentation rates are high and emerging islands are forming in the estuaries which are presently being colonized by mangroves. Also shrimp farming has caused decreasing water quality affecting the salinity, dissolved oxygen and transparency patterns.

- Posorja Zone

This zone is located in Guayas Province and has 3,313 ha of mangroves and only 10% converted. The mangroves are quite different from the rest of the country since they occur under very arid climate. Mangroves are much less structurally developed but the somewhat more transparent waters are rich in planktonic communities. Major impacts are from shrimp farming and wood extraction for rural construction.

- Salado Zone

The Salado Zone surrounds the Guayaquil city and has 40,846 ha of mangroves with 12% of the area converted to other uses. Mangrove genera are the same as in Chone Zone and the major forest type is fringe forests. The area receives intensive pressure from solid wastes dumping from the Guayaquill metropolitan area. Also reclaiming mangroves for urban expansion and some shrimp farming cause impacts on the local mangroves.

- Taura Zone

This zone is also located in Guayas Province and has 19,583 ha of mangroves with 12% converted to other uses. Major forest types are fringe and riverine and species composition is the same as in the Salado

Zone. Shrimp farming is the major impacting activity on the local mangroves.

- Churute Zone

This zone is also located in the Guayas Province and has 12,209 ha of mangroves and only 4.3% of them converted to other uses. Mangrove composition and forest structure are similar to the Taura Zone. In 1978 the Churute was declared an ecological reserve, which greatly improved the conservation of this zone. In Churute, among the mangrove associated fauna, the American crocodile *Crocodrilus acutus*, threatened to extinction in most of its occurrence area, has a protected population. There are many education, popularization and sensibilization programs to highlight the local and national importance of preserving the Churute Mangrove Reserve, they have helped in its conservation.

- Naranjal Zone

This zone is located at the border between Guayas and El Oro Provinces. It has 11,833 ha of mangroves and over 25% converted to other uses, apart from the true mangrove species, similar to the above zones, bromeliads, cactus and orchid epiphytes are abundant in this zone; major forest types are basin, fringe and riverine. Shrimp pond construction is the major impacting activity in this zone.

- Jambelí Zone

It is located in El Oro Province close to Machala City. It has 5,625 ha of mangroves and over 52% of converted mangrove areas. *Rhizophora, Conocarpus, Avicennia* and *Laguncularia* form typical fringe forests in this zone. Urban expansion of Machala metropolitan area and liquid and solid waste disposal cause impact on the local mangroves. Recently, shrimp farming started in the area.

- Hualtaco Zone

This zone is located in El Oro Province and has 13,630 ha of mangroves, 25.5% of them converted to other uses. Fringe and basin mangroves composed by the same species as in Jambelí Zone dominate. Shrimp farming is the major impacting activity in this zone.

7.2 Mangrove management criteria

The following criteria had been adopted for the sustainable management of mangrove ecosystems in Ecuador.

To reach the proper sustainable management of mangrove ecosystems, it is necessary to start with very clear concepts, since the heterogeneity of the coastal region and the different uses of its resources require no simple decisions. It is necessary to seek for integrated solutions to allow the review, improvement and systematization of positive experiences and to revert negative ones.

Superficial views on mangrove ecosystems shall not be attempted and one should take into consideration the mangrove role together with other coastal ecosystems. Long term action plans should be established.

The coastal region has to face an important challenge: the desirable development of the coastal zone has to start with the environment, since long term sustainability of fisheries and aquaculture depends on the functioning of mangrove ecosystems. Any decision to be taken has to foresee the long term future.

The mangrove ecosystem management should consider the environmental and economic importance at the local and extra-local levels, since mangroves will support food production including export goods such as shrimps, from Ecuador.

Coastal communities are important for the proper management of mangroves, their knowledge as well as their needs and expectations are important in any management strategy and their participation in the decision making process should be sought.

Territory regulation of mangrove areas is very important. However any regulation shall take into consideration the necessity to set arrangements with potential users for the introduction of policies and projects for multiple uses of mangroves.

Conservation and sustainable management of mangroves should seek an equilibrium between the biological and ecological integrity of the ecosystem with the income-yield capacity of marketable goods demanded by the society as user of the mangrove resources. The strategy therefore is to introduce activities which will utilize plants, animals, timber and aesthetics of mangroves without irreversibly deteriorating their natural resources.

7.3 Management objectives

The major objectives of the conservation and sustainable management of mangrove ecosystems are:

a. To promote the multiple use of mangroves, with emphasis on those uses that do not alter the vegetation cover, and to those that satisfy the

supply of goods and services to the local community.
b. To stop the conversion of mangrove areas to other uses.
c. To regenerate degraded mangrove areas through afforestation and reforestation projects.
d. To regulate uses which affect the vegetation cover, looking for specific areas and limiting their expansion, and improve the efficiency in exploiting goods and to establish ordination projects in these areas.
e. To improve the local communities life through better utilization of mangrove products and services.
f. To incorporate the local communities into the planning and execution of projects on the utilization of mangrove resources.
g. To keep an integrated view of mangrove management, without neglecting its role in the entire coastal ecosystems from a social, ecological and economical point of view.

7.4 Integrated programs

a. Protection of existing mangroves.

For the protection of the existing mangrove areas it is necessary to make agreements among the different users of mangrove ecosystems aiming at their preservation; to discuss the existing problems with the user groups in order to grant mangrove protection and the enforcement of any agreement; to approve and create mangrove protection areas in places of social, economic and ecologic importance; to grant and or commodate State mangrove areas to individuals or non-governmental organizations for their protection; and when necessary to purchase mangrove areas for their preservation.

PMRC, INEFAN, non-governmental organizations, user groups, private sector organizations and the local communities will be responsible for the above activities. They will rely on the cooperation with universities and municipalities. These specific projects should be introduced in the Santiago-Cayapas-Mataje, Atacames, Muisne, Chone, Naranjal, Hualtaco, Taura and Salado zones.

b. Multiple uses management

b.1 Charcoal production

It comprises the silvicultural projects and techniques involved in charcoal production. This should include mangrove plantation techniques, improving of production processes and technologies and support charcoal commercialization. Groups of organized charcoal producers, INEFAN, PMRC and UCV will be in charge of the implementation of these activities with collaboration from universities, non-governmental organizations and municipalities. The proposed zones for starting such projects are: Santiago-Cayapas-Mataje, Muisne and Posorja.

b.2 Crab and scallop fishing

It comprises the selection of mangrove sites for the management of crabs and scallop artisanal fisheries. To establish juridical procedures to validate the assignment of such sites in favor of local users and to set rules for these activities. INEFAN, PMRC, UCV and crab and scallop dealers should be in charge of the implementation of these projects. Cooperation and technical support shall be provided by universities and non-governmental organizations. The implementation zones for these projects are: Santiago-Cayapas-Mataje, Muisne, Chone, Posorja, Churute, Narnajal, Jamelí and Hualtaco.

b.3 Wood exploitation

Forestry management plans will be fulfilled by the zone communities. These plans will comprise silviculture and management aspects. INEFAN and PMRC are responsible for the execution of projects. Cooperation will come from universities and technical governmental organisms. The selected zones for implementation are: Santiago-Mataje-Cayapas and Jamelí.

c. Restoration of estuaries

The activities to be introduced are the selection of adequate areas for reforestation and project elaboration. The plantation projects should include: keeping of tidal water movements; keeping the planted area free of trunks and weeds that can damage the plantation; controlling plant growth; permanently evaluating the plantation. INEFAN, PMRC and UCV will be responsible for the implementation of the project including the regulation of other activities such as shrimp farming, charcoal production, and fisheries. Universities and non-governmental organizations will be asked to collaborate in the effort. Selected zones for implementation are: Chone, Atacames, Jamelí and Muisne.

d. Ecotourism promotion

These activities include the promotion of cultural, biological and scenic values of mangroves, with the purpose of attracting visitors to these areas, and the creation of small enterprises to organize visits. Local users groups, the private sector and INEFAN and PMRC will be responsible for the implementation with the collaboration of universities and ONGs.

Selected zones are: Atacames, Chone, Posorja and Jambelí.

e. Public education and awareness

The objective of these activities is to promote awareness of the national and local communities to the importance and value of mangrove ecosystems and should be developed at a national level. Guidelines for the management of mangroves will be provided locally. For this purpose booklets, workbooks, radio and television programs, and lectures should be used. These activities will be in charge of INEFAN, PMRC, UCV and DIGEIM and ONGs.

f. Mangrove ecosystem research

Most of the existing research work on the mangroves of Ecuador has been restricted to descriptions of major mangrove aspects (fauna, flora, forest types, structural characteristics etc.). Future research should include functional aspects of the ecosystem and its relationship with the coastal environment. Universities, INEFAN, PMRC and DIGEIM are to be responsible for research activities.

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Mangrove Ecosystems of Colombia

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1. Historical Background

The mangroves of Colombia have been traditionally used for many commercial and industrial purposes including forestry and energy production. However, only recently they have been considered as an ecosystem. This change in attitude towards the mangroves has been in many cases due to the early negative experience in attempting to manage the mangrove resources.

Although there is a significant literature on Colombian mangroves (Alvarez-León, 1984a, 1984b; 1992), there is still great need for detailed mangrove research, in particular on the taxonomy of Pacific coast species, productivity of the different communities, assessment of environmental impact caused by anthropogenic activities, and on the economic and ecological value of the ecosystem.

Ecological studies and the traditional culture of coastal populations (indians, negroes and other dwellers) indicate how mangroves have been used by the people for the extraction of timber, bark, leaves and animal resources. The use of mangroves varied from the Pacific to the Atlantic coasts, depending on the particular characteristics of the population who started the utilization during the transition period from nomad to fixed habits, between 9,000 to 3,000 years BP. Castaño-Uribe (1989) suggests that in Colombia the process of fixation of the population is a continuous chronological sequence, with important implications for the cultural development of the entire continent. An example of this was the finding, in the Atlantic coast of Colombia in mangroves and adjacent areas of the most ancient ceramics of the american continent (*c.a.* 2,400 years BP), a discovery of enormous cultural importance (Reichel-Dolmatoff, 1985; Castaño-Uribe, 1989).

The nomad human groups frequently formed semi-permanent settlements along the coast, close to lagoons and bays, where an abundant and easy to collect protein-rich diet was provided by molluscs (Reichel-Dolmatoff, 1965). In these areas, they left large amounts of shells and organic and "cultural" debris, locally called the "conchales". These remains provide important information on the characteristics of these populations (Perdomo-Rojas, 1978; Prahl *et al.*, 1990). Along the extensive mangrove fringes of the Pacific and the Caribbean, this developmental process resulted in distinct patterns of cultural adaptation which are still present today. Their technology was continuously being changed and optimized for the exploitation of these resource-rich, non-seasonal wetlands, to provide the necessary infrastructure for the establishment of large human groups, with their economy based on the collection of molluscs and on fisheries. The experience diversified, achieved its maximum development, and then expanded throughout the continent (Castaño-Uriba, 1989).

Paradoxically, by the time of the Spanish Conquest, these wetlands represented such a nuisance to troops and horses that Cristobal de Molina described them in 1552 in Peru as the "most difficult land of these kingdoms". However, this did not hamper the discovery of the quality of mangrove timber for construction, and the exploitation started immediately, mostly for poles and boat construction. Mangrove timber was exported since the 16th century to Peru and reached 6,000 poles a year in the 17th century. In 1677 for instance, thousands of mangrove poles were exported to Cuba from the Pacific coast (Prahl *et al.*, 1990).

During colonial times, the opposition by the indians led to their virtual extinction on both coasts. The Spanish then imported African work forces to improve mining and fortifications in major ports, among them Cartagena and Santa Marta. These mixed populations (indian, spanish and african) were mostly devoted to mining, agriculture and fisheries. They eventually migrated away from mangrove areas to establish themselves in the coastal plain and along rivers where they are settled however under poor living conditions (West, 1957; Prahl *et al.*, 1990).

Colombian mangroves have been subjected to forest exploitation since the middle of the present century on both coasts. However, exploitation has been different. While along the Pacific major activity was bark production from *Rhizophora* for tannin extraction, along the Caribbean only the timber was used to manufacture glomerate and pressed woodwork using wood shavings of *Rhizophora, Avicennia* and *Laguncularia* (Table 1). In both cases exploitation was very inefficient and there was no legislation or proper resource management.

Apart from forest products, other products have been, and still are the objective of artisanal and semi-industrial exploitation (see also table 14) (INDERENA, 1991). Therefore mangroves constitute a stable source of subsistence resources for a significant fraction of the coastal populations. Fortunately, industrial exploitation reached a non-sustainable economical level and processing plants have disappeared from the Pacific coast.

Although forest exploitation has run for many years, no specific legislation exists to regulate the management of this resource. Therefore the activity has been conducted under an adaptation of the present Forest Legislation. Only recently a legislation (Resolution 1681 of 1978) has been formulated regarding the preservation of the ecosystem taking into consideration its ecological and socio-economic importance.

Due to the growing interest in the sustainable use of mangroves, the National Institute for Renewable Natural Resources (INDERENA) has promoted many actions. The most important are: prohibition of using the mangrove forests of the Colombian Caribbean (Hernandez-Camacho *et al.*, 1978); organization of several national and international events (Table 2); undertaking of an extensive survey of the mangrove areas of the Pacific and the Caribbean coasts (INDERENA, 1991).

Mangrove research has been greatly favoured by the National Plan for Marine Sciences and Technologies, published in 1977, and by many international meetings on mangroves, which created several research groups who have along the years produced and published results of their work. (Table 2) (Alvarez-León, 1992).

Fundamental support for these research activities has been provided, together with the Institute for the Development of Science and Technology of Colombia (COLCIENCIAS), by many international organizations including the UNESCO, OAE, FAO, UNEP, IOCARIBE, COI, SIDA/SAREC, CPPS, ALICMAR, CIFCA, GTZ and DAAD.

2. Extent and Distribution

Colombia has the tenth largest mangrove area in the world (FAO, 1981), with 70-80% of the total areas located along the Pacific coast and 20-30% along the Caribbean coast. Table 3 shows most recent estimates of mangrove area of Colombia. Winograd (1987) and INDERENA (1991) used the best techniques available including aerial photographs, remote sensing, radiometry and detailed field surveys to accomplish the job, therefore their data are probably the closest to reality. Mangroves, including mature and young stands, represent approximately 1% of the total forest area of Colombia. They show an average timber volume of 43 m^3 in the Pacific and of 40m^3 in the Caribbean (INDERENA, 1991; Yanine-Dias, 1991).

The mangroves of Colombia grow under totally different environmental conditions depending on the coast where they occur. According to the Holdridge classification, Caribbean mangroves are typically *dry tropical forests*, whereas Pacific mangroves are *very*

Table 1. Historical Exploitation of the Mangroves in Colombia.

Coast	Activity / Utilization
Caribbean	Exploitation of trees > of 10 cm DBH, felling in alternate fringes of 100 x 600 m.
	Fabrication of pressed woodwork and active coal (1965-1985) approximately 15,000$m^3.yr^{-1}$ of timber, but wasted the bark.
	Rods, piles, levers, firewood, tannin.
Pacific	Exploitation of trees > 25 cm DBH, felling
	Exploitation of tannin (1945-1970) nearly 30,000 ton.yr^{-1} of bark, 315,000 $m^3.yr^{-1}$ of timber wasted in the exploitation.
	Rods, levers, piles, poles, firewood, coal.

Table 2. National and international events in relation with the Latin American and Colombian mangrove ecosystems

1. Only Mangrove Ecosystems
   a. Course "Ecology of Mangroves": Universidad del Valle/Florida State University, Cali (Valle) and Guapi (Cauca) Colombia, July 14-26, 1975.
   b. "Latin American Seminar on the Scientific Study and Human Importance of Mangrove Ecosystems": UNESCO/UNIVALLE, Cali, Colombia, 27 November-1 December, 1978.
   c. Technical Meeting: "Planning a Bioecology Project of the Sea", OEA/COLCIENCIAS/INVEMAR, Santa Marta (Magdalena Colombia, June 27-29, 1984.
   d. "Regional Seminar on the Integrated Regional Ordination of Mangrove Zones", FAO/INDERENA, Cali (Valle) and Tumaco (Nariño), Colombia, November 19-23, 1984.

2. With Worksession on the Mangrove Ecosystems:
   a. "Seminar on the South American Pacific Ocean" UNESCO /UNIVALLE, Cali (Valle) Colombia, September 1-5, 1976.
   b. Course: "Rational Use of Natural Resources in the Caribbean, CIFCA/COLCIENCIAS, Cartagena (Bol.) Colombia, November 26-December 7, 1979
   c. Seminar "Environmental Development and Planning of the San Andrés and Providence Islands", San Andrés (SAP) Colombia, June 2-6, 1982.
   d. "I Latin American Congress of Marine Sciences" ALICMAR/COLCIENCIAS/IVEMAR. Santa Marta (Mag.) Colombia, November 25-29, 1985.
   e. "VI National Seminar of Marine Sciences and Technologies" CCO/UBJTL, Bogotá D.E., December 5-7, 1988.
   f. "VII National Seminar on Marine Sciences and Technologies" CCO/UNIVALLE. Cali, (Valle), October 30-November 2, 1990.

humid tropical forests. Along the Pacific, mangroves attain their best development and highest forest biomass. Before indiscriminate anthropogenic actions took place, tree height of 40 to 50m and prop roots of over 10 m high, were frequently reported. These forests had been compared to those of SE Asia, and had even been considered as the best developed and extensive mangroves in the world (Aksornkoae, 1983). They occur as a broad fringe reaching 20km landward, extending from the Ecuador border to Cape Corrientes. From this point to the Panamá border they occur as patches along the coast (Fig. 1).

Caribbean mangroves of Colombia however, present a discontinuous distribution, restricted to narrow fringes along protected areas of the coast. Large stands however, do occur at the mouth of large rivers such as the Magdalena, Sinú-San Jorge and Atrato (Fig. 1). In general they are smaller and less developed than the Pacific coast mangroves, and many areas of dwarf forests occur.

Mangroves distribution in Colombia is shown in Table 4 (INDERENA, 1991). The Departments of Magdalena, Bolivar and Antioquia, present the largest mangrove areas along the Caribbean coast and include the large forests at the Magdalena/Canal del Dique and Atrato River deltas. Along the Pacific, the Department of Nariño has the largest mangrove area not only of this coast but also of the entire country.

Table 5 shows the species composition of mangroves in Colombia. Mangroves of the Caribbean coast are less diversified than those of the Pacific coast and show significant floristic differences. They have only 5 tree species while the Pacific coast harbours at least 10. This may be due to different environmental past and present conditions between the two areas.

Prahl *et al.* (1989) suggested that in the Caribbean, long dry periods and rapid changes in mean sea level of up to 130m occurred in the last one million years, considerably affecting the vegetation, while in the Pacific, environmental conditions remained fairly stable, to a point that this coast has been considered as a large Pleistocenic refuge. The relatively stable conditions found in the Pacific coast favored the appearance of several endemic species associated with mangroves such as *Ardisia granatensis, Crenea patentinervis, Pavonia rhizophorae, Rustia occidentalis* and the "nato mangrove" *Mora megistosperma.*

Table 3. Mangrove extension in Colombia (ha).

Coast/Author	1	2	3	4	5
Caribbean	153.000	73.7	189.800	35.800	82.200
Pacific	287.000	284.300	286.700	322.200	283.700
Total	440.000	358.000	396.300	358.000	365.900

Source: 1. FAO (1981); 2. INDERENA *et al.* (1984); 3. Winograd (1987); 4. Yanine-Diaz (1991); 5. INDERENA (1991).

Table 4. Natural distribution of mangroves in Colombia

Coast	Department	Area (ha)	Percent Distribution	
			Regional	National
Caribbean	Atlántico	350	0.4	0.10
	Antióquia	6.500	7.9	1.78
	Bolívar	4.875	5.9	1.33
	Córdoba	3.100	3.8	0.85
	Guajira	1.170	1.4	0.32
	Magdalena	62.000	75.5	16.94
	S.Andrés/Providencia	132	0.2	0.04
	Sucre	4.000	4.9	1.09
	SUBTOTAL	82.127	100.0	22.45
Pacific	Cauca	45.000	15.9	12.30
	Chocó	74.500	26.3	20.36
	Nariño	135.400	47.7	37.00
	Valle del Cauca	28.88	10.1	7.89
	SUBTOTAL	283.775	100.0	77.55
	TOTAL	365.902		100.00

Additionally, small tidal fluctuations (0.3-0.6m) in the Caribbean restrict mangroves to a narrow inundated fringe, whereas in the Pacific tidal fluctuations higher than 4.0m, allow the invasion of mangroves landward wherever topography permits.

Abundant and nutrient-rich freshwater supply results in the extraordinary development of trees (up to 40m high), larger productivity and export capacity in the Pacific. This results in a different trophic structure of mangrove-adjacent waters in both coasts. While in the Caribbean most food webs depend on phytoplankton productivity, in the Pacific bacterial production using mangrove detritus is dominant (Prahl, 1989).

Mangrove zonation and succession depend on several local conditions and environmental parameters, which may vary even in restricted geographical areas. In the Caribbean, soil salinity controls species distribution and associated vegetation. In the Pacific where soil and water salinities are generally low due to intense rainfall (up to 3,000mm.yr^{-1}) and tidal leaching, substrate stability is the major parameter controlling species zonation.

Response of mangroves to environmental factors such as salinity, tidal amplitude, substrate stability, nutrient and freshwater inputs and stress agents, is reflected in the variability of their structural development. A given mangrove area can present different forest types depending on local conditions. Mangrove types as described by Lugo and Snedaker (1974): riverine, fringe, overwash, basin and island occur in Colombia, but also a large variety of community types, from monospecific stands to mixed ones, without any zonation pattern at all.

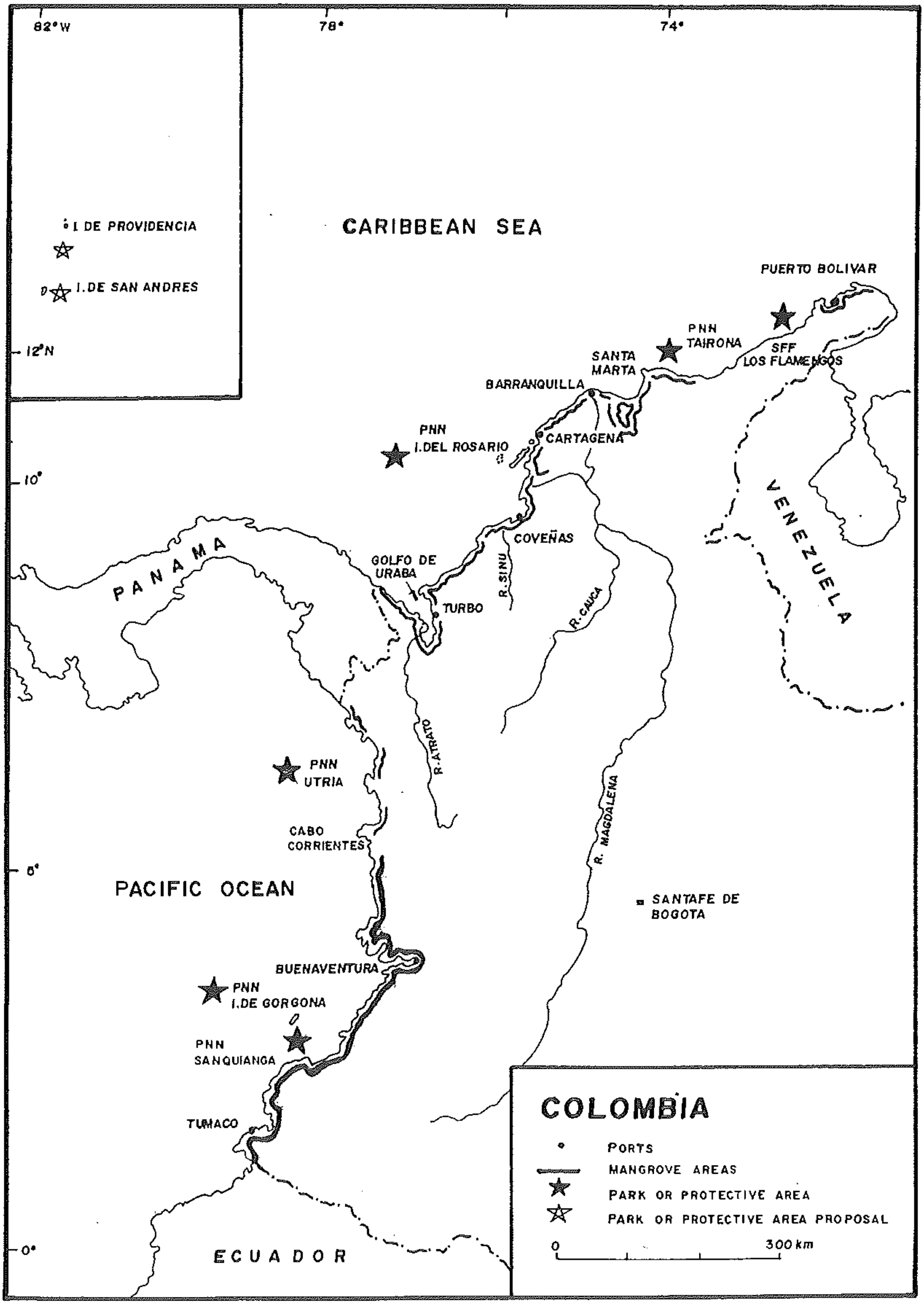

Fig. 1. Distribution of mangroves in the Pacific and Caribbean coasts of Colombia.

Table 5. Species of mangrove plants in the Caribbean and Pacific coasts of Colombia.

Scientific name	Family	Caribbean	Pacific
Avicennia germinans L. Moldenke	Avicenniaceae	x	x
Avicennia tonduzii Moldenke		-	x
Conocarpus erectus L.	Combretaceae	x	x
Laguncularia racemosa R.Gaertn.		x	x
Mora megistosperma Pitt.	Caesalpiniaceae	-	x
Pelliciera rhizophorae Tr.&Pl.	Pellicieraceae	x	
Rhizophora harrisonii Leech.	Rhizophoraceae	-	x
Rhizophora mangle L.		x	x
Rhizophora racemosa G.F.W. Meyer		-	x
Rhizophora samoensis (Hochr.) Salvosa		-	x

In the Pacific coast riverine and overwash types dominate, whereas along the Caribbean the most abundant types are riverine and basin. Dwarf mangroves (<4.0m high) typical of marginal areas (sand, gravel and corals) and under extreme environmental conditions are common in some coralline islands in the Caribbean (Islas del Rosario) and some rocky islands in the Pacific (Bahia Malaga) (Prahl, 1990).

Primary productivity of Colombian mangroves has received much attention from researchers (Table 6). In the Caribbean, six sites have been subject of intensive research. These include the major mangrove species of that coast (*R. mangle, A. germinans* and *L. racemosa*) and are located at the Ciénaga Grande de Santa Marta at the fluvial deltaic plain of the Magdalena River and the Ciénaga de Cocoliso, a lagoon area located in the largest island of the National Underwater Park Corales del Rosario.

In the Pacific, eight sites have been studied including 5 of the 10 mangrove species occurring in this coast (*R. harrisonii, R. mangle, A. germinans, L. racemosa* and *P. rhizophorae*). They are located at the National Parks of Utria and of Sanquianga, recently created to preserve mangrove ecosystems; the Estero Los Limones, at the largest fluvial-maritime harbour of the Pacific coast (Buenaventura); Guapi area; and the areas adjacent to Tumaco (Boca Grande, Cape Corrientes and Pasacaballos).

Results of these studies (Table 6) showed that Caribbean mangroves have a higher productivity (as measured through litterfall studies). This apparent paradox may be explained by the continuous stress affecting Caribbean mangroves which induces high rates of litter production.

3. Physical Setting

The physical characteristics of the Caribbean and Pacific coasts (Tables 7 and 8) help to understand the differences in mangrove development between the two coasts.

In the Pacific marine currents are directly influenced by the warm North Equatorial Countercurrent and the cold Humboldt Current. The Caribbean receives the warm Atlantic Equatorial Current, generating typical tropical conditions. Seasonality due to the counter currents formed by the trade winds (Colombian Current, to NNE, in the Pacific and the Urubá Current, to NNW, in the Caribbean), and/or the specific characteristics of oceanic and littoral water circulation, play a key role in nutrient dynamics and species distribution, sedimentation and coastal erosion and accretion.

Climate of both Colombian coasts show some general similarities, although local chronological and qualitative variations occur (Bula-Meyer, 1985; Prahl *et al.*, 1990).

In the Caribbean, four seasons are determined in relation to winds and precipitation. From December to April, intense trade winds and absence of rain characterize a "Major Dry Season". Between May and June, trade winds are replaced by South winds that bring rains characterizing a typical "Minor Rain Season". Between June and August, trade winds dominate again and rains are rare ("Minor Dry Season"). Finally, between September and November, trade winds smooth and shorten, being sometimes replaced by SW winds or calmness. Heavy rains are typical ("Major Rain Season").

The Pacific coast is in the low atmospheric pressure area, where trade winds from both hemispheres converge (Intertropical Convergent Zone). The region presents air masses with different temperature and humidity gradients with weak and variable winds (Calm Equatorial Zone) and heavy rains. There are two rainy periods, slightly different in the three regions of this coast. North and Central coasts, from April to November heavy rains (70% of the annual rainfall), from December to March, reduced precipitation. South coast, from January to June, heavy rains, from June to December precipitation is reduced. Mountain southern coast, April/May and October abundant rain and from June to September transitional rain period.

Coastal geomorphology in the Pacific presents two different zones. The first from Cape Corrientes northward with steep walls of the Baudó mountains. It continues as a tertiary arc extending between the large Atrato and San Juan rivers depression and the Occidental Cordillera, a zone of tectonic interest, in particular the Útria megafault formed in the late Cretaceous (65 My) by the rupturing of the ocean crust and the subduction of the oceanic plate. The Baudó mountains are complex, discontinuous and extend from the Gulf of San Miguel in Panamá to the Baudó River in the Chocó Department. Geology shows late Eocene basic and ultrabasic rocks and marine formations from the middle and late Tertiary.

The second sector extends from Cape Corrientes southward along the large basin and sedimentary plain of the Bolivar Depression, partially filled with Tertiary marine sediments. Surface layers are characterized by quaternary continental deposits, presently occupied by mangroves (Prahl *et al.*, 1990).

The Caribbean coast and continental shelf resulted from the disappearance of geosinclinals during the Neogenic; the presence of faults and the relative geological relationship with Central America, the Nicaragua Bank and the Deep Marine Basin of Colombia. Mud, muddy sand and sand dominate the sediments. However, depending on carbonate content these can be subdivided in: mud, sandy mud, calcareous algae, coralline sand and biolitoclastic. The Caribbean coast has 39 bays, 3 estuaries, and 59 lagoons; while the Pacific presents 35 bays, 2 estuaries, 20 marshes and 32 "bucanas" (Alvarez-León, 1989).

Table 6. Litter production of Colombian mangroves

Site/Author/Species	$t.ha^{-1}.yr^{-1}$
1. Caribbean	
Ciénaga Grande de Santa Marta (Mag.)	
Hernández-Camacho *et al.* (1980). *Rm, Ag, Lr*	31.81
Zamorano (1983). *Rm*	68.72
Ochoa *et al.*(1988). *Rm, Ag*	28.84
Ciénaga de Cocoliso (Bol.)	
Quintero *et al.* (1990). *Rm, Lr*	23.26
González *et al.* (1992). *Rm*	4.07
2. Pacific	
Guapi (Cauca)	
Hernández and Mullen (1975). *Lr, Ag*	14.08
Hernández and Mullen (1978). *Ag, Lr*	13.46
PNN Sanquianga (Cauca)	
Escallón and Rodríguez (1982). *Rh, Rm, Rr*	12.19
Estero Rio Limones (Valle)	
García and Garces (1984). *Rh, Rm, Rr*	7.50
Tumaco (Nariño)	
Vargas and Gallo (1987). *Rm*	9.97
PNN Utría (Chocó)	
Arboleda (1989). *Pr*	10.31
Bocagrande (Nariño)	
Palacios *et al.* (1990). *Rh, Rm, Rr*	10.84
Cabo Corrientes (Nariño)	
Palacios and Vargas (1991). *Rh, Rm, Rr*	10.84
Hojas Blancas (Nariño)	
Palacios and Mosquera (1992). *R.spp., Ag, Mm*	10.04
Palacios and Mosquera (1992). *Pr*	6.48
Bocana Rio Rosario (Nariño)	
Palacios and Vargas (1991), *Rm*	14.03

Rm, R. mangle; Rh, R. harrisonii; Rr, R. racemosa; Ag, A. germinans; Lr, L. racemosa; Mm, M. megistosperma; Pr, P. rhizophorae.

Table 7. Characteristics of the Colombian Caribbean SW and NE of the mouth of the Magdalena River

Southwestern Zone	Northeastern Zone
-Wide continental shelf	-Narrow continental shelf
-Flat coastal topography with small elevations.	-Abrupt coastal topography, elevations up to 5,852 m
-No emerging phenomena	-Strong, emerging junctions
-Rainfall (>650 mm)	-Rainfall (<250 mm)
-Three largest rivers: Magdalena, Atrato and Sinú	-Large rivers are seasonal
-Semi-arid/semi-humid climate	-Dry - arid climate
-Warm tropical water (> 28°C), small seasonal variations	-Colder water (27°C), large variations, drastic changes
-Salinity (<35ppt)	-Oceanic waters (> 35ppt)
-Clear waters, strong muddy currents	-Clear waters all year round
-Deep, extended and well developed coral reefs, up to 50m deep	-Restricted and little developed coral reefs to only 25 to 30m of depth.
-Little developed meadows, but well distributed and associated to reef mangroves.	-Well developed meadows, but reduced in extension and distribution, associated with reefs and mangroves.

Table 8. Characteristics of the Colombian Pacific coast, North and South of Cape Corrientes

Northern Zone	Southern Zone
- Narrow continental shelf	- Wide continental shelf
- Abrupt coastal topography up tp 1,500m	- Flat coastal topography
- Strong emerging junctions of low intensity	- No emerging areas
- High precipitation (4,0-8,0cm.year^{-1})	- Average precipitation (1,0-4,0cm.year^{-1}).
- Mouth of three minor rivers Mira, Patia and S. Juan	- Three large rivers and 19 minor
- Mild, rainy and super humid climate	- Rainy humid Equatorial climate.
- Cold, oceanic waters (20°C), salinity (34ppt)	- Warm, brackish waters (>27°C), salinity (0-30ppt)
- Clear waters all-year round.	- Frequent muddy waters
- Well developed coral reefs, isolated in coves, bays and islands	- Well developed coral reefs surrounding Gorgona island
- Well developed meadows, associated to coral reefs and mangroves	- Little developed meadows, associated to coral reefs and mangroves

4. Biological and Ecological Characteristics

The biological productivity of mangroves is related to a variety of associated organisms which can be grouped in at least 4 categories: 1- Those directly associated with the trees (roots, branches and leaves); 2- Those living in terrestrial adjacent habitats which may migrate to mangroves; 3- Those living in associated mudflats and sediments; 4- Those living in marine habitats which may migrate to mangroves during their life cycles.

Fauna and flora associated with the mangroves of Colombia are highly diverse including some true mangrove species, as the birds *Tigrisoma mexicanum* and *Dendroica petechia*; the mammals *Procyon cancrivorus pumilus*; and the crocodiles *Crocodilus acutus* and *Caiman crocodilus*.

Lists of taxa associated with Colombian mangroves are presented in Tables 9, 10, 11 and 12 and in Annexes 1, 2, 3 and 4. Although many more organisms are associated with mangroves, the lists only included those actually identified, observed and/or collected in mangroves and adjacent areas (Prahl *et al.*, 1990 Alvarez-León *in prep.*).

Table 9 and Annex 1 group the aquatic species living associated with the mangrove roots, a sub-

Table 9. Associate aquatic flora and fauna on the root systems of the Colombian mangroves.

Taxa	Caribbean			Pacific		
	F	G	S	F	G	S
Chlorophyta	6	6	11	5	7	8
Phaeophyta	2	2	3	2	2	2
Rhodophyta	7	11	17	7	7	15
Porifera	10	11	17	0	0	0
Coelenterata	6	11	14	0	0	0
Anthozoa	4	4	4	0	0	0
Bryozoa	3	3	4	0	0	0
Polychaeta	12	30	44	9	9	9
Mollusca	36	55	68	10	15	18
Echinodermata	2	2	2	0	0	0
Crustacea	21	58	98	5	15	18
Chordata	1	1	1	0	0	0

(F = Families, G = Genera, S = Species).

strate primarily dependent on tides and with a complex succession of species with distribution and abundance controlled by their adaptation to periodical submergence and desiccation. Filter feeding organisms, and in particular oysters and barnacles, dominate this habitat, although carnivores and herbivores as well as seaweeds, are also abundant.

Table 10 and Annex 2 include the organisms associated with the leaves, branches and trunks of mangrove trees. Herbivores, in particular insects but also crabs and mollusc, dominate this habitat and can use from 15% to 20% of total leaf biomass, also consuming young branches. Other animals visit the mangrove canopy rarely, such as iguanas, deer and monkeys. Others such as birds and bats use the canopy for nesting, reproduction and rest. Others, like bears and birds come to feed in termite and bee hives.

Along the Pacific, epiphyte bromeliads and orchids are abundant, retaining water and organic debris and providing habitat for a varied fauna of invertebrates which includes some vectors of tropical diseases, such as malaria.

Table 11 and Annex 3 show the largest number of organisms, including terrestrial, amphibious and aquatic species which use the mangroves for refuge, shelter and food, but do not actually dwell in the mangroves. From terrestrial environments migration

Table 10. Associated fauna in branches and leaves of mangroves of Colombia.

Taxa	Caribbean			Pacific		
	F	G	S	F	G	S
Mollusca	0	0	0	5	5	8
Insecta	0	0	0	-	7	14
Aves	14	23	29	14	4	32
Reptilia	2	2	2	4	6	8
Mammalia	-	13	14	-	11	11

(F = Families, G = Genera, S = Species).

Table 11. Fauna from adjacent aquatic and terrestrial ecosystems including mud flats and tidal creeks found in mangroves of Colombian.

Taxa	Caribbean			Pacific		
	F	G	S	F	G	S
Mollusca	2	2	3	13	14	22
Crustacea	5	8	16	18	31	69
Pisces	30	53	75	32	35	69
Reptilia	1	2	3	5	6	6
Mammalia	5	5	8	5	9	10

(F = Families, G = Genera, S = Species).

of reptiles (snakes, turtles) and mammals (rodents, monkeys) are common. Also aquatic mammals, such as the manatee, typically visit the mangroves. From the aquatic habitats, associated with the organic-rich mud or water, many species of molluscs, echinoderms, crustaceans and fish are frequent visitors and more rarely dolphins and sea-snakes from ocean waters.

Fishes are the most abundant but the most difficult to characterize as temporary dwellers of mangroves, since many species migrate to estuaries and lagoons during some stage of their life cycle. Alvarez-León and Blanco Racedo (1985) for example, reported over 244 fish species in the Ciénaga Grande de Santa Marta, Ciénaga de Tesca and Cartagena Bay, in the Caribbean, while similar results have been reported for the Pacific by Rubio (1982; 1984).

Therefore, only the species actually collected and/or observed in mangroves were included here in tables and annexes.

Finally Table 12 and Annex 4 show the vegetation associated with mangroves, including: aquatic

Table 12. Vegetation associated with the mangroves.

Taxa	Caribbean		Pacific	
	G	S	G	S
Associates	9	9	14	14
Transition Zones	12	12	24	24
Spouts, Inlets, Bays Estuaries, Marshes	15	16	0	0

(G = Genera, S = Species).

plants (submersed, emergent and floating); and those occupying the tidal habitats and the dry habitat of the tree canopy (Winograd, 1987; Prahl *et al.*, 1990; Alvarez-León, *in prep.*).

5. Mangrove Related Ecosystems

Mangroves receive large inputs of nutrients from continental ecosystems and a variable one from marine systems. Interchanges of organisms among these systems also occur. In high rainfall areas of the Pacific, mangroves are bordered by the freshwater palm (*Euterpe cuatrecasana*) communities. In areas influenced by large rivers along the Caribbean coast mangroves are bordered by freshwater marshes. In low rainfall areas, these temporary marshes dry out and are colonized by halophytes (*Batis maritima* and *Sesuvium portulacastrum*) (Prahl *et al.*, 1990).

The relationships between benthic and nectonic communities as well as with coral reefs and seagrass beds are well documented. Evidence exists on the utilization of mangrove detritus in seagrass beds and of their transfer to coral reefs. Migration of animals between these systems is common. Coral reefs protect mangroves from wave action and may provide sediments whereas mangroves may act as a filter, avoiding excessive sedimentation of coral areas with continental sediments.

In the Colombian Caribbean, coral reefs are distributed in three main regions: South of Cartagena, where water temperature is higher than 27°C, the continental shelf is broad and a permanent littoral counter current deviates the plume of the Magdalena river. In this region coral areas are the continental archipelago of Rosario and San Bernardo, Fortes and Tortuguilla Islands and the Sapzurro area. Northwest of Santa Marta, colder (20°C-27°C) water and a narrow continental shelf, result in restricted distribution of corals in protected areas of the coast (Tariona Park, Porpete Bay and Puerto Lopes). The insular Caribbean, with constant warm water (28°C), presents typical fringe, barrier and atoll reefs, with lagoons and rocky environments. This region includes San Andrés and Providence Islands, Cayos Bolivar, Albuquerque, Roncador and Serranilla. In some areas mangroves actually grow on corals (*Porites*), in particular in Malaga Bay and Corales del Rosario. However, they form only dwarf stands, continuously under stress conditions.

Seagrass beds of Colombia Caribbean are dominated by *Thalassia testudinum*. Other seagrass species also occur: like *Syringodium filiforme, Diplantera wrightii* and *Halophila baillonis*. Few studies exist on these ecosystems, notwithstanding their importance as oxygen source in coastal waters and as stabilizers of the substrate, in particular to the mangroves of the National Park of Corales del Rosario, off Cartagena Bay.

6. Mangrove Traditional and Present Uses

Traditionally mangroves have been considered as a source of wood for construction, housing and fishing gear, charcoal and fuelwood, medicine and textile preservative, and as a source of protein from the fauna. Later, mangroves were used for their timber, as a source of pulp for the paper industry, wood shavings, charcoal and tannin. Growth of coastal towns, waste disposal, the belief that mangroves cause diseases, the use of some areas for mariculture, agriculture, navigation channels and harbors, all contributed to increase the pressure upon these systems.

Along the Caribbean and Pacific coasts examples of coastal populations who used mangrove wood as basic material for house construction are many. Mangrove wood has been used for producing poles, internal structures, stairs, tables, floor and many other items which need to be strong. Abundance of timber however, has hampered the development of measures for preservation of mangrove wood, only recently introduced (E. Garcia *per. comm.*).

Table 13 summarizes the uses of the different species of mangroves in relative order of importance. Most widely used is *Rhizophora* which, apart from construction purposes are used for many other purposes including tannin production and medicine.

Present craft exploitation occurs at a subsistence level only, mostly for individual use, although it may

Table 13. Utilization of mangroves in Colombia (INDERENA, 1991).

Species	Uses
Rhizophora harrisonii *R. mangle* *R. racemosa* *R. samoensis*	Construction, piles, supports, firewood, charcoal, poles, enclosure, fishing gear, preservative and stakes for fishing, bark for tanning, medicine
Mora megistosperma	Piles, supports, firewood, charcoal, poles, artifacts, pulp, handles for tools, boat parts
Avicennia germinans *A. tonduzii*	Construction, poles, supports, firewood, medicine.
Laguncularia racemosa	Construction, firewood, pulp, fishing gear protective.
Pelliciera rhizophorae	Construction, firewood, pulp.
Conocarpus erectus	Construction, firewood

increase when these populations are involved in village re-building or providing timber for utilization in the cities (Table 14).

In Tumaco, Guapi, Buenaventura and Bahia Solano, in the Pacific, isolated houses and even small villages are built entirely with mangrove wood. In the Caribbean whole, complete villages made of mangrove wood can be seen at Bocas de Cataca, Buenavista and Nueva Venecia, as well as in the mouth of the Aracata River and the Ciénaga del Pajaral.

7. Commercial Exploitation and Marketing

This topic has been superficially discussed above, here recent statistics on mangrove products production and commercialization are presented, based on surveys made by INDERENA (1991), in eight of the eleven coastal Departments of the Pacific and Caribbean coasts (Fig. 2).

Most important products of Colombian mangroves are for construction (poles, piles, levers, rods etc.). Production of fuelwood and charcoal are also important as well as the utilization of mangrove poles for agricultural uses as support for vine and other plants (tomatoes, beans, passionflower, grapes and banana) (INDERENA, 1991). Detailed descriptions of mangrove products commercialization in Colombia are presented in Tables 15, 16).

Along the Caribbean, extraction of mangrove timber is illegal. Forest exploitation has been forbidden since 1978. However, small scale, subsistence utilization of mangrove timber by the local, indigenous populations continues.

In the Pacific, exploitation is permitted under regulation, mostly for poles, piles and charcoal. For the Departments of Chocó, Valle and Cauca, permission for exploitation has been given for 1,400ha (up to 40,000m^3) of red mangrove. Pending permissions amount 580ha (up to 30,000m^3). Mangrove products exported inland from 1985 to 1991 were mostly poles (68.4%); fuelwood and charcoal (20.3%); and piles for railroads (11.3%) (INDERENA, 1991).

Based on socio-economic surveys of mangrove exploitation made by INDERENA (1991) (Tables 15 and 16) along coastal markets it was shown that although all species of mangroves are exploited, most used ones are the red, black and "nato" mangroves. Largest exploitation in the Pacific occurs in the Chocó Department at Virundó and the San Juan River Delta, and the smallest one in the Departments of Cauca and Nariño. Along the Caribbean, largest exploitation occurs in Antioquia Department (Atrato River Delta), Cordoba (Sinú River Delta and Cispatá Bay), Sucre (Ciénaga La Caimanera and Bocacerrada), Bolivar (Verrugas) and Magdalena.

Table 14. Present exploitation of mangroves (Yanine -Diaz, 1991).

Coast	Exploitation	Utilization
Caribbean	Artisanal	Poles, levers, firewood, coal
Pacific	Artisanal	Poles, levers, firewood, coal
	Commercial	Poles < 12cm BHD, for construction
		Poles > 18cm for electric and telephonic poles
		Woodpulp with trees >18 cm BHD.

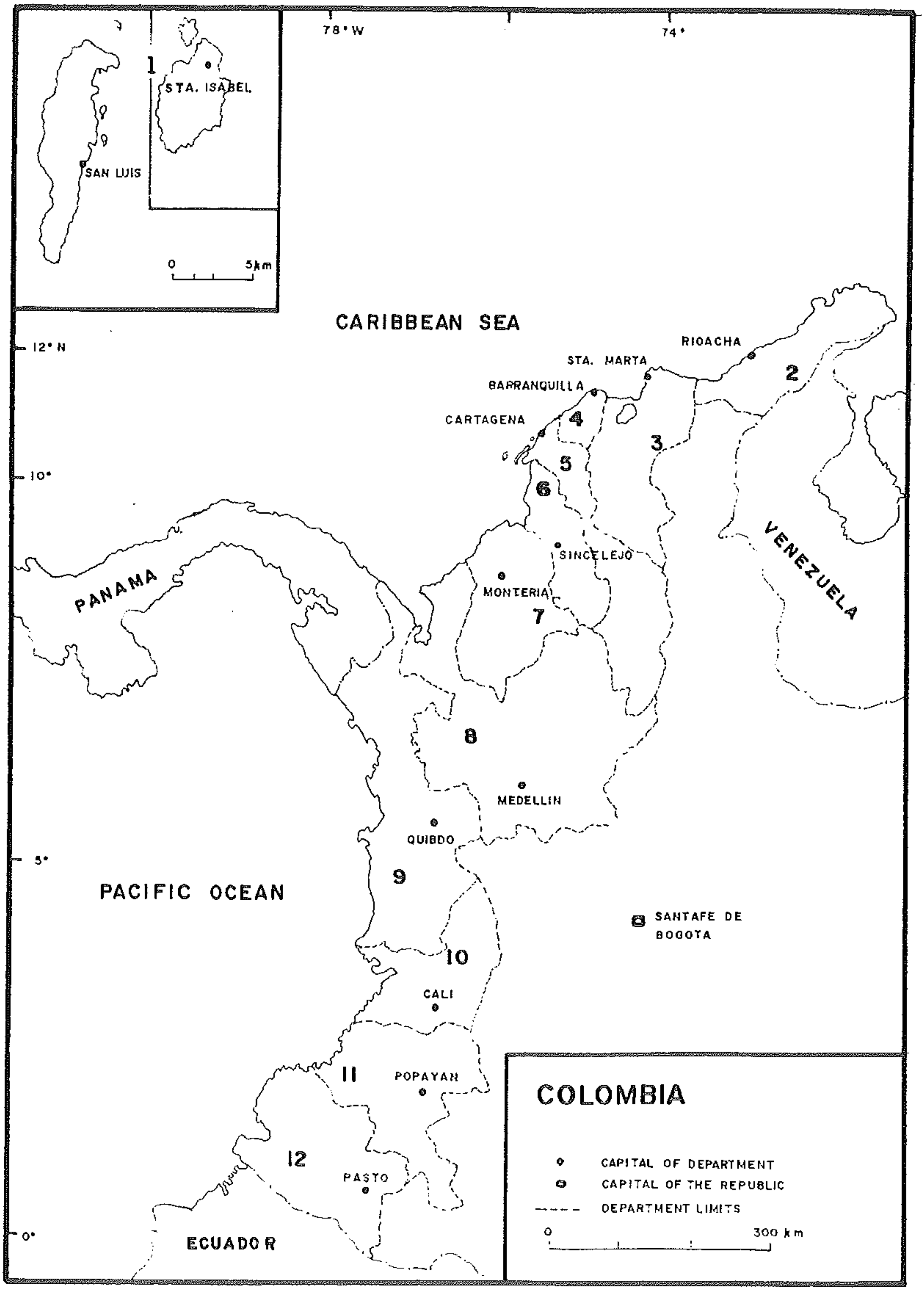

Fig. 2. Map showing coastal Colombian Departments. 1-San Andres y Providencia; 2-Guajira; 3-Magdalena; 4-Atlantico; 5-Bolivar; 6-Sucre; 7-Cordoba; 8-Antioquia; 9-Choco; 10-Valle; 11-Cauca; 12-Nariño.

Table. 15. Relation of the mangrove products (dimensions and prices-Col$ 650=US$ 1-during 1991) in the Colombian Pacific coast (INDERENA, 1991)

Department	Product/Dimensions		Price of Court	Price at site of gathering	Price after treatment
	inch	x m	Col$	Col$	Col$
Choco	Beam	(5-6x5)	200	1,000	-
		(6)	230	1,100	-
		(7)	250	1,200	-
		(8)	270	2,300	-
	Rod	(3-4x5)	120	600	-
		(6)	130	700	-
		(7)	150	800	-
		(8)	160	900	-
	Pile	(6-8x8)	700	3,500	6,000
		(10)	850	4,000	7,500
		(12)	1,000	4,500	10,500
	Coal	(bulk)	100	1,300	-
Valle del	Pile	(6-8x8)	700	3,500	6,000
Cauca	Coal	(10)	800	4,500	7,500
		(12)	1,000	4,500	10,500
	Coal	(bulk)	600	1,300	-
Cauca	Coal	(bulk)	600	1,300	-
	Pile	(6-8x8)	700	3,500	6,000
		(10)	800	4,000	7,500
		(12)	1,000	4,500	10,500
NARIÑO	Coal	(bulk)	900	-	-
	Firewood(cent)		2,500	-	-

Prices are similar in both coasts and vary according to location of production sites, distance from market and transport. Therefore the same product may have different prices. Treatment may double and even triple the price of wood products, depending on timber volume and size. Nearly 350 families are permanently involved in mangrove exploitation, 110 in the Caribbean and 240 in the Pacific coast.

8. Conversion to Other Uses

8.1 Animal farming

As a complementary to agriculture, forestry and fishing, local people along the coast grow various domestic animals close to mangroves and some species may eventually use them to complement their diets. In the mangroves of the Pacific coast, pigs often consume crabs and clams and along sandy beaches they harvest sea turtle nests whereas cattle consumes pasture on sand dunes and forage on the leaves of black and white mangroves (Prahl *et al.*, 1990). In the Caribbean, house dogs consume crabs and sea turtle eggs and cattle and horse are commercially grown in dried coastal wetlands, some of which had been occupied by mangroves.

8.2 Agriculture

Most coastal populations depend on agriculture, fisheries and, in the Pacific, small scale mining. They develop these activities in terrestrial and aquatic areas adjacent to mangroves, using the mangrove areas only as a source of subsistence products, resting and recreation, never actually living inside them.

Table. 16. Relation of the mangrove products (dimensions and prices Col$ 650=US$1 during 1991) exploited in the Colombian Caribbean coast (INDERENA, 1991).

Department	Product/Dimensions (inch x m)	Price of court Col$	Price at gathering site Col$	Price after sitetreatment Col$
Atlantico	Small Rod (2x15)	100	150	-
	Small Rod (3x6)	150	350	-
	Horcones (3-4x30)	200	600	-
	Post (8x10x8x10)	1,000-1,200	3,500-5,000	8,000-10,000
Bolivar	Rod (3x6)	200	375	-
	Rod (2x5)	100	150	-
	Horcones (3-4x3)	200	500	-
	Post (8x10x8x10)	1,000-1,200	3,500-5,000	8,000-10,000
	Piles (5-8x8)	700-1,000	3,000-3,500	-
Sucre	Rod (3x5-6)	200	300	-
	Horcones (6-8x3-5)	300	500	-
Córdoba	Rod (2-3x5-6)	100-200	200-300	-
	Horcones(5-8x3-5)	300	500-700	-
	Piles (5-8x8)	700-1,000	3,000-3,500	-
	Post (8-10x8-10)	1,000-1,200	3,500-5,000	8,000-10,000

Better soils for agriculture exist throughout the country, therefore substitution of mangrove areas for other human uses has been extremely limited (Prahl *et al.*, 1990). Agriculture close to mangroves occurs in dry soils behind the forests and along river floodplains, of mostly tropical species cultivated with local, indigenous technology. Major cultures are rice, potato, corn, banana, sugar cane, palms, cocoa and other tropical fruits and legumes. Large scale agriculture started in the 18th century, first with corn, and then followed in the 19th by coconut and cocoa. In the beginning of the 20th century, palm, rice, banana and soya bean cultures were introduced.

In the Caribbean, agriculture closest to mangroves are banana, at the Ciénaga Grande de Santa Marta and Urabo Gulf, and rice at the Ciénaga de Tesca and Cispatá Bay, and coconut at Sapsurro Bay. These cultures may affect mangroves, but their impacts have not been evaluated.

8.3 Mining

Mining close to mangroves is restricted to clay exploitation at Cartagena Bay area, resulting in siltation of adjacent areas and increased flux of minerals to the coastal zone due to leaching of mined areas. In the Caribbean coast other mining activities include coal, at Carrejón (Dept. Guajira) and Jagua (Dept. Ceasar); iron-nickel ore at Cerromatoso (Dept. Sucre) and gold in the Cauca River (Dept. Antioquia and Bolivar), these take place far from the littoral, however storage and export through Puerto Bolivar and Cartagena harbors are directly related to mangroves.

In the Pacific coast, mining has drastically decreased the indian population and introduced African working force mainly from Guinea, Congo, Sudan and Angola at the end of the 16th century, up to the end of the Colonization. During this period three important settlements were founded in the higher Atrato and San Juan River basins, high and middle Telembi and Mangui rivers and their tributaries and high and middle rivers crossing the plain between Buenaventura and Guapi.

Although the mining areas are far from mangroves, they had a considerable impact on them, favoring their expansion on the "new" coastal deposits formed at the mouth of these rivers.

8.4 Aquaculture

Aquaculture is highly diversified in Colombia due to a variety of suitable species, the food habits of the coastal populations and the research carried out with many species of molluscs, crustaceans and fish (Alvarez-León, 1992).

In the Caribbean, coastal populations received complete training on the growing of the mangrove oyster *Crassotraea rhizophorae* (Wedler, 1984). Research on all marine shrimp species provided the basis for the present shrimp culture industry in the Cartagena area (Martinez, 1977; Winder, 1992). Since the 80's work started on the culture of mangrove fish like mullets (*Mugil liza* and *M. incilis*); the tarpon *Tarpon atlanticus*, the "mojarras" *Diapterus rhombeus* and *Eugerres plumieri* and the "robalos" *Centropomus ensiferus* and *C. undecimalis* (J.E. Mercado & E. Rodas *pers. comm.*).

Shrimp farming is greatly developed. Most ponds are built adjacent to mangroves in salt flats, sandy plains and mud flats. Impacts are greater during pond construction and stabilization and during the release of nutrient-rich waters. The industry from 1984 to 1991 has covered over 2,054 ha mostly for the culture of the marine species *Penaeus stylirostris* and *P. vannamei* imported from the Pacific coast and from Panamá and Nicaragua.

The freshwater species *Macrobrachium rosenbergii* is also grown but to a much lesser scale (Larsson, 1992).

In the Pacific, experiments were started with the cockles *Anadara similis* and *A. tuberculosa* close to Buenaventura and with the blue crab *Callinectes faxotes*, but with little success (Rodriguez, 1985). With the oyster *Crassostraea columbiensis* however, great success was achieved using floating boxes (Peláez, 1985). The culture of marine shrimps in large ponds after various experimental steps during the 70's started prospering in Tumaco (Dept. Nariño). In this area nearly 1,282 ha of ponds grow the white shrimps *Penaeus stylirostris* and *P. vannamei* (Huang and Chiu, 1980, INPA, 1991).

8.5 Urbanization

The Spanish always avoided building cities in difficult places. However, when pressed by necessity due to lack of proper areas or for military defence reasons, they had to build in difficult areas. Typical examples are Cartagena de Indias in the Caribbean and Buenaventura and Tumaco in the Pacific coast. The three cities were totally surrounded by mangroves.

At the beginning mangroves were an efficient defence for these cities, particularly Cartagena. However, with the growth of the towns, large areas of mangroves were occupied. The situation is most critical in Cartagena where unplanned growth nearly destroyed most mangroves which are now restricted to the islands and margins off Cartagena Bay and Ciénaga de la Virgen. Serious problems of erosion and sedimentation make necessary periodical dredging and cleaning of canals and of beaches.

In Buenaventura and Tumaco presently with 100,000 and 200,000 inhabitants respectively, slower changes and less intensive migration have allowed for survival of the traditional culture involving surrounding mangroves (Prahl *et al.*, 1990).

8.6 Salt pans

The utilization of coastal lagoons, salt flats or the construction of ponds for salt production has spread throughout the Colombian Caribbean, following the artisanal production done by the Guajiro indians Wayú. The National Government founded 25 years ago the companies "Salinas de Colombia" and the "Alcalis de Colombia", to produce and commercialize salt for human consumption.

Artisanal exploitation of salt is carried out by fishermen in Salamanca Island by digging wells or using natural salt deposits which occur between the mangroves and the highway between Barranquilla and Ciénaga. This salt is fed to cattle and horses. In other localized areas, salt is extracted from natural depositional environments such as Laguna Occidental de Chenge, Manaure and Galerazamba. In these areas *Artemia franciscana* is another important resource explored commercially for use in aquaculture.

9. Impacts on the Mangrove Environment

9.1 Human induced stresses

9.1.1 Deforestation of adjacent ecosystems

Anthropogenic changes in adjacent ecosystems can affect the stability and productivity of mangroves. For example, if overfishing occurs along the coast there could be a significant shortage of shrimp and fish of reproductive age with consequent drop of recruitment of larvae and young in coastal lagoons and estuaries. Other impacts such as degradation of coral reefs and seagrass beds due to increased sedimentation (*e.g.* Corales del Rosario Islands); trawling and dynamite fishing or electric wire fishing, may have serious consequences on the integrity of the mangroves. In certain areas in the Caribbean, oyster fishermen cut *Rhizophora* roots to facilitate oyster collection, leaving the tree with considerably less support and exposed to collapse.

Deforestation of adjacent terrestrial areas decreases nutrient input to mangroves and increases sedimentation. Damming waterways for agriculture and cattle farming, results in changes in the watershed's water balance causing less water in summer and floods in winter, with serious consequences to man-made structures and natural vegetation. Various areas in Santa Marta, Barranquilla and Cartagena have been damaged by such activities.

9.1.2 Civil engineering

Hydrological constructions for protection of harbor areas, such as in the Magdalena River estuary, resulted in the closing of channels leading to coastal lagoons and burying of mangrove roots. The lack of prior environmental impact assessment studies resulted in serious impacts on the coastal zone. Typical examples are the construction of roads along the Caribbean, where the importance of free flowing tidal waters between the sea and coastal lagoons were underestimated, resulting in decrease or stoppage of water flow. This led to the collapse of necton communities and massive death of mangroves due to hypersalinity. For example, at Salamanca Islands, creeks, tidal flats and lagoons became progressively more saline. Soil salinity increased from 53 to 151 ppt; creek and lagoon water, from 27 to 56ppt and porewaters from 42 to 130 ppt (Botero, 1990). This salinization resulted in massive death of over 16,460 ha of mangroves mostly *Rhizophora* stands (Gonzalez, 1989).

9.1.3 Erosion, accretion and siltation

Erosive processes in the Caribbean occur along the coastline between Cartagena and Barranquilla. The area is characterized by unstable, mobile beaches, highly affected by winds, waves and currents, losing significant amounts of sand during ebb tides (Correa, 1985). Between Pueblo Viejo and Lomarema, changes in coastal geomorphology from 1947 to 1985 resulted in significant retreat of the coastline nearly 700 m landward. During this period annual erosion rate reached up to 19 $m.yr^{-1}$. Destruction of mangroves due to the lack of physical support occurred throughout the entire area. Between Puerto Soldado and La Boquilla, accretion is dominant resulting in the formation of parallel bars, modelled during the high tide forming many creeks and tidal flats. These areas are excellent environments for the colonization of mangroves. However, the quantities of sediment involved and their major sources are still unknown (Leclerc *et al.*, 1971; Vernette *et al.*, 1984).

In the Pacific excessive accretion also forms bars and ridges parallel to the coast particularly south of Buenaventura. However, the distance between the bars and the coastline is much larger, resulting in the formation of lagoons which trap fine sediments, allowing the formation of extensive mud flats protected from wave action. These are colonized by mangrove seedlings, particularly of *R. mangle*, *R. racemosa* and *R. harrisonii* (Prahl *et al.*, 1990).

9.1.4 Pollution

Major activities that may potentially cause contamination of mangrove ecosystems in Colombia are: - The use of pesticides upstream the mangrove areas such as in the Banana plantation of Ciénaga, Magdalena Department and Urabá, Antioquia Department; rice fields in Ciénaga de la Virgen, Department of Bolivar and Tinajones-Cispatá, Department of Córdoba; African palm in Turbo, Department of Antioquia; and coconut in Sapzurro Bay, Department of Chocó. - Oil spills at harbor areas; the most serious was the spill from the Liberian tanker Saint Peter, that affected mangroves south of Tumaco, as far as Ecuador. - Release of heavy metals (Cr, Al, Zn and Hg) from industry, mining, agriculture, shipyards and domestic wastes. - Release of nutrient-rich waste water and solid wastes from coastal towns, industry, offshore platforms and ships. - Thermal effluent from electricity plants and other industries.

9.2 Impacts from natural stressors

Typical atmospheric phenomena of the Caribbean sea do not reach the Colombian coast. The exception was the Hurricane Joan which reached the coast in October 17th and 18th, 1978, with wind speed of 180 $km.h^{-1}$ and with over 24 hours of continuous rain. Inundation of coastal areas and collapse of trees occurred including various mangrove areas which also suffered severe defoliation.

In the Pacific, tropical storms with winds over 90 $km.h^{-1}$ are frequent and responsible for uprooting mangrove trees in particular *Avicennia germinans* and *A. tonduzii*. High tidal waves also cause sedimentation and erosion of mangrove areas. Such tides can have effects up to 20km inland. The "El Niño" phenomenon also affects the Pacific coast mangroves.

10. Socio-Economic Implications

Exploitation of mangrove resources has been traditionally done at subsistence level (see Table 1). Exploitation for industrial uses started in 1945, with

Table 17. State of scientific and technical knowledge on the Colombian mangrove ecosystems

Geographical area	Scientific and technical knowledge
1. Caribbean coast	
-Ciénaga Grande de Santa Marta	-Forest Structure and productivity, associated organisms, soils, environmental impacts
-Canal del Dique	-Forest structure, environmental impacts, soils
-Bahía de Cartagena	-Forest structure, associated organisms, environmental impacts
-Ciénaga de Tesca	-Forest structure, associated organisms
-Ciénaga de los Vasquez	-Ecology and biology of associated organisms
-Ciénaga Cocoliso	-Forest structure
-Bahía de Cispatá	-Forest structure, associated organisms
2. Pacific coast	
-Parque Nacional Natural Úria	-Forest structure and productivity, associated organisms
-Bahía Buenaventura	-Forest structure and associated organisms
-Bahía de Málaga	-Forest structure and associated organisms
-Parque Nacional Sanquianga	-Forest structure and productivity
-Ensenada de Guapi	-Forest structure
-Bahía de Tumaco	-Forest structure and productivity, associated organisms, environmental impacts

large scale extraction of mangrove bark for tannin production in the Pacific coast. This activity reached its maximum between 1952 and 1968 and then stopped. In the Caribbean industrial exploitation of charcoal and wood shavings started in 1965 and lasted till 1978 when it was banned due to serious impacts on the environment.

Presently, utilization for construction, energy generation and in agriculture (see Table 14) still occurs. INDERENA (1991) reported 350 families living on the extraction of mangrove timber, 110 in the Caribbean and 240 in the Pacific. Since these families average 6 persons each, over 2,760 people are estimated to depend directly on mangrove timber. Also many other people involved in transport, preparation and commercialization depend indirectly on this resource. Income from such activities are unknown since they are very variable depending on timber demand, necessity of treatment etc. (sea Tables 15 and 16). For example, red mangrove poles can be used for over 5 years in civil construction when previously treated or only one year if not. White and black mangrove poles can only be used once without treatment and two to three times when treated (E. Garcia *pers. comm.*).

Other activities such as fishing, hunting, agriculture and aquaculture also benefit from mangroves. Artisanal fishermen are 40,000; 65% of them permanently involved with the activity.

11. Research and Training Programs

The importance of mangrove ecosystems to the Colombian coastline was well expressed by Henry von Prahl *(q.e.p.d.)*:

"No hay más excusas, tenemos que afrontar desde ahora nuestra responsabilidad. Nuestra ignorancia no puede seguir siendo la disculpa. Es fundamental lograr realizar programas lógicos y prácticos en el plazo mas corto posible, porque la responsabilidad de recuperar este ecosistema ya no es tan solo de la naturaleza "

Mangrove research in Colombia has been intermittent, starting with scientists attracted by the spectacular dimensions of these forest (West, 1957; Cuatrecasas, 1958). Later this important research was done by the silviculture group in the early 70's aiming at the utilization of mangrove forests (Sylva Ltda., 1974a,b). Neat management plans were also made in this period but were based on Asian and Venezuelan experiences (Hernán-Oviedo, 1977a,b).

In 1975, a National Course on Mangroves was offered in Cali by the Universidad del Valle and Florida State University (USA). As a result an interdisciplinary group for mangrove research was founded in the Faculty of Sciences, Universidad del Valle. In 1978, the exploitation of mangrove forests in the Caribbean was banned and integrated research on mangroves was started by the National Institute of Renewable Natural Resources (INDERENA), including a UNESCO sponsored Latin American Seminar on Mangroves (Hernández-Camacho *et al.*, 1978; 1980).

The 1976's Saint Peter oil spill, the first large ecological disaster of the Colombian coast, triggered the founding of the Contamination Control Center of the Pacific (CCCP), in Tumaco, which, together with the Institute of Marine Research in Santa Marta, promoted important workshops sponsored by OAE and FAO.

Since 1977, with the promulgation of the National Plans; mangroves, coral reefs and seagrass beds

Table 18. Protection and management zones.

Protective and Managment Zone	Act (Month-Day-Year)	Department
1. Caribbean Coast		
- NNP Isla de Salamanca	Agreement 004 (04-04-64)	Magdalena
- NNP Tayrona	Agreement 004 (04-04-64)	Magdalena
- NRZ Bahía de San Andrés	Resolution (10-21-69)	San Andrés Providencia
- AFR Golfo de Morrosquillo	Resolution 726 (05-31-74)	Sucre - Cordoba
- AFR Golfo de Urabá	Resolution 1130 (10-19-76)	Antioquía Chocó
- FFS Ciénaga Grande de Santa marta	Agreement 029 (05-02-77)	Magdalena
- FFS Los Flamencos	Agreement 030 (05-02-77)	Guajira
- NNP Submarino Islas del Rosario	Resolution 165 (05-02-77)	Bolívar
- AFR Parque Tayrona	Resolution 903 (10-21-77)	Madalena
- SMA Bahía de Cartagena, Canal del Dique y Adjacencia	Decreet 1741 (08-04-78)	Bolívar
- AFR Ciénaga Grande de Santa Marta	Resolution 157 (06-09-78)	Magdalena
2. Pacific Coast		
- NNP Sanguianga	Resolution 161 (05-02-77)	Nariño
- NNP Gorgona	Resolution 141 (07- -84)	Cauca
- NNP Utría	Resolution 190 (10-19-87)	Chocó

AFR: Artisanal Fisheries Reserve; FFS:Flora and Fauna Sanctuary; NNP: National Park;
NRZ: National Reserve; SMA: Special Management Area

Table 19. National Legislation (Administration, handling and protection of forest resources)

Legislation	Contents
Law 037 (Nov.18, 1924)	Transfer benefits of National Forests to the Municipalities of Tumaco and Buenaventura.
Agreement 012 (May 21, 1978)	Addition to the Agreement 03 of 1969 that adopted the Forestry Statute
Law 2811 (Dec. 8, 1978)	National Natural Renewable Resources Code and Environmental Protection
Agreement 029 (Aug. 19, 1975)	Additions and changes in the Forestry Statute
Resolution 1681 (Aug. 19, 1978)	Regulates the exploitation, administration and development of hydrological resources
Resolution 463 (April 21, 1982)	Prohibits taking and commercialization of wood poles
Agreement 013 (April 25, 1984)	Complements the Agreement 20 of 1982 symplifying the process of forestry matter of Agreement 029 of 1975

were considered priority areas. Mangrove research is supported by the COLCIENCIAS and international agencies. A biannual meeting with a specific mangrove section, is the focus for communication of results.

Major ongoing scientific interesting areas were studies are taking place are shown in Table 17. Basic research projects study forest structure, zonation, distribution and succession, while applied research is aimed at the study of the economic utilization of forest products and are restricted to areas of large mangrove cover and of easy access. Studies of the ecology of associated fauna, of productivity, pedology and environmental impact, although still at the beginning have witnessed an impressive boom in recent years.

Major ongoing interdisciplinary research projects include: 1- establish a mangrove data bank, 2- review and evaluate the applicability of environmental impact assessment studies presently required by law, 3- regulation, management and conservation of Colombian mangroves, 4- establishment technical assistance and supervising groups (INDERENA, PAFC, World Bank), 5- Study of the ecology of the Chocó region in the Pacific, 6- selection and creation of protection, preservation and sustainable utilization mangrove sites. Additionally, mangroves are included in the National Plan for Marine Sciences and Technology and the National Plan for Marine Ecosystems presently operational (1990-2000) where productivity and trophic relations are the main research topics (DNP *et al.*, 1990).

12. National Mangrove Committees and National Policies for Mangrove Management

After the 1984 Regional Seminar on Integrated Ordination of Mangrove Zones, supported by FAO (see Table 2), the National Institute for the Renewable Natural Resources and Environment (INDERENA) started the organization of a National Mangrove Committee (NATMANCOM), with the formation of a core commission of three researchers: H. von Prahl, Universidad del Valle (Pacific coast); R. Alvarez-León, PRODECOSTA (Caribbean coast) and D. Yanine-Diaz, INDERENA, in charge of the characterization of such committee. Presently the NATMANCOM is ready to be established.

The NATMANCOM will have, under the National Government, the major aim of formulating the legislation, political, technical and scientific policies on the conservation and sustainable utilization of mangroves in Colombia. The committee will include members of the Ministry of Agriculture, National Department of Planning, INDERENA, COLCIENCIAS, the National Navy, the Maritime Department, and Regional Autonomous Corporations.

The basics for a rational policy on the management and conservation of Colombian mangroves were already suggested by Yanine-Diaz (1991).

- Although mangroves are relatively well represented in National Natural Parks, Refuges, Fauna and Flora Sanctuaries and Special Management Areas (Table 18); it is recommended that protected mangrove areas be enlarged.

- It is recommended that mangroves be put in a higher conservation category due to their ecological importance and functioning. Categories suggested are: Protection Areas, Areas of Public Interest, Forestry and Fisheries Reserve, Areas of Special Management or Areas of Special Protection.

Table 20. National Plan of the Forest Agreement, in effect for execution from 1 to 6 months

Central points / Sub-themes
1. General Reference of the Area
- Location
- Juridical Condition
2. Description of the Forest
- Area
- Species
- Volume to exploit
3. Forest Utilization
- Area
- Inventory
- Calculation of existences
- Indications techniques
* System of letters
* Diameter of letters
* System of extraction
* Transport system
* Way of extraction
* Equipping and personal
* Destiny of the products
4. Industrialization
- Equipping
- Production and efficiency
- Destiny of products and marketable
5. Environmental Effect Declaring of
6. System of recovery or regeneration natural of forest.
7. Annex
- Maps in Scales
- Calculations, graphics, registers.
- Inventory forest

- It is recommended to complete forests inventories of mangroves and their successional stages and suggest substitutes for the exploitation of mangrove products which presently is affecting natural regeneration processes and even destroying some areas.

- To transform into law the banning of exploiting mangroves during successional stages.

- To allow medium and long term forest utilization only when the petition fulfills the present legislation requirements relative to natural resources and the environment, as well as when supported by technical, scientific and environmental impact assessment studies.

INDERENA (1991) recommended that as a short term solution, total prohibition of the use of mangrove species, for the conservation of mangrove resources. The prohibition would find support on Resolution 463 of 1982 (Table 19), which already prohibits the use of mangrove species prior to the full development of the forest stand and also restricts some of the uses (*e.g.* electric power companies agreed to substitute mangrove posts by concrete ones). The prohibition shall last until technical-economical studies define the strategies for sustainable use and management of the mangrove.

In the present legislation (Table 19) a Forest Ordination Plan has to be executed in 1 to 6 months and should include: -basic information on the project area; -description of the forest; -forest uses; -industrialization level; -plans for the recuperation of the area (Table 20).

With the aim of mapping the present state of mangrove areas of the country, INDERENA (1991) organized a diagnostic survey of the natural regeneration of mangroves according to different stages: seedlings (20-150 cm in height); scrub (150-300 cm) and forest (trees with DBH >15cm).

The results showed that the seedlings stage had 20,300 seedlings.ha^{-1} in the Pacific coast and 12,625 seedlings.ha^{-1} in the Caribbean, well above the critical limit given by FAO (1981) of 1,000 seedlings.ha^{-1}. The best areas for recuperation were found in the Departments of Valle, Cauca, Córdoba and Sucre. In the Pacific, seedlings were significantly taller than in the Caribbean (0.77 vs. 0.59 cm respectively).

The scrub stage in the Pacific coast had 1,655 stems.ha^{-1} and 1,149 stems.ha^{-1} in the Caribbean. Again well above the critical limit of FAO (1981) of 280 stems.ha^{-1}. The best developed areas were in the Departments of Valle and Córdoba. Mean stem height in the Pacific reached 380 cm whereas in the Caribbean it reached 230 cm. However, the extraction of sticks and piles results in many dwarf mangrove stands.

The forest stage is also better developed in the Pacific (244 trees.ha^{-1}) than in the Caribbean (197 trees.ha^{-1}). On both coasts they are represented by trees which have been left by loggers due to inadequate height or trunk deformities. The two coasts presented tree densities smaller than the critical limit of 280 trees.ha^{-1} established by FAO (1981).

Additionally, it is worth mentioning the replanting experiments carried on in the Colombian Caribbean. In the Isla de Salamance Park in 1984 and 1985, experiments were carried out with transplanting of seedlings (M. Moreno *pers. comm.*). In Isla Grande (Isla del Rosario Archipelago) in 1986 with growing hypocotyls (Bohoquez and Prada, 1986), and an ongoing (1992-1993) project in Canal del Dique (D. Gonzalez *pers. comm.*). All these experiments resulted in great success and shall be used massively in any impacted mangrove area.

Finally, the National Government, through INDERENA and within the National Parks System, acknowledging the importance of the protection of such key ecosystems, has created 14 protection areas (Table 18) where mangroves are directly or indirectly included.

13. Acknowledgements

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Annex 1. Associate flora and fauna in the root systems of the mangroves of Colombia.

Taxa	Caribbean	Pacific
CHLOROPHYTA		
Ulvaceae		
Enteromorpha compressa	x	-
E. flexuosa	x	-
E. lingulata	x	-
E. ramulosa	x	-
Ulvaria oxysperma	-	x
Cladophoraceae		
Cladophora albida	-	x
C. delicatula	x	-
C. graminea	-	x
Chaetomorpha californica	-	x
Rhizoclonium riparim	-	x
Codiaceae		
Bodleopsis verticilata	-	x
Siphonocladaceae		
Cladophoropsis adhaerens	-	x
Dasycladaceae		
Acetabularia crenulata	x	-
Bryopsidaceae		
Bryopsis pennata	x	-
B. plumosa	x	-
B. phiniosa	-	x
Caulerpaceae		
Caulerpa sertularioides	x	-
C. taxifolia	x	-
Codiaceae		
Halimeda tuna	x	-
PHAEOPHYTA		
Dictyotaceae		
Dictyota adnata	-	x
D. ciliolata	x	-
D. dichotoma	x	-
Padina crispata	-	x
Ectocarpaceae		
Ectocarpus confervoides	x	-
RHODOPHYTA		
Sphacelariaceae		
Sphacelaria furcigera	-	x
Rhodomelaceade		
Acanthophora spicifera	x	-
Laurencia obtusa	x	-
L. papillosa	x	-
Lophosiphonia cristata	x	-
Polysiphonia nigrescens	x	-
P. ramientacea	x	-
P. subtilissima	x	
Rhabdoniaceae		
Catenella caespitosa	-	x
C.impudica	-	x
Delesseriaceae		
Caloglossa leprieurii	-	x
C. ogasawarensis	-	x
C. stipitata	-	x
Rhodomelaceae		
Bostrychia calliptera	-	x
B. kelanensis	-	x
B. radicans	-	x
B. tenella	-	x
Ceramiaceae		
Antithamnionella antilbrum	-	x
A. breviramosa	-	x
Ceramium fastigiatum	x	-
C. nitens	x	-
C. procumbens	-	x
Gelidiaceae		
Gelidium bulae	-	x
G. pusillum	x	x
Ceramiaceae		
Spyridea aculeata	x	-
S. filamentosa	x	-
Hypneaceae		
Hypnea cornuta	x	-
H. spinella	x	-
Corallinaceae		
Lithothamnium calcareum	x	-
Lithophyllum daedaleum	x	-
Derbesiaceae		
Derbesia osterhoutii	x	-

Annex 1. (Continued)

Taxa	Caribbean	Pacific
PORIFERA		
Spongiidae		
Hyatella intestinalis	x	-
Microcionidae		
Microciona prolifera	x	-
Clionidae		
Cliona lobata	x	-
C. vastifica	x	-
Lissodendoryx isodiactylis	x	-
Haliclonidae		
Haliclona hogarthi	x	-
H. implexiformis	x	-
H. manglaris	x	-
H. rubens	x	-
Dysideidae		
Dysidea etheti	x	-
Aplysillidae		
Aplysilla gracilis	x	-
Geodiidae		
Geodia papyracea	x	-
Mycalidae		
M. arndt	x	-
Clathriidae		
Rhaphidophlus juniperinus	x	-
Halichondriidae		
Halichondria magniconulosa	x	-
H. meladonocia	x	-
COELENTERATA HYDROIDA		
Eudendriidae		
Calyptospadix coerulea	x	-
Myrionema hargitii	x	-
Plumularidae		
Halopteris diaphana	x	-
Plumularia halecioides	x	-
P. margaretta	x	-
Campanularidae		
Clytia cylindrica	x	-
C. gravieri	x	-
Obelia bicuspidata	x	-
O. dichotoma	x	-
Halucordylidae		
Halocordyle disticha	x	-

Taxa	Caribbean	Pacific
Haleciidae		
Halecium halecium	x	-
Sertulariidae		
Dynamena crisioides	x	-
Sertularia halecioides	x	-
Thyroscyphus ramosus	x	-
ANTHOZOA		
Actiniidae		
Bunadosoma grameliferum	x	-
Stoichactiidae		
Stiochactis helianthus	x	-
Aiptasiidae		
Aiptasia pallida	x	-
Poritidae		
Porites porites	x	-
BRYOZOA		
Vesiculariidae		
Amathea vidovici	x	-
A. distans	x	-
Membraniporidae		
Conopeum seurati	x	-
Beanidae		
Beania kuglei	x	-
POLYCHAETA		
Orbinidae		
Scoloplos ohlini	-	x
Chaetopteridae		
Spiochaetopterus costarum	-	x
Polynoidae		
Harmothoe aculeata	x	-
Lepidonotus variabilis	x	-
Thormora taeniata	-	x
Nereidae		
Cerathonereis miriabilis	x	-
Neathes acuminata	x	-
N. galathea	-	x
N. succinea	x	-
Nereis pelagica occidentalis	x	-
Nereis riisei	x	-
N. succinea	x	-

Annex 1. (Continued)

Taxa	Caribbean	Pacific
Perinereis anderssoni	x	-
P. floridana	x	-
Platynereis dumerilii	x	-
Eunicidae		
Eunice afra	x	-
E. filamentosa	x	-
E. mutilata	x	-
Lysidice collaris	-	x
L. ninetta	x	-
Marphysa aenea	x	-
M. sanguinea	x	-
Hesionidae		
Hesione picta	x	-
Dorvilleidae		
Dorvillea sociabilis	x	-
Glyceridae		
Glycera abranchiata	-	x
Nephtydae		
Nephtys monroi	-	x
Lysaretidae		
Oenone fulgida	-	x
Trichobranchiidae		
Terebellides stromii	-	x
Cirratulidae		
Cirriformia filigera	x	-
Terebellidae		
Streblosoma bairdi	x	-
Pista palmata	x	x
Terebella rubra	x	-
Sabellidae		
Branchionma bairdi	x	-
B. nigromaculata	x	-
Hypsicomus elegans	x	-
Megaloma lobiferum	x	-
M. pacifica	x	-
Sabella melanostigma	x	-
S. micropthalma	x	-
Sabellastarte magnifica	x	-
Serpulidae		
Hydroides dirampha	x	-
H. parvus	x	-
H. sanctaecrusis	x	-
Spirabranchus tetraceos	x	-
Vermiliopsis annulata	x	-

Taxa	Caribbean	Pacific
Spionidae		
Polydora websteri	x	-
Syllidae		
Branquiosyllis oculata	x	-
Haplosyllis spongicola	x	-
Syllis cornuta	x	-
S. (Typosyllis) corallicoides	x	-
Trypanosyllis gemmipara	x	-
Phyllodocidae		
Nereiphylla fragilis	x	-
MOLLUSCA		
Polyplacophora		
Ischnochitonidae		
Ischnochiton pseudovirgatus	x	-
I. striolatus	x	-
Chitonidae		
Chiton tuberculatus	x	-
Pelecypoda		
Mytellidae		
Brachiodontes citrinus	x	-
B. domingensis	x	-
B. exustus	x	-
Ischadium recurvum	x	-
Musculus lateralis	x	-
Lithophaga aristata	x	-
L. bisulcata	x	-
Isognomonidae		
Isognomon alatus	x	-
I. bicolor	x	-
I. janus	-	x
I. radiatus	x	-
Pteriidae		
Pinctada radiata	x	-
Pteria colymbus	x	-
Ostreidae		
Crassostrea columbiensis	-	x
C. rhizophorae	x	-
Lopha frons	x	-
Ostrea equestris	x	-
O. permollis	x	-
Dreissenidae		
Congeria sallei	x	-

Annex 1. (Continued)

Taxa	Caribbean	Pacific	Taxa	Caribbean	Pacific
Anomiidae			Thaidae		
Anomia fidenas	-	x	*Thais haemastoma floridana*	x	-
Pododesmus foloiatus	-	x	*T. kiosquiformis*	-	x
Chamidae			*T. trinitatensis*	x	-
Chama macerophylla	x	-	Nassariidae		
Petricolodae			*Nassarius albus*	x	-
Rupellaria typica	x	-	*N. wilsoni*	-	x
Pholadidae			Melongenidae		
Martesia striata	x	x	*Melongena melongena*	x	-
Teredinidae			Strombidae		
Bankia destructa	x	-	*Strombus pugilis*	x	-
B. fimbriartula	x	-	Modulidae		
B. gouldi	-	x	*Modulus modulus*	x	-
Gastropoda			Potamididae		
Fissurellidae			*Batillaria minima*	x	-
Diodora cayenensis	x	-	Triphoridae		
D. dysoni	x	-	*Triphora nigrocincta*	x	-
Fissurella angusta	x	-	Crepidulidae		
Neritidae			*Crepidula convexa*	x	-
Nerita scabricosta	-	x	*Crucibulum auriculata*	x	-
N. tessellata	x	-	Cymatiidae		
Neritina virginea	x	-	*Cymatium pileare*	x	-
Theodoxus luteofasciatus	-	x	Buccinidae		
Acmeidae			*Cantharus tinctus*	x	-
Acmaea pustulata	x	-	Columbellidae		
Littorinidae			*Anachis obesa*	x	-
Littorina angulifera	x	-	*Mitrella lunata*	x	-
L. fasciata	-	x	*M. dichroa*	x	-
L. nebulosa	x	-	*Nassarina monilifera*	x	-
L. scabra aberrans	-	x	*Nitidella variegata*	x	-
L. varia	-	x	Marginellidae		
L. zebra	-	x	*Gibberula lavalleeana*	x	-
Cerithiopsidae			Turridae		
Cerithiopsis greeni	x	-	*Strictispira paxillus*	x	-
Cerithiidae			*Pilsbryspira hardfordiana*	x	-
Alabama incerta	x	-	Haminoeidae		
Cerithium algicola	x	-	*Haminoea succinea*	x	-
C. lutosum	x	-	Bullidae		
Diastoma varium	x	-	*Bulla striata*	x	-
Calyptraeidae			Melampidae		
Crepidula plana	x	-	*Elloium stagnalis*	-	x
Muricidae			*Marinula concinna*	-	x
Murex antillarum	x	-	*Melampus carolinus*	-	x
M. woodringi	x	-	*M. cofeus*	x	-

Annex 1. (Continued)

Taxa	Caribbean	Pacific	Taxa	Caribbean	Pacific
M. olivaceus	-	x	*P. pandaliformis*	x	-
M. tabogenses	-	x	*Periclimenis americanus*	x	-
Ampullariidae			*P. atlanticus*	x	-
Ampullaria porphyrostomus	x	-	*P. caribicus*	x	-
Fasciolariidae			*P. longicaudatus*	x	-
Fasciolaria tulipa	x	-	*P. maxillulidens*	x	-
Latirus mcgintyi	x	-	Alpheidae		
Leucozonia nassa	x	-	*Alpheus cristulifrons*	x	-
			A. floridanus	x	-
CRUSTACEA			*A. heterochaelis*	x	-
Cirripedia			*A. paracrinitus*	x	-
Chtamalidae			*A. viridari*	x	-
Chtamalus angustitergum	x	-	*Synalpheus apiocerus*	x	-
C. fragilis	x	-	*S. fritzmuelleri*	x	-
C. proteus	x	-	*S. longicarpus*	x	-
Euraphia rhizophorae	x	-	*S. minus*	x	-
Balanidae			*S. scaphoceris*	x	-
Balanus amphitrite niveus	x	-	Hippolytidae		
B. eburneus	x	-	*Hippolyte curacaoensis*	x	-
B. improvisus	x	-	*H. zostericola*	x	-
Megabalanus tintinnabulum	x	-	*Latreutes antiborealis*	-	x
Lepadidae			*L. fucorum*	x	-
Lepas anserifera	x	-	*L. parvulus*	x	-
Isopoda			*Thor manningi*	x	-
Exocorallanidae			Sicyoniidae		
Exocoralla triconis	x	-	*Sicyonia laevigata*	x	-
E. quadricornis	x	-	Stenopodidae		
Cirolanidae			*Stenopus hispidus*	x	-
Cirolana parva	x	-	Porcellanidae		
Limnoriidae			*Megalabrachium roseum*	x	-
Limnoria quadripunctata	x	-	*Pachycheles chacei*	x	-
Sphaeromatidae			*P. serratus*	x	-
Paracerceis caudata	x	-	*Petrolisthes armatus*	x	-
Sphaeroma terebrans	x	-	*P. galathinnus*	x	-
Ligiidae			*P. Jugasus*	x	-
Ligia exotica	x	-	Caemobitidae		
Tanaidacea			*Caenobita clyppeatus*	x	-
Paratanaidae			Diognidae		
Leptochelia forresti	x	-	*Calcinus tibicen*	x	-
Decapoda			*Clibanarius antillensis*	x	-
Palaemonidae			*C. cubensis*	x	-
Leander ternuicornis	x	-	*C. sclopitarius*	x	-
Palemon northropi	x	-	*C. tricolor*	x	-

Annex 1. (Continued)

Taxa	Caribbean	Pacific
C. vittatus		
Processidae		
Processa fimbriata	x	-
Paguridae		
Pagurus brevidactylus	x	-
P. maclaughlinae	x	-
Xanthidae		
Cataleptodius floridanus	x	-
Eurytium limosum	x	-
E. tristuni	-	x
Eurypanopeus depressus	x	-
E. transversus	-	x
Hexapanopeus angustifrons	x	-
H. caribbaeus	x	-
H. nicaraguensis	x	-
Leptodius agassizii	x	-
Neopanope packardii	x	-
Menippe mercenaria	x	-
M. nodifrons	x	-
Micropanope granulimanus	x	-
M. spinipes	x	-
M. truncatifrons	x	-
Panopeus bermudesnsis	x	-
P. chilensis	-	x
P. crassa	x	-
P. hartii	x	-
P. herbstii	x	-
P. lacustris	x	-
P. occidentalis	x	-
P. purpureus	-	x
P. typica	x	-
Pilimnus dasypodus	x	-
P. reticulatus	x	-
Rhithropanopeus harrisii	x	-
Majidae		
Calloedes gibbosus	-	x
Macrocoeloma trispinosum	x	-
M. villosum	-	x
Maiopsis panamensis	-	x
Microphrys bicornutus	x	-
Mithax caribbaeus	x	-
M. coryphe	x	-
M. holderi	x	-
M. forceps	x	-
M. pleuracanthus	x	-
Notolopas lamellatus	-	x
Pelia mutica	x	-
Podochela angulata	-	x
P. grossipes	x	-
Stenorynchus seticornis	x	-
Gonodactylidae		
Gonodactylus oestedii	x	-
Pinnotheridae		
Pinnotheres angelicus	-	x
P. ostreum	x	-
Porturridae		
Callinectes sapidus	x	-
Grapsidae		
Aratus pisonii	x	x
Cyclograpsus integer	x	-
Goniapsis cruemtuta	x	-
Glyptugrapsus impressus	-	x
Grapsus cruentatus	x	-
Metasesarma rubripes	x	-
Pachugrapsus gracilis	x	-
P. traversus	x	x
Sesarma angustum	-	x
S. aeguatoriale	-	x
S. cinereum	x	-
S. curacawensis	x	-
Sholometopus miersi	x	-
S. occidentulis	-	x
S. rhizophorae	-	x
S. ricordi	x	-
ECHINODERMATA		
Ophiuroidea		
Ophiactidae		
Ophiactis savignyi	x	-
Ophiotrichidae		
Ophiothrix angulata	x	-
CHORDATA		
Ascidiacea		
Gtyelidae		
Botryllus complanata	x	-

Annex 2. Associate fauna in the canopy of Colombian mangroves

Taxa	Caribbean	Pacific
MOLLUSCA		
Gastropoda		
Littorinidae		
Littorina fasciata	-	x
L. scabra aberrans	-	x
L. varia	-	x
L. zebra	-	x
Anomiidae		
Anomia fidenas	-	x
Semelidae		
Leptomya ecuadoriana	-	x
Pholadidae		
Martesia striata	-	x
Teredinidae		
Bankia gouldi	-	x
INSECTA		
Collembola		
Axelsonia littoralis	-	x
Isotomurus palustris	-	x
Halachorutes schusteri	-	x
Rapoportella manzanoae	-	x
Coleoptera		
Poecilips rhizophorae	-	x
Diptera		
Anopheles albimanus	-	x
A. apinacula	-	x
A. aquasalis	-	x
A. neivai	-	x
A. nuneztovari	-	x
A. punctimaculata	-	x
AVES		
Pelecanidae		
Pelecanus o. occidentalis	x	-
P. o. carolinensis	x	-
Phalacracuracidae		
Phalacrocorax olivaceus	x	x
Fregatidae		
Fregata magnificens	x	x
Ardeidae		
Casmerodius albus	-	x
C. albus egretta	x	-
Egretta thula	-	x
E. thula thula	x	-
E. caerula	-	x
Hydranassa tricolor	-	x
H. tricolor ruficolis	x	-
Butorides striatum	x	x
Bubulcus ibis ibis	x	x
Nyctanassa violacea	x	-
N. riolacea caliginis	-	x
Tigrisoma l. lineatum	x	x
T. mexicanum	x	x
Anatidae		
Cairina moschata	x	x
Cathartidae		
Catharthes aura	-	x
C. aura aura	x	-
C. b. burrovianus	x	-
Coragyps atratus	x	x
Pandionidae		
Pandion haliaetus	x	x
Accipitridae		
Buteo magnirostris insidiatrix	x	-
Butagalius anthracinus	x	-
B. subtilis	-	x
Elanoides fortificatus	-	x
Lencopternis princeps	-	x
L. semiplumbea	-	x
Falconidae		
Falco peregrinus anatun	x	-
F. sparverius	-	x
F. sparverius isabellinus	x	-
Scolopacidae		
Numenius phaeopus	-	x
N. phaeopus hudsonicus	x	-
Psittacidae		
Amazona autumnalis	-	x
A. farinosa	-	x
Aratinga pertinax		
aeruginosa	x	-
Plonus maestruus	-	x
Pionopsitta pulchra	-	x
Trochilidae		
Amazilia tzacate	-	x
Lepidopyga gandotluminosa	x	-

Annex 2. (Continued)

Taxa	Caribbean	Pacific
Alcedinidae		
Ceryle alcyon	x	-
C. torquata	-	x
C. torquata torquata	x	-
Chloroceryle aenea	x	x
C. amazona	-	x
C. americana	-	x
C. americana isthmea	x	-
Ramphastidae		
Pteroglosssus sanguineaus	-	x
Icteridae		
Quiscalus mexicanus	x	x
REPTILLA		
Sauria		
Iguanidae		
Basiliscus basiliscus	-	x
B. galerictus	-	x
Iguana iguana	x	x
Serpentes		
Colubridae		
Chironicus gradisquamis	-	x
Boidae		
Boa constrictor	x	x
Trahyboa boulengeri	-	x
Viperidae		
Bothros atrox	-	x
B. nasuta	-	x

Taxa	Caribbean	Pacific
MAMMALIA		
Chiroptera		
Artibens jamaicensis	-	x
Carollia perspicillata	-	x
Desmodus rotundus	x	x
Glossophaga soricina	x	x
Leytonycteris nivalis	x	x
Macropnylum macrophlum	x	x
Molussus molossus	x	-
Noctilis leporinus	x	x
Uroderma bilobatum	x	-
U. magnirostrum	x	-
Edentata		
Myrmecophagidae		
Tamandua mexicana	-	x
Marsupialia		
Chironectes minimus	-	x
Didelphis marsupialis	-	x
Primates		
Alouatta seniculus	x	-
Aotus trivirgatus	x	-
Cebus albifrons	x	-
Sanguinus oedipus	x	-
Artiodactyla		
Odocoileus virginianus	x	-
Carnivora		
Procyon cancrivorus	-	x
P. lotor	x	-

Annex 3. Fauna of mangrove mud flats, mangrove waters and neighboring land and water habitats

Taxa	Caribbean	Pacific
MOLLUSCA		
Pelecypoda		
Arcidae		
Anadara grandis	-	x
A. similis	-	x
A. tuberculosa	-	x
Corbiculidae		
Polymesoda inflata	-	x
Veneridae		
Chione subrugosa	-	x
Protothaca asperrima	-	x
P. grata	-	x
Semelidae		
Leptomya ecuadoriana	-	x
Corbulidae		
Corbula inflata	-	x
C. ovulata	-	x
Gastropoda		
Modulidae		
Modulus catenulatus	-	x
M. disculus	-	x
Cerithiidae		
Cerithium stercusmuscarum	-	x
Potamididae		
Cerithidea mazatlanica	-	x
C. montagnei	-	x
C. pulchra	-	x
C. valida	-	x
Rhinocoryne humboldti	-	x
Naticidae		
Natica unifaciata	-	x
Muricidae		
Muricanthis radix	-	x
Thaididae		
Thais biserialis	x	-
Melongenidae		
Melongena melongena	x	-
M. patula	-	x
Strombus gigas	x	-
S. pugilis	x	-

Taxa	Caribbean	Pacific
CRUSTACEA		
Decapoda		
Alpheidae		
Alpheus mazatlanicus	-	x
Automare delichognatha	-	x
Processidae		
Ambidexter panamensis	-	x
Sicyonidae		
Sicyonia disdorsalis	-	x
Penaeidae		
Penaeus brasiliensis	x	-
P. californiensis	-	x
P. natialis	x	-
P. schmitti	x	-
P. stylirostris	-	x
P. vannamei	-	x
Coenobitidae		
Coenobita compressus	-	x
Diogenidae		
Clibanarius albidigitus	-	x
C.panamensis	-	x
Porcellanidae		
Petrolisthes armatuus	-	x
P. lindae	-	x
P. nobili	-	x
P.' zacae	-	x
Callianasidae		
Callianasa branneri	-	x
Lepidophthlmus sinuensis	x	-
Dromidae		
Hypoconcha panamensis	-	x
Drippidae		
Ethusa ciliatifrons	-	x
E. lata	-	x
Ilicantha hancocki	-	x
Leucosiella jurinei	-	x
Percephone towsendi	-	x
Calappidae		
Hepatus kossmani	-	x
Portunidae		
Arenaeus mexicanus	-	x
Callinectes arenatus	-	x
C. bocourti	x	-

Annex 3. (Continued)

Taxa	Caribbean	Pacific
C. danae	x	-
C. sapidus	x	-
C. toxotes	-	x
Cronius tumidulus	x	-
Charibdis helleri	x	-
Portunus acuminatus	-	x
P. iridescens	-	x
P. panamensis	-	x
P. tuberculatus	-	x
P. xantusii	-	x
Goneplacidae		
Chasmocarcinus latipes	-	x
C. longipes	-	x
Cryptoplax panamensis	-	x
Speocarcinus ostrearicola	-	x
Pinnotheridae		
Pinniza valerii	-	x
Grapsidae		
Goniopsis pulchra	-	x
Glyptograpsus impressus	-	x
Gecarcinidae		
Cardisoma crassum	-	x
C. guanhumi	x	-
Gecarcinus quadratus	-	x
Ocypodidae		
Uca argillicola	-	x
U. batuenta	-	x
U. beebei	-	x
U. brevifroms	-	x
U. burgersi	x	-
U. deichmanni	-	x
U. dorotheae	-	x
U. festae	-	x
U. g.-galapagensis	-	x
U. g. herradurensis	-	x
U. heteropleura	-	x
U. inaequalis	-	x
U. intermedia	-	x
U. latimanus	-	x
U. leptodactyla	x	-
U. maracoani insignis	-	x
U. minax	x	-
U. ornata	-	x
U. orstedi	-	x
U. saltitanta	-	x
U. stenodactylus	-	x
U. stylifera	-	x
U. termipedis	-	x
U. thayeri umbratila	-	x
U. vocator	x	-
U. vocator ecuadoriensisi	-	x
U. zacae	-	x
Ucides cordatus	x	-
U. cordattus occidentalis	-	x
Squillidae		
Cloridopsis dubia	-	x
Squilla aculcata aculcata	-	x
S. bifrons	-	x
S. mantoidea	-	x
S. panamensis	-	x
S. parva	-	x
Palinuridae		
Panulirus argus	x	-
PISCES		
Agnatha		
Myxinidae		
Branchiostoma caribeum	x	-
Chondrichthyes		
Carcharhinidae		
Carcharhinus leucas	x	-
C. porosus	x	-
Sphyrnidae		
Sphyrna tiburo vespertina	-	x
Urolophidae		
Urotrygon aspidurus	-	x
U. asterias	-	x
U. venezuelae	x	-
Dasyatidae		
Dasyatis guttata	x	-
Myliobatidae		
Aetobatus narinari	x	x
Ostheichthyes		
Elopidae		
Elops saurus	x	x

Annex 3. (Continued)

Taxa	Caribbean	Pacific
Megalopidae		
Tarpon atlanticus	x	-
Albulidae		
Albula vulpes	x	-
Muraenidae		
Echidna nocturna	-	x
Muraena clapsydra	-	x
Ophichthiidae		
Ophichthus callaensis	-	x
O. zaphochir	-	x
Clupeidae		
Ilisha furthii	-	x
Lile stolifera	-	x
Odonthognathus compressus	x	-
Engraulidae		
Anchoa ischana	-	x
A. nasus	-	x
A. panamensis	-	x
A. parva	x	-
A. spinifer	x	-
Cetengraulis edentulus	x	-
C. mysticetus	-	x
Chararacidae		
Hoplias malabaricus	x	-
Ariidae		
Ariopsis bonillai	x	-
Arius herzbergi	x	-
A. multiradiatus	-	x
A. proops	x	-
A. troscheli	-	x
Bagre marinus	x	-
B. panamensis	-	x
B. pinnimaculatus	-	x
Batrachoididae		
Batrachoides manglae	x	-
B. pacifici	-	x
Deactor dowi	-	x
Gobiesocidae		
Gobiesox adustus	-	x
Ophiidae		
Lepophidium prorates	-	x
Hemirhamphidae		
Hyporhamphus roberti	x	-
H. unifaciatus	x	x

Taxa	Caribbean	Pacific
Belonidae		
Strongylura marina	x	-
S. scapularis	-	x
Atherinidae		
Atherinella brasiliensis	x	-
Hubbesia gilberti	-	x
Poeciliidae		
Gambusia affinis	x	-
Poecilia gilli	x	-
P. sphenops	x	-
Sygnathidae		
Oestethus brachyurus	x	-
Centropomidae		
Centropomus ensiferus	x	-
C. nigriscens	-	x
C. pectinatus	x	-
C. paralelus	x	-
Serranidae		
Epinephelus itajara	x	-
E. labriformis	-	x
Carangidae		
Caranx hippos	x	-
C. latus	x	-
Oligoplites mundus	-	x
O. palometa	x	-
O. saurus	x	-
Lutjanidae		
Lutjanus apodus	x	-
L. argentiventris	-	x
L. synagris	-	x
Lobotiodae		
Lobotes surinamensis	x	-
Gerreidae		
Diapterus auratus	x	-
D. peruvianus	-	x
D. rhombeus	x	-
Eucinostomus argenteus	-	x
E. gula	x	-
Eugerres periche	-	x
E. plumieri	x	-
Haemulidae		
Conodon nobilis	x	-
Haemulon aurolineatum	x	-
Pomadasys crocro	x	

Annex 3. (Continued)

Taxa	Caribbean	Pacific
P. corvinaeformis	x	-
P. leusiscus	-	x
P. macracanthus	-	x
Sciaenidae		
Bairdiella ronchus	x	-
Cynoscion phoxocephalus	x	-
Menticirrhus americanus	x	-
M. panamensis	-	x
Paralonchurus goodei	-	x
Stellifer erycimba	-	x
S. furthi	-	x
S. venezuelae	x	-
Umbrina coroides	x	-
Cichlidae		
Petenia kraussi	x	-
Mullidae		
Pseudopenaeus grandisquamis	-	x
Pomacentridae		
Abudefduf concolor	-	x
A. troscheli	-	x
A. saxatilis	x	-
Eupomacentrus otophorus	x	-
Chaetodontidae		
Chaetodon ocellatus	x	-
Mugilidae		
Mugil cephalus	-	x
M. curema	x	x
M. incilis	x	-
M. liza	x	-
M. trichodon	-	x
Labridae		
Halichoeres dispilus	-	x
Blennidae		
Hypsoblennius piersoni	-	x
Lupinblennius dispar	x	-
Clinidae		
Paraclinus fasciatus	x	-
Gobiidae		
Bathygobius andrei	-	x
B. ramosus	-	x
B. soporator	x	-
Gobioides broussoneti	x	-
Gobionellus boleosoma	x	-
G. manglicola	-	x
G. microdon	-	x
G. oceanicus	x	-
G. sagittula	-	x
Gobiomorus maculatus	-	x
Gobiosoma paradoxum	-	x
G. spes	x	-
Lophogobius cyprinoides	x	-
Eleotridae		
Dormitator maculatus	x	x
Eleotris amblyopsis	x	-
E. picta	-	x
Microdesmidae		
Microdesmus affinis	-	x
M. dipus	-	x
M. dorsipunctatus	-	x
M. intermedius	-	x
M. knappi	-	x
M. retropinnis	-	x
Trichiuridae		
Trichirus lepturus	x	-
Bothidae		
Citharichthys gilberti	-	x
C. spilopterus	x	-
Ciclopsetta querna	-	x
Soleidae		
Achirus achirus	x	-
A. lineatus	x	-
A. mazatlanus	-	x
Trinectes paulistanus	x	-
Cynoglossidae		
Symphurus elongatus	-	x
S. plagusia	x	-
Tetraodontidae		
Arothron hispidus	-	x
Sphoeroides annulatus	-	x
S. greelei	x	-
S. testudineus	x	-
S. spengleri	x	-
REPTILIA		
Testudinata		
Chelydridae		
Chelydra serpentina	-	x

Annex 3. (Continued)

Taxa	Caribbean	Pacific	Taxa	Caribbean	Pacific
Kinosternidae			Dasyproctidae		
Kinosternon leucotomun	-	x	*Dasyprocta punctuta*	x	x
Sauria			Hydrochaeridae		
Ignanidae			*Hydrocheris h. hydrochaeris*	x	-
Anolis notofolis	-	x	*H. h. isthimus*	x	-
Serpentes			Echimyidae		
Hydrophiidae			*Hoplomys gymnurus*	-	x
Pelamis platurus	-	x	*Proechimys semispinosus*	-	x
Crocodilia			Carnivora		
Crocodylidae			Mustelidae		
Caiman crocodilus	x	x	*Eira barbata*	-	x
C. sclerops	x	-	*Gallectis vittata*	-	x
Crocodylus acutus	x	x	*Lutra longicaudalis*	-	x
			L. longicaudalis colombiana	x	-
MAMMALIA			Felidae		
Marsupialia			*Felis onca*	x	x
Didelphidae			*F. pardalis*	-	x
Chironetes minimus	-	x	*F. wiedii*	x	-
Didelphis marsupialis	-	x	*F. yagouarondi*	x	-
Rodentia					

Annex 4. Associated and related vegetation with the mangrove ecosystems of Colombia

Taxa	Caribbean	Pacific
ASSOCIATES		
Acrostichum aureum	x	x
Ardicia granatensis	-	x
Batis maritima	x	-
Conostegia polyandra	-	x
Cyperus spp	x	x
Dalbergia sp	-	x
Dichaea panamensis	-	x
Dietichlis spicata	x	-
Euterpe cuatrecaciana	-	x
Guzmania musaica	-	x
Mulleria fritescensa	x	-
Musa paradisiaca	-	x
Pavonia rhizophorae	-	x
Phryganocydia uliginosa	x	-
Rhabdadenia biflora	x	-
Rustra occidentalis	-	x
Sesuvium portulacastrum	x	-
Tillandsia sp	-	x
Traxillaria sp	-	x
Tuberostylis rhizophorae	-	x
Typha latifolia	x	-
Vriessia gladioliflora	-	x
TRANSITION ZONES SPECIES		
Anona glabra	x	-
Apeiba sp	-	x
Campnosperma panamensis	-	x
Carapa sp	-	x
Cassipourea polyantha	-	x
Ceiba pentandra	x	-
Coccoloba uvifera	x	-
Coccus nucifera	x	-
Cyperus spp	x	-
Dialyanthera sp	-	x
Erythrena glauca	x	-
Ficus sp	-	x
Hibiscus populneus	x	-
H. tiliaceus	-	x
Irianthera sp	-	x
Lecythis minor	x	-
Lemaireocercus griseas	x	-
Manicaria sp	-	x
Mora megistosperma	-	x
Miconia sp	-	x
Opuntia wendiana	x	-
Oriza latifolia	-	x
Pachira acuatica	-	x
Panicum barbinode	-	x
Prioria copaifera	-	x
Prosopis juliflora	x	-
Symphonia sp	-	x
Tabebuia palustris	-	x
Tetrapteris subaptera	-	x
Tococa guianensis	-	x
Tovamita sp	-	x
Tuberostylis axilliaris	-	x
Typha domingensis	x	-
Virola sp	-	x
Wedelia brasiliensis	-	x
Zamia sp	-	x
INLETS, ESTUARIES,.MARSHES, BAYS		
Cerataphyllum sp	x	-
Cynodon dactylodon	x	-
Cyperus ligularis	x	-
Eichornia azureus	x	-
E. crassipes	x	-
Halophila baillonis	x	-
Halodule wrightii	x	-
Hymenachne amplexicaulis	x	-
Juncus roemerianus	x	-
Lemna minor	x	-
Limnocharis flava	x	-
Marsilia polycarpa	x	-
Najas sp	x	-
Pitia stratiotes	x	-
Salvinia sp	x	-
Spartina patens	x	-
Sporobolus virgineus	x	-
Syringodium filiforme	x	-
Thalassia testudinum	x	-

Annex 4. (Continued)

Taxa	Caribbean	Pacific	Taxa	Caribbean	Pacific
Alcedinidae			MAMMALIA		
Ceryle alcyon	x	-	Chiroptera		
C. torquata	-	x	*Artibens jamaicensis*	-	x
C. torquata torquata	x	-	*Carollia perspicillata*	-	x
Chloroceryle aenea	x	x	*Desmodus rotundus*	x	x
C. amazona	-	x	*Glossophaga soricina*	x	x
C. americana	-	x	*Leytonycteris nivalis*	x	x
C. americana isthmea	x	-	*Macropnylum macrophlum*	x	x
Ramphastidae			*Molussus molossus*	x	-
Pteroglosssus sanguineaus	-	x	*Noctilis leporinus*	x	x
Icteridae			*Uroderma bilobatum*	x	-
Quiscalus mexicanus	x	x	*U. magnirostrum*	x	-
			Edentata		
REPTILLA			Myrmecophagidae		
Sauria			*Tamandua mexicana*	-	x
Iguanidae			Marsupialia		
Basiliscus basiliscus	-	x	*Chironectes minimus*	-	x
B. galerictus	-	x	*Didelphis marsupialis*	-	x
Iguana iguana	x	x	Primates		
Serpentes			*Alouatta seniculus*	x	-
Colubridae			*Aotus trivirgatus*	x	-
Chironicus gradisquamis	-	x	*Cebus albifrons*	x	-
Boidae			*Sanguinus oedipus*	x	-
Boa constrictor	x	x	Artiodactyla		
Trahyboa boulengeri	-	x	*Odocoileus virginianus*	x	-
Viperidae			Carnivora		
Bothros atrox	-	x	*Procyon cancrivorus*	-	x
B. nasuta	-	x	*P. lotor*	x	-

Status and Uses of Mangroves in the Republic of Panamá

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1. Historical Background

The Republic of Panamá has mangrove forests on both the Pacific and Caribbean coasts. There are 1,697 km of coastline in the Pacific and 1,160 km in the Caribbean.

Resources derived from mangroves have been utilized from pre-colombian times to the present. Presently, some forest products from mangroves are widely utilized in rural constructions, also as sticks in horticultural crops and they are still used for the extraction of tannin. Also, an increasing scientific literature documents the importance that had the fishing of euryhaline species from mangrove bordered estuaries and channels for pre-colombian human settlements located at or near the central coast of Panamá, probably 5,000 years ago (Cook and Ranere, 1992). The existing archaeological data reveal that people from these settlements fished estuarine and coastal species such as Ariidae, Carangidae, Clupeidae, Sciaenidae, and Batrachoididae using fences, harpoons, fishhooks and other primitive devices.

Presently, fishing activities derived from species related to mangrove bordered estuaries range from artisanal fisheries based on euryhaline species fished near the coast, to the fishing industry that exploits the penaeid shrimps resource that include several species with life cycles related to the mangroves (D'Croz and Kwiecinski, 1980), they represent nearly 90% of the fishing income of the country.

In spite of all the historic, archaeologic and biologic evidence that focus on the importance of mangroves for the Panamanian society these forests continue to be one of the biological communities subject to the strongest anthropogenic pressure. There are historical records of mangrove deforestation, mostly for reclamation of land for agriculture, cattle raising, urban development, and most recently for penaeid shrimp farming. The extraction of forest products is somehow disordered and with little or no technical orientation. Nevertheless, in spite of this there are some promising signs, including a few concrete actions from the governmental side and also from non-government organizations, that are concerned with the fate of mangroves in Panamá.

2. Extent and Distribution

Although most studies indicate that Panamá has near 5,000 km^2 of mangrove forests (Saenger *et al.*, 1983; Letourneau and Dixon, 1984; Rollet, 1986), the evaluation of the national mangrove surface by remote sensing carried out by the Instituto Geografico Nacional Tomy Guardia (IGNTG) (Anguizola and Cedeño 1988, Anguizola *et al.*, 1989), suggests that mangrove surface in the country is significantly smaller than the values reported earlier. The results from the surveys carried out by the IGNTG, are summarized in Table 1 and the location of major mangrove areas of the country is shown on Fig. 1.

The inventory from the IGNTG indicates that there are approximately 2,000 km^2 of mangrove in the country, including nearly 200 km^2 of salt-flats, known as "albinas". This evaluation, seems to be more accurate than the previously published ones. Most mangroves are located in the Pacific coast, in particular in the Gulfs of San Miguel and Chiriqui where they cover 464.89 and 446.88 km^2 respectively. In the Caribbean coast the mangroves cover 60 km^2, and half of this is concentrated at the Province of Bocas del Toro. Mangroves are the principal forests in the brackish areas in the Pacific coast of Panamá and are mainly composed by the red mangrove (*Rhizophora mangle* and *R. brevistyla*) whose trees are among the tallest (30-40 meters). Almost monospecific stands of red mangrove are formed along the deltas and river's mouths where semidaily tides fluctuate between 2 to 6 meters. Stands of black mangrove (*Avicennia germinans* and *A. bicolor*), white mangrove (*Laguncularia racemosa*), mora (*Mora oleifera*), and "castaño" (*Montrichardia arborescens*) develop along the gradient of salinity at the mouth of rivers. Other species are also important within the structure of the forest on the Pacific side, such as the "mangle piñuelo" *Pelliciera rhizophorae*. Along most of the Caribbean red mangrove predominates with trees less than 5m tall, arranged into a slender fringe. Less abundant are the white mangrove (*L. racemosa*)

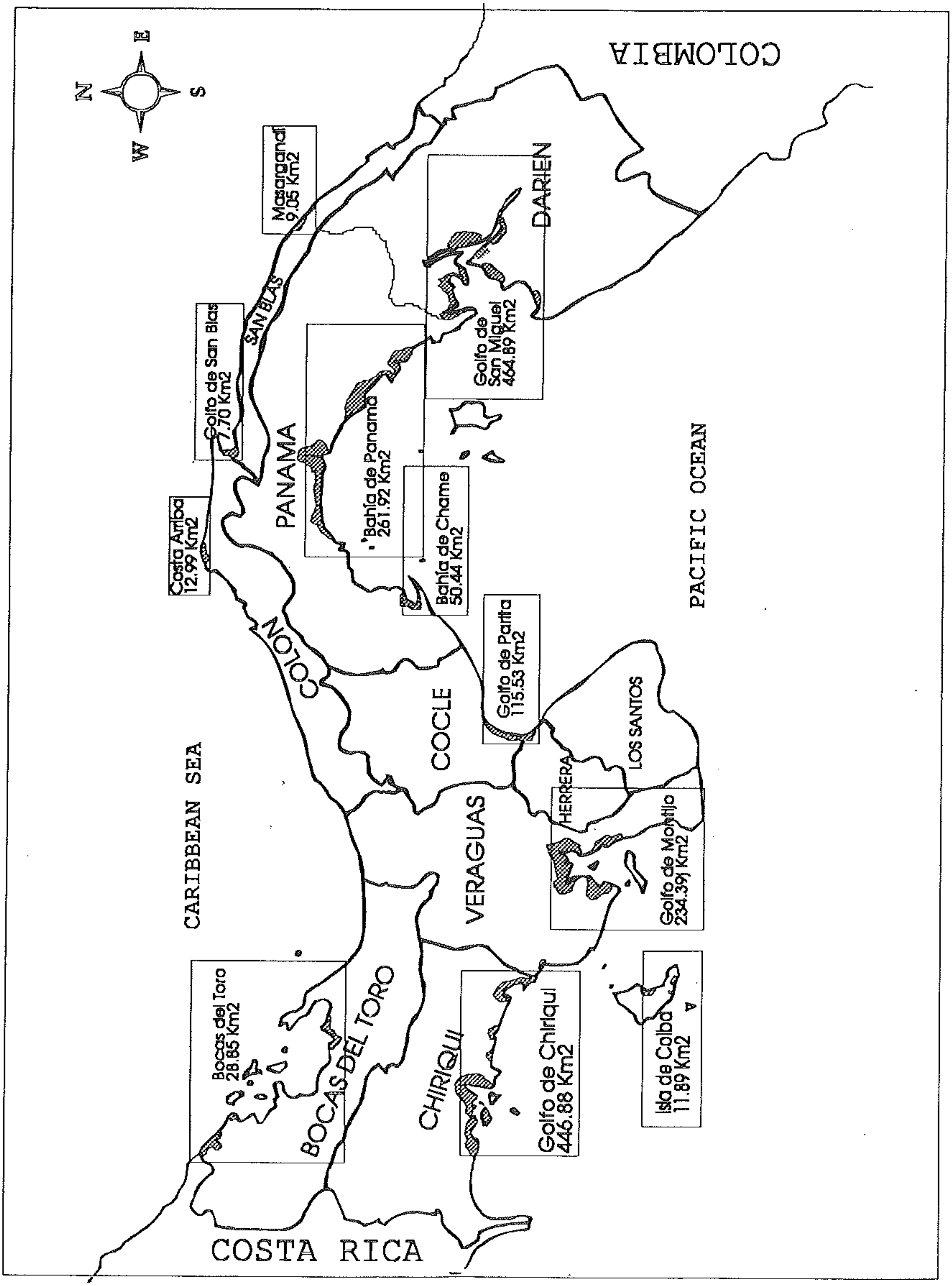

Fig. 1. Mangrove distribution in the Republic of Panamá

Table 1. Mangrove areas (km²) in the Republic of Panamá according to Instituto Geográfico Nacional Tomy Guardia (1988).

Site	Present surface	Converted surface	Salt flats
Chiriquí Gulf	446.88	17.48	0.0
Coiba Island	11.89	0.0	0.0
Montijo Gulf	234.39	12.82	0.0
Azuero Peninsula	62.13	0.34	4.77
Parita Bay	115.53	4.01	166.18
Chame Bay	50.44	3.48	9.56
Panamá Bay	261.92	5.77	0.0
Las Perlas Archipelago	1.61	0.0	0.0
San Miguel Gulf	464.89	0.0	7.12
Total Pacific coast	1,649.68	43.90	187.63
Bocas del Toro	28.85	0.0	0.0
Coast North of Colón	12.99	1.23	0.0
San Blas Gulf	7.70	0.0	0.0
South of San Blas Gulf	9.05	0.0	0.0
Total Caribbean coast	58.59	1.23	0.0
Total	1,708.27	45.13	187.63

"Converted areas" refers to former mangrove areas presently used for other purposes; see section 8 for details.

with canopies higher than the red mangrove. However, mangrove forests at the western extreme of the Caribbean coast of Panamá are much more developed.

3. Physical Setting

According to the National Atlas of the Republic of Panamá (IGNTG, 1988), the position of the Intertropical Convergence Zone (ITCZ) is one of the factors that influences more strongly the rainfall on the Isthmus of Panamá. The ITCZ is formed by the convergence of winds from both hemispheres. A strip of weak and variable winds, masses of cumuliform clouds and frequent and intense rains are generally associated to the ITCZ. Rainfall pattern on the isthmus is related to the position of the ITCZ, which is determined by the direction and intensity of the winds. In general, the ITCZ covers the isthmus between May and December, leading to the rainy season. Between January and April, the northern winds move the ITCZ southward, producing the dry season. This seasonality on the rains is highly marked in the coast of the Pacific. However, the Caribbean coast stands out for a greater uniformity in rainfall throughout the year, although maxima and minima rainfall coincide with the general pattern of the isthmus.

The precipitation over the country varies between 1,000 to 7,000 mm per year (Fig. 2). In the west coast of the Gulf of Panamá the annual precipitation is around 1,070 mm. In the eastern section, and in particular in the area of Chimán where extensive mangrove forests exist, the precipitation is almost 3,000 mm. In the Gulf of Montijo, where a large mangrove cover also exists, the precipitation is over 3,000 mm while in the coast of the Gulf of Chiriquí, rainfall fluctuates between 2,500 and 3,000 mm. In the Caribbean coast, maximum rainfall is nearly 6,000 mm and particularly in the area of Bocas del Toro, coincident with a significant mangrove cover. However, most of the coastal rainfall ranges between 2,000 and 4,000 mm.

The continental runoff from the isthmus flows toward both the Pacific and the Caribbean coasts. The division line is formed by a mountain chain that spreads from the east to the west. The Pacific side occupies 70% of the surface of the country, while the Caribbean accounts for 30% (IGNTG, 1988). Rivers are short, on average they are 106 km long on the Pacific and 56 km on the Caribbean watershed respectively, and their courses are generally perpendicular to the coast. Total annual runoff for the isthmus of Panamá is 4,570 $m^3.s^{-1}$ and approximately the 60% of this value drains toward the Pacific coast (Fig. 3).

Runoff that affects the mangroves on the Pacific side is highly variable. According to the National Atlas, the mangroves in the Bay of Parita and at Chame receive the least runoff of the Pacific side (less than 500 mm/year and 500-700 mm/year respectively). Large formations of mangroves on the Pacific coast, as those in Chiriquí and Darién, receive between 1,000 and 2,000 mm/year. The largest runoff that affects mangroves on the Pacific coast of Panamá occurs in the Gulf of Montijo (2,000-3,200 mm/year). Mangroves of Bocas del Toro, in the Caribbean, also receive high annual runoff (2,000-3,200 mm).

The mangroves of the isthmus are subject to tidal oscillations that are very different between the coasts of the Pacific and the Caribbean. In the Pacific coast tides are semi-diurnal, with wide amplitude (6 m) and predictable. This tidal amplitude generates estuaries where the tidal effect is evident for several kilometers upstream. On the contrary, tides in the Caribbean coast are diurnal, with narrow amplitude (0.5 m), irregular and thoroughly influenced by meteorological conditions.

Other environmental factors affecting the distribution of the mangroves are coastal currents. In the Caribbean eastward currents predominate whereas in the Pacific they are mostly westward. The marine sediments which prevail in the Pacific coast are composed of sand and mud whereas the Caribbean coast exhibits abundant coral formations.

4. Biological and Ecological Characteristics

The available information on the characteristics of the mangrove forests of Panamá is scattered. Among the available information is that by Mayo (1965) and Golley *et al.* (1975) on the mangroves of Darién. The following description of the Panamanian mangroves is summarized from this later work.

Golley *et al.* (1975) indicate that the principal forest community in the brackish areas of the Pacific side of Panamá are formed by the red mangrove (*Rhizophora* spp.) with trees among the tallest in the world (30-40 m). Almost pure stands of this mangrove species are formed along deltas and rivers, where tides oscillate between 2 and 6 meters. Communities of the black mangrove (*Avicennia germinans*), "alcornoque" (*Mora oleifera*) and "castaño" (*Montrichardia arborescens*) develop along the gradient of salinity in rivers and estuaries in Darién.

The canopy of the forest is relatively open and only 50% of the surface is covered by branches and leaves. Tree density in Darién, with DBH greater than 10 cm ranges from 300 to 400 $trees.ha^{-1}$. The reported basal area reaches 13.5 $m^2.ha^{-1}$. The maximum tree height encountered for mangroves was 41 meters.

In the Caribbean, the islands near to the coast and the bays support a thin fringe of red mangrove (*Rhizophora mangle*) of little growth. The stands are in general shorter than 5 meters tall and with short aerial roots. Less abundant are the stands of white mangrove (*Laguncularia racemosa*), although they are taller than the red mangrove (Golley *et al.*, 1975). Exceptions are the mangrove forests at the other extreme of the Caribbean of Panamá (Bocas del Toro) which are much more developed. A FAO report prepared by Letourneau and Dixon (1984) describes the Chame and Chepo mangroves. According to these authors the mangroves of Chame are of "low quality" due to unfavorable conditions of rain and runoff. Nevertheless, Letourneau and Dixon (1984) indicate that the forest is ecologically stable. The area of Chepo has large stands of red mangrove "which spreads several kilometers to the back of the Chepo River".

Concerning the mangroves from Chiriquí, a report by D'Croz and Del Rosario (1986) pointed out that there are near 10,000 ha of halophyte vegetation, mainly mangroves, in the lower basin of the Chiriquí River. Most of this cover is composed by mangrove trees, predominantly the red mangrove *Rhizophora mangle* and the "mangle piñuelo" *Pelliciera rhizophorae*. Also present are the "alcornoque" *Mora oleifera*, the black mangrove *Avicennia germinans*, the white mangrove *Laguncularia racemosa* and the giant fern *Acrostichum aureum*. Approximately 3,000 ha are red

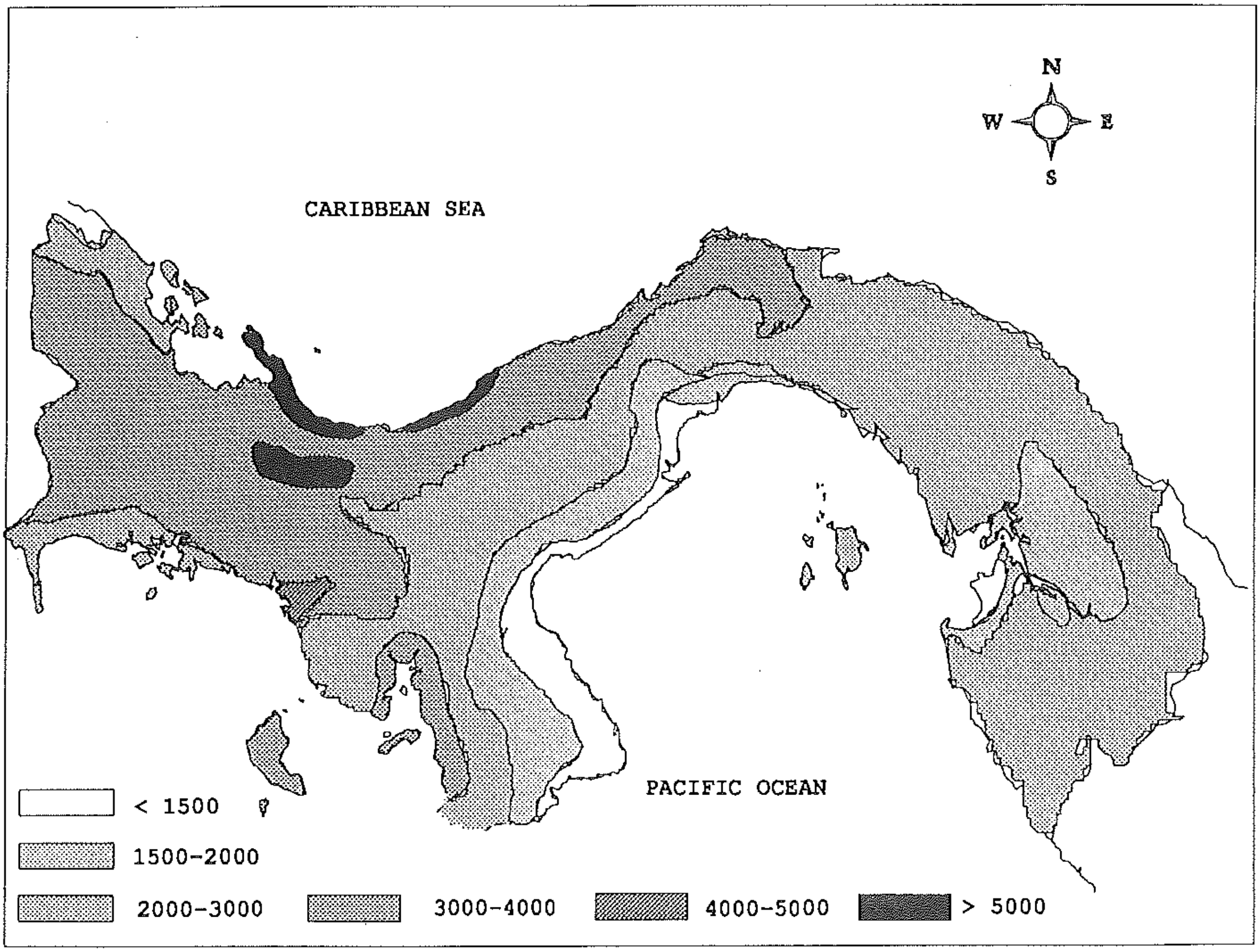

Fig. 2. Annual rainfall (mm) in the Republic of Panamá (IGNTG, 1988).

mangrove with canopy heights ranging from 10 to 20 meters. The stands of *Pelliciera* generally have canopies ranging from 5 to 15 meters in height and frequently encircled by red mangrove trees. These stands cover almost 3,000 ha and the highest canopies are predominantly adjoining the terrestrial vegetation. Nearly 3,500 ha are mixed stands of *Rhizophora* and *Pelliciera*. The structure of the forest is of riverine type. Since there is no topographical barrier, high tides flood all the area, which probably explains the absence of species zonation.

The major Panamanian experience on the ecological value of the mangroves is related to their function as nursery sites for animal species of commercial value and to their contribution to the organic output into the coast. It is well-known that the coasts bordered with mangrove have populations of juvenile stages of aquatic marine and brackish water species which spend part of their life among the mangrove roots, searching for food and protection. These organisms are protected by the great quantity of roots from the red mangrove (*Rhizophora* spp.) that provides efficient shelter.

Numerous species of penaeid shrimps from the Pacific coast of Panamá are found in the mangrove channels and estuaries as juveniles (Table 2). The three species of white shrimps (*P. occidentalis, P. stylirostris* and *P. vannamei*) are the most abundant in tidal mangroves (D'Croz and Kwiecinski, 1980). These shrimps were spawned offshore and reach the coast as post-larvae (approximately 12 mm long). They live in the mangroves for a period of 4 to 5

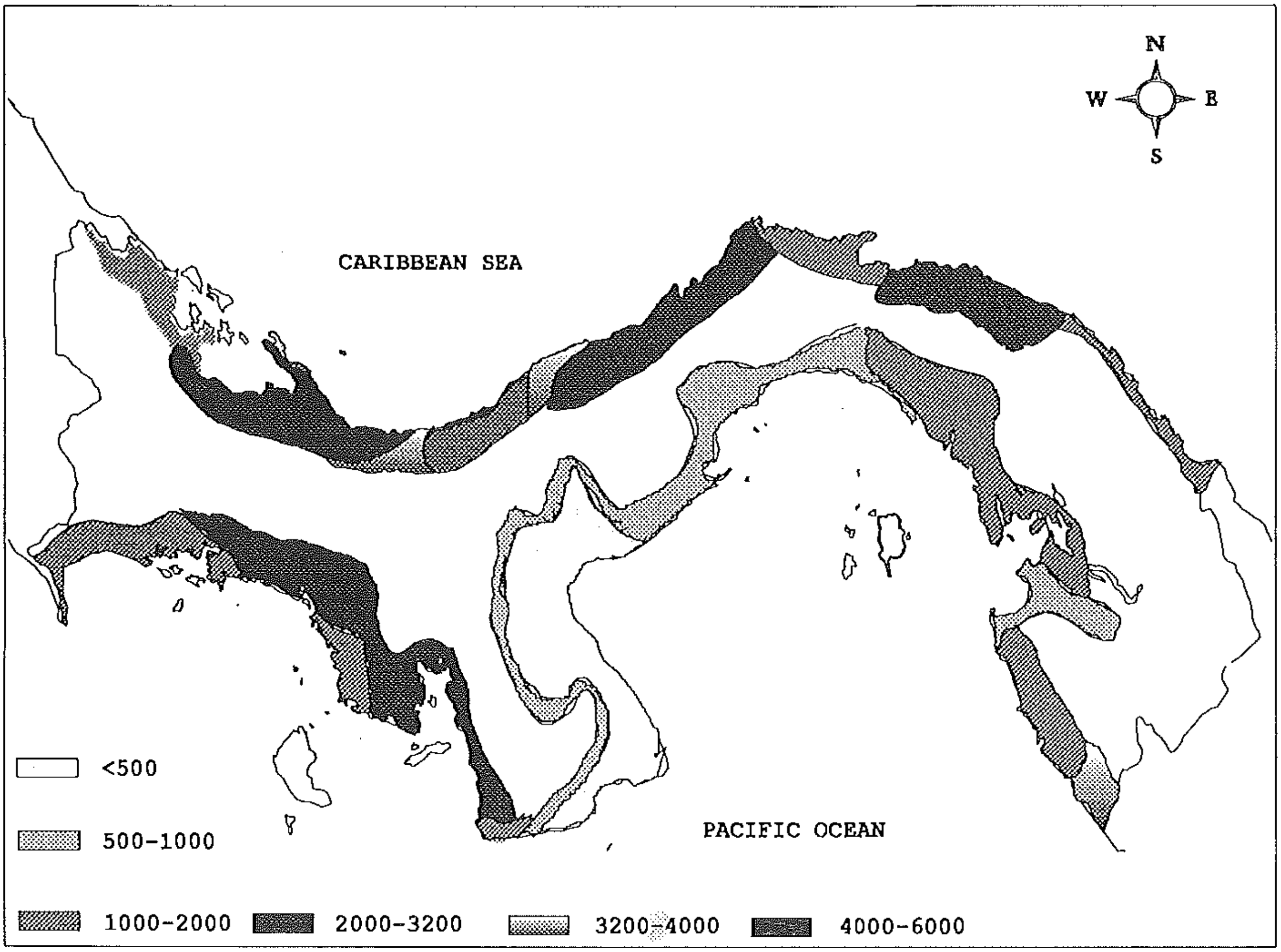

Fig. 3. Annual runoff (mm) to the coastal areas of the Republic of Panamá (IGNTG, 1988).

months. After which they migrate toward the ocean where they complete their life cycles. When they leave the estuary they are between 50 to 80 mm long.

Presently numerous small farms that cultivate shrimps along the Pacific coast, obtain their "seed" (postlarvae) from adjacent estuaries and mangroves.

Over 30 fish species have been reported to be associated to mangroves from the Pacific coast during their juvenile stages. The most common are *Mugil curema, Eucinostomus californiensis, Centropomus armatus, C. nigrescens, C. robalito* and *C. uninensis, Lutjanus aratus* and *L. argentiventris* and *Micropogon altipinnis*. A detailed discussion on the fish species using mangroves and estuaries along the Pacific coast has already been published (D'Croz and Kwiecinski, 1980; D'Croz, 1985).

Information regarding the Caribbean coast is more scarce. Cubit *et al.* (1975) reported the pink shrimp *Penaeus duorarum* to inhabit tidal creeks and small bays of the mangroves of Colón. This study reported that artisanal fishermen find along the mangrove fringe of brackish lagoons; sardines, mullets, anchovies and sharks among others. These reports suggest that mangroves have a similar ecological role along both coasts. In addition to the fish, Cubit *et al.*, (1985) also reported crocodile species (*Crocodilus acutus* and *Caiman crocodilus fuscus*) and iguanas (*Iguana iguana*) inhabiting the Caribbean mangroves of Panamá.

Preliminary studies on mangrove productivity in Panamá showed that annual litter production varies from 900 g.m^{-2} for the mangroves of Chame, to 2,000 g.m^{-2} for the highly developed mangroves of the Chiquirí River (D'Croz, 1985; D'Croz and Del Rosario, 1986). Mangrove litter is transformed in the soil and water into food material by microorganisms and small invertebrates and is eventually consumed by adjacent marine and estuarine fauna. This transformation process has been studied in Panamá by Golley *et al.* (1975) and D'Croz *et al.* (1989). These studies showed that under biological action, mangrove litter loses fibers, lignin, tannic acids which are undigestible to the marine fauna and shows an increase in nitrogen and phosphorus associated with proteins, resulting in a progressive increase of its nutritional value (Fig. 4).

5. Associated Ecosystems

Panamá has coral reefs along both coasts. However, only along the Caribbean they are associated with mangroves. Along the Pacific, coral reefs develop offshore, close to islands far from the influence of the heavy load of terrestrial sediments.

Along the Caribbean coast of Panamá over 250km of reefs occur parallel to the coastline. These reefs are at a post-climax stage and are frequently associated with mangroves forming a typical *Rhizophora-Thallassia*-coral association. Coral reefs are best developed along the Colón region, between Margarita Island and Minas Bay, in Bocas del Toro and San Blas. The reefs are composed of about 50 species of hermatipic corals, 16 species of anhermatipics and 4 species of *Millepora*.

6. Human Settlements and Traditional Uses

There is little information on human settlements in the mangroves of Panamá. However, the Action Plan for Tropical Forests of the Republic of Panamá (PAFT-PAN, 1990) reports the existence of nearly 1,000 families which depend solely on mangrove resources. These families are located mostly along the Pacific coast.

7. Commercial Exploitation

The major importance of mangroves in Panamá is related to their value in forestry and fishery. According to Letourneau and Dixon (1984), under optimal conditions, natural red mangrove stands have 200-300 m^3.ha^{-1} of timber. Whereas regenerated stands can produce from 8 to 10m^3.ha^{-1}.y^{-1}, with annual diameter growth of 0.5 to 0.6 cm in the first 25 years. Major mangrove products are: fuelwood and charcoal of very good quality, dense, fine grained wood for planks, posts, poles and high quality tannin.

In general however, utilization of mangroves as a source of raw materials is somewhat limited in Panamá. Primitive extraction and production methods seem to be responsible for the low utilization, production and profitability of mangrove products. Forest production of mangroves of Panamá is shown

Table 2. Penaeid shrimp species commercially fished in the Pacific coast of Panamá, according to D'Croz y Kwiecinski (1980).

Species	Depth of catches (ft)	% of total catches	Estuarine stage
Penaeus occidentalis	3-15	34.0-40.5	+
Penaeus stylirostris	3-15	1.9-2.25	+
Penaeus vannamei	3-15	1.9-2.25	+
Penaeus brevirostris	30-45	25.00	+
Xiphopenaeus rivetti	**	27.50	-
Protrachypene precipua	**	?	-
Trachypenaeus byrdi	**	2.70	+
Trachypenaeus faoea	**	?	+
Solenocera agassizi	45-60	0.18 - 1.86	-

(** in brackish waters close to estuaries) on Table 3. Although the activity is considered as of subsistence, it does support an important portion of the population living in rural areas. The most used mangrove species are red and black mangroves. Trees are felled and cut in 4 to 12m pieces. Roots are also cut to help securing mangrove poles during the transport to the estuary where the timber is loaded in small boats and transported to adjacent human settlements for sale.

Bark is generally extracted only from large trees of *Rhizophora* (DBH >40cm) and is mainly located at the Chiriquí Province. Until June, 1983 Panamá exported over 720 tons of bark yearly to Costa Rica. In 1986, average bark production for local consumption was over 430 tons, delivered to 14 tanneries located in the Provinces of Chiriquí, Herrera and Los Santos.

It is estimated that about 70% of the rural population in Panamá depends on fuel wood as the major energy source. Mangroves of Chiriquí produce from 2 to 3 million wood piles for fuel (Table 4). Using trees with diameter between 6 to 14 cm and height from 3 to 8 m. According to INRENARE (1988) demand for this product was 2.1 million in 1983, equivalent to 1,000 m^3 of mangrove wood. Charcoal production in mangroves occurs mainly in the regions of Azuero, la Chame and Chepo. The most used species are red and white mangroves. Production in 1986 reached 118,200 bags, equivalent to 1,087,440 kg (INRENARE, 1988).

Poles production for use in agriculture occurs mostly in Azuero, Capira and Chame and is approximately of 8,780 units per year. In recent years this production is on the decrease.

Table 4 summarizes major subsistence products from the mangroves of Panamá as well as the number of people involved in the production.

Regarding the inter-dependence of fisheries resources with mangroves, it is known that out of 9 or 10 species of shrimps, forming the shrimp resource of the Pacific coast, six of them are found as juveniles in mangroves and estuaries; the white shrimps *Penaeus occidentalis, P. stylirostris* and *P. vannamei*; the red shrimp *P. brevirostris* and the "carabali" shrimps *Trachypenaeus byrdi* and *T. faoea*. Additionally, two species of seabob shrimps (*Xiphopenaeus riveti* and *Protrachypene precipua*) are commonly found in coastal waters in front of mangroves and close to estuaries bordered by mangroves. Therefore, nearly all shrimp species of economic importance along the Pacific coast of Panamá are to some extent associated with mangroves. Only one species, *Solenocera* spp., which represents less than 10% of the total catches, is not associated with mangroves. Shrimp fisheries in Panamá is the most important fishery activity and produces incomes varying from 60 to 70 million dollars per year.

Another important fishery of Panamá is the anchovies (*Centengraulis mysticetus*). This species is used in the production of fish meal. According to Bayliff (1966) juvenile anchovies are pelagic being found in deeper waters from January to March. In April, as an adult, they approach the coast, in particular in the muddy and shallow (< 10m) areas. The areas of largest anchovies catches in the Gulf of Panamá, correspond to the coast with most mangrove cover and mangrove bordered estuaries (D'Croz and Kwiecinski, 1980). Largest catches are from Chame, Bayano and Gulf of San Miguel, areas of extensive mangroves with large detritus input which may be important as food to the detritivorous adult anchovies. These observations suggest that organic debris from mangroves may be of great importance to the life cycle of anchovies. Bayliff (1986) reports that reproduction of anchovies occurs in shallow, sometimes brackish waters, in particular along the coast of Juan Diaz and Panamá Viejo. Economical benefits from this important fishery may reach up to 20 million dollars per year.

Apart from these commercially exploited species, an important fraction of the artisanal fisheries are associated with estuarine and mangrove species, in particular snappers (*Lutjanus* spp.), corvinas (*Micropogon altipinnis*) and robalos (*Centropomus spp.*). Estimates for the year 1980, showed that each kilometer of coastline covered by mangroves along the Panamá Bay, produced benefits of nearly US$ 100,000 per year (D'Croz and Kwiecinski, 1980).

8. Conversion to Other Uses

Mangrove areas converted to other uses in Panamá have been estimated by Anguizola and Cedeño (1988) to reach 5,647 ha. Major converted areas are located in the Sona District, Veraguas Province (1,345 ha) and in the Chiriquí Province (2,157 ha). These areas are presently used for agriculture and cattle growing (Table 5).

Although the dominant trend is a reduction of mangrove cover, in some areas small increases of

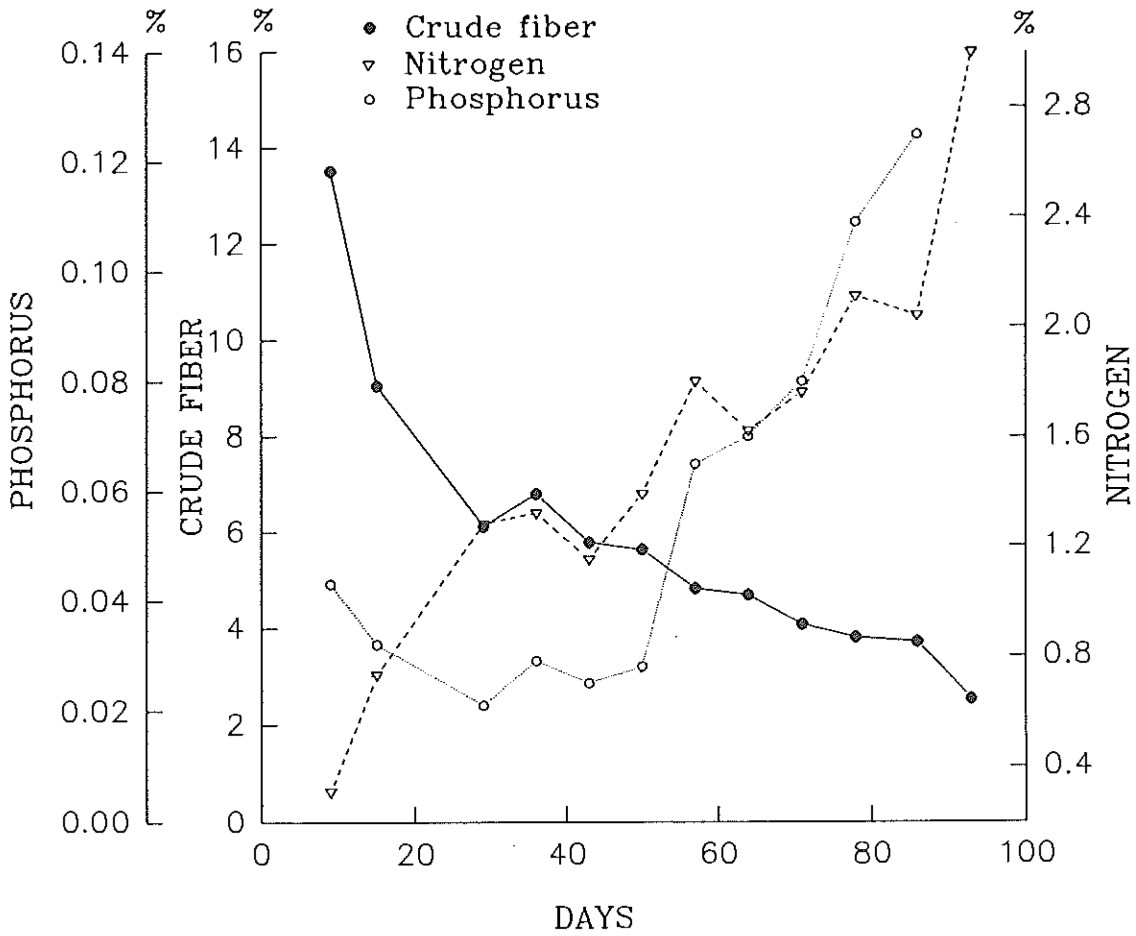

Fig. 4. Chemical Changes of *Rhizophora mangle* leaves during decomposition in the Bay of Panamá

mangrove forests have been documented. A survey done by IGNTG (1988) showed an increase of 135 ha of mangroves in Parita Bay, close to the estuary of the Boca Estero de Palo Blanco River, and between the mouth of the Anton River (La Uva estuary) and the Charco Los Camarones Bay (70 ha).

Approximately 47% of the converted mangrove areas are presently used for agriculture, notwithstanding the low fertility of the mangrove soils. An important fraction of these converted areas remain as non-vegetated lands subject to inundation and approximately 22% of converted mangrove areas are used for extensive cattle growing of very low productivity (Anguizola *et al.*, 1989).

Regarding pressure from urbanization, the mostly affected mangroves were those located close to Panamá City, converted to urban settlements, in particular the mangroves of Juan Diaz, located west of the city. However, the Ministry of Housing, with the help of the Institute of Renewable Natural Resources (INRENARE) and other institutions, had established an effective policy for the conservation of mangrove stands in the City's surrounding area.

9. Environmental Impacts

Some developmental activities have resulted in negative impacts on mangroves. According to the Action Plan for Tropical Forests of the Republic of Panamá (PFT-PAN, 1990), mangrove cover prior to 1960 reached approximately 300,000 ha. Presently however, most recent estimates (IGNTG, 1988) show a total mangrove cover of approximately 176,000 ha. These estimates suggest that mangrove deforestation caused the decrease. However, it is important to confirm this information.

The decrease in mangrove cover seems to be restricted to the Pacific coast, in particular along the

Table 3. Volume and surface of mangroves affected by forestry activities in the Republic of Panamá, according to INRENARE, (1988).

Product	Site	Annual production	Required timber	Surface
Charcoal	Chame	75,000 bags	4,726,071	26.3
	Azuero	43,200 bags	2,722,217	15.1
	Total	118,200 bags	7,448,288	41.4
Fuel wood	Chiriquí	2,100,000 to 3,411,792 units	1,766 to 1,087	14.3-23.2
Bark	Chiriquí Montijo Gulf and Parita	9,600 kg	954.1 (wood) 143.1 (bark)	66.7
Sticks	Azuero	266,000 units	16,125.695	211.6
Poles	Chame			
	Azuero	8,780 units	1,895.983	38.2

oriental margin of the Chiriquí Gulf. Half of deforested mangrove areas are presently being used for agriculture and cattle farming, notwithstanding the low fertility of such soils. More recently, increasing pressure from the shrimp farming industry resulted in deforestation of mangroves close to saline areas, where there are the best sites for this activity. This is particularly important in Cocle and Azuero peninsula in the Pacific. Some deforestation was caused by urban expansion of the metropolitan area of Panamá city in Juan Diaz area. Although regulation exists to avoid deforestation in the area some stands continue to be deforested, suggesting lack of enforcement of the law.

Oil spills are another important impact upon mangroves in Panamá. Although public environmental authorities make efforts to control these incidents, their efforts seem to be insufficient or inadequate. Breaking the law regarding protection of mangroves results in such small penalties that lawbreakers rather pay fines than avoid doing the damage. Until when the Government will not consider mangroves as an important part of the Nation's natural heritage, attempts to stop degradation will continue to be ineffective.

Although contamination of mangrove areas has not been reported as a serious impact on mangroves, the enormous quantity of oil transported through the Panamá Isthmus is a constant threat to natural systems. Approximately 70 million tons of oil are transported yearly from one ocean to the other, either through the Panamá Canal itself or through pipelines. The large volume transported is rather from international oil commerce than for Panamá's utilization. Among the consequences of the transport and stock of such large oil quantities, there was a large oil spill in April, 1986, involving 50,000 barrels of crude oil from the only oil refinery of the country, located in the Colon Province at the Caribbean coast. The spill seriously affected coral reefs, mangroves and seagrass beds (Jackson *et al.*, 1989). Approximately 27 km of coastline bordered by mangroves were affected. Considerable tree mortality occurred and complete destruction of the epibiota of mangrove roots followed the spill. Also, mangrove seedlings replanted in the area failed to produce leaves.

10. Research and Training Programs

The most significant effort for the conservation and sustainable utilization of mangroves of Panamá was the Action Plan for Tropical Forests of the Republic of Panamá (PAFT-PAN, 1990), with support from the United Nations Developmental Program (UNDP) and Food and Agriculture Organization (FAO). This Government plan is coordinated by the National Institute of Renewable Natural Resources (INRENARE) and includes the national policy and strategy for the management of mangroves in Panamá. Its major objectives are: to protect and manage the stands to maintain biodiversity; to ordinate and manage the forest for its sustainable utilization; to rehabilitate degraded soils; to manage watershed; to

Table 4. Major subsistence forest products from the mangroves of Panamá, according to INRENARE (1988).

Product	Site	Species	Tree DBH (cm)	Annual production	Annual demand	Users
Fuelwood	Chiriquí Azuero	*L. racemosa* *P. rizophorae*	5-15 cm	2.8 million	2.1 million	350
Charcoal	Azuero Chame, Capira	*Rhizophora spp.* *L. racemosa*	5-30 cm	1,087,440 kg	150 kg/person	2,060
Bark	Azuero, Chiriquí	*Rhizophora sp.* *Rhizophora sp.*	40-70 cm	430,909 kg 718,182 kg	454,545 kg 727,272 kg(*)	107
Sticks	Azuero	*Rhizophora sp.*	5-10 cm	266,000 units	-	375
Poles	Chame, Capira, Azuero	*Rhizophora* sp.	10-20 cm	8,780 units	-	120

(*) Exported to Costa Rica

enhance environmental education, capability and extension in forestry; to promote alternatives for sustainable production to reduce deforestation.

Additionally, some important research and training programs have been initiated through international collaboration. Among them the Regional Wetlands Program for Central America of the International Union for the Conservation of Nature and Natural Resources (IUCN) and the Central America Program for Fisheries Development (PRADEPESCA).

11. Management Policies and Legislation

The Constitution of the Republic includes the Ecological Act. The State is responsible for the protection, conservation and improvement of the environment and natural resources. The Constitution also establishes as a State duty to involve the population in the process of nature protection. Additionally the Republic has turned most Regional and International agreement into National Laws regarding disposal of toxic substances in the oceans. On the 10th June 1991, the National Congress approved the law to support the protocol of conservation and management of coastal and marine areas of the Southeastern Pacific. Regarding fisheries resources, the Act 225 of the Constitution regulates the fisheries activities to preserve its benefits.

Although levels of contamination and degradation of coastal resources are still not critical, some local cases create preoccupation of potential degradation and destruction of coastal and marine ecosystems of Panamá, including mangroves. This is due to several reasons, including:

- there is no specific policy for the management and conservation of coastal and marine ecosystems, notwithstanding their enormous social and economic importance for the country.
- the existing legislation is inadequate, when regarding water and environmental quality, since laws developed for sanitary control and/or related to agriculture activities are still in force.
- although the INRENARE is responsible for the management of mangroves, there is inadequate interinstitutional interaction. Frequently the regulation of a resource, as the mangroves, is shared by various state authorities, which have different views. In some cases these views are even opposed. In the case of mangroves, fisheries, harbor, forestry, agriculture and urban interests are involved, resulting in inefficient management of the resource. This frequently results in over exploitation of the resource and a certain degree of passivity regarding the constructions which negatively affect the environment.
- economical constraints are permanent in the controlling institution, resulting in inefficient enforcement of legislation.
- the increasing marginal population finds diverse resources at the coastal zone for their subsistence, resulting in increasing pressure on the natural ecosystems.

Table 5. Converted mangrove areas in Panama (km²), according to Anguizola *et al.* (1989).

Conversion uses	Chiriqui	Montijo	Parita	Chame	Panamá	Total
Salt flats	0.0	0.0	1.61	0.26	0.0	1.87
Shrimp ponds	0.0	0.0	2.56	1.40	0.0	3.96
Tidally flooded	0.0	3.47	0.41	0.0	1.57	5.45
Crops	15.92	1.36	3.94	0.0	4.38	25.60
Cattle farming	3.87	5.50	1.91	0.81	0.0	12.09
Non-vegetated	1.78	0.0	0.14	0.75	1.71	4.38
Agriculture	0.0	3.12	0.0	0.0	0.0	3.12
Totals	21.57	13.45	10.57	3.22	7.66	56.47

Mangroves, coral reefs, and other biological communities that are the rich biodiversity of the country are justification enough for the establishment of a coastal zone policy in Panamá. Currently, the general principles for such a policy are already approved and executed by several of the government agencies, although on an institutional base rather than in a comprehensive way. In addition, several laws of the republic, including the Constitution, deal with the environment and natural resources. In order to make coherent all of these laws and regulations some future action will be necessary such as:

- the formulation of a national policy on the coastal resources and the environment.
- the updating of the laws in respect to the importance of the coastal resources and environment.
- to adequate the institutional framework from which is performed the management of the coastal resources and environment. This should imply the centralization of actions and decisions at a high level commission from the executive, including the National Commission for Mangrove sponsored by INRENARE.
- to reformulate the education policy to include an important component on natural resources, the environment and its relevance for the country.
- to create a national council on science and technology to plan the development of the scientific and technological knowledge necessary to straighten and promote the conservation, development and use of natural resources and the environment. This will allow a better knowledge of the environment and its resources through scientific research and its effective utilization through the application of new technologies delivered through the universities, technical institutes and professional associations, and any other organization of interest in mangroves.

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Mangroves of Costa Rica

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1. Introduction

The Pacific coast of Costa Rica is characterized by the presence of a large number of protective embayments which favour the development of large extension of mangrove forests in sheltered situations. Close to 99% of the estimated area covered by mangroves in Costa Rica occur on the Pacific coast (Fig. 1) (Saenger, Hegerl and Davie, 1983).

During the past few years increasing interest in the mangroves has lead to some studies, particularly about the floristic aspects of the forest (e.g. Soto and Jiménez, 1982, Jiménez 1987, 1988a, 1988b, 1992). Forests from the southern humid regions have the highest floristic diversity and structural development, with *Pelliciera rhizophorae* and *Rhizophora racemosa* as the most frequent and dominant species (Jiménez and Soto, 1985, Jiménez, 1992). In the seasonally dry areas, structural development is usually reduced and the forest shows a clear zonation pattern. In such cases *Rhizophora* species dominate the seaward edge and *Avicennia* spp populate the inland fringe of the forest (Jiménez, 1992).

Since pre-columbian times indigenous people were linked to the mangrove forest resources. An analysis of archaeological remains (indigenous "concheros") excavated in the marginal lands of the mangroves of Tivives and the south part of the country, indicates that the indigenous people used fish as a common protein source (Villalobos *et al.*, 1984; Campos, Fournier and Soto, 1990) and also that they used fish species that are not usually exploited today (Quintanilla, 1990).

More recently firewood, charcoal, timber and bark are among the most common forest products directly harvested by local communities that developed over the past 50 years a "mangrove culture", particularly at the Térraba-Sierpe Forest Reserve. In addition some people extract *Anadara* spp cockles, mainly at the south coast of the Térraba-Sierpe Mangrove Forest Reserve, which are also source of income and dietary protein.

2. Extent and Distribution

The large number of bays, estuaries, gulfs and other geographical disruptions resulted in the Pacific coast being five times longer (1016 km) than the Caribbean coast (212 km). Close to 99% of nearly 41,300 the of mangroves estimated by Solórzano *et al.* (1990) for Costa Rica occur on the Pacific coast (Table 1.1) This means that the forest occupies about 35% of the Pacific coastline.

Table 1. Approximate extension of the largest mangrove forests on the Pacific coast of Costa Rica (after Sotórzano *et al.*, 1990)

Location	Extension (ha)
Tamarindo	400
Golfo de Nicoya	15,173
Damas/Palo Seco	2,312
Térraba-Sierpe	17,737
Coto Colorado	875
Other areas	4,792
Total	41,289

3. Physical Setting

Jiménez and Soto (1982) described three different mangrove zones along the Pacific coast, according to their structure and flora. These zones correspond to the climatic regions, separated on the basis of rainfall and river discharge.

The Northern Pacific zone, from the border with Nicaragua to the north of the Tivives mangrove, includes the Tamarindo forest and all the coastal strip surrounding the Gulf of Nicoya. The least structurally developed forests of all are found there, in areas where the mean annual rainfall is relatively low (hardly reaches the 2,000 mm) and the dry season is long (December to April).

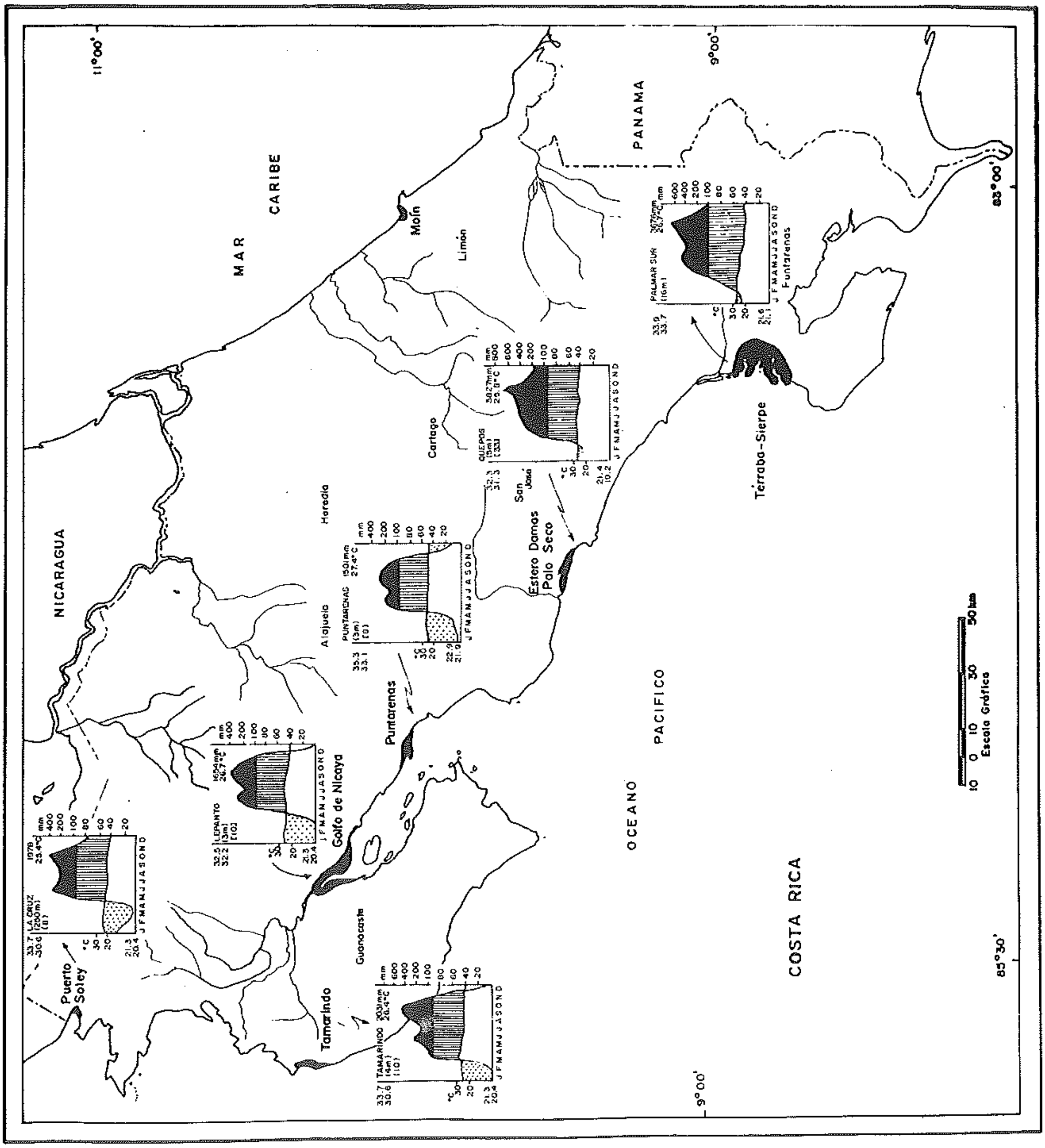

Fig. 1. Distribution of principal mangrove sites of Costa Rica.

The Central Pacific zone is a transition area extending south of the Tivives mangroves to the city of Quepos. The mean annual rainfall in this zone exceeds the 2,000 mm level and the dry season lasts for about three months. The forest shows greater structural development than that of the North and its productivity appears to be higher, according to figures published elsewhere (Cintrón and Schaeffer-Novelli, 1985).

The Southern Pacific zone includes south from the city of Quepos to the Térraba-Sierpe Forest Reserve, the Coto Colorado, Golfito and Rincón mangroves and other small areas all within the Golfo Dulce. In this zone the forests are more developed, species diversity is higher and silvicultural economic importance is also greater as a consequence of the high mean annual rainfall, which reaches 3,647 mm (Chong, 1988) and a shorter, less than three months long dry season.

The tides on the Pacific coast of Costa Rica are semi-diurnal with marked diurnal inequality and a mean amplitude of 3.55 m. The two distinct periods when the tidal range is greater are January to March and August to October. Mangrove sandy soils in Térraba-Sierpe have lower phosphorus contents, whereas soils with high clay content have higher levels of both phosphorus and potassium and are less acidic (Chong, 1988).

Temperature is not a limiting factor in plant growth (Chong, 1988), as the average annual temperature is around 26°C all the year long, with highest temperatures recorded in March and lowest in October.

4. Biological and Ecological Characteristics

The major species are *Rhizophora mangle*, known as the "mangle gateador" (crawling mangrove) because of its distinctive prop roots; *R. racemosa*, which reaches heights of up to 45 m, *Pelliciera rhizophorae*, known as the "piñuela mangrove", *Laguncularia racemosa* ("mariquita") and *Avicennia germinans* and *A. bicolor*, both known as the "salado mangrove". Also considered typical mangrove species are *Mora oleifora* or "alcornoque", the fern *Acrostichum aureum* or "negraforra" and *Tabebuia palustris* (N. Duke, *pers. comm.*)

Despite some opinions to the contrary (e.g. Breteler, 1969, 1977, Jiménez, 1987) mangrove species taxonomy has not been clearly established. Consequently the existence of a hybrid between *R. mangle* and *R. racemosa*, *R.* x *harrisonii* has not been conclusively demonstrated (N. Duke and J.A. Jiménez pers. comm.). For this reason it is preferred and recommended that only *R. mangle* or *R. racemosa* are referred to until the hybrid's existence is confirmed.

On dry coastal regions the basal areas measured are low (7-20 m^2/ha) and the canopy is about 20 m high (Jiménez, 1988). As salinity increases, the height of the trees decreases, following a marked gradient between the mouth of the channel and the inland area (Jiménez, 1981). Salt pans or flats can also be found and here salinity can reach up to 200‰ (Pizarro and Angulo, 1993). In these arid areas, *R. racemosa, R mangle, A. germinans, A bicolor* and *L. racemosa* dominate the vegetation.

Jiménez (1988a, 1988b, 1990) worked on some aspects of the structure and dynamics of *R. racemosa* and *A. bicolor* stands at the Tivives mangroves, where the growth was strongly related to the canopy sociological position and the species showed a clear clumped distribution in size classes smaller than 15 cm DBH. The four species studied shed their fruits during the rainy season when the water level within the forest is highest.

The cohort analysis and reciprocal planting observations of Jiménez and Sauter (1991) showed that the species zonation was primarily regulated by the depth of tidal inundation and the differential ability of the propagules to become established.

In areas where rainfall exceeds 1,800 mm, basal areas vary between 20 and 60 m^2/ha, trees may reach 45 m in height and species diversity is higher; then the dominant species are *R. racemosa, R. mangle, P. rhizophorae* and *Mora oleifera*. These zones show a more moderate salinity gradient and within the forest typical mangrove vegetation is found mixed with marsh-land species such as *Pterocarpus officinalis* and *Campnosperma panamensis* (Pizarro and Angulo, 1993).

Some figures of structure parameters for three stands at a 200 ha site in the Térraba range are shown on Table 2. The first stand was hardly touched, where the second one was selectively cut over a period of 4 years and the third one underwent strong interventions about 40 years ago.

Table 2. Structure parameters of three stands at the Térraba range (after Espinosa, 1992).

Stand	Height (m)	Mean basal area (m^2/ha)	Density (ind/ha)	Volume (m^3/ha)	Mean DBH (m)
I	33.7	18.2	1,369	131	0,13
II	24.2	26.3	1,410	166	0,15
III	23.5	6.8	201	29	0,21

5. Associated Ecosystems

Amongst the species common in the less flooded edges of the mangrove are the Leguminoseae *Pterocarpus officinalis*, ("sangregao") and the palms *Raphia taedigera* ("yolillo") and *Bactris minor* ("tagua"). Eastward from the Sierpe town at the Sierpe river is a huge area of c.a. 4,000 ha of "yolillo" palm, which provides shelter for many mammals such as *Odocoileus virginianus* and monkeys, according to the local inhabitants.

The following plant species are amongst those associated with the mangrove in dry zones: *Canavalia maritima, Ipomoea pescaprae, Caesalpinia bonduc, Prosopis juliflora, Sesuvium portulacastrum, Blutapapron vermiculare, Jouvea straminea, Fimbristylis spadicea, Capparis odoratissima, Randia* sp and *Tamarindus indica* (Pizarro and Angulo, 1993).

Associated to the prop roots of *Rhizophora* spp., as in other mangroves algal complexes are common *Bostrichia-Caloglossa-Catenella* (Pizarro and Angulo, 1993).

Two species of the valuable crocodiles *Crocodilus acutus* ("lagarto") and *Caiman crocodilus* ("cuajipal") are present in small numbers, specially at the Térraba-Sierpe Reserve (Chong, 1988, Pizarro and Angulo, 1993). The lizards *Iguana iguana, Basiliscus basiliscus* and *Ctenosaura similis* ("garrobo") are quite common, as well as snakes and river turtles. Marine turtles are known to lay their eggs along sandy beaches.

The fisheries from the Gulf of Nicoya have been studied for more than 20 years (Erdman, 1971; León, 1973; López and Bussing, 1982; Bartels *et al.*, 1983; Araya, 1984; Stevenson, 1987) and the most important commercial species found in the Gulf belong to, among others, the Engraulidae, Lutjanidae, Penaeidae and Sciaenidae (Ramírez *et al.*, 1989; Ramírez *et al.*, 1990). The trophic relationships between fishes and other life forms have lead to some studies on the biology of crab larvae (Dittel and Epifanio, 1982, 1984; Epifanio and Dittel, 1990), and also on the meiofauna (De la Cruz and Vargas, 1987) and benthic communities (Maurer and Vargas, 1984; Maurer *et al.*, 1984, Vargas *et al.*, 1985; Vargas, 1987; Sibaja, 1988b) in the Gulf of Nicoya.

About 17 km in front of the Térraba-Sierpe Mangrove Reserve is located the Biological Reserve Isla del Caño, surrounded partially by coral reefs constructed mainly from *Pocillopora* spp (Soto and Bermúdez, 1990). Other important species present are *Porites lobata, Pavona clavus, P. varians* and *Psammocora* spp. (Soto and Bermúdez, 1990).

6. Economic Importance

Extraction activities in the Costa Rican mangroves have taken place since more than thousand years (Campos, Fournier and Soto, 1990). One of the most important economic activities associated with Costa Rican mangroves is cockle collection. On the Pacific coast, the species *Anadara tuberculosa* and *A. similis* are commercially exploited in quantities exceeding thirteen million individuals per year (Jiménez, 1990).

The production and consumption of mangrove timber presently reached its lowest level. Solórzano *et al.* (1990) calculated the timber potential of the Gulf of Nicoya mangroves as an exercise to evaluate natural resource depreciation in the country (Table 3).

The bark of *Rhizophora* spp produces very fine tannin suitable for leather work. The bark supplied by mangrove workers in Coronado de Térraba and Coto Colorado is used in the single tannery in Golfito.

The amount of charcoal produced by small farmers at the Térraba-Sierpe mangrove Reserve accounted in 1987 for about 1911 m^3 of felled wood

Table 3. Calculation of timber volumes for different mangrove strata in the Gulf of Nicoya (after Solórzano *et al.*, 1990)

Stratum	Volume (m^3/ha)	Growth (m^3/ha/yr)
Rhizophora high	90.7	5
Rhizophora med.	45.2	3
Rhizophora small	8.9	2
Avicennia high	170.0	8
Avicennia med.	41.6	5
Avicennia small	7.0	3
Mixed high	72.4	nd
Mixed med.	39.8	nd
Mixed small	10.4	nd

nd = no data.

(Chong, 1988). At present the highly inefficient charcoal production method was partially replaced trough the construction of four brick kilns at Coronado de Osa. Most of the product is still sold locally, although some important amounts are taken to the Central Valley.

Trees with a small diameter are used as poles in constructing houses or "ranchos" (open sided buildings, often with a thatched roof). *P. rhizophorae* is commonly used as fence posts in cattle ranches and for construction purposes in homesteads. Trees with a diameter greater than 25 cm can be sawed for planks, which are used especially by neighboring residents for building and repairing dwellings.

The mangrove areas are particularly attractive to ecotourism groups because of the opportunities they afford for wildlife-watching. Residents living close to the mangroves occasionally hunt mammals and reptiles as a subsistence activity (Pizarro and Angulo, 1993).

Although fishing is prohibited in estuaries and channels associated with mangroves, it is permitted on a small scale along the length of the Pacific coast. In the Gulf of Nicoya an important artisanal fishery contributed about 67% of the total yield in 1987 (about US$ 32.9 million)(Solórzano *et al.*, 1990). Artisanal, semi-industrial and industrial fisheries are an important activity, based on the fact that the rate of fish production to the gross internal product has increased from 0.56% to 3.15% between 1970 and 1987 (Solórzano *et al.*, 1990).

Chong (1988) gives some figures of income of the families that live in the Térraba range (Table 4).

7. Adaptation of Lands for Other Uses

Although the mangrove do enjoy a degree of protection and corresponding legislation does exist, several activities such as agriculture, cattle raising, aquaculture and urban development occur causing changes in the use of the land.

There is a steady pressure on mangroves to develop agricultural activities. The agricultural front continues to extend in all areas that border the forest, despite the fact that economic yields from cultivated mangrove soils are low, due to problems of drainage, salinity and acidity produced by accelerated oxidation in the conversion process (Sánchez, 1986). In fact, lands converted from mangrove to aquaculture have been subsequently abandoned due to high maintenance costs (Pizarro and Angulo, 1993).

The construction of basins for salt production has greatly contributed to the destruction of vast areas of the mangrove, mainly in the dry Pacific zone (Pizarro and Angulo, 1993). Other consequences of salt production include irreversible changes in the soil (Sánchez, 1986) added to deforestation for the fuelwood needed to crystallize the product.

The forest is the easiest and cheapest alternative for house building for the marginal populations of the coastal areas. Small groups fell and clear an area of mangroves and build their housing facilities (Pizarro and Angulo, 1993). The port of Puntarenas and the city of Quepos where built at the expense of mangrove areas; nowadays hotels, restaurants and commercial centers also encroach on mangrove areas.

There are no figures on the loss of the forest for agriculture and housing. Nevertheless, Table 5 shows changes occurred in the area covered by mangroves in the Gulf of Nicoya between 1964 and 1989.

Table 4. Mean family income per year in the Térraba range in 1987 (after Chong, 1988).

Activities	US$ per year
Cockle collection	1,671
Extensive ranching	1,335
Tourism	1,165
Bark extraction	960
Artisanal fishery	859
Charcoal production	841
Gold mining	722
Agriculture	486
Shrimp fleet products trade	440
Services	324
Pensioners	230

8. Environmental Impacts

In the last ten to twenty years the mangrove forests have suffered increased pressure as a result, among others of the unemployment created by the closure of the banana company in 1984, the building of walls and closing of natural channels and the increased use of timber, bark and other sub-products (Pizarro and Angulo, 1993).

In the North Pacific coast the felling of the forest for aquaculture development and salt production are also an important degradation factor. Agriculture or livestock development and the construction of housing facilities near cities are important degradation factors. In fact the mangroves surrounding the city of Quepos and of the port of Puntarenas have almost disappeared.

The hunting and collection of wildlife species that are permanently resident or occasional visitors in the ecosystem, like monkeys, small mammals, crocodiles, turtles (and turtle eggs), lizards, birds and some mollusc contributes to the ecosystem degradation.

The impact of the bark collectors on the Térraba range was greater than any other because they felled only the largest and most vigorous *Rhizophora* trees and considerable damage was caused during felling, creating innumerable gaps in the canopy. It took much more than 2 years for the large trunks to decompose (Chong, 1988). These gaps where revegetated quickly in the Térraba range, but not necessarily with *Rhizophora* spp (Chong, 1988).

Table 5. Changes in the area covered by mangroves in the Gulf of Nicoya in the period 1964 - 1989 (after Solórzano *et al.* 1990).

	Extension (ha)		
Stratum	1964	1989	Difference
Rhizophora high	1,696	1,478	-218
Rhizophora med.	3,911	4,052	141
Rhizophora small	1,260	979	-218
Avicennia high	443	354	-89
Avicennia med.	2,807	953	-1,854
Avicennia small	3,334	3,464	130
Mixed high	42	214	172
Mixed med.	1,408	1,808	400
Mixed small	1,369	1,872	503
Total forest	16,270	15,174	-1,096
Ponds	344	977	633
Saltpans	468	583	115

Though not a direct consequence of the impact on the forest, the fisheries of the Gulf of Nicoya have been settled under pressure in the last twenty years. Stevenson and Carranza (1981) demonstrated that in the second half of the seventies the catches of *Opistonema* spp exceeded the level of maximum sustainable effort in the Gulf of Nicoya. Madrigal (1985) showed that for two species of the Sciaenidae the ratio of fishing mortality to total mortality exceeded the optimal level of 0.5 in 1982.

9. Research and Teaching

The National University's Management and Dynamics of Estuarine Ecosystems Program is carrying out a project on integrated management of mangrove associated resources on the Pacific coast of Costa Rica. It has also set up permanent plots to study the growth of mangrove species of Tivives and Térraba-Sierpe and has figures available from 1981 onwards some of which have already been published elsewhere (Jiménez, 1988a; 1988b; 1990; Jiménez and Sauter, 1991).

The IUCN (World Conservation Union) and CATIE (Agronomic Tropical Center for Research and Training) have undertaken jointly the conservation of the Térraba-Sierpe mangroves and their resources, as well as the improvement of the quality of life of the people dependent upon them. Through the implementation since 1991 of a field project whose main objectives are to promote the wise use of the natural resources of the Térraba-Sierpe Mangrove Forest Reserve and to introduce a series of management activities for humid mangrove forests.

The main field activities of the project include the improvement of the extraction and processing of *Rhizophora* spp wood for charcoal production, improvement of the commercialization channels, promotion of other local resources as a source of income, incorporation of charcoal producers in a management plan and strengthening of national institutions mainly through training programs. Other activities include biological and socioeconomic baseline studies and the development of an environmental education program in the towns inside the Forest Reserve.

Some studies related to the wise use of the natural resources of the Térraba-Sierpe Mangrove Forest Reserve where done as part of theses of the MSc. program at CATIE (Marín, 1991; Espinosa, 1992).

10. Legislation in Force

As a response to disturbances inflicted on the mangrove forests during the seventies, a legal framework was devised to protect the resources of the ecosystem. As in other countries, the location of mangroves at the sea-land interface creates permanent jurisdictional conflicts between state organizations and some clash of interests between them and private organizations wishing to develop tourism or construct housing.

Article 12 of the Maritime-Terrestrial Zone Law (number 6043 of 1977) states that the land between mean high tide level and 200 m landward belongs to the state and the municipalities and the Costarican Tourism Institute, these are the entities that can rule their use.

On May 16, 1986 the General Forest Law of November 25, 1969 was modified. Articles 32 and 55 of this law state that exploitation of forest reserves could be done only under concessions given by the General Forest Directorate (or DGF). The Executive Decree 7210-A of July 19, 1987, based on the high productivity of the mangrove forests, their inter-relationship with coastal fishing and their ability to stabilize coastal sediment granted the category of Forest Reserve to all of them.

Executive Decree 16852-MAG of January 23, 1986 specified that the administration of mangrove areas shall be the exclusive responsibility of the DGF for the purposes of exploiting forest resources and the General Fishing Directorate for exploitation of the aquatic fauna. The decree furthermore established rules and tariffs for exploitation concessions and extended protection categories to areas in Pochote, Parrita and Punta Morales.

Executive Decree 13371 of February 16, 1982, established the minimum size for capture and sale of *A. tuberculosa* at 47 mm and decree 16726-MAG of November 8, 1985, prohibited its export.

The General Wildlife Law of October 19, 1992 makes wetlands, including the country's mangroves, wildlife areas subject to the administration of the General Wildlife Direction (DGVS) which is under the Ministry of Natural Resources, Energy and Mines. Within this framework it is expected that the former forest reserves will be declared Wildlife Refuges.

Representatives of the General Forest Directorate, General Wildlife Directorate, National Park Service, National University, CATIE, Tropical Scientific Center, among others, built a National Mangrove Committee which work periodically since the second semester of 1992. The main objective of the Committee is to design sound policies for mangrove management in Costa Rica.

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Mangrove Forests of Nicaragua

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1. Introduction

Nicaragua is the largest and least densely populated country in Central America. It covers an area of 130,000 km² with a population of 4,000,000 inhabitants (INEC census of 1992). Sixty percent of the population lives in the Pacific coastal region where the density is 86 inhabitants/km², compared to a density of 5 inhabitants/km² on the Caribbean coast.

The mean annual temperature is 27°C and the mean annual rainfall 1,300 mm. Following Köppen's classification, four climatic zones can be distinguished: Tropical Savannah (AW) on the Pacific slope and part of the central region, Wet Tropical Forest with Monsoon (AM) in part of the central region and Atlantic coast, Wet Tropical Forest (AF) on the Atlantic coast and Highland Climate (H), a modification of the first two.

The area covered by mangroves is approximately 155,000 ha distributed on both coasts. Despite the large area, the number of isolated studies that have been done at a local level have yielded scant and disjointed information that has been difficult to translate into a practical form.

The problems affecting these ecosystems in Nicaragua have become more acute in recent years, mainly due to socioeconomic factors. Amongst these are scarcity of petroleum, foreign currency shortages, lack of appropriate policies, institutional weakness demonstrated by poor control and regulation of resource use, lack of a strategy for the sustainable use of these resources, of integrated management of the mangroves, of basic research, of public awareness and of the degradation of coastal systems due to inappropriate exploitation practices. Among these practices fishing with explosives, partial closure of the mouths of natural lagoons, construction of shrimp rearing ponds in unsuitable areas, etc. can be mentioned.

2. Extent and Distribution

According to land mapping carried out in 1983 by INETER and the Ministry of Planning, about 71,300 ha of the Nicaraguan mangrove forests (46%) are found on the Pacific slope and 83,700 ha (54%) on the Caribbean. Despite of the huge extension covered by mangrove forests on the Atlantic coast, there is scarce information available (see Roth and Grijalva, 1991; Roth, 1992).

On the Pacific slope, the Nicaraguan Institute of Natural Resources and Environment (IRENA, formerly DIRENA 1988) identified five large areas of mangroves in 1984 (Fig. 1, Table 1).

Table 1. Largest areas of mangroves on the Pacific coast of Nicaragua (taken from DIRENA, 1988 and DANIDA-Mangroves Project data).

LOCATION	Area in ha.
Estero Real and Golfo de Fonseca coast	23,000
Estero Padre Ramos	4,590
Aserradores - Poneloya	10,700
Las Peñitas to Salinas Grandes	2,420
Estero Ciego to Puerto Sandino	1,990
TOTAL	42,700

3. Physical Setting

The mangroves in Nicaragua have grown in coastal lagoons and the estuaries of the major rivers of the Caribbean slope and the northern part of the Pacific coast.

The predominant climate of the northern Pacific - where the largest areas of mangroves occur on this coast - is dry tropical.

The mean annual rainfall varies between 1,500 and 1,700 mm, with maximum and minimum values, 2,400 and 840 mm. Rainfall is markedly seasonal: the

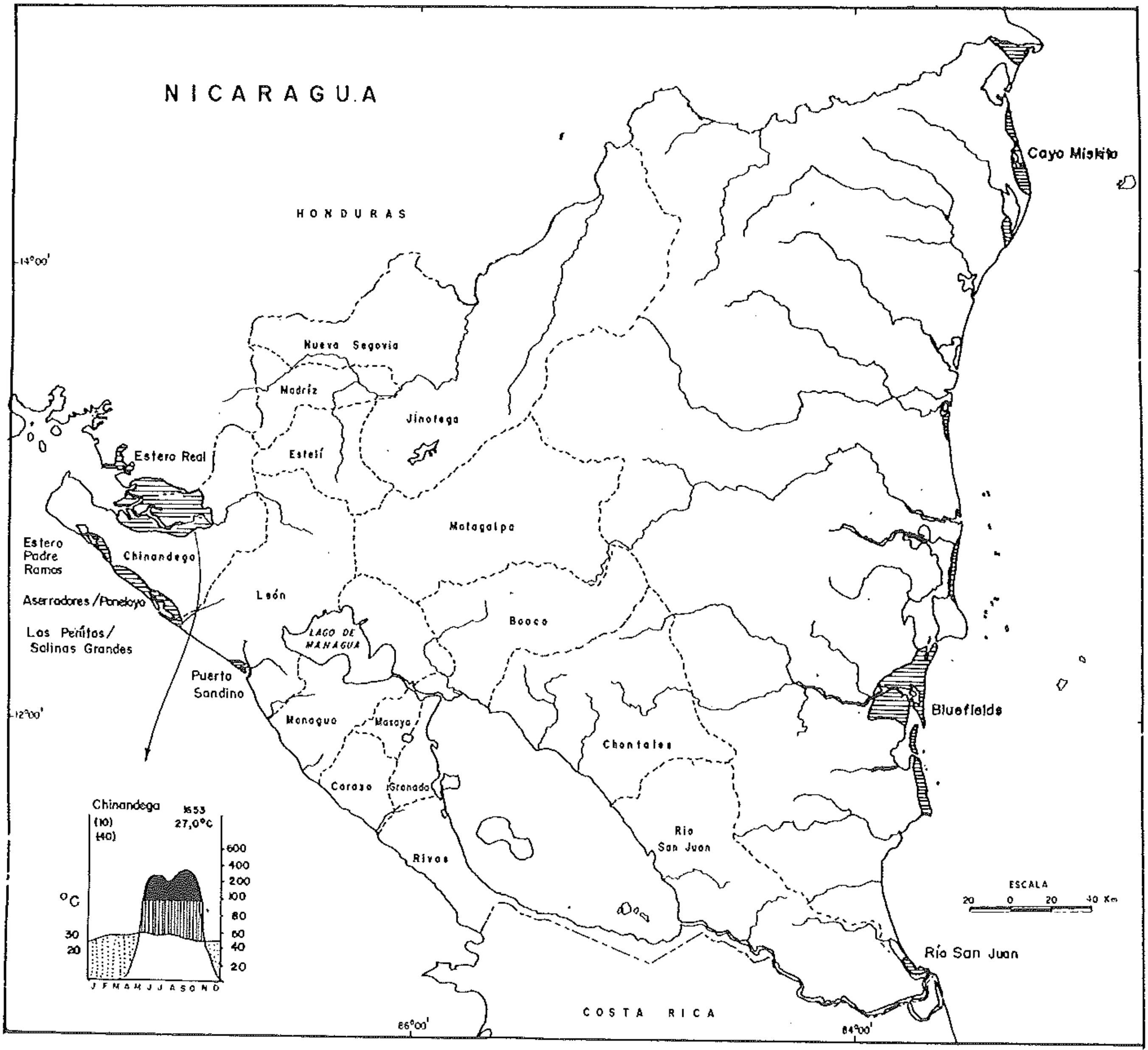

Fig. 1. Distribution of principal mangrove sites of Nicaragua.

wet season starts in May and continues through October, and the dry season is from November through April. During the latter period there is hardly any precipitation. Potential evapotranspiration is over 2,000 mm per year contributing to the dryness of the climate. The mean annual temperature is approximately 27°C with a relative humidity of 74%.

The mean high tide is 3.3 m and the rivers have a characteristically small volume or are intermittent, discharging only during the rainy season.

The soils are hydromorphic, they show varying levels of gleification in the deeper profiles and accumulation of organic matter on the surface.

4. Biological and Ecological Characteristics

The species present in the mangrove forests of Nicaragua are *Rhizophora mangle* and *R. racemosa* (known as "mangle rojo" or red mangrove), *Avicennia bicolor* and *A. germinans* ("palo de sal" or "iguanero"), *Laguncularia racemosa* ("ajelí"), *Conocarpus erectus* ("botoncillo") and the fern *Acrostichum aureum*. Only on the Caribbean slope, *Pelliciera rhizophorae* has also been found (Roth and Grijalva 1991).

Mangrove distribution is closely related to coastal geomorphology, occurring where the major water courses have developed in deltas and absent in areas of greater flow.

In 1981, the Division of Forest Management, Inventories and Forest Inheritance of IRENA carried out observations on 15 plots, each with 240 m², in Estero Real, and found a density of 1,338 trees per hectare.

The Olafo project (see section 10) has produced unpublished data on litterfall in mangroves in the Las Peñitas - Salinas Grandes sector (part of the geographic region known as Héroes y Mártires de Veracruz) with figures between 2.05 and 4.11 g/m²/day. A mean density of 2,999 individuals/ha was calculated along with a timber volume of 32.35 m³/ha and tree heights between 7 and 11 m. Table 2 shows values calculated for Estero Real (IRENA, 1986), Héroes y Mártires de Veracruz (Windevoxhel, 1992) and Isla del Venado on the Caribbean coast (Roth, 1992).

Although poor structural development would be expected in mangroves growing in dry zones

Table 2. Calculation for density, volume and basal area of mangroves in Estero Real and Héroes y Mártires de Veraçruz by genus (data from IRENA, 1986; Windevoxhel, 1992).

Genus	Density (ind/ha)	Volume (m³/ha)	Basal area (m²/ha)
Estero Real			
Rhizophora	-	21-77	-
Avicennia	-	7-23	-
Laguncularia	-	1- 2	-
Héroes y Mártires			
Rhizophora	2,804	37	-
Avicennia	3,067	32	-

(Cintrón and Schaeffer-Novelli, 1985), values shown here are among the lowest in Central America, according to Jiménez (1992). Apart from low rainfall, run-off and nutrient supply, the heavy extraction pressure on the forest also contributes to this situation.

In the Estero Real mangroves it is common to find *Rhizophora* individuals infested with the mistletoe *Orychtanthus* (Lorantaceae). *Laguncularia* is also overgrown by this plant and insects have been observed eating its leaves seasonally in Héroes y Mártires de Veracruz.

IRENA (1992) carried out a faunal inventory at the Juan Venado Natural Reserve, on the Pacific coast, and counted 95 birds (among these *Calocitta formosa, Bubulcus ibis, Ajaja ajaja*), 24 reptiles (e.g. *Caiman crocodilus, Lepydochelis olivacea*), 23 mammals (e.g. *Odocoileus virginianus, Dasypus novemcinctus*), 14 fishes and 6 amphibian species.

5. Associated Ecosystems

The main ecosystem associated with mangrove in the terrestrial sector is dry forest. Some of the predominant species are *Capparis odoratissima, Coccoloba caracasana, Crescentia alata, Sabal mexicana, Calotropis gigantea, Crysobalanus icaco*, a highly appreciated fruit on Nicaragua's tables, *Prosopis juliflora, Hippomane mancinella, Mimosa pigra* and *Sesuvium portulacastrum*.

6. Economic Importance

Windevoxhel (1992) asserts that in the Héroes y Mártires de Veracruz zone, the benefits directly obtained from mangroves which are products of direct exploitation of the goods, are extremely important, especially in the case of products that are basic for the local or regional economy, such as fuelwood. However, the greatest economic benefits from the ecosystem come from services such as maintenance of open water fishing and recreation.

The following is a summary of timber and non-timber goods extracted from the mangrove together with some details of practices used for their exploitation.

6.1 Timber extraction

Nicaraguan mangrove forests are used for the extraction of "varules", or poles used as supports in banana plantations and as roof supports. IRENA calculates that each "varul" has a volume of 0.263 cm^3. Although their use has been prohibited by IRENA since 1992, the institution has only limited power to enforce the prohibition and, consequently, extraction continues, albeit to a lesser extent.

Timber is also used in the form of pillars, crossbeams and joists in the construction of rustic dwellings and "ranchos" or open-sided buildings used for restaurants and other tourist-related activities.

In Nicaragua 40% of the population obtains its energy from fuelwood. For this reason, its extraction is the activity which has greatest impact on the mangrove, where species of high calorific value (e.g. *Rhizophora* spp) are found. Fuelwood from the mangroves either partially or totally furnishes the needs of important nearby coastal cities such as León, Chinandega and the port of Corinto.

IRENA established that a fuelwood gatherer can produce on average 120; 6 inches long "rajas" of firewood per day, the equivalent of 0.45 m^3. The Danida-Mangrove Project (see section 10) has counted 92 fuelwood gatherers in the Estero Real region and the Olafo Project has counted 253 in Héroes y Mártires de Veracruz.

Taking into account only those permits granted by IRENA to mangrove community members, Jiménez (1988) has calculated that 9,000 m^3/year of fuelwood, between 4,000 and 7,000 m^3/year of timber for posts and 5,000 m^3/year of timber are extracted in Nicaragua. Nevertheless, most of the volume of timber removed from the mangrove is not subject to any control or recording. For this reason, Windevoxhel (1992) calculates in 1989 that 18,812 m^3 fuelwood were extracted from Héroes y Mártires de Veracruz.

Olafo (1992, see section 10) indicate that the fuelwood gatherers waste 50% of the aerial biomass of each tree and that they leave most of the roots and branches in the mangrove, hindering natural regeneration. This situation mainly stems from a lack of adequate tools and techniques for extracting the material efficiently since this activity falls within the framework of marginal economies characterized by very low acquisitive power.

Windevoxhel (1992) and Olafo (unpublished data), calculate that the volume of timber extracted from mangroves in Héroes y Mártires de Veracruz exceeds the regenerative ability of the forest. Whilst the volume of timber liable to exploitation is calculated at 1,950 m^3 per year, extraction for the same period is around 4,345 m^3.

Because of its high tannin content, bark is another product extracted from the red mangrove (*Rhizophora* spp). Well developed, standing trees are stripped of their bark under commission from tanneries in the larger cities. The trees subsequently die and their timber is wasted, since the fuelwood gatherers lack the appropriate tools to exploit it and avoid working with dried wood. IRENA estimates that about 36,000 kg of mangrove bark were extracted in Nicaragua during 1984 (Table 3).

6.2 Non-timber products

The great pressure on mangrove ecosystems is not limited to timber products. Some mollusc and crustacean species that are permanent residents of the mangrove and reptiles that use it as a transit area are sold and eaten within the country. Over-exploitation has resulted in the extinction of some species from certain regions and put others at critical levels. Of recorded cases the following are worth mentioning: the extinction of *Tagelus peruvianus* ("barba de hacha") on Juan Venado island in Héroes y Mártires de Veracruz; the over-exploitation of the "concha negra" (*Anadara tuberculosa*), harvested before sexual maturity at 38 mm in length - IRENA has found harvested individuals measuring 29 mm in length - and the intensive hunting of iguanas and "garrobos" (*Iguana iguana* and *Ctenosaura similis*) which are considered a delicacy by Nicaraguans. It is known that the country's largest populations of *Crocodilus acutus* live in Estero Real.

Although extraction of *Anadara* sp is not a permanent or full-time activity, the consumption of this bivalve is the year round. While IRENA calculated that 2,352,000 individuals were harvested from Estero Real in 1984 (Table 3), data from the OLAFO Project indicate that almost 8 million/year are being sold from Héroes y Mártires de Veracruz.

Another over-exploited species is the crab *Ucides occidentalis*. IRENA calculated that 720,000 individuals were captured in Estero Real during 1984 (Table 3) and the Olafo Project has more recently estimated 690,000/year from Héroes y Mártires de Veracruz.

IRENA calculates that some 25,000 kg of the shrimp genus *Penaeus* were caught in 1984. Escoto (pers. comm.) estimates that 75% of the shrimp processed by the Seafood Processing Company (ALINSA) in Corinto port are harvested from waters close to the mangroves of Estero Real. In 1983 the Nicaraguan Fishing Institute (INPESCA) calculated that ALINSA unloaded 378,737 lb of shrimp.

Over the last year, harvesting of post-larval stages of the genus *Penaeus* (*P. stylirostris, P. vannamei, P. occidentalis* and *P. californiensis*) has become an important activity, especially in estuaries north of Corinto. The post-larval stages are bought by intermediaries who subsequently sell them in Honduras with fat profits.

Estuary fishing is not an economically important activity, although several families sustain their economies from it (131 in Héroes y Mártires de Veracruz alone). The use of explosives and poisons is not infrequent and this damages the environment considerably. Species found in the Pacific include *Arius* spp, *Bairdiella* spp, *Bagre* spp, *Caranx hippos, Carcharinus porosus, Centropomus* spp, *Cynoscion* sp, *Epinephelus analoqus, Lobotes pacificus, Lutjanus colorado, Mugil curema, Parapsetus panamensis* and *Pomadasys macracanthus*. The Olafo Project has noted 32 fish species from 17 families in Héroes y Mártires de Veracruz.

7. Conversion to Other Uses

By means of Landsat images taken between December 1972 and June 1979, IRENA calculated that there has been a 2,500 hectare reduction in the area of mangroves at Estero Real, equivalent to a loss of 385 ha/yr (IRENA, 1981). Similarly, according to information registered by Windevoxhel (1992) a mean mangrove loss of 472 ha/year on the Pacific coast can be measured from 1968 photomaps, 1983 aerial photos and 1987 maps.

This information indicates an increase in the area covered by water or salt flats, however mangrove lands were not lost to farming or urban encroachment, at least during the last ten years. While an increase in the area allotted to shrimp farming is expected, this activity only occupies salt flats.

8. Environmental Impacts

In Nicaragua, specifically in the Pacific zone, the mangroves suffer two types of pressure. Internally, some of their components (timber, fish, molluscs, crabs and substrate removal) have been extracted and destroyed. Externally, adjacent agriculture and aquaculture activities affect the flow of water and

Table 3. Economic value calculated for products extracted from the Estero Real mangrove in 1984 (from IRENA data).

Product	Quantity	Unit price $ US	Value $ US
Poles	600,000 u	0.07	40,714.30
Construction			
Timber	4,800 m²	9.00	43,200.00
Fuelwood	8,900 m²	5.30	47,424.30
Bark	35,880 kg	2.40	85,800.00
Ucides sp	20,000 u	0.05	34,285.70
Anadara sp	2,352,000 u	0.02	47,040.00
Shrimp	25,000 kg	100.00	2,500,000.00

sediments. Another instance is the installation of small salt pans at the expense of mangrove lands.

As well as direct forest exploitation, dumping of urban and industrial waste, agrochemicals and deforestation of the watersheds should be mentioned because they cause an increase of the supply of sediments to the mangrove. The access channel for the port of Corinto has needed dredging several times in recent years for this very reason.

With regard to agrochemicals, although estimates of quantities disposed of are not available, it is likely that forty years of cotton growing on ca. 200,000 ha of Region II (Chinandega and León departments in western Nicaragua) have played an important role in ecosystem degradation.

9. Research and Teaching

The Conservation for Development (Olafo) Project of the Tropical Agricultural Research and Training Center (CATIE) and the Nicaraguan Institute for Natural Resources and the Environment (IRENA), started in 1989 with funds from Swedish and Norwegian Cooperation Agencies (ASDI and NORAD), proposed the demonstration of appropriate and sustainable ecosystem use as a development alternative in an area of 10,600 ha of mangrove from the southern part of Aserradores in the North to Salinas Grandes in the South, until 1995. In 1991, this area contained 25,469 recorded inhabitants. Of these, in the zone running from Las Peñitas to Salinas Grandes, 35% commonly use the mangrove, 25% are fuelwood gatherers. In the Reparto Alemania Federal, north of Corinto, 93% of the 827 inhabitants intensively use the 1,400 ha of surrounding mangrove forests for fuelwood.

Windevoxhel (1992) carried out an economic valuation of the mangroves in the same area as part of his MSc. thesis. One of his main conclusions was that sustainable management of the resources would generate greater benefits for society than current intense and non-sustainable extraction.

In July 1991, the Project Wise Use of Mangrove Resources began its activities in Estero Real as a joint effort between CATIE and IRENA with funding from the Danish cooperation Agency DANIDA (Project DANIDA-Mangroves). This effort is focused on the sustainable and proper utilization of the mangroves in this region that borders the Golfo de Fonseca, to the benefit of the local communities. Within this framework, as is the case with Olafo, biophysical and socioeconomic baseline studies have been carried out seeking viable production alternatives that are in harmony with the functioning of the ecosystem. Both projects are promoting fishing as an alternative to fuelwood extraction and in Estero Real has been developed an environmental education program to promote public awareness of the value of the mangrove resources.

Olafo, DANIDA-Mangroves and IRENA are designing and developing the implementation of plans for the integrated management of mangroves as a solution to the high exploitation pressure on the resources of the ecosystem. These plans for Héroes y Mártires de Veracruz and Estero Real have begun with a categorization of the areas to be managed. This leads to a forest inventory of those areas considered suitable for production, given that this one is the activity which causes greatest degradation. With the information obtained, IRENA will grant concessions to groups that exploit fuelwood whilst the projects and local fuelwood gatherers continue the forest inventory in remaining areas so as to include them in the productive activity at a later date. At the same time, efforts will be undertaken to promote other productive activities in harmony with the ecosystem.

10. National Policies and Legislative Aspects

The Nicaraguan Institute for Natural Resources and the Environment is the state organization responsible with overseeing conservation and the protection of all the country's natural resources. IRENA has legal tools at its disposal to carry out this activity in Nicaragua's mangroves.

The cutting of mangrove timber for financial purpose is prohibited under the last paragraph of Article 4, Chapter I, Decree 235 of the Emergency Law on Rational Utilization of Forests, enacted on March 10, 1976 and currently in effect.

Decree 1320 of September 19, 1983, created several Nature Reserves in Nicaragua's Pacific zone with the aim of restoring coastal ecosystems. Article 2 refers to the protection of mangrove forests in Estero Real, Estero Padre Ramos and Isla Juan Venado and article 4 details the corresponding sanctions.

Finally, the January 25, 1991 communication from IRENA totally restricts felling in mangrove forests within the national territory, notes that permits may be granted and details the sanctions that may be applied to those who fail to comply.

Currently, IRENA is promoting Natural Resource Defense Committees at the community level. These comprise the police, army, educational institutions, civil authorities, conservation and development projects, NGOs and environmental movements. The fundamental objective of these committees is to assist IRENA in the work of conservation and protection.

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Mangroves of Cuba

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1. Introduction

The Republic of Cuba is formed by two major large islands; the Isla de Cuba, with 105,000km^2 and Isla de la Juventud, with 2,200km^2; and over 4,000 small islands, cays and reefs. The country has a total surface of 110,920km^2. Cuba Island is 1,200km in length and 40 to 200km in width and has a total coastline of 5,746km. The coastline can be divided in three different sectors: depositional, erosive and sandy coasts (Table 1).

Mangrove ecosystems in Cuba occupy preferentially the low, biogenic depositional sections of the coastline, in places were there is constant flow of tidal and fresh waters. Freshwater, due to the lack of large rivers, is probably the key limiting factor controlling mangrove distribution and development in Cuba. Therefore they reach their maximum development close to river mouths.

Mangroves have immense importance to the islands. They are the first and most efficient barrier to heavy seas, storms and hurricanes, protecting the coastal areas from erosion and salinization. They serve as nursery ground for various economically important marine species as well as refuge for some threatened species. Finally they are a very important forest resource themselves, since mangroves constitute one of the major forest formations in the country and the largest in extension.

2. Extent and Distribution

Mangrove ecosystems of Cuba are the largest among the Caribbean islands and third in extension of all tropical America. They cover 4.8% of the total country surface and over 26% of the total forested area. Major mangrove forests of Cuba are shown in Fig. 1. Largest forests are located in the Isla de Cuba itself along its South coast, from Santa Cruz to Cape Françes, including the Isla de la Juventud. Further, mangroves are present in nearly all Cuban islands and cays.

The total timber reserve estimated for these forests is 19.5 x 10^6 m^3, with an average timber volume per hectare of 40 to 150 m^3. Natural mangroves of Cuba cover 531,100 ha. Nearly 25,800 ha of mangroves were replanted during the last 15 years. Table 2 and Fig. 1 show total natural and replanted mangrove areas, the area of adjacent lagoon ecosystems and the area where mangroves could be introduced.

The mangrove ecosystems of Cuba have been classified according to their major importance by the National Forest Ordination Plan (Table 3). Most areas were classed as shore protection formations

Table 1. Division of the Cuban coastline according to geomorphology (length in km).

Type of coast	depositional	erosive	sandy	total
North coast	1,189	1,800	220	3,209
South Coast	1,395	1,012	130	2,537

Table 2. Distribution of natural and replanted mangrove forests, adjacent coastal lagoons and areas potentially suitable for the introduction of mangroves in the Cuban archipelago.

Natural Forests	Replanted Forests	Lagoons and others	Potential for introduction
531,100	25,800	233,100	70,000

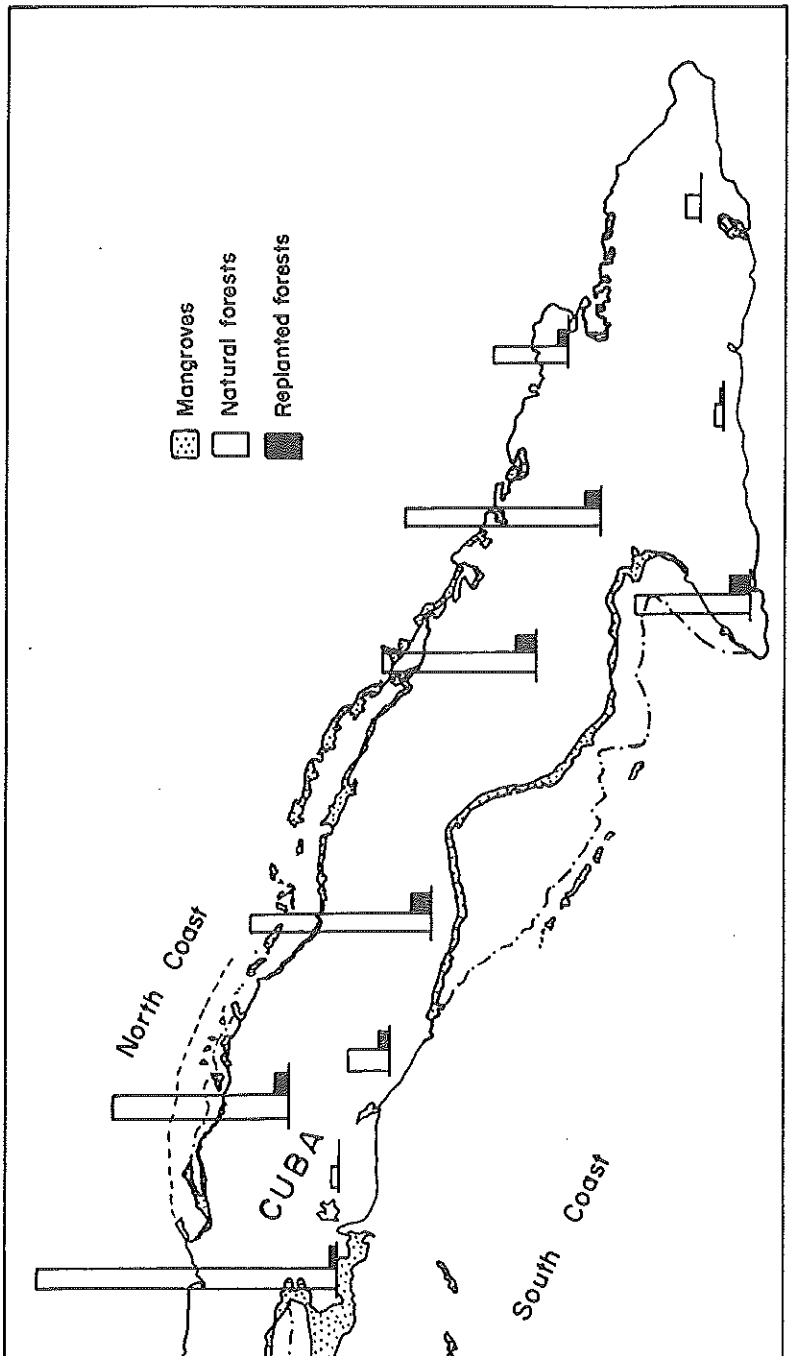

Fig. 1. Distribution of natural and replanted mangroves in Cuba. Bars are unitless proportions.

(56%) and barriers to salinization of coastal soils and groundwater (21%). The third largest percentage of mangroves in Cuba has the status of fauna and flora protection units.

3. Physical Setting

The mangroves of Cuba develop under tropical climate and low rainfall. Mean annual temperature is 26ºC, ranging from 10ºC to 36ºC. Mean annual rainfall is 1,200mm, ranging from 587mm in the dry season to 1,732mm during the rainy season. Soils are hydromorphic with varying degrees of gleysation in deeper horizons and organic matter accumulation in the surface horizons. Coastal soils are generally rich in sulphates. Tidal amplitude is small (0.34m) with mean ebb tide of 0.25m and mean flood tide of 0.90m.

Table 3. Status of mangroves of Cuba according to the National Forests Ordination Plan.

Classification	Percentage of total mangrove area
Coast protection	56
Protection of soils and groundwater	21
Conservation of fauna and flora	16
National Parks	0.5
Natural Reserves	0.3
Recreational areas	0.2
Timber production	6

4. Biology and Ecology

4.1 Flora and fauna composition

Mangroves of Cuba are composed of four tree species; the red mangrove *Rhizophora mangle* L., the black mangrove *Avicennia germinans* L.; the white mangrove ("Patabán") *Laguncularia racemosa* R. Gaertn. and the button wood ("Yana") *Conocarpus erectus* L. Typical accompanying species are *Batis maritima, Dalbergia ecastaphillum, Acrostichum aureum* and various species of *Bucida*, generally found in *C. erectus* forests.

Mangrove structure is dependent on the environmental conditions of each area. Forest height ranges from tall (20-25m) stands under optimal conditions to dwarf (2-3m) stands under stressing conditions. Some forests are mono-specific, while others are dominated by a mix of the major species. Therefore, a diversity of communities or "ecological types" are possible. In areas of high salinity, extreme halophyte communities of *Salicornia* spp., *Suaedea liniaris* Moq. and *Batis maritima* L., are common. In general, *R. mangle* occurs at the seaward fringe and margins of creeks and lagoons. *Avicennia germinans* and *L. racemosa* typically occur behind the *R. mangle* fringe followed landward by *C. erectus*. However, extensive forests are found where the four species occur together. Also, large areas of dwarf *R. mangle* can occur far from the coast, sometimes associated with *C. erectus*.

Various seaweeds are associated with mangroves, the major genera are *Bostrichia, Catenella, Caloglossa* and *Muralella*. The most frequent species are *B. escorpioides, C. repens, C. lapriuri* and *M. pirielados*. Suárez (1984; 1985) reported 18 genera of Rhodophyta, 22 of Clorophyta and 7 of Phaeophyta associated with Cuban mangroves. Large prairies of the seagrass *Thalassia testudinum*, dependent on illumination, occur close to mangrove roots.

A rich and diversified fauna occurs in the mangroves of Cuba. Birds are particularly important due to the high species diversity and the presence of endemic species such as *Dendroica petechis gundlachi* and *Rallus longirostris caribaeus*. Other marine birds move into the mangroves for refuge and reproduction such as the pelican *Pelecanus occidentalis*, the frigate *Fragata magnificens*, the egrets *Ajaja ajaja, Andrea cocci* and *Casmerodius albus*, the royal duck *Cairina muschata* and the flamingo *Phoenicopterus ruber*, a beautiful migrating bird of great interest to bird watchers. Among the mammals endemic to the mangroves, there are 5 species of *Capromys*: *C. pilorides*, with ample distribution and *C. sanfelipensis, C. garridoi, C. angelcabrerais* and *C. auritus*, with a more restricted distribution. Among the reptiles there are two species of economic important crocodiles: *Crocodilus rombifer* and *C. acutus*.

On the roots of mangroves a highly diverse fouling community occurs, composed of various species of sponges, coelenterates, bryozoans, polichaetes, cirripeds and molluscs. Of great importance is the mangrove oyster *Crassostraea rhizophorae* (Sáenz, 1974). Large populations of the crab *Uca pugilator* also occur in the mangroves contributing with nutrients to the mangrove environment. Influenced by the mangroves there is also a diverse fish fauna, the most typical and abundant species being: *Lutjanus* spp., *Diapterus rhombeus, Eugerrea brasilianus, Tarpon atlanticus* and *Centropomus undecimalis*.

Mangrove entomofauna has been poorly studied. Recently, in the mangroves of the cays north of Villa Clara, a new species of Lepidoptera Pyralidae was found, whose larvae bore into mangrove roots. Other important herbivores are the coleoptera Scolitidae, which attack the seedlings of red mangroves and micro-lepidoptera, which also attack the seedlings of both the red and black mangroves. Another lepidopteran, *Phocides pigmalion batabano*, largely attacks the leaves of the red mangrove.

4.2 Ecology

The Majana Ecological Station for Mangrove Research, south coast of the La Habana province, carries on studies on the structure and function of mangroves since 1986.

The structural characteristics of the Majana mangroves are shown in Table 4. Species composition includes *R. mangle, A. germinans* and *L. racemosa*, mean height of the forest is 10m, with an average tree density ranging from 2,930 to 4,150 trees per ha and basal area ranging from 18 to 23.2 $m^2.ha^{-1}$. Litterfall rates have been measured for two years and range from 0.59 to 1.37 $t.ha^{-1}$. Litterfall occurs along the year. However, litterfall was more intense during the rainy period from May to September. These values are in accordance with many others reported for Caribbean mangroves. Decomposition rates of deposited litter at Majana showed 70% decomposition after 8 months for both *R. mangle* and *A. germinans*.

Table 4. Structural characteristics of the mangrove forests of Majana.

Density ($trees.ha^{-1}$)	Basal Area ($m^2.ha^{-1}$)	Height (m)	Litterfall ($t.ha^{-1}.yr^{-1}$)
2,930-4,150	18.0-23.2	10	0.59-1.37

Phenology of the mangrove species at Majana was also studied. Red mangrove, *R. mangle* produces flowers and fruits the year round. However, flowering peaks occur during the dry season from October to February, while fruiting is more intense from April to August. The black mangrove, *A. germinans* showed a typical flowering period from May to June, although isolated flowering trees are found from April to July. Fruits ripen from June to August although some fruits were still found as late as November. The "Patabán" *L. racemosa*, and *C. erectus* also show typical flowering and fruiting periods. *Laguncularia racemosa* flowers from April to October, fruits being more abundant after June. *C. erectus* reproduces from March to September, although young individuals show flowers the year-round.

Rhizophora mangle colonizes the seaward fringe and dwarf stands located in open areas flower and fruit throughout the year. However, when this species occurs mixed with *A. germinans*, flowering is less intense. These observations suggest that light penetration is probably a key factor controlling the reproduction of *R. mangle*.

Regeneration experiments showed that artificially replanted *R. mangle* seedlings show less mortality than naturally established ones. Highest mortality occurred during the winter and during dry months, probably as a result of low rainfall and heavier seas. Highest growth rates were measured in rainy months.

5. Associated Ecosystems

Major associated ecosystems of the mangroves of Cuba are wetland forests and marshes, microphilous coastal and sub-coastal forests, aquatic vegetation and coastal dunes. Some agro-ecosystems are also related to mangroves in particular rice fields and pastures. The use of these associated ecosystems affects in varying degrees the development, evolution and conservation of mangroves.

6. Economic Importance

Mangroves of Cuba are considered a valuable resource due to their high productivity and the diverse timber resources they provide, in particular as a source of fuelwood and charcoal. Already during the last century, Spanish immigrants exploited *C. erectus* for its timber. They also used mangrove areas for oyster and shrimp exploitation and other fisheries, hunting of crocodile for its skin and to a lesser extent for honey production.

Although there were specific legislation for the protection of mangroves since the 1920's, there was a continuous use of the resource for charcoal production mostly from poor people who depended on it. However, this deforestation was to a lesser degree than what happened to other forests of the country which nearly disappeared. Until 1959 forested areas of Cuba decreased from 90% of the country's surface to less than 14%. The evolution of the deforestation process is shown in Table 5. Only after 1959 the importance of forests was recognized and mangroves play a key role in the awareness of the importance of forest cover.

Table 5. Deforestation rates of Cuba's territory in the last 150 year.

Year	Forests/Country surface (%)	Forests/Population (ha/habitant)
1812	89.2	19.80
1900	54.0	3.30
1959	14.0	0.22
1989	18.2	0.19

6.1 Timber production

The production of timber products from mangroves is very low, mainly due to the lack of appropriate technology and equipment for the extraction of large trees and transport along the coast. Historical production of mangrove products is detailed in Table 6.

It is important to note that in 1987 mangrove timber represented from 6-8% of the total production of forests while in 1991 this percentage decreased to a low of 1.5%, showing an evident decrease in extractive levels. Mangrove bark, which still has large demand in the market, decreased from 2,300 tons in 1976 to 121 tons in 1991.

6.2 Apiculture

During the flowering months of mangrove trees, in particular of *A. germinans*, over 40,000 bee hives are transported to the mangroves where they are kept for four months every year. Production reaches 1,700 to 2,700 tons of honey, 20 tons of wax and 80kg of propolis. This is located mostly along the South coast where mangroves attain their highest productivity. However, it is still far from the full potential of these forests.

6.3 Fisheries

Some species associated with the mangroves of Cuba have great economic importance. The most important are shrimps and lobsters, with catches around 15 tons per year, mostly for export. Oyster and many fish species are also important for the national market.

Presently, repopulation centers for oyster and shrimps use larvae collected in mangrove areas.

The substitution of mangrove roots for artificial substrates for oyster production and the prohibition to cut the seaward fringe of mangroves, has effectively reduced the impact of such activities on the mangroves.

Shrimp farming is carried on outside the mangroves, freshwater and nutrients from the ponds are diverted to mangroves and has a positive impact on the ecosystem. Recuperation of coastal lagoons and improvement of freshwater supply to coastal areas, will also benefit the mangroves.

6.4 Tourism and recreation

Improving tourism and recreation is an important objective of the management plan for the mangrove ecosystems of Cuba. Plans for the utilization of the natural values of mangroves for tourism and recreation were established. Four classes of utilization have been defined. They are: 1-nature watch; 2-health tourism; 3-hunting and 4 - fishing.

7. Conversion to Other Uses

Conversion to other uses hasn't affected much the mangroves of Cuba. Most conversions occurred in the last 50 years due to the socio-economic

Table 6. Historical production of timber products from the mangroves of Cuba.

Product	1987	1988	1989	1990	1991
Fuelwood ($m^3 \times 10^3$)	19.3	19.5	17.2	19.0	23.8
Sticks for tobacco plants ($m^3 \times 10^3$)	0.4	0.3	0.3	0.3	0.3
Charcoal (bags x 10^3)	22.0	22.4	22.2	23.0	23.9
Bark (tons)	1,027	711	608	351	121

development of the country. Most conversions were for urban development and road construction, extractive mining and increasing agriculture and pasture lands. These have caused impacts of varying degrees to mangroves and are presently being investigated. Major impacted areas are shown in Fig. 2.

8. Environmental Impacts

It is estimated that over 30% of the mangrove area of Cuba has been affected by either natural or anthropogenic impacts. Natural impacts are in general localized and short-lasting. The most common causes of these impacts are: coastal erosion and desiccation of coastal lagoons; sand accumulation over proproots and pneumatophores; cyclones and hurricanes; aridity.

Most common anthropogenic impacts are caused by: release of industrial wastes mostly from oil, sugar production plants, paper and alcohol industries, and beef processing; river damming and decrease of freshwater and nutrient inputs; road construction; conversion to other uses; mining wastes; forest fires; illegal deforestation. Most affected areas are shown in Fig. 2.

9. Research and Training

Mangrove studies in Cuba were started with a survey and ordination of coastal ecosystems, including all mangroves in the country (Betancourt and Rivero, 1947). Matos and Quesada (1969) firstly reported total mangrove area of the country based on an extensive survey of the forest resources of Cuba. In 1976, the research for the ordination of the coastal ecosystems started more systematically, allowing for the precise determination of total mangrove areas, their status and distribution leading to a classification according to structural and functioning characteristics.

More recently various studies on mangrove ecology, conservation and sustainable utilization of the mangrove resources, have been started by many institutions. These include: the Institutes of Ecology and Systematics; of Oceanology; Meteorology and Geography, of the Academy of Sciences of Cuba; the Institutes of Forest, of Soils and of Apicultural Research and the Department of Silviculture of the Ministry of Agriculture; and the Research Center of the Ministry of Fisheries Industry.

Major research being carried is varied. On ecology and management of the ecosystem, they include: forest structure, productivity, nutrient cycling, animal-plant interactions and the characterization of fauna, flora, soils and waters of mangrove ecosystems and impact assessment. On forestry, they include: timber volume evaluation, reforestation techniques, management of the resource and investigation on better forestry technology, extraction of secondary chemicals and optimization of charcoal production. On fisheries; they include stock management, improvement and recuperation of coastal lagoons, shrimp farming, oyster culture and management and farming of the crocodile population. On oceanography, important research includes cartography and characterization of marine ecosystems, functioning, population dynamics and the relationship between other coastal ecosystems functioning and mangroves.

Most of the above is taking place at Research Stations along the coast at Guanal, Majana, Ciénaga de Zapata, Itabo, Cayo Coco and Cabo Cruz (Fig. 2).

10. National Policies and Strategies Towards Mangroves

The conservation of the mangroves of Cuba is a question of ecological and economic importance. Alternatives are studied to elaborate and execute plans integrating the conservation of the ecosystem with its sustainable uses in particular with tourism, mining, apiculture, fisheries and others. Various laws and specific legislation regulate mangrove exploitation, protect mangroves on coralline islands, the establishment of the National Park of Sierra Maestra etc. Presently two legislation on the coastal zone and on forests and wildlife are being approved.

Integrated projects being developed include: Integrated Management of the Mangroves of the Forest Reserve of Guanal, Project on the Conservation of the Biodiversity and its Sustainable Uses of the Sabana Archipelago - Camaguey (GEF/PNUD) and on Induced Spawning and Larval Growth of Marine Fish. The National Tropical Forests Action also includes a specific mangrove project: "Management and Integrated Development of Mangroves".

The Ministry of Agriculture administrates the mangrove resources and supports a National Mangrove Committee formed by specialists of all organizations involved with mangroves, with the

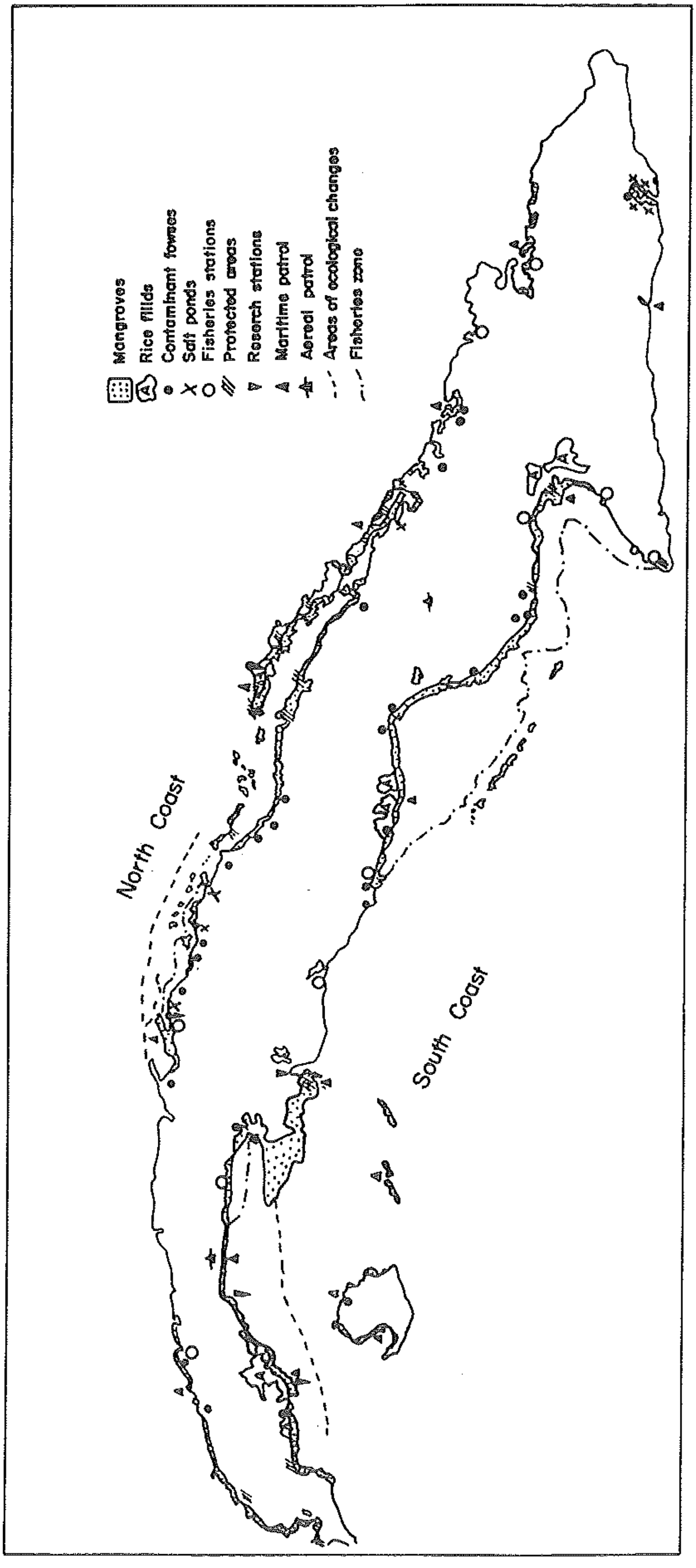

Fig. 2. Major converted mangrove areas of Cuba

objectives of conservation, protection and sustainable uses of mangroves.

Since 1980, a re-planting program which was started until 1987 had planted 7,100 ha of mangroves. The program was incremented after 1987 and presently over 25,700 ha of mangroves have been re-planted. Also a program to control forest fires was started, to control deforestation and permanent patrol using aerial and maritime infrastructure. Management plans are being carried on in 15 protected areas.

The National Forestry Policy focuses on the mangrove subject based on the present state of the ecosystem. Major policies are: - To continue the national mangrove reforestation program; - To select species taking into consideration site characteristics and objectives; - To maximize the production potential of the ecosystems, in particular for fuelwood, charcoal, poles and timber; - To approve the Wildlife and Forest Act; - To increase the protection against forest fires, pests, erosion and any other cause of mangrove deterioration; - To develop structures for the establishment of integral management areas, protected areas and tourism zones; -To strengthen the educational program for personal involved with these activities; - To improve living conditions of the coastal populations; - To transfer scientific findings to the actual works being carried on in mangroves.

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Mangroves in the Lesser Antilles, Jamaica and Trinidad and Tobago

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Introduction

a. Mangroves in the Caribbean Islands

This report describes mangrove resources in the English-speaking islands of the Greater and Lesser Antilles. It is based largely on a comprehensive mangrove site inventory conducted during 1991 in nine member states of the Caribbean Community (CARICOM) on behalf of the Commission of the European Communities (CEC) and work done by the Wetlands Evaluation Research Project (WERP) of the University of the West Indies.

The islands covered include Anguilla, Antigua & Barbuda, the Bahamas, Barbados, Bermuda, the British Virgin Islands, the Cayman Islands, Dominica, Grenada & the St. Vincent Grenadines, Jamaica, Montserrat, St. Kitts/Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago, and the United States Virgin Islands (Fig. 1).

A range of descriptive studies is available for some of the target islands, but no previous comprehensive mangrove area inventory has been conducted. Furthermore, available literature suggests that no quantitative inventory of mangrove forest resources, which contains forest mensuration data, has ever been carried out in the majority of the islands. Mangrove forests have, thus, received considerably less attention than many terrestrial forests and further effort is needed to produce a baseline inventory for the many different countries.

Mangroves have been reported throughout the Insular Caribbean, often occupying extensive areas of the coastal zone (Chapman, 1977; Scott and Carbonell, 1986; Lugo *et al.*, 1990). In the smaller islands of the Eastern Caribbean areal coverage by mangroves may be restricted and the mangrove has poor tree development; often forming low coastal scrub in response to hypersaline conditions and frequent storm and hurricane damage. While their ecological and economic values are recognized widely, a large proportion of the region's mangrove forests have been lost already to coastal development activities, with many further areas threatened or under stress.

Seven species and one variety of mangroves occur in the Insular Caribbean (Table 1). *Rhizophora mangle* is the most abundant throughout the region, with *R. harrisonii* and *R. racemosa* apparently restricted to Trinidad; *Avicennia germinans* is widespread, whereas *A. schaueriana* is present on several islands but nowhere common; *Laguncularia racemosa* is present on most islands but rarely forms large stands and *Conocarpus erectus* is a common component of wetland margins and littoral woodlands; *C. erectus var. sericeus* appears to be restricted to the northern islands of the Caribbean.

Mangroves form a range of estuarine, coastal fringe, basin and scrub communities; frequently associated with salt marshes and salinas. The largest areas are found at river mouths, while communities fringing sheltered bays, lagoons and ponds are the most widespread.

In the Caribbean, mangroves occur throughout a broad latitudinal range and wide climatic variation (Table 2); the physiological and ecological responses by the mangroves across this range have been poorly investigated.

b. Review of previous studies

The location of major mangrove areas in the Eastern Caribbean region was shown in the ECNAMP data atlases (Putney, 1982); but these were not described. Wetland sites in all islands, including mangrove areas, were listed in the Directory of Neotropical Wetlands (Scott and Carbonell, 1986). As the Directory was concerned largely with waterfowl habitat it contained only superficial reference to mangrove vegetation. Prior to this, there had been a range of studies in specific countries dealing with the larger or more important mangrove-containing wetland sites - and these are discussed in the individual Country Reports. These studies give data only on the main mangrove species present and their general areal coverage, sometimes with accompanying lists of fauna, particularly the birds, and, almost entirely, are without data on the mangrove forest itself.

Consequently, little of the available literature can be used for making scientific decisions about

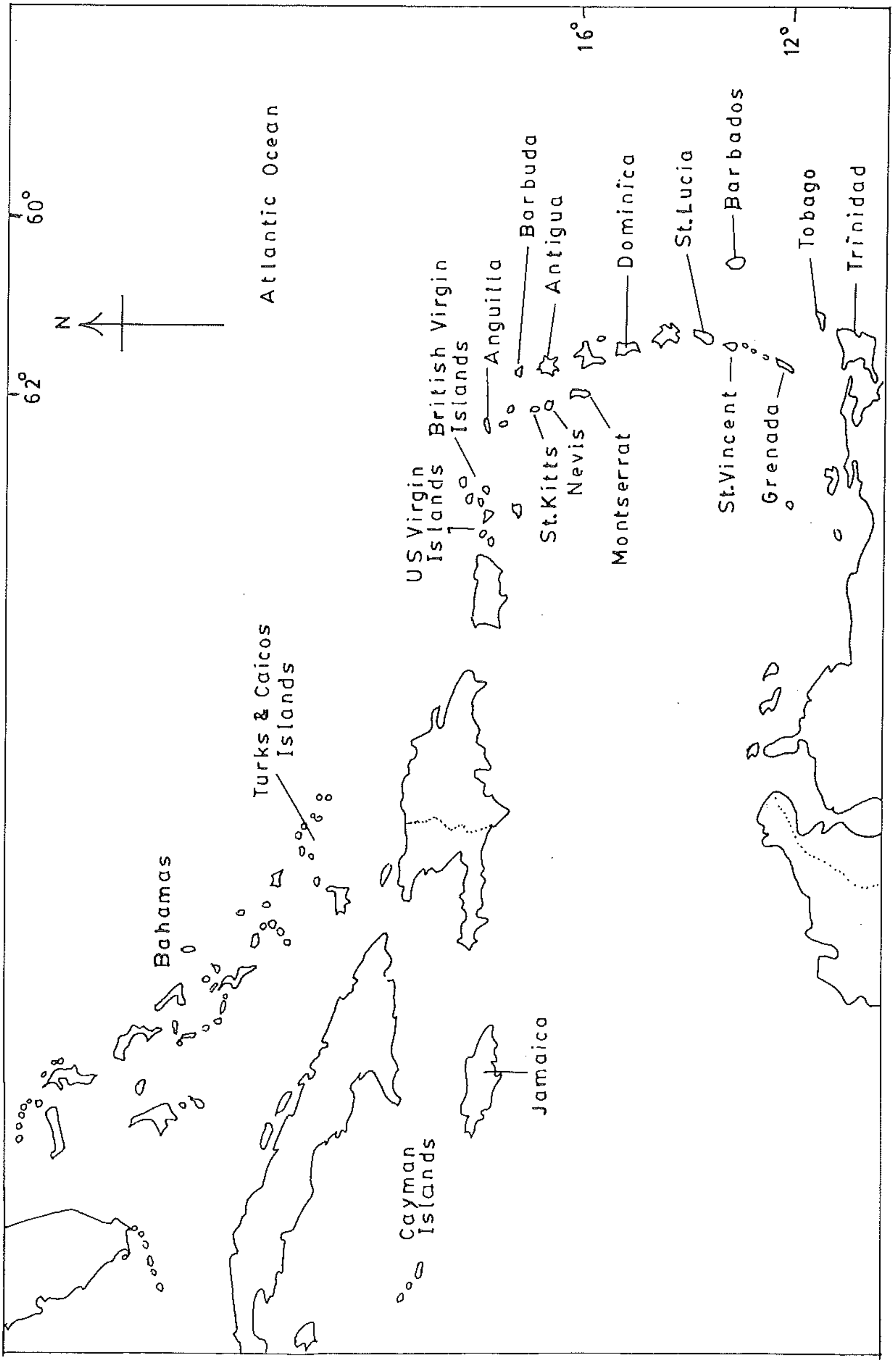


Fig. 1. The Insular Caribbean showing islands mentioned in the text.

Table 1. Mangrove species in the Insular Caribbean

Families and species (in order of abundance)	Common name	Abbreviation used in this report
Fam. Rhizophoraceae		
Rhizophora mangle L.	Red mangrove	Rm
R. harrisonii Leechman	" "	Rh
R. racemosa G.F.W.Meyer	" "	Rr
Fam. Avicenniaceae		
Avicennia germinans L.	Black mangrove	Ag
A. schaueriana Stapf. & Leechman	" "	As
Fam. Combretaceae		
Laguncularia racemosa Gaertn.	White mangrove	Lr
Conocarpus erectus L.	Button mangrove	Ce
C. erectus var *sericeus*	" " (*)	Cs

* Native to Bahamas and Turks & Caicos
Introduced as an ornamental in Eastern Caribbean.

Table 2. Climatic data for the Insular Caribbean (Blume, 1974).

A. Physiographic sub-divisions

Island Group	N°. humid months	Climatic type
Bahama Islands	4 - 6	Tropical; with seasonal rainfall
Greater Antilles	3 - 12	Tropical; (a) arid with seasonal rainfall, (b) moist with summer rainfall and (c) wet.
Windward Islands	4 - 9	Tropical; with seasonal rainfall or moist with summer rainfall.
Leeward Islands	3	Tropical arid.

B. Climatic data

City/Island	Altitude (m OD)	Average annual precipit (mm)	Average annual tempt (°C)
Nassau/Bahamas	4	1,185	25.1
Grand Turk/TCI	4	750	26.3
Port Antonio/Jamaica	3	3,328	26.5
Kingston/Jamaica	7	732	26.3
St. Johns/Antigua	24	1,251	26.0
Roseau/Dominica	8	1,928	26.8
St. Georges/Grenada	155	1,839	26.0
Port of Spain/Trinidad	40	1,606	25.1

mangrove forest management in any of the Caribbean islands. Mangrove forests appear to have been neglected by foresters, so there are minimal data in government forestry department reports, whereas mangrove areas figure widely in both technical and popular conservation literature. In this latter case, mangroves tend to be treated generically; so all are thought to possess value for fisheries, coastal protection or wildlife habitat without attention to site-specific differences in functional values. From the management point of view, such literature has limited use, in that it fails to identify the inherent diversity of sites in each country and the range of resources and of development opportunities that exist.

Recent attempts to quantify mangrove areal coverage and mangrove resource uses, as part of individual site descriptions, include those of the British Virgin Islands Department of Conservation and Fisheries (Blok-Meeuwig, 1990); and the Tropical Forestry Action Plan of the Commission of the European Communities (Bacon, 1991). Work is in progress in Jamaica, through the Wetlands Evaluation Research Project, and in St. Lucia, through the Caribbean Environmental Health Institute (CEHI) also.

A great deal more of baseline inventory work is needed to give a comprehensive view of mangrove resources in the Insular Caribbean. This report reviews existing information on an island by island basis from a management perspective. Each section lists mangrove sites so far identified and their approximate areal extent. Many of the listed sites contain a limited amount of mangrove, but separating individual sites is important because management decisions usually relate to specific parcels of coastal land.

In the majority of cases, mangrove wetland boundaries have not been mapped precisely so an estimate had to be given. In many areas, mangroves are contained within a larger wetland system, such as a salina or lagoon (Table 3), and it proved difficult without accurate mapping to give estimates of the true extent of mangrove forest.

Table 3. Mangrove sites and community types

A. Estuarine	
1. Estuarine *Rhizophora*	Estuarine/river mouth sites dominated by red mangrove
B. Fringe	
2. Fringe *Rhizophora*	Areas dominated by red mangrove fringing open coasts
C. Basin	
3. Basin *Rhizophora*	Red Mangrove occupying pond margins or depressions not connected directly to the sea.
4. Basin *Avicennia*	Black Mangrove occupying low lying areas, depressions, not connected directly to the sea.
5. Basin *Laguncularia*	White Mangrove occupying pond margins or depressions or behind barriers separated from the sea.
6. Basin Mixed Mangrove	Areas containing more than one forest mangrove species behind beach barriers or in depressions not connected directly to the sea.
D. Scrub	
7. Scrub *Rhizophora*	Very short, but mature, red mangrove forest, with trees showing poor trunk development.
8. Scrub *Avicennia*	As above, with Black Mangrove.
9. Mixed scrub mangrove	As above, with mixed red and black mangrove.
10. Scrub *Conocarpus*	As above, with Button Mangrove.

c. **Mangrove site types and associated ecosystems**

Insular Caribbean mangrove sites (mangals) can be classified into general categories on the basis of their geomorphology and dominant plant community. Table 3 shows 4 mangal types with 10 communities that can be recognized easily in the field. These terms are used in the country reports that follow. Throughout the Caribbean, mangroves are associated with many coastal ecosystems, which are recognizable also from dominant plant types (Table 3).

In most islands, as in other regions, mangrove communities are facies of broader coastal wetland systems; in many cases these are complex systems

Table 4. Associated ecosystems with mangroves of the Caribbean

A. Salt Pond	Saline or hypersaline water bodies not connected to the sea.
B. Salina	Areas with hypersaline soils, frequently dry with a crust of salt; subjected to seasonal inundation; un-vegetated, except for algae.
C. Salt Marsh	Areas dominated by low, salt tolerant herbs, such as *Batis*, *Salicornia* or *Sesuvium*; and frequently interspersed with scrub mangrove.
D. Freshwater Marsh	Areas dominated by aquatic freshwater herbs, either rooted or floating, such as *Typha*, *Phragmites*, *Nymphaea*, *Eichhornia* or *Pistia*.
E. Swamp Forest	Areas dominated by trees with adaptations to permanent or seasonal inundation by fresh water; either on river banks or in swampy depressions, such as *Pterocarpus*, *Symphonia*, *Roystonea*, *Sabal*, *Mauritia*.
F. Littoral Woodland	Low, often scrub-like trees bordering the coast or on beach barriers; adapted to salt spray and sea breezes; such as *Coccoloba*, *Terminalia*, *Hippomane* or *Thespesia*.
G. Strand and Dune	An herbaceous plant community occupying back-beach and/or sand dune areas; dominated by *Ipomoea pes-caprae*, *Sporobolus virginicus*, *Canavalia maritima* and *Sesuvium portulacastrum*.

Table 5. Number of mangrove sites identified and described

Country	Recorded sites	Approx. Area (ha)
Anguilla	10	270
Antigua	36	559
Barbuda	9	616
Bahamas	20	141,957
Barbados	14	20
Brit.Virgin Is.	55	627
Cayman Islands	25	7,268 *
Dominica	10	10
Grenada	24	149
Grenada-Grenadines	4	67
Jamaica	101	10,624
Montserrat	4	4
St. Kitts	8	71
Nevis	8	8
St. Lucia	18	157
St. Vincent	4	2
St.Vin.-Grenadines	13	48
Trinidad	38	7,020
Tobago	11	130 ?
Turks & Caicos	95	23,600
US.Virgin Is.	21	978 *
Totals	528	**66,420** ha (approx.)

* Area of wetland containing mangrove (Actual mangrove coverage not known)

with a range of hypersaline, saline and brackish habitats associated with beach barriers and lagoons and influenced by both land drainage and periodic tidal flushing. For conservation and management purposes the entire wetland containing the mangroves must be considered. The numbers of sites in each of the target islands are given in Table 5.

d. Regional research and management activities

The Caribbean Coastal Marine Productivity Project (CARICOMP) has a component involving all island marine laboratories in the region in the measurement of mangrove productivity and the World Conservation Union (IUCN) is working with the Caribbean Natural Resources Institute (CANARI) to develop training and education programs. There are no international conventions specific to Caribbean mangrove protection and management.

1. Anguilla

1.1 Historical Background

Scott and Carbonell (1986) summarize the few studies done on wetlands in Anguilla, which are mainly salt ponds, although there is only general reference to mangrove areas (Putney, 1982; Towle, 1979; Goodwin *et al.*, 1984).

1.2 Mangrove Ecosystems, Extent and Distribution

Mangroves occur in 10 sites on the margins of 7 saline ponds on the main island and around 3 others on adjacent Scrub Island (Fig. 2 and Table 6). Mangroves cover approximately one third of the 270 ha occupied by these wetland systems.

1.3 Physical Environment

Anguilla is a low lying limestone island, 90 km^2 in extent with a maximum elevation of 65 m. It has a dry tropical climate (province 8.41.13), with mean annual rainfall about 1,000 mm, and a wet season from August to November (Scott and Carbonell, 1986).

No other information on Anguilla mangroves is available.

2. Antigua and Barbuda

2.1 Historical Background

The inventory of Antigua's mangroves is incomplete although there is considerable information available on many of the larger sites. An early reference by Loveless (1960), describes the botany of mangroves and notes losses and system modification due to exploitation. Harris (1965) produced maps of four major swamp areas and Morello (1983) noted the presence only of Rm, Ag and Lr. The World Resources Institute (1987) reported 4,901 ha of salt ponds and mangroves swamps in Antigua and Barbuda, although not indicating the data base from which this estimate was made. A number of descriptive reports are available, such as Coulston and Mussington (1987) for Cove Lagoon and the Country Environmental Profile (CCA/IRF, 1991) which gives the general distribution of mangrove sites in Antigua. Kelley and Royer (1989) identified 20 mangrove sites in Antigua, noting deleterious impacts in 8 of them. Mangrove forest data do not appear to be available.

More comprehensive information is available on mangroves in Barbuda, particularly on the habitats that support them, from the work of Harris (1965), Russell & McIntyre (1966) and Brasier & Mather (1975). A detailed description of environmental conditions and vegetation at inland mangrove sites is given by Stoddart *et al.* (1973) with studies on associated invertebrates by Gibbs and Bryan (1972). However, none of the reports give mangrove forest structure or mensuration data.

2.2 Mangrove Ecosystems: Extent and Distribution

Thrity six sites with mangroves were identified in Antigua and 9 in Barbuda. These are listed in Table 7 and their location shown on Fig. 2. In Antigua the sites range from small, single species stands of trees to the large, complex swamp of 225 ha at Hansons Bay. In Barbuda, the narrow, scrubby borders of mangroves around some salt ponds contrast with the more luxuriant 352 ha fringe mangrove in Codrington Lagoon. **Rm** is dominant in both islands, with **Ag** and **Lr** common, and **Ce** occasional at a few sites. 32 sites were visited and preliminary descriptions of the mangrove forest provided by Bacon (1991). The Fisheries Department started a detailed inventory of mangrove sites in 1991, but a great deal of work remains to be done.

2.3 Physical Environment

Antigua is a high island of 280 km^2, with maximum altitude of 402 m. Barbuda is a low, limestone island of 161 km^2; 20% of which covered by wetlands. CCA/IRF (1991) state that year round high temperatures (average 29°C in summer and 24°C in winter) and yearly rainfall of 1100 mm with marked wet and dry seasons characterise Antigua; while Barbuda is one of the driest islands of the Caribbean, with average rainfall between 750 and 975 mm.

2.4 Biological and Ecological Characteristics

General site descriptions for Antigua's mangroves are contained in Bacon (1991). The largest area in Hanson's Bay has **Rm** forming dense stands at the seaward side where the estuary fringe is from 4-5 m high, with upstream **Rm** to 10 m high grading into taller **Ag**. The landward side shows much dieback into a salina with *Sesuvium*. **Lr** extends the furthest inland, following the rivers into adjacent pasture land and has bushes to 4 m high. There is little information on the mangrove fauna, but 692 individual waterfowl belonging to 17 species were observed in a 1/2 hour visit in July, 1991. Mangroves at site AN31 had **Rm** and **Ag** trees to 7.5 m and 8 m respectively. In Barbuda, the 352 ha Codrington Lagoon has **Rm** dominant in an irregular fringe, largely

Table 6. List of mangrove sites in Anguilla (Code = AN)

Code	Name of Site	Type of mangal	Approximate size (ha)
AN01	Cauls Pond	Basin	60
AN02	Cove Pond	Basin	75
AN03	Long Salt Pond	Basin	23
AN04	Meads Bay Pond	Basin	20
AN05	Rendezvous Pond	Basin	25
AN06	Savannah Pond	Basin	20
AN07	West End Salt Pond	Basin	18
Scrub Island (island sub-unit)			
ANs01, 3 ponds with mangrove		Basin	c.a.30

of low scrub to 3-4 m high, with several overwash islands in the northern section.

Other sites on Barbuda are dominated by scrub mangroves, usually with mixed **Rm**, **Ag**, **Lr** and Ce. No soil or hydrographic information is available for any mangrove site.

2.5 Mangrove Related Ecosystems

Major associated systems are Salina and Salt Marsh; Littoral Woodland and Strand/Dune systems are poorly developed. Coral reefs and seagrass beds are closely associated at several sites in both islands. Codrington Lagoon has well developed Salt Marsh with *Batis maritima* and *Salicornia perennis* and extensive seagrass/algal beds with *Thalassia, Halodule, Batophora* and *Acetabularia* dominant.

2.6 Human Habitation and Traditional Mangrove Usage

There are no human settlements within mangrove areas in either island. Little attempt has been made to assess mangrove resources in Antigua, other than references to site values for wildlife, such as Williams (1991), and De Albuquerque's (1991) examination of conflicting economic claims on coastal salt ponds. The CIDE (1988) report describes mangrove losses at Deep Bay, Fort James, Falmouth Harbour, Jumbie Bay, Darkwood, Cocks Hill Jolly Pond and McKinnons Pond but gives no figures; while several other authors, such as Williams (1991), report destruction and filling of mangrove areas.

The mangrove sites of Barbuda are known to be important for their variety of aquatic life and avifauna (Holland & Williams, 1978; Mussington, 1983; Halewyn & Norton, 1984),

2.7 Commercial Exploitation and Conversion to Other Uses

No commercial exploitation of mangroves in Barbuda exists. Cutting for charcoal occurs for subsistence use only. Some reclamation for tourism and residential development.

2.8 Impacts on the Mangrove Environment

Although minor damage from cutting and charcoal burning was identified, the major cause of damage appears to be coastal development, particularly that associated with the tourism sector (Bacon, 1991). Threats of further losses will continue until a mangrove protection and management policy is prepared and mangrove-specific legislation enacted for both islands. Private land owners and developers appear unaware that property rights do not extend to mangrove stands growing below the high tide mark.

2.9 Research and Training Programs

The Fisheries Department has begun a mangrove site mapping project and is seeking to educate fishermen on the values of mangroves to their industry.

2.10 National Policies and Strategies for Mangrove Management

The Forestry Act (chapter 99 of 1941) makes no specific reference to mangrove forests; although its provisions could be used to protect mangrove areas; as could the Town & Country Planning Ordinance (chapter 276 of 1948) and the National Parks Act (No. 11 of 1984). No specific reference to mangroves, in relation to fish sanctuaries or fishery nursery areas, is made in the Fisheries Act 1983 or the Regulations 1990; provisions in the Act concerning "marine flora" have not been used in relation to mangrove conservation. Mangrove replanting, site clearing, stand improvement and management of

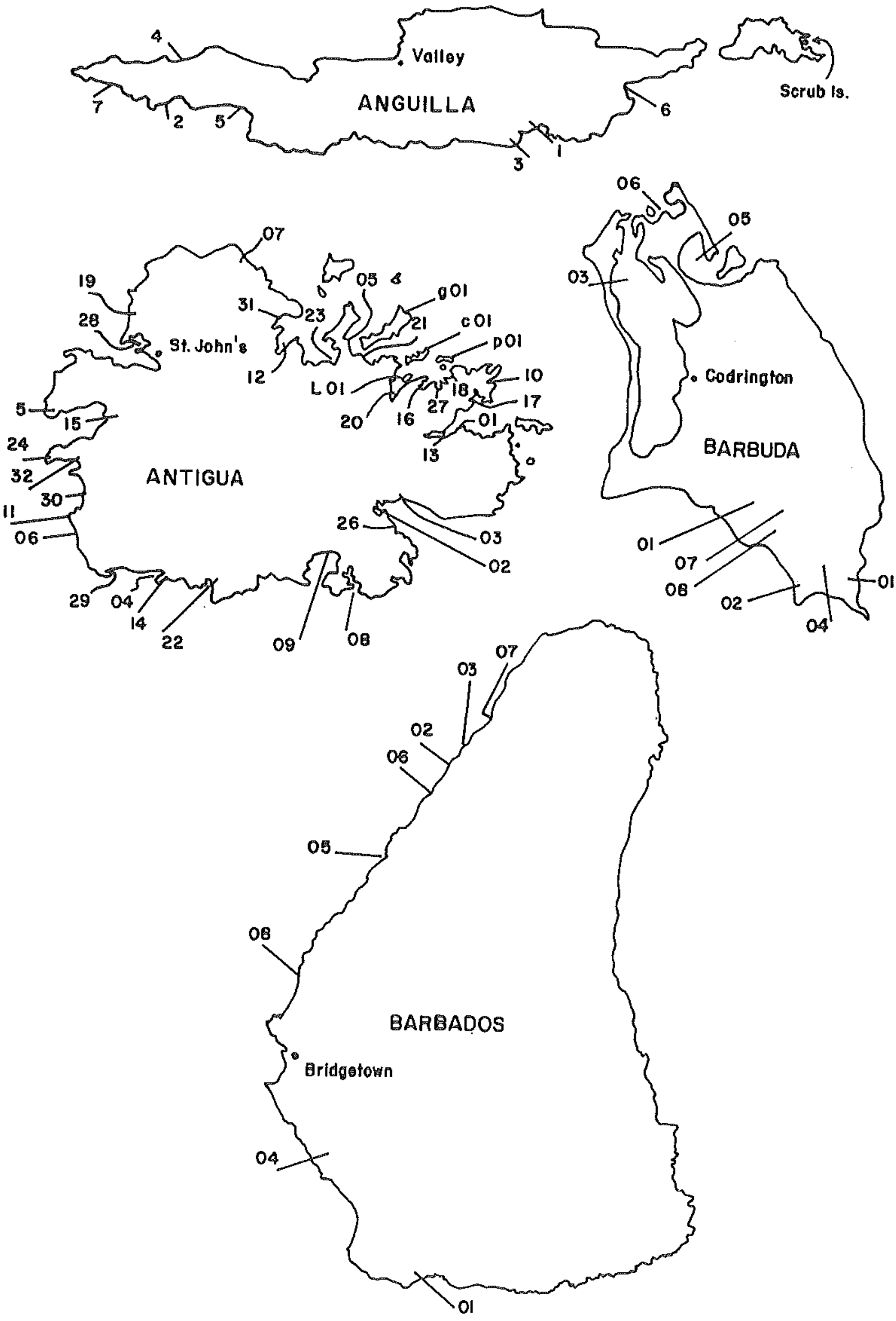


Fig. 2. Mangrove sites in Anguilla, Antigua, Barbuda and Barbados.

Table 7. List of mangrove sites in Antigua (AT) and Barbuda (Bb).

Code	Name of site	Type of mangal	Approximate size (ha)
	Main island		
AT01	Ayres Creek	Fringe	4
AT02	Bethesda	Bas. & Fr.	22
AT03	Blakes	Fr. & Bas.	20
AT04	Cades Bay	Basin	6
AT05	Crabs Mill	Fringe	10
AT06	Dark Wood	Basin	3
AT07	Elys Bay	Basin	7
AT08	English Harbour	Fringe	3
AT09	Falmouth Harbour	Fringe	15
AT10	Fanny's Cove	Fringe	1
AT11	Ffryes Point	Basin	2
AT12	Fitches Creek Bay	Est. & Fr.	17
AT13	Gaynors	Estuarine	11
AT14	Goat Head	Fr. & Bas.	9
AT15	Hansons Bay & Flashes	Estuarine	225
AT16	Keeves Landing	Fringe	10
AT17	Ledeatt Cove	Fringe	4
AT18	Lords Cove	Fringe	2
AT19	McKinnon's Salt Pond	Basin	7
AT20	Mercer's Creek	Fringe	32
AT21	Nibb's Wharf	Fringe	10
AT22	Old Road	Basin	20
AT23	Parham Harbour	Fringe	32
AT24	Pearns Bay Ponds	Basin	1
AT25	Pelican Mill	Basin	2
AT26	Red Hill	Basin	2
AT27	Spencers	Fringe	3
AT28	The Cove	Fringe	7
AT29	Urlings	Fr. & Bas.	17
AT30	Valley Church Bay	Basin	5
AT31	Winthorpes Foot Creek	Est. & Fr.	40
AT32	Yorks Salt Pond	Fringe	1
	Offshore islands		
ATc01	Crump Island	Fringe	1
ATg01	Guiana Island	Fringe	5
ATl01	Laviscounts Island	Fringe	2
ATp01	Pelican Island	Fringe	1
	Barbuda		
Bb01	Bull Hole	Basin	100.0
Bb02	Codrington Lagoon & The Creek	Tinge	325.0
Bb03	Cocoa Point Salt Pond	Basin	12.8
Bb04	Gravenor Bay Salt Pond	Basin	2.0
Bb05	Goat Island Flush and Cobb Cove	Fringe	32.6
Bb06	Goat Island North	Fringe	43.8
Bb07	Inland Swamp #2 North	Basin	27.0
Bb08	Inland Swamp #3 South	Basin	72.0
Bb09	Pelican Bay Salt Ponds	Basin	1.0

improve forest products and wildlife values is required in many sites. On the other hand, few sites seem suitable for extending the present mangrove coverage.

Efforts are being made by the Antigua & Barbuda Environmental Awareness Group to create public awareness of environmental issues, including wetland conservation. The Guiana Island Society, established in May 1991, has as a specific objective protection of the flora of the island, which would include mangrove trees. Apart from these efforts there is no evidence that the general public, land owners and developers are aware of the importance of mangrove conservation. Furthermore, there is a lack of educational and public awareness materials - such as booklets, brochures and posters.

3. Bahamas

3.1 Historical Background

There is surprisingly little published information on the wetlands of the Bahamas archipelago. Much of the survey and research work has been conducted by, or on behalf of, the Bahamas National Trust and most has been in connection with protected areas development or waterfowl and seabird studies. These have been summarized by Scott and Carbonell (1986).

3.2 Mangrove Ecosystems, Extent and Distribution

Scott and Carbonell (1986) suggest that there are some 425,870 ha of saline wetlands with mangroves in 20 sites in the Bahamas (Table 8). There are no data available on the actual area covered by mangroves, but this is estimated at about one third of the total wetland area.

3.3 Physical Environment

The Bahamas consists of an archipelago of some 29 inhabited islands, 660 cays and 2,400 rocky islets situated on the Bahamas Bank and stretching between Latitude 20°50' - 27°29'N and Longitude 70°00' - 80°32'W. The islands are low lying with maximum elevation of 60 m. No information is available on biological and ecological characteristics; mangrove related ecosystems; human habitation and traditional mangrove usage; commercial exploitation and marketing; conversion to other uses; socioeconomic implications:

3.4 Impacts on the Mangrove Environment

Scott and Carbonell (1986) comment on the loss of some wetland areas to tourism. However, no other information exists on this topic.

3.5 Research and Training Programs

Much of the work on wetland areas has been focused on the ecology and conservation of birds, in particular the Roseate Flamingo, *Phoenicopterus ruber*, particularly on Great Inagua.

3.6 National Policies and Strategies for Mangrove Management

The Ministry of Agriculture, Fisheries & Local Government is responsible for environmental conservation. The Wild Bird (Protection) Act 1905 gives protection to waterfowl habitat.

4. Barbados

4.1 Historical Background

Botanical studies on mangroves in Barbados date back to the mention of *Avicennia* and *Rhizophora* by Hughes (1750); the geographical distribution of **Ag** and **As** was given by Moldenke (1943) and (1960) respectively, and the floristics of **Rm**, **Ag**, **As**, Lr and Ce were given by Gooding *et al.* (1965), also confirming that 5 species occur in the island. Apart from the maps given by Randall (1970) showing distribution of Rm, **As** and Ce, and the report by Williams (1990) showing the extent of mangrove losses, most recent work has been concerned with the Graeme Hall Swamp which is the largest remaining mangrove area in the country.

4.2 Mangrove Ecosystems, Extent and Distribution

Mangroves were found at 14 sites in Barbados; as indicated in Table 9 and Fig. 2. The majority of these are small stands at the mouths of seasonally blocked streams, probably remnants of once larger mangals. The largest mangal was at Graeme Hall Swamp, where some 6.75 ha of well developed **Rm** and Lr forest exist. Preliminary forest structure data were collected in Graeme Hall and notes on mangroves at other sites by Bacon (1991).

4.3 Physical Environment

Barbados is a low-lying limestone island with a cliffed coast on the east and small bay with pocket beaches on the west and south. The island is 430 km^2 in area with interior hills rising to 338 m. The climate is tropical but cool because of dominant NE trade winds with temperature regularly at 32°C with

Table 8. List of mangrove sites in the Bahamas

Code	Name of site	Type of mangal	Approximate size of saline wetland and associated (ha)
	Aklins Island (BAa)		
BAa01	The Bight of Acklins	Scrub & tidal flats	14,200
	Andros (BAn)		
BAn01	Owens Town	Scrub & tidal flats	270,000
	Bimini Islands (BAb)		
BAb01	Alice Town	Fringe	800
	Cat Island (BAc)		
BAc01	Bennetts Hbr. Creek	Scrub & brackish marsh	1,950
	Conception island (BAo)		
BAo01	Conception Island	Scrub & saline lagoons	675
	Eleuthera (BAe)		
BAe01	The Bluff	Scrub & mudflats	1,600
	Exuma Cays (BAx)		
BAx01	Shroud Cay	Scrub & tidal flats	800
	Grand Bahama (BAg)		
BAg01	Northern coast	Scrub & tidal flats	49,800
	Great Abaco (BAr)		
BAr01	The Marls	Scrub & tidal flats	38,400
	Great Exuma (BAt)		
BAt01	Stuart Manor	Fringe & coastal flats	1,350
	Great Inagua (BAi)		
BAi01	Close in Point Lakes	?	
BAi02	Lake Rosa	?	
BAi03	Palacca Point	?	
BAi04	Union Creek	?	
	Long Island (BAl)		
BAl01	Joe's Sound	Scrub & tidal flats	1,500
BAl02	New Found Harbour	Scrub & tidal flats	5,700
	New Providence (BAw)		
BAw01	Lake Cunningham	Mixed basin	70
BAw 02	Lightbourn Creek	Fringe & tidal flats	200
BAw 03	Millers Sound	Fringe	600
	San Salvador (BAs)		
BAs01	Pigeon Creek	Scrub & saline marsh	5,625

(BA = State name; island sub-units indicated by lower case initial letter).

Table 9. List of mangrove sites in Barbados (BR)

Code	Name of site	Type of mangal	Approximate size (ha)
BR01	Brandon Beach	Basin	< 1
BR02	Chancery Lane Swamp	Basin	< 1
BR03	Coral Reef Club	Est/Bas.	< 1
BR04	Gibbes Bay	Est/Bas.	< 1
BR05	Godings Bay	Est/Bas.	< 1
BR06	Graeme Hall Swamp	Basin	7
BR07	Graeme Hall West	Basin	< 1
BR08	Heywoods	Est/Bas.	< 1
BR09	Holetown	Est/Bas.	< 1
BR10	Maxwell Swamp	Est/Bas.	< 1
BR11	Queens Fort	Est/Bas.	< 1
BR12	Read's Bay	Est/Bas.	< 1
BR13	Six Men's Bay	Fringe	< 1
BR14	Spring Garden	Basin	< 1

average rainfall of 1900 mm over the high ground.

4.4 Biological and Ecological Characteristics

Site descriptions are contained in Bacon (1991). The largest remaining stand of mangroves in Graeme Hall Swamp has **Rm** to 14 m high with maximum DBH of 27.0 cm and a thick sapling ground cover. Tidal flushing is restricted by a sluice gate, so the site is dominated by groundwater inputs but is usually brackish at 20‰. The **Rm** fringes a 35 ha lake and grades eastward through stands of **Lr** into a freshwater marsh. The lake hydrology, hydrochemistry, vegetation, fish and waterfowl have been studied (Cattaneo *et al.*, 1988).

4.5 Mangrove Related Ecosystems

Wetland margins are largely reclaimed throughout the island. Small patches of seasonal freshwater Marsh and Strand /Dune systems are present at some sites. Many sites occur at the mouths of ephemeral streams draining the limestone interior.

4.6 Human Habitation and Traditional Mangrove Usage

No human settlements are present in mangrove areas. Hutt (1977) and Scott and Carbonell (1986) gave details of the avifauna utilizing Graeme Hall and Chancery Lane Swamps. They stressed the importance of these sites for wildlife conservation and the potential of the former for recreation. The Caribbean Conservation Association (1985a, 1985b) outlined a plan for management of Graeme Hall Swamp and gave a preliminary indication of the feasibility and economic viability of developing recreation at this site. No other assessment of mangrove resources appears to have been undertaken.

4.7 Impacts on the Mangrove Environment

Williams (1990) noted that more than half the original mangrove area in Barbados had been destroyed, largely through development of coastal areas for tourism. The CCA (1985a, 1985b) described encroachment, impacts and future threats to Graeme Hall Swamp, resulting largely from continuing delays in reaching agreement on the future development of this wetland. Williams (1990) statement that tourism expansion is the main cause of mangrove losses was supported by Bacon (1991), who recorded on-going destruction at Holetown.

4.8 Socioeconomic Implications

Loss of mangroves and current threats to Graeme Hall and Chancery Lane Swamps endanger their recreational potential.

4.9 Research and Training Programmes

The Government Environmental Unit is working with land owners and developers to increase awareness of mangrove values. In addition, the Unit organizes lectures and projects in schools and prepares posters and brochures on environmental issues, including but not stressing mangrove area conservation. The Barbados Environmental Association is active in conservation and has targeted Graeme Hall Swamp as a key area of concern. The BEA is supported by considerable expertise from the University and private citizens. University researchers are working in the area.

4.10 National Policies and Strategies for Mangrove Conservation

There is no legislation which specifically protects mangroves from this and other impacts, although coastal conservation regulations which are in preparation should address this issue. Despite considerable study and planning effort, supported by widespread public opinion, Graeme Hall Swamp has not been declared a protected area. Government appears reluctant to acknowledge the importance of this site for landscape and conservation in Barbados, probably because part of the site is owned privately and alternative development options have been presented. Among these are development of a gòlf course and use of the swamp basin for effluent disposal, and the Environmental Unit, Ministry of Labour, is making an effort to harmonize the different options, in order to maximize the social and economic benefits derived from Graeme Hall Swamp. At all sites there is need for recovery of damaged or lost mangroves. Recovery effort will need to include site renovation, particularly channel clearance and mangrove replanting. At Graeme Hall Swamp there is need for active management for stand improvement, particularly of the **Lr** stands; this should be done in conjunction with a visitor use plan for the site. The level of awareness of wetland/mangrove values among the general public has not been assessed.

5. British Virgin Islands

5.1 Historical Background

Mangroves were designated as a critical natural resource by the Government in November 1986, following which the Organisation of Eastern Caribbean States Natural Resource Management Unit (OECS-NRMU) assisted the Ministry of Natural Resources with the establishment of a mangrove conservation project. In 1990 all mangroves on Tortola, Anegada, Beef Island, Virgin Gorda and Jost van Dyke were mapped and in May 1990 a workshop was held to prioritize mangrove systems for management purposes. The mapping and priority rating procedures were described by Blok-Meeuwig (1990). Previous to this, botanical descriptions were published for various islands including information on mangroves (D'Arcy, 1975; Mirecki, 1977) and Lettsome (1981) had provided an overview description of mangroves in the BVI. Putney (1982) showed the major mangrove sites on his Eastern Caribbean atlas and further records of mangroves were included in descriptions of proposed parks and protected areas (Geoghegan *et al.*, 1986). Scott and Carbonell (1986) list four important sites for waterfowl.

5.2 Mangrove Ecosystems, Extent & Distribution

Fifty-five sites have been identified in the British Virgin Islands (Table 10), the majority of which have been described by Blok-Meeuwig (1990). The greatest area of mangroves occurs on Anegada, particularly the coastal fringe at East End and around the extensive salt pond-salina systems at the western end. The other islands have stands of fringe **Rm** pond/basin systems with all four mangrove genera present in some. The precise area under mangroves in the archipelago is not recorded.

5.3 Physical Environment

The British Virgin Islands group contains nearly 40 islands, including 3 large ones of which the largest, Tortola, is 62 km^2 with maximum altitude of 520 m. Most of the islands are of volcanic origin and have steep interiors dissected by numerous small streams or ghuts and very narrow coastal plains. The island shelf is also narrow and drops off into deep water close to shore. Anegada to the north is a limestone island with maximum elevation of 8 only m and extensive areas of sand dune and salina. It has a broader shelf with well developed coral reefs and seagrass beds.

5.4 Biological and Ecological Characteristics

General descriptions of mangrove ecology in the BVI are given in Blok-Meeuwig (1990) and Overing (1991). Paraquita Bay has one of the best developed areas of mangroves on Tortola with **Rm** and **Lr** present; plots showed a mean height of 6.49 m, mean DBH of 8.76 cm and basal area of 54.75 $m^2\ ha^{-1}$ (Overing, 1991).

Much other mangrove, particularly on Anegada, is scrubby. No data are available on growth rates or productivity of BVI mangroves and there is no information on soils, hydrology or water quality.

5.5 Mangrove Related Ecosystems

Small areas of Salt Marsh, Littoral Woodland and Strand/Dune are present on most islands and there are numerous coastal salt ponds with associated Salina habitats. Salt Marsh with *Salicornia*, *Batis* and *C. erectus* and Salinas are developed

Table 10. List of mangrove sites in the British Virgin Islands archipelago (BV). Anegada (BVa); Tortola (BVt); Virgin Gorda (BVv); Great Camanoe (BVg); Jost van Dyke (BVj); Sandy Cay (BVs) Beef Island (BVb)

Code	Name of site	Type of mangal	Approximate size (ha)
	Anegada		
BVa01	Cow Graveyard	Basin, mixed	1.0
BVa02	Crasy Pond	Basin, Ce	1.0
BVa03	Cutting Grass Pond	Basin, mixed	1.0
BVa04	Donny Pond	Basin, mixed	1.0
BVa05	East End	Fringe Rm	342.7
BVa06	Bones Bight/Red Ponds	Scrub, mixed	96.7
BVa07	Nene Slob	Basin, Ce	1.0
BVa08	Perro Slob	Basin, Ce	1.0
BVa09	Windlass Pond	Basin, mixed	1.0
	Tortola		
BVt01	Baughers Bay	Basin, mixed	0.35
BVt02	Belmont Pond	Basin, Lr	18.70
BVt03	Brandywine	Basin, Lr	2.50
BVt04	Cane Garden East	Basin, Lr	0.37
BVt05	Cane Garden West	Basin, Rm	1.60
BVt06	Chapel Hill	Basin, mixed	2.30
BVt07	Duffs Bottom	Fringe Rm	1.20
BVt08	Fat Hogs Bay	Basin, Ag	1.80
BVt09	Fish Bay	Basin, mixed	0.25
BVt10	Flamingo Pond	Basin, Ag	1.30
BVt11	Fort Recovery	Basin, mixed	0.14
BVt12	Half Moon Bay	Fringe Rm	0.15
BVt13	Hodges Creek	Fringe Rm	0.44
BVt14	Josiahs Bay	Basin, mixed	11.10
BVt15	Kingston	Basin, Lr	0.28
BVt16	Nanny Cay Central	Fringe Rm	0.62
BVt17	Nanny Cay East	Fringe Rm	0.34
BVt18	Nanny Cay West	Basin, mixed	0.48
BVt19	Paraquita	Fringe Rm	35.90
BVt20	Pockwood Pond	Basin, Rm	5.60
BVt21	Port Purcell	Basin, Lr	0.13
BVt22	Road Reef	Fringe Rm	1.10
BVt23	Road Town	Fringe Rm	0.78
BVt24	Sandy Point	Basin, mixed	0.39
BVt25	Sea Cows Bay	Fringe Rm	1.90
BVt26	Slaney Pt. & Prospect	Basin, mixed	0.61
BVt27	Sophie Bay	Basin, mixed	1.10
BVt28	West End	Fringe Rm	0.42
BVt29	Witches Brew	Basin, mixed	9.50

Table 10. (Continued)

Code	Name of site	Type of mangal	Approximate size (ha)
	Virgin Gorda		
BVv01	Biras Creek	Fringe Rm	?
BVv02	Deep Bay	Fringe	?
BVv03	Pond Bay	Fringe	10
BVv04	White Bay	Fringe	?
	Great Camanoe		
BVg01	Cam Bay	Fringe	3
	Jost van Dyke		
BVj01	East End	Fringe	?
	Sandy Cay		
BVs01	Sandy Cay Swamp	Basin	5
	Beef Island		
BVb01	Airport Pond	Basin	10
BVb02	Banana Wharf	Basin/Fringe	3
BVb03	Beef Island Channel (N)	Fringe Rm	8
BVb04	Beef Island Channel (S)	Fringe Rm	10
BVb05	Bluff Bay Pond	Basin	3
BVb06	Hans Creek	Fringe	18
BVb07	Hans Creek Pond	Basin	2
BVb08	Long Bay Pond	Basin	2
BVb09	Trellis Bay	Fringe	4
BVb10	Trellis Bay Pond	Basin	1

extensively on Anegada.

5.6 Human Habitation and Traditional Mangrove Usage

There are no settlements in mangrove areas and only minor use is made of these areas for poles, and firewood. There is no commercial exploitation or marketing.

5.7 Conversion to Other Uses

There has been minor reclamation for tourism infrastructure, but extensive use of wetlands as sites for dumping solid waste. Their impacts on mangroves have not been documented and the socioeconomic implications are unknown.

5.8 Research and Training Programmes

The Government Conservation & Fisheries Office is conducting a programme of mangrove research in collaboration with the German Government (GTZ) and the Organisation of Eastern Caribbean States Natural Resources Management Programme (OECS/NRMP). Under this programme staff of the Conservation Office have received training in mangrove area evaluation, protection and monitoring (Blok-Meeuwig, 1990; Overing, 1991).

5.9 National Policies and Strategies for Mangrove Management

A parks and protected areas system plan has been produced (Geoghegan *et al.*, 1986) including some mangrove areas. Mangroves were designated as a "Critical Natural Resource" by the BVI Government in 1986. There are pieces of legislation appropriate to mangrove protection, including the Bird Sanctuary (Flamingo Pond, Anegada) Order (1977), the National Parks (Amendment) Ordinance (1978) and the Coast Conservation and Management Act (1991). Planning studies have been carried out on a number of sites, such as Belmont Pond (Town & Country Planning Dept., 1990) which was surveyed earlier by Grigg & Van Eepoel (1972), while monitoring sites have been established at Paraquita Bay, Hodge's Creek and Sea Cows' Bay in Tortola (Overing, 1991).

6. Cayman Islands

6.1 Historical Background

Numerous studies on mangroves in the Cayman Islands were conducted in the 60's and 70's by the Mosquito Research and Control Unit, although little was published internationally. Later research concentrated on waterfowl (Johnston *et al*, 1971; Johnston, 1975; Diamond, 1975a, 1975b), palaeoecology of mangrove and coastal areas (Woodroffe, 1979, 1981), and the geomorphology and mangrove vegetation of Little Cayman Stoddart (1980a, 1980b).

6.2 Mangrove Ecosystems, Extent & Distribution

Twenty-five mangrove sites have been identified, 17 occupying about 36% of Grand Cayman, 3 occupying 1% of Cayman Brac and 5 occupying 40% of Little Cayman and totaling nearly 75 km^2 of mangrove forest and scrub (Table 11).

Ecology and avifauna of the major wetland sites are described by Scott and Carbonell (1986). Rm and Ag are abundant on the three islands, with Lr and

Table 11. List of mangrove sites in the Cayman Islands

Code	Name of site	Type of mangal	Approx. size of wetland with mangrove (ha)
	Cayman Brac		
CAb01	Salt Water Pond	Basin & fringe	7.8
CAb02	The Marshes	Basin, mixed	19.2
CAb03	Westerly Ponds	Basin & fringe	16.8
	Grand Cayman		
CAg01	Barkers Wetland	Fringe	200.0
CAg02	Central Mangrove swamp	Fr., Ba. & tidal flat	4677.0
CAg03	Central Swamp	Scrub Ce	148.0
CAg04	Colliers Bay Pond	Basin Ag	32.5
CAg05	Frank Sound	Basin, mixed	132.0
CAg06	Lower Valley Pond	Basin Lr	0.8
CAg07	Malportas Pond	Fringe, mixed	52.0
CAg08	Meagre Bay Pond	Basin, mixed	38.4
CAg09	Newlands Pond	Basin Lr	1.4
CAg10	North Swamp	Scrub Ce	443.0
CAg11	Pease Bay Pond	Basin, mixed	8.2
CAg12	Point Pond	Basin, mixed	2.4
CAg13	Prospect Marsh	Basin, mixed	38.0
CAg14	Rock Pond	Scrub Ce	360 ?
CAg15	Savannah Pond	Basin Lr	1.0
CAg16	South Sound Swamp	Basin, mixed	300.0
CAg17	South Swamp	Scrub Ce	348.0
	Littte Cayman		
CAl01	Booby Pond	Basin, mixed	44.0
CAl02	Charles Bight	Basin Lr	50.0
CAl03	North Mangrove Swamp	Fringe Rm	103.0
CAl04	Tarpon & Werris Bays	Basin, mixed	236.0
CAl05	Westerly Wetland	Basin, Lr	8.5

Ce present. No information was available at the time of this report on forest structure or productivity.

6.3 Physical Environment

The Caymans consists of three low lying limestone islands, Grand Cayman 197 km^2, Little Cayman 28 km^2 and Cayman Brac 38 km^2, totaling 263 km^2. The three islands are composed of Tertiary limestones, with fossil cliffs of the karst plateaux rising to only about 15-20 m above sea level, with Pleistocene coastal plains with recent coral limestones and sand dunes. There are large interior lagoons and ponds and extensive fringing coral reefs.

6.4 Biological and Ecological Characteristics

Descriptions of geomorphology, sediments, hydrology and the distribution of mangrove vegetation are given in Woodroffe (1979, 1980, 1981). General site descriptions and reports on wetland avifauna are available in Scott and Carbonell (1986).

6.5 Mangrove Related Ecosystems

The wetland systems of the Cayman Islands appear to be entirely salina. They are associated with the remnants of once extensive Littoral Woodland and Strand/Dune vegetation, which has been cleared for real estate development. Salina habitats, containing *Salicornia bigelowia, Sesuvium portulacastrum* and *Sporobolus virginicus*, are widespread.

6.6 Human Habitation and Traditional Mangrove Usage

There are no settlements within mangrove swamps, and use of mangrove for charcoal, poles and firewood is less now than previously. There is no commercial exploitation.

6.7 Conversion to Other Uses

The Development Plan for Grand Cayman (1977) scheduled 97% of the island's wetlands for reclamation to urban and agricultural uses. Much of this area had been converted by the early 1980's, through road construction, a golf course, marinas and housing.

6.8 Impacts on the Mangrove Environment

Extensive loss of mangrove forest and associated habitats has occurred as a result of the Development Plan for Grand Cayman (1977). In Cayman Brac the Westerly Ponds site has been largely filled for airport runway extension. The socioeconomic implications of these losses have not been documented.

6.9 Research and Training Programmes

Extensive research has been conducted through the Mosquito Research & Control Unit.

6.10 National Policies & Strategies for Mangrove Management

The Department of Agriculture, Lands & Natural Resources is responsible for conservation policy. They are advised by the Mosquito Research & Control Unit which has done considerable research on mangrove swamps.

7. Dominica

7.1 Historical Background

Early reports by Beard (1949) and Hodges (1943, 1954) suggested that mangroves were absent from Dominica, but the Forestry Division discovered them in 1979 in the northern part of the island as reported by James (1980). Eight sites were identified, 3 with Lr and 5 with Ag, and their locations and general ecology described (James, 1985, 1986a, 1986b). In all cases the sites were reported to support only restricted stands of mangroves. These sites were confirmed during the Earthsat (1986) natural vegetation mapping programme. The work of the Forestry Division was reviewed by Godt (1990) who mentioned the occurrence of another species of Ag, but did not say which species he had located.

A number of other reports, such as Johnson (1988), Evans (1989) and the Country Environmental Profile for Dominica (CCA/IRF, 1991), describe the occurrence of mangroves based on the earlier researches of James and the Forestry Division. Inventory and monitoring work by the Forestry and Wildlife Division was in progress during 1991, with data on tree density, girth, DBH and growth rate being collected at three mangrove sites; and these data are being analysed. Existing inventory shows that Dominica has very restricted mangrove development compared with some of the other islands; suggesting that the major emphasis for site management should be tree protection and extension planting.

7.2 Mangrove Ecosystems, Extent & Distribution

Ten sites containing small stands of mangroves have been located, as indicated in Table 12 and Fig. 3. The mangroves of Bout Sable Bay were separated into two sites located at the Northern and Southern ends of the bay, sufficiently far apart to merit individual management. The other additional site at Lagon River contained a single tree, but this site was

Table 12. List of mangrove sites in Dominica

Code	Name of site	Type of mangal	Approximate size (ha)
DM01	Anse de Mai	Basin	< 1
DM02	Bout Sable Bay (N)	Basin	< 1
DM03	Bout Sable Bay (S)	Basin	< 1
DM04	Cabrits	Est/Bas.	< 1
DM05	Eden River	Estuarine	< 1
DM06	Hampstead	Est/Bas.	< 1
DM07	Lagon River	Estuarine	< 1
DM08	Nyah Estate	Basin	< 1
DM09	Rough Bay	Basin	< 1
DM10	Tou-ma-Tante	Basin	< 1

reported by Scott & Carbonell (1986) to contain a few hectares originally. In addition, the presence of a third mangrove species, Ce, was confirmed by Bacon (1991), following its identification by the Forest Officers earlier this year. It was present, however, as a single remaining tree whose preservation was thus of the utmost importance.

7.3 Physical Environment

The 750 km^2 island of Dominica is a volcanic island with very steep, rugged topography rising to 1,730 m in the north. There are over 300 rivers and streams which run in steep valleys and enter the sea through a narrow coastal plain (CCA/IRF 1991).

7.4 Biological & Ecological Characteristics

A well developed mangrove stand at Bout Sable Bay had Ag to 11 m high with DBH 29.3 cm, while the largest trees at Cabrits were 21 m high with DBH 27.0 cm. Most other stands were lower, with scattered trees and sparse seedling growth. Little information is available on soils and hydrology in mangrove areas. Mangroves in Dominica occur in small systems with little associated fauna.

7.5 Mangrove Related Ecosystems

Most mangroves occur at the mouth of stream gullies and are associated with *Pterocarpus* Swamp Forest and with Littoral Woodland (*Tabebuia pallida*, *Coccoloba uvifera* and *Pandanus* sp.).

7.6 Human Habitation and Traditional Mangrove Usage

The mangrove forests of Dominica are undoubtedly too small to sustain any form of exploitation. However, their value for biodiversity and as sites of special scientific interest may be high; James (1980, 1985) has included them in educational booklets produced by the Forestry and wildlife Division. There is some evidence of minor cutting and clearance of mangroves at some sites, such as Eden River (source Forestry & Wildlife Division).

7.7 Commercial Exploitation and Marketing & Conversion

There is no commercial exploitation, but some clearing for cultivation was observed. The impacts and socioeconomic implications of this have not been investigated.

7.8 Research and Training Programmes

The Forestry Department has an active research and training programme on wetlands.

7.9 National Policies and Strategies for Mangrove Management

All identified mangrove sites were on private lands and some cutting and clearance was observed. Forestry is in process of negotiating with land owners to protect trees on their properties, although the cutting is probably not done by the owners themselves.

There is no legislation in Dominica which specifically protects mangroves, although the Forestry and Wildlife Act (No. 12 of 1976) contains provisions that could be extended to tree and habitat preservation. The National Parks and Protected Areas Act No. 16 of 1975 is of little direct use for mangrove protection, as most mangrove sites are outside the designated protected areas. A clearly defined Forest Policy for Dominica makes no specific mention of mangroves, largely because they do not form large forest stands and have little direct commercial value.

There is no legal requirement for environmental impact analysis of development projects in Dominica and only large developments need to be approved by the National Planning Board. All sites require management to maintain tree density and regeneration, as some natural die back and losses caused by human activity were evident in all cases. Insofar as the number of trees at all sites is small, or very small in some cases, recovery and extension planting would be beneficial. It is important that seed be collected and germinated from the solitary Ce tree, to maintain this element of the biological diversity of Dominica's coastal forests. The Forestry & Wildlife Division is active, and has been successful, in producing educational materials concerning wetlands in

Dominica. Their work with land owners and the public is creating an awareness, as is the publicity given to environmental matters by the National Development Corporation.

8. Grenada and the Grenadines

8.1 Historical Background

There is relatively little published information on mangroves in Grenada and the Grenadines. Howard (1952) includes mangrove communities in his overview of the vegetation of the Grenadines and Eschweiler (1982) estimated that only 190 ha of mangroves remained in Grenada and 98 ha in Carriacou in 1982.

Although pointing out that several significant areas remained , such as Levera Pond, he gave little information about any of the sites. Weaver (1989) estimated some 530 ha of mangrove woodland in Grenada, without giving individual site hectarages from which a total could be calculated.

The Grenada Country Environmental Profile (CCA/IRF, 1991) summarised existing information, drawn largely from Eschweiler (1982) and Weaver (1989).

Table 13. List of mangrove sites in Grenada and Carriacou

Code	Name of site	Type of mangal	Approximate size (ha)
	Grenada (GR = main island)		
GR01	Antoine Bay	Basin	4
GR02	Black Bay	Fringe	1
GR03	Calivigny Harbour	Fringe	11
GR04	Cato Bay Salt Ponds	Salt Pond	3
GR05	Conference Bay	Basin	28
GR06	Content	Fr & Est.	3
GR07	Egmont Harbour	Fringe	15
GR08	Gt. River Bay South	Basin	3
GR09	Gt. River Mouth	Basin	2
GR10	Hardy Bay	Basin	2
GR11	La Sagesse S.Pond	Salt Pond	3
GR12	Levera Pond	Basin	33
GR13	Mt. Hartman Bay	Fringe	4
GR14	Perseverence	Basin	?
GR15	Petit Bacaye Bay	Basin	2
GR16	Prickly Bay	Fringe	3
GR17	Requin Bay	Fringe	< 1
GR18	St. David's Hbr.	Basin	1
GR19	True Blue Bay Pond	Bas./S.Pond	1
GR20	Westerhall Bay	Fringe	13
GR21	Wharf	Fringe	2
GR22	Woburn Bay	Fringe	11
	Grenada offshore islands		
GRa01	Calivigny Island	Salt Pond	1
GRh01	Hog Island	Salt Pond	2
	Carriacou (GRc = Grenadine sub-unit)		
GRc01	Lauriston Point	Basin	25
GRc02	Petit Carenage Bay	Basin	15
GRc03	Tyrrel Bay	Fringe	25
	Other Islands		
GRs01	Saline Island	Salt Pond	2

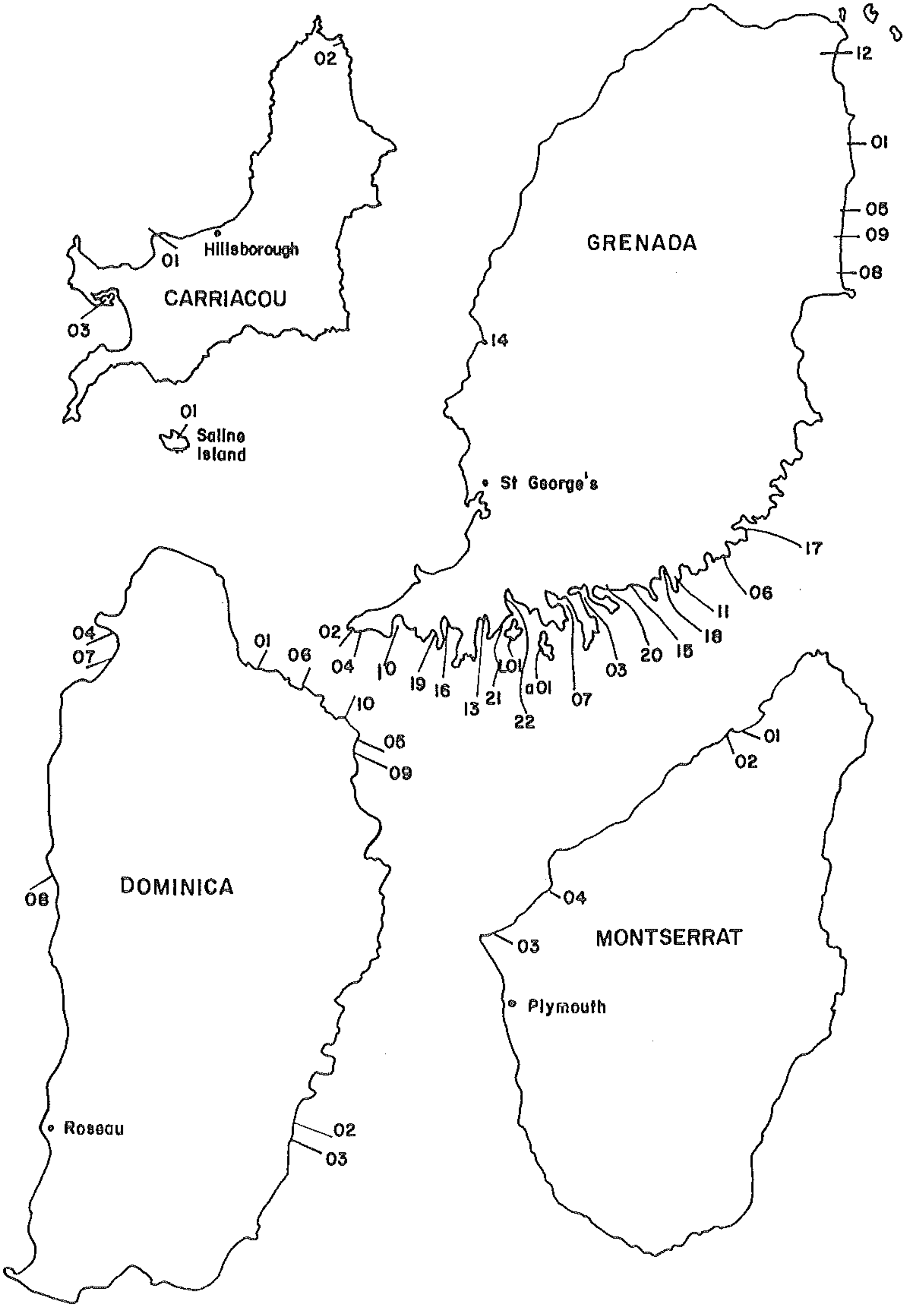


Fig. 3. Mangrove sites in Dominica, Montserrat, Grenada and Carriacou.

8.2 Mangrove Ecosystems, Extent & Distribution

Twenty-two sites have been identified and described to some degree in Grenada, with 2 others in offshore islands, 3 sites in Carriacou and 1 on Saline Island (Table 13 and Fig. 3).

Most mangrove areas were small, the largest area being 33 ha around Levera Pond. **Rm** was dominant forming extensive coastal fringes, with **Ag** and **Lr** common and **Ce** occasional; **As** which was reported by Moldenke (1960) was not found, but more thorough surveys may reveal its presence particularly in drier areas on the south coast.

Much of the mangrove was small in stature, but some very well developed forest stands were observed and forest structure data given for some of these.

8.3 Physical Environment

The island of Grenada is 312 km^2 in area and is mainly volcanic with steep mountains rising to 840 m. Carriacou is 34 km^2 and is generally flatter (CCA/IRF 1991). Petit Martinique was not surveyed. The southern coastline of Grenada is deeply indented and provides a series of sheltered bays and river mouths suitable for mangrove development, while the western and northern coasts are steep and have fewer streams.

8.4 Biological and Ecological Characteristics

The largest area of mangrove on Grenada is at Levera, where **Rm** is dominant, **Ag** abundant and **Lr** and Ce common. One **Rm** plot had mean tree height of 17.25 m with DBH 26.5 cm, while a neighbouring **Ag** stand had mean tree height of 14.7 m with DBH 27.1 and the largest tree with DBH 102 cm. The well developed **Ag** woodland at Conference Bay had the largest tree 22.0 m high with DBH 98.7 cm. On Carriacou, the forest was generally lower but the largest trees found at Lauriston Point were **Rm** of 11.00 m high with DBH 27.4 cm and **Ag** of 15.75 m high with DBH 34.4 cm. No detailed soils, hydrology or water quality data were available.

8.5 Mangrove Related Ecosystems

The landward margins of most mangrove areas in Grenada and Carriacou are cultivated. Associated habitats include saline mudflats and patches of *Acrostichum aureum*, while at Levera there are small patches of *Fimbristylis* sp. on the seaward border mixed with manchineel and seagrape and the swamp grades into cactus and *Acacia* thorn scrub on the landward side. Associated habitats in Carriacou include Littoral Woodland with well developed *Hippomane mancinella* and *Coccoloba uvifera* and meadows of *Batis maritima*.

8.6 Human Habitation and Traditional Mangrove Usage

There appears to be no assessment of mangrove forest resources and no study of the importance of fringing mangrove areas to the local fisheries. The reports of Lack & Lack (1973), Scott & Carbonell (1986), Blockstein (1987) and Ludeke *et al.* (1989) describe important wildlife resources in mangrove wetlands and GOG/OAS (1988) recommend that four areas with mangroves are worthy of inclusion in a system of protected areas because of their diverse biotic resources- Levera Pond and La Sagesse Salt Pond, Grenada, and Petit Carenage Bay and Tyrrel Bay, Carriacou.

8.7 Commercial Exploitation and Conversion to Other Uses

There is minor sale of charcoal and firewood and losses to tourism and agriculture.

8.8 Impacts on the Mangrove Environment

Joseph & Paterson (1991) reported that mangroves were being destroyed in Grenada and the Grenadines through dumping, cutting and charcoal burning. They note that one site at Perseverence was used as the official solid waste dump, indicating a low level of awareness of mangrove values by the authorities. There was evidence of a great deal of clearing and cutting of mangroves, for charcoal production and also to access sea frontage. Dumping of solid waste was observed in Grenada and Carriacou; in the latter island, likely airport expansion is a potential threat to one of the largest sites in the country. One factor contributing to the loss of fringe mangroves is the absence of clear guidelines for use of coastal/tidal lands and ownership rights to the seafront. Damage and loss is occurring at several sites where state land boundaries are not clearly demarcated. The socioeconomic implications of these impacts are not known.

8.9 Research and Training Programmes

The Forestry Department has been active in promoting environmental awareness, particularly as it applies to the Nation's forest resources. Active also are the Tourism Department, the Historical Society and the National Trust, although mangrove conservation has not been a priority subject with any group. Work is in progress through the Fisheries Department to desiguate a series of fish sanctuaries, several of which will include mangrove nursery areas. In Carriacou, the Nature Conservancy/Historical Society has been at work drafting management plans for Petit Carenage Bay and Tyrrel Bay, and the White Island/Saline Island Management Committee is monitoring environmental standards and enforcing available legislation.

8.10 National Policies and Strategies for Mangrove Management

There is no legislation specifically dealing with mangrove, or other wetland, protection. However, Ludeke *et al.* (1989) and Joseph & Paterson (1991) suggest that the Forestry, Soil and Water Conservation Act 1984 gives the Forestry Department the authority to manage mangroves, insofar as most are below high water level and, thus, belong to the State. Several mangrove sites are included in the Northeastern and Southern Protected Seascapes and the White Island/Saline Island Protected Seascape and proposals have been made (GOG/OAS, 1988) to establish Levera Pond, Tyrrel Bay and Lauriston Point swamps as National parks. As indicated above, where illegal cutting or landfill of mangrove sites has occurred, there is need for recovery of the habitat and vegetation. Apart from this and removal of solid waste from several sites, only minor recovery effort is needed. There is limited opportunity to extend the area covered by mangroves at any site.

9. Jamaica

9.1 Historical Background

The earliest record of the presence of mangroves in Jamaica was by Sloane (1707), followed by studies on mangrove tannin by Von Wehrs (1810), Trimble (1892) and Koorders (1893). Detailed botanical and general mangrove ecology studies resulted from the 1939 Cambridge University Expedition to Jamaica (Chapman, 1939, 1940a, 1940b, 1940c, 1943, 1944, 1945; Colman, 1940; Steers, 1940a, 1940b, 1940c; Steers *et al.*, 1940) and later research by Asprey and Robbins (1953) and Chapman (1976). Environmental conditions in selected mangrove areas were given by several authors as a basis for faunal studies and wetland management (Warner, 1969; Woodley, 1971; Wade *et al.*, 1972; Siung, 1976; NRCD, 1981; McCain, 1989; Bacon and Alleng, 1990; Bacon *et al.*, 1992), while comprehensive descriptions of mangrove ecosystems are available only for the West Harbour (Chow, 1989) and Port Royal (Alleng, 1990) areas. Wetland sites are included in the protected areas system plan (Conrad Douglas, 1991).

A Wetlands Evaluation Research Project (WERP) of the University of the West Indies and Natural Resources Conservation Authority has produced a preliminary inventory of mangrove areas and resources for the island, which is the basis of this report.

9.2 Mangrove Ecosystems, Extent & Distribution

One hundred and one mangrove sites have been identified in Jamaica, containing about 10,624 ha of mangroves (Table 14). Mangroves occur on all coasts, but particularly along the south coast in association with a variety of bays, inlets and lagoons (Fig. 4). Rm is dominant throughout the island, with extensive areas of Ag, there are numerous small stands of Lr and Ce is less common in wetlands than in Littoral Woodland.

9.3 Physical Environment

Jamaica has an area of 11,424 km^2, and is a high island with maximum elevation 2256 m. About two thirds of the island is composed of limestones forming plateaux between steep sided mountains and showing large areas of karst scenery. The alluvial plain is narrow along the north of the island but more extensive on the south coast where larger river basins and floodplains occur. The submerging coastline on the south has very active longshore drift which has produced a number of lagoon barriers and saline ponds. The south coast shelf is shallow and supports many coral/sand cays and barrier coral reefs.

9.4 Biological and Ecological Characteristics

Some of the best developed mangrove forest in Jamaica are found at the wetter, more sheltered north coast sites, such as at Florida Lands, Falmouth where Rm plots had 40+ trees ha^{-1}, with maximum height of 20 m, mean height 16 m, mean DBH 23.3 cm and total basal area of 17 m^2 ha^{-1}. There was some evidence of seasonal variation in productivity, as indicated by measurements of litter fall, at this and other north and south coast sites.

Florida Lands, showed a mean litterfall of 2.71 g m^{-2} day^{-1}, varying from 1.25 g m^{-2} day^{-1} in January to 5.81 g m^{-2} day^{-1} in July. Mangrove forests developed in drier south coast locations generally show low, frequently scrubby forest with poor tree development. For example, in the West Harbour and Port Royal swamps the mangroves rarely exceed 6 m in height.

Table 14. List of mangrove sites in Jamaica

Code	Name of site	Type of mangal	Approximate size (ha)
	St. Andrew: JAa		
JAa01	Ferry	Basin/Est.	10
JAa02	Ocean Lakes	Basin	2
JAa03	Port Royal	Lagoon fringe	130
JAa04	Rockfort	Estuarine	< 1
	Offshore Island sites		
JAa05	Drunkenmans Cay	Overwash	< 1
JAa06	Lime Cay	Overwash	< 1
JAa07	Twin Cays	Overwash	< 1
	St. Ann: JAn		
JAn01	Blue Hole	Fringe	1
JAn02	Crater Lake	Basin	10
JAn03	Discovery Bay East	Basin	4
JAn04	Discovery Bay West	Fringe	5
JAn05	Llandovery	Fringe/Basin	5
JAn06	Pear Tree Bottom	Estuarine	1
JAn07	Priory	Fringe	3
	Hanover: JAh		
JAh01	Great River	Fringe	5
JAh02	Lucea Harbour	Fringe	10
JAh03	Negril Great Morass(N)	Basin	300
	St. Catherine: JAc		
JAc01	Amity Hall	Estuarine	480
JAc02	Bowers Gully	Estuarine	10
JAc03	Cabarita	Fringe/Basin	640
JAc04	Coleburn's Gully	Fringe/Salina	10
JAc05	Dawkins Pond	Lagoon fringe	54
JAc06	Engine Head	Fringe	2
JAc07	Engine Head Pond	Basin	1
JAc08	Flashes/Great Salt Pond	Lagoon fringe	1792
JAc09	Hellshire Point Mangrove	Fringe	3
JAc10	Hellshire Point Pond	Basin	1
JAc11	Hunts Bay	Lagoon fringe	9
JAc12	Manatee Bay	Fringe	370
JAc13	Long Pond	Basin	5
JAc14	Lousy Bay Pond	Basin	1
JAc15	Old Harbour Bay	Fringe	120
JAc16	Old House Point	Fringe	30
JAc17	Wreck Bay	Fringe	5
JAc18	Wreck Bay Pond	Basin	1
	Offshore Island sites		
JAc19	Great Goat Island	Fringe	35
JAc20	Little Goat Island	Fringe	22
JAc21	Salt Island	Basin	2

Table 14. (Continued)

Code	Name of site	Type of mangal	Approximate size (ha)
	Clarendon: JAl		
JAl01	Carlisle Bay	Fringe/Basin	35
JAl02	Cockpit/Salt River	Basin/Fringe	60
JAl03	Macarry Bay	Fringe	120
JAl04	Milk River Bay	Estuarine	90
JAl05	Peake Bay	Fringe	300
JAl06	Portland Ridge	Fringe	3
JAl07	Rocky Point	Basin	22
JAl08	West Harbour	Lagoon fringe	988
	St. Elizabeth: JAe		
JAe01	Alligator Pond	Basin	25
JAe02	Black River (Great Morass)	Estuarine	350
JAe03	Chocolata Bay	Fringe	58
JAe04	Font Hill	Basin/Est.	170
JAe05	Great Pedro Bay	Basin	50
JAe06	Hodges	Basin/Fringe	180
JAe07	Malcolm Bay	Basin	120
JAe08	Moco Point	Fringe/Basin	27
JAe09	Parottee Bay	Basin	20
JAe10	Scots Cove	Estuarine	2
	Manchester: JAm		
JAm01	Canoe Valley	Basin	200
JAm02	Gut River	Estuarine	3
JAm03	Rogers River	Estuarine	5
	St. Mary: JAr		
JAr01	Little Bay	Est/Basin	1
	St. James: JAj		
JAj01	Bogue Islands	Lagoon fringe	145
JAj02	Donald Sangster Airport	Basin	10
JAj03	Mahoe Bay	Fringe	5
JAj04	Montego Bay Point	Fringe	3
JAj05	Seacastles	Basin	3
	Portland: JAp		
JAp01	Black River	Estuarine	2
JAp02	Daniels Harbour	Fringe/Basin	2
JAp03	Palmetto Bay	Fringe	1
JAp04	Turtle Crawle Harbour	Est/Basin	2
	St. Thomas: JAt		
JAt01	Albion Pond	Basin	35
JAt02	Bowden	Estuarine	30
JAt03	Canoe Bay Central	Fringe	10
JAt04	Canoe Bay East	Fringe	5
JAt05	Canoe Bay West	Fringe	8
JAt06	Great Morass	Basin	1600
JAt07	Port Morant West	Fringe	2
JAt08	Wards River	Est/Basin	2

Table 14. (Continued)

Code	Name of site	Type of mangal	Approximate size (ha)
JAt09	Yallahs Salt Pond East	Basin/Scrub	5
JAt10	Yallahs Salt Pond West	Basin/Scrub	10
	Trelawny: JAy		
JAy01	Devils Cook Room	Basin	2
JAy02	Duncans Bay	Basin/Fringe	5
JAy03	Falmouth- Florida Lands	Fringe/Basin	70
JAy04	Falmouth-Hague Lands	Basin/Est.	5
JAy05	Flamingo Pond	Basin	1
JAy06	Half Moon	Basin/Fringe	30
JAy07	Mountain Spring Bay	Basin	1
JAy08	Saltmarsh	Lagoon fringe	1000
JAy09	Trelawny Beach	Basin	10
	Westmorland: JAw		
JAw01	Auchindown	Basin	< 1
JAw02	Bay Road	Est/Basin	2
JAw03	Belmont Pond	Est/Basin	2
JAw04	Bluefields	Basin	8
JAw05	Bluff Point	Fringe/Basin	71
JAw06	Cabarita (Westmoreland)	Estuarine	240
JAw07	Crab Pond Point	Basin/fringe	58
JAw08	Gun Point	Basin	63
JAw09	Negril Great Morass (S)	Basin	200
JAw10	Paradise Park	Fringe/Basin	54
JAw11	Parkers Bay	Basin/Fringe	3
JAw12	Ricketts River	Est/Basin	< 1
JAw13	Whitehouse Point	Basin/Fringe	5

9.5 Mangrove Related Ecosystems

Mangroves are associated with Salina and Salt Marsh habitats dominated by *Sesuvium portulacastrum, Salicornia virginica* or *Batis maritima* grading into *Acacia* thorn scrub, particularly along the drier areas of the south coast. Where fringe or basin systems occur, beach barriers are colonised by Littoral Woodland with *Coccoloba uvifera, Terminalia catappa, Thespesia populnea, Hibiscus tiliaceus* and often *Conocarpus erectus.*

In a few areas, mangroves grade landwards into brackish marsh dominated by *Cladium jamaicense* or freshwater Swamp Forest with *Roystonea princeps, Sabal jamaicensis* or *Pterocarpus officinalis* and *Haematoxylon campechianum* (Bacon, 1990).

9.6 Human Habitation and Traditional Mangrove Usage

There are no permanent human settlements in mangrove areas. Traditional uses are charcoal cutting, fishing and oyster collecting; but none of these activities is documented.

9.7 Commercial Exploitation and Marketing

Minor commercial activity is associated with use of mangrove stakes for oyster racks, garden poles and beach hut construction. These products are not marketed centrally.

9.8 Conversion to Other Uses

Extensive areas have been drained and filled for real estate, particularly to tourism development on the north coast and for airport expansion (Hudson (1983) and Bacon (1987). The landward margins of many south coast areas have been reclaimed for agriculture. Near West Harbour, mangroves have been modified to make fish, shrimp or salt production ponds.

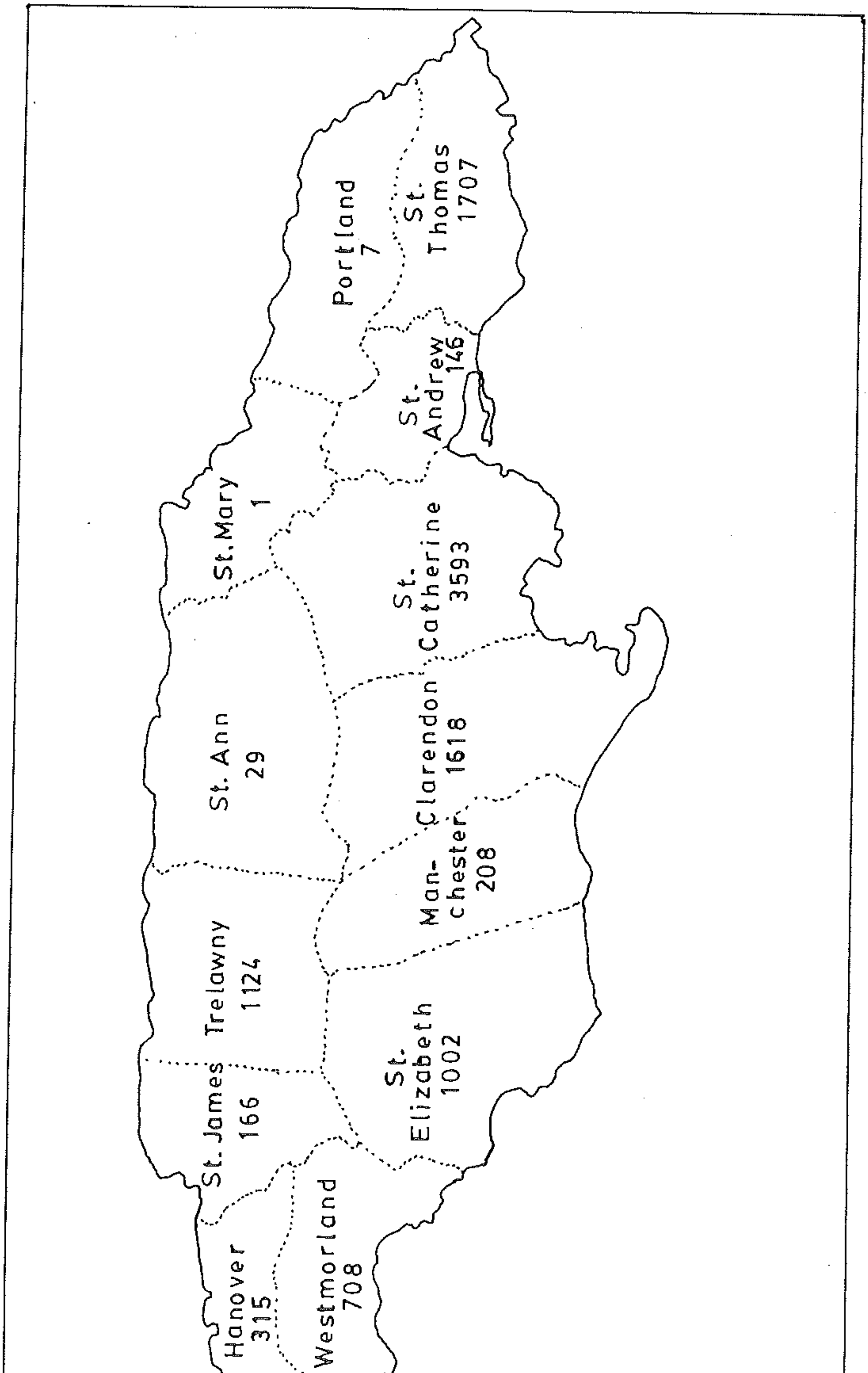


Fig. 4. Jamaica: Mangrove area (ha) by parish

9.9 Impacts on the Mangrove Environment

Nearly 30% of the original mangroves are lost and minor, but continuous damage is occurring by uncontrolled artisanal activities, dumping of solid waste and urban sprawl.

9.10 Socioeconomic Implications

Major impacts of mangrove loss are probably in the fisheries sector, due to reduction in feeding and nursery habitat. Value of mangroves for production of stakes and charcoal, oysters and crabs lowered at the subsistence level. Losses need to be balanced against economic benefits of alternative use of previous mangrove sites.

9.11 Research and Training Programs

Mangrove ecology and wetlands management are components of undergraduate courses at the University of the West Indies (UWI). UWI had a Wetland Research Group which also provided training at the postgraduate level. This group cooperated with the Natural Resources Conservation Authority in setting up a national wetlands inventory and developing a site evaluation methodology. Further research is being conducted at UWI on the use of mangrove areas in wastewater treatment.

9.12 National Policies and Strategies for Mangrove Management

There are no policies or strategies for mangrove management and there are no regulations specifically dealing with mangroves. Responsibility for mangroves is assumed by the Natural Resources Conservation Authority and the Forestry Division.

10. Montserrat

10.1 Historical Background

There is very little published information on mangroves in Montserrat and no detailed inventory of any mangrove area.

Mangrove areas were shown to be important as bird habitat by Benito-Espinal and Portecop (1984) and Arendt and Arendt (1985) studied a colony of cattle egrets using mangroves at Fox's Bay. Bovey (1986) made brief mention of mangroves as a component of coastal habitats and disputed the claim that damage to the trees was being caused by the egret colony nesting in mangroves at Fox's Bay. This site was rated highly, as an unique habitat in Montserrat by Pennington (1985), who briefly described a tour of the trails through the mangroves. Scott and Carbonell (1986) described Fox's Bay also, mentioning that three mangrove species were present, while Margetson 1991 stated that only two "minuscule" wetland sites were present in Montserrat, one of which contained mangroves. Butler *et al.* (1991) described an additional site at Carr's Bay, which contained three species in a degraded condition.

10.2 Mangrove Ecosystems, Extent and Distribution

Mangroves have been identified at 4 sites, with the largest stand of 2.4 ha at Fox's Bay and small patches at the mouths of three rivers further North (Table 15 and Fig. 3). Four species of mangroves were present, **Rm**, **Ag**, **Lr** and **Ce**.

10.3 Physical Environment

The volcanic island of Montserrat is about 98 km^2 and has steep interior mountains and virtually no coastal shelf. Mangroves occur where stream mouths are blocked by sand barriers and form small basins with periodic inundation. The largest area, Fox's Bay has a permanent brackish pool which shows considerable fluctuation in water level.

10.4 Biological and Ecological Characteristics

When examined in 1991 mangrove forests in Montserrat were still showing signs of damage from Hurricane Hugo 1989. At Carr's Bay there had been large **Ag** up to about 14.0 m high with DBH 44.6 cm which had been felled by the storm. At Fox's Bay the dominant **Lr** had a mean height of 11.0 m with mean DBH 7.6 cm and smaller **Rm** were present with mean height 6.8 m and mean DBH 6.3. cm. No information appears to be available on soils, hydrology and water quality.

Table 15. List of mangrove sites in Montserrat

Code	Name of Site	Type of mangal	Approximate size (ha)
MN01	Carr's Bay	Est/Bas.	<1
MN02	Collins River	Est/Bas.	<1
MN03	Fox's Bay	Basin	2
MN04	Old Road Bay	Basin	<1

10.5 Mangrove Related Ecosystems

Mangroves were associated with Littoral Woodland containing *Thespesia populnea* and *Hippomane mancinella*, with some seagrape, *Acacia* spp. and *Annona glabra*. Small patches of *Acrostichum* were present and beach barriers had common Strand/Dune species.

10.6 Human Habitation and Traditional Mangrove Usage

The only attempts at mangrove resource assessment are those made by the authors mentioned above with respect to Fox' Bay. This site is widely recognised for its uniqueness and its importance as wildlife habitat, for visitor use and for heritage purposes. However, no quantification of its current or potential socioeconomic value appears to have been made. There appears to be no commercial exploitation and sites are unlikely to be converted to other uses because of their location at stream mouths.

10.7 Impacts on the mangrove environment

Margetson (1991) and Butler *et al.* (1991) report damage to Fox's Bay and Carr's Bay by Hurricane Hugo and pressures on the former site from wandering livestock and encroaching residential development. The status of the mangrove forests appears not to have been assessed. Apart from hurricane wind damage observed at 2 sites and dumping of garbage at one of these, no direct damage to mangroves was observed.

10.8 Research, Training, National Policies and Strategies for Mangrove Management

There appear to be no research or training programs on the mangroves of Montserrat. Two sites enjoy some degree of protection; Fox's Bay is a Bird Sanctuary managed by the Montserrat National Trust and the Old Road Bay site is on privately owned lands unofficially designated as a nature area. The Forestry Ordinance 1951 permits demarcation of Protected Forests and Conservation Areas, but has not been used specifically for mangrove conservation.

The mangrove stands at Carr's Bay and Fox's Bay would benefit from clearance of hurricane damaged trees and debris and replanting is required at the former site. There is opportunity to extend the area covered by mangroves at Carr's Bay and Old Road Bay, with improvement to landscape value and wildlife habitat.

Fox's Bay Bird Sanctuary has received good publicity through the Montserrat National Trust and its value, and that of the mangroves, is well appreciated. No opportunity was available to assess awareness of mangrove area values by the general public, but it is probably very low.

11. St. Kitts and Nevis

11.1 Historical Background

There are several reports which contain general information and details of habitats for mangrove sites in St. Kitts. These include a consultant's report dealing with site development at Frigate Bay (Rasmussen, 1985); the wetland directory of Scott and Carbonell (1986) which gives details of 4 sites and their avifaunas; guidelines for forestry development (Prins, 1987) which make brief mention to charcoal production and the occurrence of mangrove swamps; a detailed plan for the management of Greatheeds Pond (CCA/ICOD, 1989) and a Country Environmental Profile (CCA/IRF, 1991) which summarizes existing knowledge for 3 mangrove species. Much of the previous inventory work emphasises wildlife and potential recreational values, and there are virtually no data available on species distributions or forest structure. The location of mangroves in Nevis is indicated by CCA/IRF (1991), based on the work of Rodrigues (1990a, 1990b) who identified 10 sites and described 3 of these in detail.

11.2 Mangrove Ecosystems, Extent and Distribution

Eight mangrove sites were identified and described in St. Kitts and 8 in Nevis (Table 16 and Fig. 5). One Nevis site identified by Rodrigues (1990a) as "Bath Bog" did not appear to have mangroves and insufficient survey work was done at Nisbett Settlement, near Newcastle, to determine whether one or two separate sites are present.

The majority of sites in both islands contained few mangroves, but well developed forest was present at some sites, such as Friar's Bay Pond and Greatheads Pond, St. Kitts, and Nisbett Settlement, Nevis. The largest stands of mangroves were at Greatheeds where approximately 22 ha are present. Five species were identified in St. Kitts, with **Ag** and **Lr** abundant, **Rm** common and **As** and **Ce** occasional. Only **Lr** and **Ce** were observed in Nevis, with **Lr** dominant.

Table 16. List of mangrove sites in St. Kitts and Nevis

Code	Name of site	Type of mangal	Approximate size (ha)
	ST. Kitts		
SK01	Cockleshell Bay Pond	Basin	< 1
SK02	Friar's Bay Pond	Basin	13
SK03	Frigate Bay Salt Pond	Basin	< 1
SK04	Greatheeds Pond	Basin	22
SK05	Gt. & Lt. Salt Ponds	Basin	11
SK06	Half Moon Bay Pond	Basin	15
SK07	Major's Bay Pond	Basin	< 1
SK08	Muddy Pond	Basin	8
	Nevis		
Ne01	Bath River	Estuarine	< 1
Ne02	Cades Bay	Estuarine	< 1
Ne03	Cades Estate	Estuarine	< 1
Ne04	Jones Bay	Estuarine	< 1
Ne05	Mosquito Bay	Estuarine	< 1
Ne06	Nisbett Settlement	Est. & Bas.	2
Ne07	Pinney's Beach Hotel	Estuarine	< 1
Ne08	Vaughans	Estuarine	< 1

11.3 Physical Environment

The island of St. Christopher, or St. Kitts, is oval in shape with a peninsula to the south. It is about 176 km^2 in area with maximum altitude at 1,156 m. The sister island of Nevis in 93 km^2 in area with Nevis Peak at 985 m (CCA/IRF, 1991). All the mangroves occur in association with saline ponds which have been separated from the sea by wide sand barriers. The ponds are subjected to flooding by land run-off and occasional overwash from the sea. Otherwise they remain hypersaline and in the past most were modified for salt production.

11.4 Biological and Ecological Characteristics

Greatheeds Pond was dominated by Ag which was mainly in the form of low scrub 5-6 m high, but some stands reached 10 m height with DBH 19 cm. At all other sites mangroves of all species rarely reached above 5 m high. Mangrove along the smaller pond margins often showed die back, probably as a result of extreme salinities. No information on soils, hydrology and water quality.

11.5 Mangrove Related Ecosystems

In St. Kitts, mangroves are associated with Salt Marsh and Salina systems, plus poorly developed Littoral Woodland, Strand/Dune. In Nevis, mangroves occur largely at the mouths of fast flowing, ephemeral streams on rocky coasts.

11.6 Human Habitation and Traditional Mangrove Usage

Mills (1989) reviewed wildlife management issues for St. Kitts and Nevis and noted the importance of wetland sites with mangroves. The CCA/ICOD (1989) plan for Greatheeds Pond notes the importance of this area for charcoal production, but does not quantify this. Other than this, there appears to have been no mangrove resources survey. Morris and Lemon (1984), Arendt (1985) and Mills (1988) list the wildlife found in wetland and mangrove sites, indicating the occurrence of over 70 species of birds.

11.7 Commercial Exploitation And Conversion To Other Uses

There appears to be no commercial exploitation. Minor losses have occurred with tourism expansion, major conversions on St. Kitts to salt production ponds (now abandoned).

11.8 Impacts on the Mangrove Environment

Apart from mention of cutting for charcoal and use for dumping (CCA/ICOD, 1989), the status of the mangrove forests has not been studied. On St. Kitts, causes of mangrove destruction were as previously identified. In addition, some losses are associated with natural successional processes around salt pond/ salina habitats. Clearance of mangroves at the Nisbett Settlement site in Nevis results also from land ownership disputes and lack of appreciation of mangrove values by the resort developers. The socioeconomic implications of mangrove loss haven't been studied.

11.9 National Policies and Strategies for Mangrove Management

Some mangrove areas are protected, such as the Great and little Salt Ponds, under the South-East Peninsular Land development and Conservation Act, No. 12 of 1986; although some encroachment and landfilling was in progress during August 1991. Provisions of the National Conservation and Environment Protection Act (No. 5 of 1987) do not appear to have been used specifically to protect any mangrove site. Loss of mangroves by cutting and encroachment continues at Greatheeds Pond, despite the recommendations and plans prepared to have this largest national mangrove site declared a protected area (CCA/ICOD, 1989). Several areas on the margins of salt ponds in the Southeast Peninsula have storm damaged trees and areas where cutting has taken place. There is need for some recovery effort, but in most cases seeds and seedlings were observed so natural recovery is likely. This topic needs further investigation. No opportunity was provided to assess public awareness or opinion about mangroves. It is apparent, however, that the need for natural resource conservation in both St. Kitts and Nevis is well understood in government and professional agencies.

No mangrove-focused educational programmes or projects are on-going in the islands at the present time.

12. St. Lucia

12.1 Historical Background

Mangroves were listed as important natural resources in the ECNAMP (1983) report on conservation of the South East Coast. The first major study on St. Lucia's mangroves conducted by Portecop & Benito-Espinal (1985) identifed and described 13 sites, giving species composition and mapping general distribution but not discussing forest structure. This was followed by detailed inventory work for three sites by Scott and Carbonell (1986) and for 15 sites by Devaux (1988), although neither report gives much information about the mangrove forests themselves. Later reports, such as Charles and Butler (1984) and Charles (1991) are concerned largely with wetlands in relation to wildlife conservation. The Country Environmental Profile (CCA/IRF, 1991) summarizes published information and estimates some 179.30 ha of mangroves in St. Lucia occupying about 0.29% of the country.

12.2 Mangrove Ecosystems, Extent and Distribution

Eighteen sites containing mangroves were identified and described to some degree (Table 17 and Fig. 5). These were largely the sites described by Portecop & Benito-Espinal (1985), although the areal coverage at several sites appeared to differ from their estimates. Five species of mangrove are present, at some sites covering large areas and having well developed forest. The majority of sites were at river mouths, particularly where these were blocked by sand bars.

12.3 Physical Environment

St. Lucia is mountainous rising to 950 m at Mount Gimie and is 616 km^2 in extent. Some mangroves occur as coastal fringes in sheltered bays but the greatest number have developed in basins where river/stream mouths have been blocked by beach barriers. In these basins they are subjected to periods of stagnation which alternate with flooding and temporary connection to the sea. There are litte data on mangrove area soils, hydrology or water quality; Jennings-Clark and D'Auvergne (1990) found salinities at Savannes Bay lower than sea water probably from land drainage.

12.4 Biological and Ecological Characteristics

General background ecological data in Portecop and Benito-Espinal, 1985, Scott and Carbonell, 1986, and Bacon, 1991: are vegetation, forest structure and fauna, particularly avifauna. Well developed **Rm** forest at Esperance Harbour had a mean height of 23 m; DBH 18.4 cm and was bordered by **Lr** thickets with mean height 10.7 m and DBH 4.7 cm. At Savannes Bay, the 10 m wide **Rm** fringe forest was largely less than 10 m high with maximum DBH 14.5 cm. **Ag** forest here showed mature trees to 15 m high and DBH 65.6 cm. Jennings-Clark and D'Auvergne (1990) found litterfall rates in red mangrove at Savannes Bay and at Esperance Harbour to be 3.36 g m^{-2} day^{-1} and 4.56 g m^{-2} day^{-1} respectively.

12.5 Mangrove Related Ecosystems

Mangroves are associated with *Pterocarpus officinalis* Swamp Forest in several areas, Freshwater Marsh and Salt Marsh. Well developed Littoral Woodland with Strand/Dune occur in many sites.

Table 17. List of mangrove sites in St. Lucia.

Code	Name of Site	Type of mangal	Approximate size (ha)
SL01	Anse Ger	Estuarine	< 1.0
SL02	Anse Lapins	Estuarine	< 1.0
SL03	Anse Lavoutte	Estuarine(Basin)	24.0
SL04	Anse Louvet	Estuarine(Basin)	17.0
SL05	Bois d'Orange	Basin(Estuarine)	2.5
SL06	Cas en Bas	Estuarine(Basin)	1.5
SL07	Choc Bay	Estuarine(Basin)	1.2
SL08	Couples	Estuarine(Basin)	< 1.0
SL09	Dennery	Estuarine(Basin)	1.3
SL10	Esperance Harbour	Est. & Fringe	17.0
SL11	Fond d'Or	Basin(Estuarine)	2.5
SL12	La Sorciere	Basin(Estuarine)	< 1.0
SL13	Man Kote	Basin	35.0
SL14	Marigot Harbour	Fringe	6.0
SL15	Marquis Bay	Estuarine	2.5
SL16	Micoud	Fringe	1.3
SL17	Praslin	Fringe	17.0
SL18	Savannes Bay	Fringe & Basin	25.0

12.6 Human Habitation and Traditional mangrove usage

Apart from their importance as wildlife habitat, particularly for birds (Portecop and Benito-Espinal, 1985; Scott and Carbonell, 1985; Devaux, 1988), there has been no assessment for the national mangrove resource. An attempt has been made to assess the social and economic importance of mangrove charcoal resources at one site, Man kote, (ECNAMP, 1983; Walters and Burt, 1991).

12.7 Commercial Exploitation and Marketing

There are minor charcoal production (Savannes Bay, Man Kote). Yields are quantified at latter site; no data on marketing.

There is only minor reclamation for agriculture and tourism.

12.8 Impacts on the Mangrove Environment

Portecop and Benito-Espinal (1985) gave general information on levels of pollution and causes of loss of mangroves at several sites and Towle (1985) described losses of mangroves caused by landfill at Gros Islet. Apart from these, there appears to be no other report which assesses the status of the mangrove forests. Relatively little damage to mangrove areas was observed, apart from the landfill operation at Choc and cutting for charcoal production at Esperance Harbour and Savannes bay. Mangrove cutting at Man kote is being controlled by cooperation between Government and a local charcoal producers' association. The socioeconomic implications of this damage have not been studied.

12.9 Research and Taining Programmes

The Caribbean Environmental Health Institute has established regular monitoring of mangrove sites as part of their programme to provide information on pollution of sites and organisms. This programme, in which this author participated, is providing baseline information on mangrove forest structure at the monitoring stations.

12.10 National Policies and Strategies for Mangrove Management

Mangrove areas are administered by the Fisheries Department under the Fisheries Act No. 10 of 1984, in conjunction with the St. Lucia National trust and other agencies. The majority of the larger sites have been declared Marine Reserves because of their importance to the fisheries. Apart from replanting to replace trees lost to charcoal production at Esperance Harbour and to improve habitat quality at Choc, little need for rehabilitation of sites or recovery of mangrove vegetation was identified. Although no formal opportunity was provided to gauge public opinion, the Fisheries Department have been active in public education and report good results.

13. St. Vincent and the St.Vincent Grenadines

13.1 Historical Background

Apart from some early references to mangroves in the floras of St. Vincent (Kew, 1893, and following), little published information exists on the vegetation. Scott and Carbonell (1986) included Milikin Bay and Union Island mangroves in their Directory of Neotropical Wetlands, but gave mangroves only passing reference. The only study which includes forestry data is that of Metz (1989), while Weeks and Metz (1991) and the Country Environmental Profile (CCA/IRf, 1991) summarize existing information and draw heavily on Metz (1989). Weeks and Metz (1991) identify and describe 4 mangrove sites on St. Vincent, 2 on Mustique and 8 on Union Island, and note that mangroves occur on Canouan, Mayreau and Bequia and possibly on Prune Island.

13.2 Mangrove Ecosystems, Extent and Distribution

Four sites are present on St. Vincent, all with small stands of mangroves. Only two species were present, Lr and Ce. The Forestry Department is conducting a study of the two mangrove sites on Mustique and forest structure data arae being prepared for publication. Eleven sites were identified and described on Union Island, adding 3 small sites to the list given by Metz (1989). **Rm**, **Ag**, **Lr** and **Ce** are present on Union Island, forming well developed forest in some areas (Table 18 and Figs. 5 and 6).

13.3 Physical Environment

St. Vincent is a mountainous volcanic island of about 344 km^2 with maximum altitude of 1,219 m. The main island is associated with a chain of smaller islands which form the Grenadines. In all islands the coastal plain is very narrow and the numerous small streams discharge straight to the sea. Mangroves are found on St. Vincent mainly where stream mouths are blocked by sand barriers forming small basins. In the Grenadines there are patches of fringe **Rm** and

Table 18. List of mangrove sites in St. Vincent & the Grenadines*

Code	Name of Site	Type of mangal	Approximate size (ha)
	St. Vincent (SV - main island)		
SV01	Almond Tree Bay	Fringe	0.1
SV02	Careenage	Est./Bas.	< 1.0
SV03	Milikin Bay	Est./Bas.	0.4
SV04	Sion Hill Bay	Fringe	< 1.0
	Grenadines (island sub-units)		
	Mustique (SVq)		
SVq01	Airport Swamp	Basin	4.0
SVq02	Lagoon Bay	Basin	8.0
	Union Island (SVu)		
SVu01	Ashton Bay	Fringe	20.2
Svu02	Belmont Salt Pond	Basin	1.0
Svu03	Clifton Pond	Basin	< 1.0
Svu04	Clifton Reserve	Fringe	1.3
SVu05	Miss Campbell Estate	Fringe	1.3
SVu06	Miss Irene Estate	Basin	< 1.0
Svu07	Miss Murray Estate	Basin	2.0
SVu08	Petit Bay	Fringe	< 1.0
SVu09	Point Lookout	Basin	< 1.0
SVu10	Queensbury Point	Fr. & Bas.	1.0
SVu11	Richmond Bay	Fr. & Bas.	5.7

*This inventory is incomplete

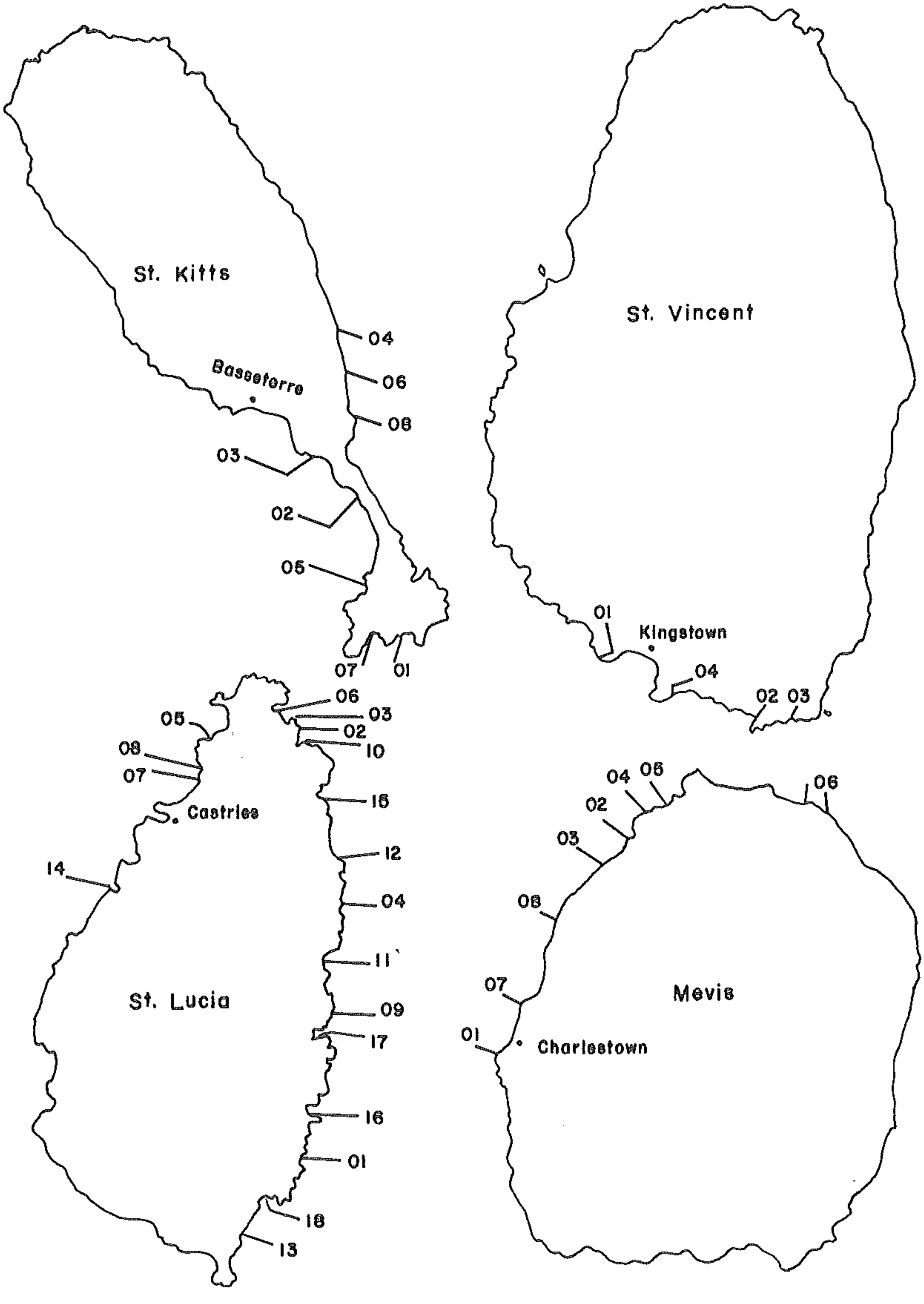
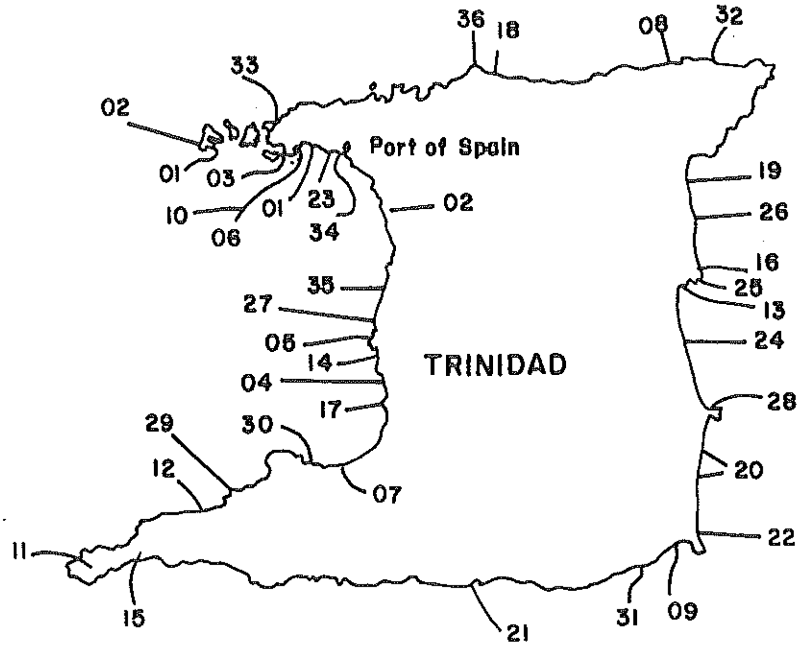


Fig. 5. Mangrove sites in St. Kitts, Mevis, St. Lucia and St. Vincent.



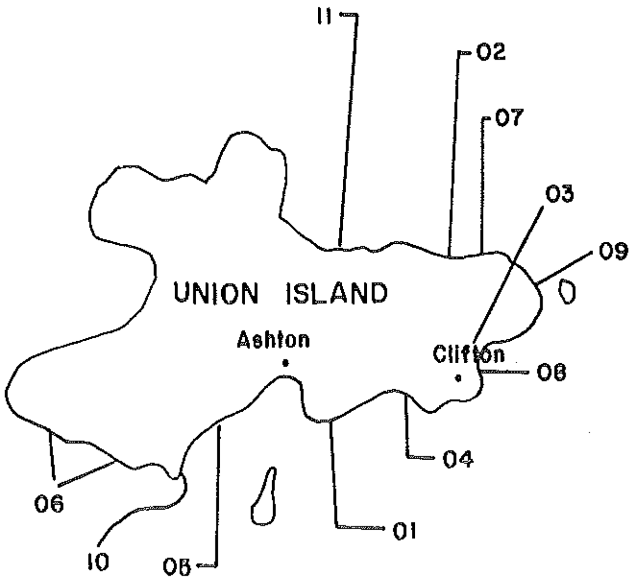


Fig. 6. Mangrove sites in Trinidad and Union Island.

mangroves around coastal saline ponds. There are little data on mangrove soils, hydrology or water quality.

13.4 Biological and Ecological Characteristics

General site descriptions are contained in Scott & Carbonell (1986), Metz (1989), Bacon (1991) and Weeks & Metz, 1991. The small gully at Carenage in St. Vincent had **Lr** to 10.0 m high with DBH 21.0 cm and clumps of **Ce** to 4.0 m high. At Ashton Harbour on Union Island, Fringe **Rm** was only 5.0 m high with DBH 9.4 cm and Basin **Ag** 4.3 m high with DBH 6.6. cm. Much of the mangrove in the Grenadines is low and scrubby.

13.5 Mangrove Related Ecosystems

St. Vincent mangrove sites are associated with rocky coastal areas and beach barrier systems. Union Island mangroves are associated with Salinas, Littoral Woodland and Strand/Dune.

13.6 Human Habitation and Traditional Mangrove Usage

Scott and Carbonell (1986) and Weeks and Metz (1991) describe the importance of wetlands to wildlife, particularly birds, but no other assessment appears to have been published. Charcoal production reported is on Union Island.

13.7. Commercial Exploitation, Marketing, Conversion to Other Uses

Minor charcoal production occurs, whereas several are used as solid waste dumps.

13.8 Impacts on the Mangrove Environment

Metz (1989) describes human impacts on mangroves in Union Island and Weeks and Metz (1991) describe losses and damage to sites, although little attempt is made to quantify damage or assess status of existing mangrove resources. At virtually all sites visited there was evidence of cutting, particularly for charcoal production. Much of the mangrove forest in these islands is re-growth from previous cutting. In St. Vincent two sites are threatened by solid waste disposal and resort development. On Union Island two sites were being filled during an August 1991 visit. The socioeconomic implications of this damage are not known.

13.9 Research and Training Programmes

The Forestry Department has active forest mensuration programmes at some sites, (Union Island), (Weeks and Metz, 1991).

13.11 National Policies and Strategies for Mangrove Management

There is no legislation which specifically protects mangroves, although the Forestry Act and the National Trust Act might be useful. Copies of these acts could not be obtained. The Ministry of the Environment has established an inter-agency task force to improve natural resource management. The Forestry Department has established a cooperative agreement with one land owner to manage mangroves and is negotiating similar agreements for other sites. This progressive step has high public awareness value also.

Despite widespread cutting at most sites, replanting does not appear to be required because good seedling growth was present. However, recovery of mangroves to sizes suitable for harvesting requires the introduction of proper cropping routines and stand improvement measures. No opportunity was given to gauge public appreciation of mangrove values. However, conversation with residents on St. Vincent and Union Island indicated little knowledge of mangroves, other than their use for charcoal. The Forest Department is working with land owners to improve their awareness of the value of stands on their properties.

14. Trinidad & Tobago

14.1 Historical Background

Mangroves are found on all coasts of Trinidad, particularly the Atlantic and Gulf of Paria sides where well developed mangals occur in association with complex wetland systems and perennial rivers. More than 7000 ha of mangroves have been recorded in 35 sites, with the largest area of > 3,000 ha in Caroni Swamp. The only offshore island with mangroves appears to be Chacachacare, with 2 sites, but the sister island Tobago has at least 10 sites.

Estuarine mangal is the dominant type in Trinidad and Tobago, but there are lagoonal and coastal fringe types and a salt pond. Six species of mangroves were reported from Trinidad by Marshall (1934) and an additional species present in the National Herbarium collections was added to the list by Bacon (1970). Taxonomic work on the Verbenaceae by Moldenke (1939, 1955) included distributional records for Ag and **As**. Early descriptions by Marshall (1939) and Beard (1946) placed mangroves in the *Rhizophora-Laguncularia-Avicennia* Association. A FAO Report (1957) dealing with swamp reclamation included maps, physical, hydrographic and soils data for the larger wetland sites in Trinidad, including mangrove areas, but gave no details of the vegetation.

The extent and distribution of mangrove species and mangrove habitats in Caroni Swamp were described by Bacon (1970) and these were related to the particular environmental conditions produced by attempted reclamation (Bacon, 1975). At this time detailed mapping of the swamp was undertaken by the Forestry Division. Their maps of protected areas also showed the locations and extent of other major wetlands containing mangroves. Ramcharan *et al.* (1982) provided maps and summaries of existing data on the vegetation of the major mangrove areas and listed, but did not describe, several additional sites. These authors listed the mangrove species and associated flora found in several sites. The Institute of Marine Affairs (IMA) provided a coastal classification for Trinidad which demarcated mangrove-dominated areas (Georges, 1983) and mapped the distribution and losses of mangroves from the Point Lisas industrial development zone (IMA,1982; McShine-Mutunhu, 1985). Modifications to the Caroni Swamp mangrove area through reclamation, river training and flood control have been described by Bacon (1975), Gerald (1985) and Alleng (1987), but few of the other changes to coastal wetlands have been documented. James *et al.* (1986) produced an inventory of wetlands of international importance in Trinidad and Tobago which gave considerable detail of wildlife and conservation aspects, but little information on the mangrove forests included in their list. Accurate estimates of wetland areas are provided by the Forest Resource Inventory and Management project of the Forestry Division (Faizool, 1990), which has documented the majority of the Nation's mangrove areas. The Division has mapped these areas, most of which are shown also on existing topographic map sheets.

Work on mangroves in Tobago is confined almost entirely to studies by Goreau (1967) and the Institute of Marine Affairs of the Buccoo Reef/Bon Accord system in relation to conservation and protected areas development. A map of the area produced by the IMA shows the zonation of mangrove species around Bon Accord Lagoon. Studies of development impacts have been carried out also at Kilgwyn, by the IMA and others, but results appear not to have been published.

The inventory of mangrove forests of Trinidad and Tobago consists of general data on distribution and areal extent of the major species with some supporting ecological information. Forest structure does not appear to have been documented at any site. It is understood that some charcoal and bark yield estimates have been made in the Caroni and Nariva Swamps by the Forest Division which include mensuration data, but these could not be accessed.

Substantial work has been done on mangrove and associated wetland faunas in Trinidad, for example, microfauna (Saunders, 1958), shellfish (La Croix, 1971; Bacon, 1971; Chin Yuen Kee, 1978), fish (Kenny & Bacon, 1981), birds (French, 1977; James *et al.*, 1986; Bildstein, 1990) and comprehensive faunal studies such as those of Bacon (1970, 1976, 1977) for Caroni Swamp and Bacon *et al.* (1979) for Nariva swamp. Ramcharan *et al.* (1982) summarized existing data on the fauna of the major mangrove swamps.

14.2 Mangrove Ecosystems, Extent And Distribution

Forty nine mangrove sites were identified, 36 in Trinidad, 11 in Tobago and 2 in offshore islands, as shown in Table 19 and Fig. 6. The national mangrove resource in Trinidad and Tobago covers in excess of 7,000 ha and contains 7 mangrove species; **Rm** is the more widespread, with **Rh** and **Rr** particularly well developed in east coast swamps, both **Ag** and **As** are present although the latter is uncommon and **Lr** and **Ce** occur in small stands in the majority of mangrove areas.

14.3 Physical Environment

General data on the islands' topography and climate are contained in Cooper & Bacon (1981). There is a considerable body of data on mangrove swamp sediments & hydrology; for Nariva Swamp, FAO (1957), Bacon *et al.* (1979) and Ramcharan (1980); for Caroni Swamp, Bacon (1970).

14.4 Biological and Ecological Characteristics

Detailed descriptions of geography, general ecology, flora and fauna are available for several mangrove sites (Bacon, 1970; Bacon *et al.*, 1979; Ramcharan *et al.*, 1982; Scott & Carbonell, 1986). There are minimal data on forest structure and mangrove communities which range from tall basin forest of *Avicennia germinans* 23.0 m high, with DBH 77.0 cm; or of *Rhizophora racemosa* at 17.0 m high with DBH 25.5 cm, to mangrove scrub with trees only 3 - 4 m high with no significant trunk development (Bacon, 1991). The best forest development is in estuarine situations, as in the Caroni, Nariva and North Oropuche Swamps, but there is also great variation in distribution and relative sizes of mangroves in the larger swamps.

Distinct zonation patterns occur in several areas, with the *Rhizophora* species occupying the margins of tidal channels, *Avicennia germinans* mixed with *Rhizophora* spp. or in pure stands in basins behind levees and Lr patchy in its distribution among other species. As is common in drier situation and Ce found distinctly on swamp margins or beside artificial channels.

14.5 Mangrove Related Ecosystems

Mangroves are associated with a wide range of hypersaline, saline, brackish and freshwater communities. The Caroni Swamp mangroves have shallow mudflats on the western Gulf of Paria side and grade eastwards through brackish marsh with *Eleocharis, Fimbristylis* and other Cyperaceae into Freshwater Marsh and cultivation.

The seaward side of Nariva Swamp is separated by a narrow sand barrier mostly cultivated in coconuts, while the landward side grades through Swamp Wood with a *Symphonia globulifera - Virola surinamensis - Pterocarpus officinalis* Freshwater Marsh dominated by a *Cyperus giganteus - Gynerium sagittatum - Montrichardia arborescens* Association. Included are extensive patches of floating marsh and Palm Swamp forest with *Mauritia setigera* or *Carappa guianensis* and *Bactris* spp. (Bacon, 1988).

Much of the landward side of other wetlands is cultivated.

14.6 Human Habitation and Traditional Mangrove Usage

Apart from the charcoal and bark yield data mentioned above, no other mangrove forest product data appear to be available.

Directly exploitable faunal resources have been assessed only superficially. There is information on shellfish resources, particularly oysters (Bacon, 1970b; La Croix, 1971; Chin Yuen Kee,1978); but recent data are absent. Published information on fisheries yields in or associated with mangrove areas is sparse, although considerable fishing occurs in and adjacent to all the major swamps. Ramdial (1975) gave information on the numbers of persons involved in fishing in Caroni Swamp, but there are no recent statistics. Hunting has been reduced by protected area regulations in most mangrove areas, but earlier records at the Forestry Division have not been analysed and recent data are not available.

Recreational resources centred on mangals have received greater attention. Ramdial (1975) analysed visitor use in Caroni Swamp and documented the direct and indirect economic impacts. Since his study the Forestry Division has collected statistics on local and foreign visitor arrivals in Caroni, but these are not yet published. They have also promoted visitor use of the Caroni Swamp (see James, 1990a). Bacon *et al.* (1979) suggested that Nariva Swamp had recreational potential; with the mangal adding to attractions available to visitors.

Studies by the IMA on the Buccoo Reef/Bon Accord ecosystem have documented its current and potential importance for tourism and recreation; although the contribution of mangrove stands to this has not been specified. The indirect values of mangroves in Trinidad and Tobago have been assumed rather than documented; and there is considerable popular literature that emphasises their importance to fisheries, wildlife and coastal stability (see McFarlane, 1985; James, 1985). The scenic/landscape and hydrologic value of mangals have not been assessed.

14.7. Commercial Exploitation and Marketing

There is some timber and charcoal extraction, but recent use is not quantified. Commercial use of fisheries products from mangrove areas, such as oysters, crabs and shrimp has been documented by La Croix (1971), Ramdial (1975) and Chin Yuen Kee (1978). Ramdial (1975) calculated the value of fisheries production from the Caroni Swamp in terms of the 212 full time and 57 part-time oyster, crab and shrimp collectors who took 890 tonnes of fisheries harvest worth TT$ 1.2 million in 1974. Local opinion is that yields have fallen off in recent years, but there are no data to support this.

14.8 Conversion to Other Uses

Large areas have been reclaimed for permanent and ephemeral cultivation particularly around the larger wetland, such as Nariva, Caroni, North and South Oropuche and Fishing Pond; some information on this is summarised by Bacon (1970, 1991) & Bacon *et al.* (1979).

14.9 Impacts on the Mangrove Environment

Changes in ecosystem structure and function resulting from reclamation have been reported for Caroni Swamp (Bacon, 1970a; Gerald, 1985) and Nariva

Table 19. Mangrove sites in Trinidad and Tobago

Code	Name	Type of mangal	Approximate size (ha)
	A. Trinidad		
TR01	Bayshore	Estuarine	< 1
TR02	Caroni Swamp	Estuarine	3728
TR03	Chaguaramus Bay	Fringe	< 1
TR04	Claxton Bay	Fringe	92
TR05	Couva River	Est. & Fr.	171
TR06	Cuesto River	Estuarine	< 1
TR07	Godineau	Estuarine	660
TR08	Grande Riviere	Estuarine	?
TR09	Guayaguayare	Estuarine	23
TR10	Hart's Cut	Estuarine	< 1
TR11	Icacos	Basin	237
TR12	Irois Bay	Fringe	15
TR13	L'Ebranche River	Estuarine	47
TR14	Lisas Bay	Fringe	26
TR15	Los Blanquizales	Basin	840
TR16	Manzanilla Windbel	Estuarine	44
TR17	Marabella	Fringe	65
TR18	Marianne River	Estuarine	?
TR19	Matura River	Estuarine	15
TR20	Mayaro Bay	Estuarine	6
TR21	Moruga River	Estuarine	33
TR22	Mouville	Fr. & Bas.	22
TR23	Mucurapo	Fringe	3
TR24	Nariva-Cocos Bay	Est. & Bas.	282
TR25	North Manzanilla	Estuarine	< 1
TR26	North Oropuche	Est. & Bas.	154
TR27	Orange Valley	Fringe	< 1
TR28	Ortoire River	Fr. & Bas.	110
TR29	Point Fortin	Fringe	33
TR30	Roussillac Swamp	Fr. & Bas.	300
TR31	Rustville	Estuarine	102
TR32	Sans Souci	Estuarine	?
TR33	Scotland Bay	Fr. & Est.	< 1
TR34	Sealots	Estuarine	< 1
TR35	Waterloo	Fringe	< 1
TR36	Yarra River	Estuarine	?
	B. Offshore islands (Chacachacare)		
TRc01	La Chapelle Bay	Fringe	< 1
TRc02	Salt Lake	Basin	< 1
	C. Tobago		
TRt01	Bloody Bay River	Estuarine	?
TRt02	Bon Accord Lagoon	Fringe	10
TRt03	Friendship/Kilgwyn	Fringe	12
TRt04	Goldsborough River	Estuarine	?
TRt05	Hillsborough River	Estuarine	?

Table 19. (Continued)

Code	Name	Type of mangal	Approximate size (ha)
TRt06	Lambeau/Petit Trou	Fringe	?
TRt07	Louis D'Or	Fringe	?
TRt08	Minister Bay	Fringe	?
TRt09	Parletuvier	Fringe	?
TRt10	Studley Park	Fringe	?
TRt11	Turtle Beach River	Estuarine	?

Swamp (Bacon *et al.*, 1979); with general agreement that some negative impacts have occurred. Several authors have lamented the polluted state of Caroni Swamp and other mangals (Bacon, 1974; McFarlane, 1985) but the only scientific studies are those of Deonarine (1981) for pesticides in Caroni Swamp and McShine-Mutunhu (1985) for industrial effluents at Point Lisas. Threats to mangrove areas were identified by James *et al.* (1986), largely in relation to wildlife. Several sites are being reduced in size by land reclamation, for solid waste dumping and residential development. Some sites are being cut over for charcoal production or bark stripping, although this is minor, and a few sites show evidence of pollution from sewage effluent or petroleum residues. In Tobago, airport and resort expansion threaten the two largest sites.

14.10 Socioeconomic Implications

The major work on socioeconomic aspects of mangrove conservation is Ramdial (1975), who used an assessment of visitor use to value the resources of Caroni Swamp.

14.11 Research and Training Programs

Current research is conducted through the Forestry Division and is concerned largely with protected areas and resource conservation.

14.12 National Policies and Strategies for Mangrove Management

Although general statements on the importance of wetland protection occur in several planning documents, there is little specific legislation or regulatory provision for mangrove management. Mangroves are not specified in the Forestry Act, although the Act deals with forest reserves which in several cases contain mangroves. Incidental protection is offered also through the Fisheries Act and the National Parks Act. The system of protected areas in Trinidad and Tobago includes the larger mangrove sites (Bacon & French, 1971; Thalen & Faizool, 1979, 1980; Chalmers, 1981; Faizool, 1990; James, 1990b). The degree of protection offered in these parks and reserves is minimal, due principally to budgetary and staffing constraints in the Forestry Division, and is largely concerned with law enforcement.

James *et al.* (1986) documented land use, protected area status and management problems for the major wetlands and indicated that the level of active management was low. There is no national policy for mangrove protection and use. The formulation of a policy has been hampered by the incomplete data base, particularly in respect of site specific forestry data. Very few sites were identified where replanting or habitat rehabilitation was required. In most impacted or cut over sites there was adequate seedling growth to effect stand recovery. The exceptions were sites near Port of Spain and in the Point Lisas area where recovery effort is needed, subject to plans for further development of the sites. Several mangrove forests would benefit from active management for stand improvement, particularly with respect to timber crops and enhancment of wildlife habitat. In most cases, insufficient data are available for the degree of required recovery effort to be assessed accurately.

It appears that Forestry Department staff and citizens have an awareness of the value of the major mangrove swamps, such as Caroni Swamp, and of a high conservation value being placed on their resources. A range of formal and public educational materials is available which use wetlands and mangrove swamps as examples of the need to protect and manage the natural environment. A number of non-governmental organizatios (NGO), such as the Trinidad Field Naturalists' Club and the Pointe-a-Pierre Wildlife Trust, are active in environmental education.

15. Turks & Caicos Islands

15.1 Historical Background

The general distribution of wetlands and tidal areas was shown in a series of maps produced by Doran (1955). The first inventory of wetlands was conducted by C.H.Floyd on behalf of the Government of the Turks & Caicos Islands and published in a directory by Scott and Carbonell (1986). Mangroves were not mapped separately by Floyd or during the subsequent studies by Clarke and Norton (1988) and Wager *et al.* (1988), so no accurate estimate of mangrove area is available although the total wetland area is known with some accuracy. Clarke and Norton (1988) documented the avifauna of a large number of sites. Bacon (1988, 1990) described habitat conditions and fauna of mangroves on Parrot Cay and West Caicos respectively during assessments of the impact of proposed developments.

15.2 Mangrove Ecosystems, Extent and Distribution

Wetlands occupy approximately 650 km^2 in the Turks and Caicos Islands, more than two thirds of this is mangrove and associated tidal flats and salinas (Fig. 7 and Table 20), with mangrove occupying some 23,600 ha. The largest expanse in the Caicos Islands, where the southern portion of North, Middle and East Caicos is occupied by virtually continuous mangrove and salt flats. Some 95 mangrove sites were recognised by Bacon (in Wager *et al.*, 1988), as listed in Table 21, the majority were occupied by scrub Rm and Ag with extensive areas of Ce and Cs.

15.3 Physical Environment

The Turks and Caicos Islands group includes eight large, low lying islands and more than 40 cays. The total land mass is approximately 500 km^2 rising from two shallow submarine banks (Table 20) with the maximum elevation < 100 m. The islands are formed as a complex of low plains intricately mixed with expanses of shallow water and ridges of recently consolidated marine deposits or aeolian sands. Wetlands have developed between the ridges and along shallow sea coasts and cover approximately 50% of the land area (Doran, 1955).

15.4 Biological & Ecological Characteristics

There is little information on mangrove forest structure in the Turks and Caicos Islands, most descriptions of the wetlands are very general. Wager *et al.* (1988) and Bacon (1988a, 1990) reported the following: Fringe Rm is developed in patches along sheltered coastal areas and the margins of channels, but trees are generally between 3.0 - 4.5 m high. At South Creek, Grand Turk, Rm trees were all < 5.0 m high with DBH < 10.0 cm whereas on Parrot Cay some trees reached to 10.0 m high with DBH 16.6 cm.

Avicennia germinans is widespread on the margins of salt ponds and lagoons, as in the interior of West Caicos, but is largely a dwarf mangal about 2.0

Table 20. Area of land units and marine environments of the Turks and Caicos Islands.

a. Estimated Areas of Islands (km^2)		b. Marine Environments (km^2)		
			Caicos Bank	Turks Bank
Middle Caicos	124.3			
North Caicos	106,2	Tidal		
Providenciales	91.9	1. Tidal flat	296	1
East Caicos	46.6	2. Mangrove	235	1
West Caicos	23.3			
South Caicos	22.0	Subtidal		
Grand Turk	18.1	3. Sand flat	3,946	139
Salt Cay	6.5	4. Mixed coral & vegt.	1,134	94
sub total	439.9	5. Coral	425	83
The Cays	60.8	6. Seagrass	104	6
Total	499.7	Totals	6,140	324

(Source: Olsen, 1986; Nat. Phys.Plan, 1987; Wager *et al.*, 1988)

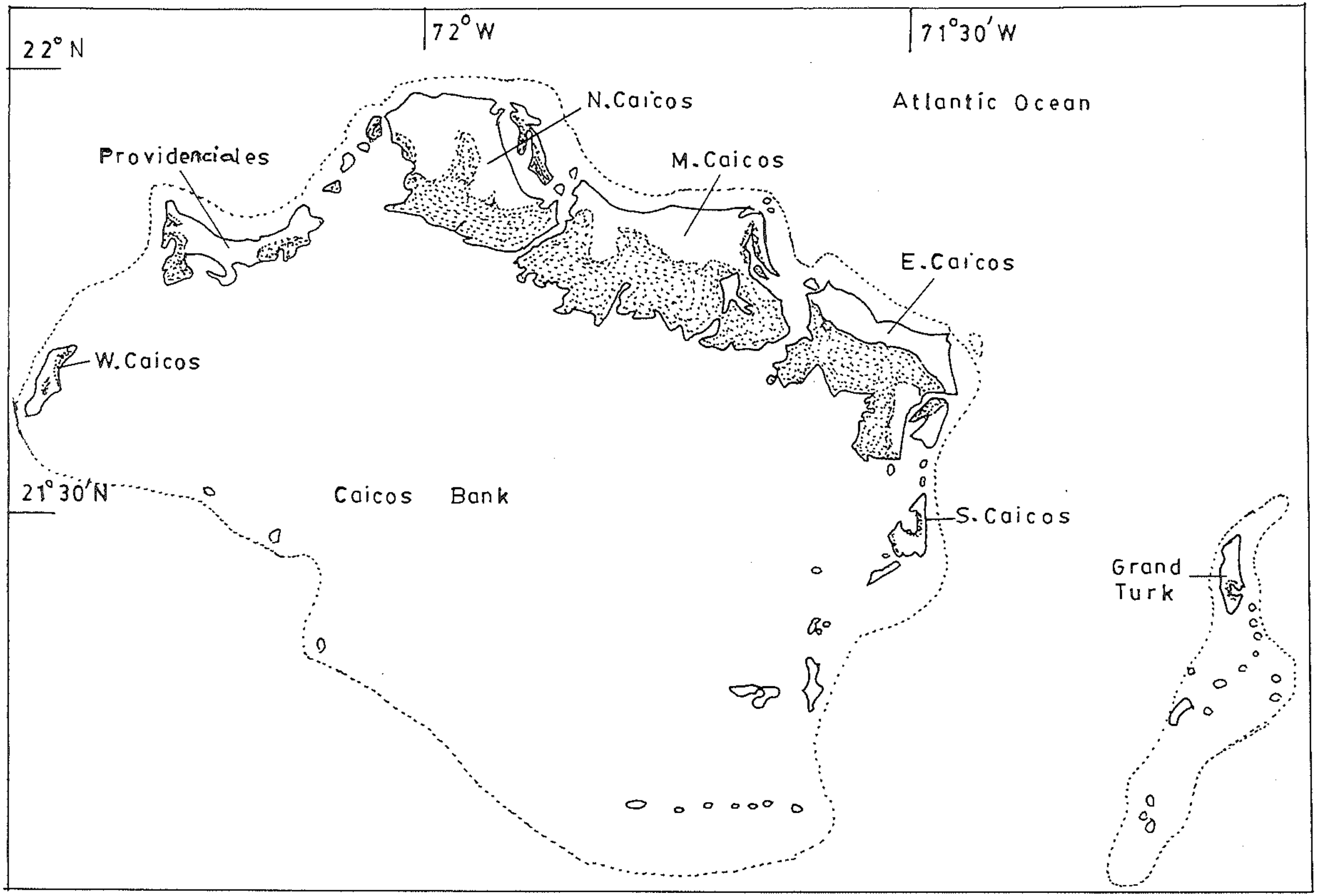


Fig. 7. Turks and Caicos Islands: Major areas of saline wetland

Table 21. List of Wetland Sites Containing Mangroves in the Turks & Caicos Islands

Turks & Caicos Islands (TC = State name & archipelago)

Code	Name of site	Type of mangal	Approximate size (ha)
	A. Turks Islands		
	Grand Turk (TCg)		
TCg01	Bayle's Pond Salina	Salina*	< 20
TCg02	Great Salina	Salina*	39
TCg03	Hawes Pond Salina	Salina*	< 20
TCg04	Hawke's Nest Salina	Salina*	40
TCg05	North Creek	Lagoon fringe	149
TCg06	North Salina	Salina*	< 20
TCg07	South Salina	Salina*	< 20
TCg08	The Sound & South Creek	Lagoon fringe	49
TCg09	Town Pond	Salina*	1
	Salt Cay (TCs)		
TCs01	Grey Salina	Salina*	< 20
TCs02	North Creek	Salina	< 20
TCs03	North District Salina	Salina*	< 20
TCs04	Pilchard Hole Salina	Salina*	< 20
TCs05	South Creek	Lagoon fringe	< 20
TCs06	Town Salina	Salina*	101
	Turks Cays (TCc)		
TCc01	Cotton Cay (4 sites)	Salina	< 20
	B. Caicos Islands		
	East Caicos (TCe)		
TCe01	Black Rock Salina	Salina	< 20
TCe02	Breezy Point Salina	Salina	< 20
TCe03	Drum Pt. Bay Salina	Salina	< 20
TCe04	Flamingo Hill	Salina	582
TCe05	Flamingo Pond	Fringe	63
TCe06	White Salina Bank	Fringe	7810
TCe07	(3 un-named sites)	Salinas	< 20
	Middle Caicos (TCm)		
TCm01	Armstrong Pond & Swamp	Basin	1120
TCm02	Big Pond & Lagoons	Fringe/Salina	2984
TCm03	Buttonwood Pond	Basin	< 20
TCm04	Eel Pond & Swamp	Salina	150
TCm05	Finaway Creek	Fringe/Salina	524
TCm06	Fish Ponds	Salina	1377
TCm07	Flamingo Pond	Fringe/Salina	28
TCm08	Gerry Well Swamp	Salt Pond	< 20
TCm09	Increase Pond	Fringe/Salina	219
TCm10	Jack Pond	Salina	229
TCm11	Mary Forbes Pond	Salt Pond	< 20
TCm12	Montpeller Pond	Salina	< 20
TCm13	Rocky Hill Pond	Salina	< 20

Table 21. (Continued)

Code	Name of site	Type of mangal	Approximate size (ha)
TCm14	The Creek & Swamp	Fringe/Salina	350
TCm15	Topham Pond	Salt Pond	< 20
TCm16	Village Pond	Salt Pond	< 20
	North Caicos (TCn)		
TCn01	Bay Cay Salina	Salina	830
TCn02	Conch Cay Salina	Salina	71
TCn03	Dick Hill Creek	Lagoon	392
TCn04	Flamingo Pond	Salt Pond	3113
TCn05	Mangrove Pond	Basin	31
TCn06	Monacah Salina	Salina	30
TCn07	Moore Hall Pond	Salina	< 20
TCn08	Mountain Pond	Basin	< 20
TCn09	Mud Hole Pond	Salina	77
TCn10	Pumpkin Bluff Pond	Salt Pond/Salina	177
TCn11	Red Salina	Salina	< 20
TCn12	Sawgrass Pond	Basin	45
TCn13	Snaky Pond	Basin	< 20
TCn14	St.James Hill Pond	Basin	< 20
TCn15	St. Thomas Hill Pond	Basin	< 20
TCn16	Whitby Salina	Fringe	30
	Providenciales (TCp)		
TCp01	Chalk Sound	Lagoon fringe	978
TCp02	Cheshire Hall Creek	Fringe	150
TCp03	Cooper Jack Pt.Pond	Basin	< 20
TCp04	Corrinice Ponds	Fringe/Salina	36
TCp05	Crab Pond	Salt Pond	< 20
TCp06	Crist Pt.Salina	Fringe/Salina	< 20
TCp07	Davy Bight Pond	Salt Pond/Salina	28
TCp08	Fish Pond & Swamp	Salt Pond/Salina	64
TCp09	Flamingo Lake	Salt Pond	< 20
TCp10	Frenchman's Creek	Fringe	1326
TCp11	Juba Point Salina	Salina	661
TCp12	Pelican Pt.Pond	Salt Pond	< 20
TCp13	Pigeon Pond & Salina	Salina	179
TCp14	South Dock Road Swamp	Salina	36
TCp15	Stubb's Creek	Fringe/Salina	65
TCp16	Stubb's Cove Salina	Fringe/Salina	< 20
TCp17	The Bight Swamp	Salina	142
	South Caicos (TCu)		
TCu01	Basden Pond	Salina*	22
TCu02	Goat Hill Salina	Salina	< 20
TCu03	Mangrove(John Deane Bay)	Fringe	23
TCu04	Sail Rock Estate Salina	Salina	< 20

Table 21. (Continued)

Code	Name of site	Type of mangal	Approximate size (ha)
TCu05	The Lagoon	Fringe/Basin	< 20
TCu06	Victoria Salina	Salina	346
	West Caicos (TCw)		
TCw01	Company Pt.Salina	Salina*	< 20
TCw02	Cove Anchorage	Fringe	1
TCw02	Eastside Salina	Salina*	356
TCw03	Greenlands Pools	Basins	< 20
TCw04	Lake Catherine	Salt Pond	118
TCw05	Northeast Salinas	Salinas	50
	Caicos Cays (TCy)		
TCy01	Dellis Cay	Fringe	111
TCy02	Donna Cay	Salina	< 20
TCy03	Little Water Cay	Salina	< 20
TCy04	Mangrove Cay	Fringe/Basin	85
TCy05	Parrot Cay	Fringe/Basin	343
TCy06	Pine Cay	Salina	50
TCy07	Water Cay	Fringe/basin	85

* = man modified
Sources: Original data from B.Floyd; see also Clarke & Norton, 1988; Wager *et al.*, 1988.

- 3.0 m high. A few taller stands were located, for example on Parrot Cay where there is a well developed forest to 5.0 m high with DBH 12.4 cm. *Avicennia schaueriana* is present in some areas, such as West Caicos, although difficult to distinguish in the field from stunted Ag living under stressed edaphic conditions. In most mangrove areas Lr is uncommon. The Button Mangrove, Ce, is widespread on the drier landward margins of wetlands and abandoned salt making ponds where it exhibits a low, shrubby habit. Taller Ce trees to 4.0 - 5.0 m high are found in several areas, such as at Whitby in North Caicos and around the Eastside Salina on West Caicos. The Silver-leaved Buttonwood, *Conocarpus erectus var sericeus* is common on salina margins on North Caicos.

The generally low, scrubby development of mangroves over much of the Turks and Caicos Islands is probably a response to the high ambient salinites. Bacon (1990) found salinities in three mangrove-lined salinas on West Caicos in October 1989 to be 42.0, 68.0 and 84.5‰ respectively and 38‰ in the sea along the Caicos Bank coast of West Caicos.

15.5 Mangrove Related Ecosystems

Extensive areas of Salt Marsh occur on most islands and are dominated by *Salicornia bigelovi, Borrichia arborescens, Sesuvium portulacastrum,* and *Sporobolus virginicus;* with *Batis maritima* forming dense meadows in some places. These marshes are inter-digitated among mangroves and tidal flats and are particularly widespread in the southern part of the larger Caicos Islands. Salt Marsh is associated with a maze of salt ponds, salinas and creeks with dominantly hypersaline conditions. Most Salinas have been modified and were once used for salt making; they have a leveled sandy substratum supporting thick blue-green algal mats. A low dry scrub is present on interior ridges which define wetland basins and a Strand/Dune community with xerophytic herbs and grasses dominates on ridges at the seaward margins.

15.6 Human Habitation, Traditional and Commercial Mangrove Usage

There are no human settlements in mangrove areas. Historically there has been considerable cutting of mangrove for poles and charcoal. The major use of mangrove areas is fishing and lobster catching in fringe zones. Apart from fish caught in mangrove creeks, little other produce is marketed.

15.8 Conversion to Other Uses

Several mangrove areas and the majority of salinas have been converted for salt manufacture or cleared for resort development, particularly marinas.

Mangroves and other trees were cleared from salt-making pond margins to increase wind evaporation, so much of the existing mangrove forest is relatively young. In some areas, such as Providenciales, Parrot Cay, North Caicos and Grand Turk, mangrove areas have been filled, drained and or canalised during resort and residential development projects (Bacon, 1988; Wager *et al.*, 1988).

15.9 Impacts on the Mangrove Environment

Salt making destroyed much mangrove. With abandonment of salt manufacture mangrove is recolonising many salina areas. The impact of mangrove clearance for tourism development has not been assessed, but to date is probably minor. The socioeconomic implications however are minimal since mangroves play only a minor part in the local economy, apart from their support to the important fishing industry.

15.10 Research and Training Programs

There are no on-going government sponsored research or training programme. Some research is done by visiting scientists.

15.12 National Policies and Strategies for Mangrove Management

The National Physical Development Plan recommends mangroves protection. A Site Ramsar has been set which stretches in the southern parts of North, Middle and East Caicos.

16. United States Virgin Islands

16.1 Historical Background

Most of the research and conservation effort which relates to wetlands in the US Virgin Islands has been carried out under protected areas management programmes or shorebird surveys. A further series of studies was undertaken under environmental impact assessments for development projects, but little of this work is published.

Table 22. List of mangrove sites in the US Virgin Islands

Code	Name of site	Type of mangal	Approximate size (ha)
	US Virgin Islands (UV = State name, archipelago)		
	St. Croix (UVc)		
UVc01	Altona Lagoon	Basin, mixed	100
UVc02	Cassava Garden	Basin & saline pools	15
UVc03	Coakley Bay Pond	Basin, mixed	7
UVc04	Great Pond	Basin, mixed	50
UVc05	Krause Lagoon	Basin, mixed	200
UVc06	Manning Bay	Fringe & tidal flats	10
UVc07	Salt River Bay	Estuarine	100
UVc08	Southgate Pond	Basin, mixed	16
UVc09	Westend Salt Pond	Basin, mixed	100
	St. John (UVj)		
UVj01	Calabash Boom Pond	Basin	0.4
UVj02	Friis Bay Pond	Basin	0.4
UVj03	Europa Bay Pond	Basin	6.0
UVj04	Fortsberg Pond	Basin	1.9
UVj05	Grootpan Bay Pond	Basin	9.9
UVj06	Hart Bay Pond	Basin	1.4
UVj07	Lameshur Bay Pond	Basin	0.8
UVj08	Mary Point Pond	Basin, red	4.8
	St. Thomas (UVt)		
UVt01	Magen's Bay	Basin, mixed	3.6
UVt02	Mangrove Lagoon & Benner Bay	Fringe, basin & tidal flats	345
UVt03	Perseverence Bay Pond	Basin, mixed	2.8
UVt04	Vessup Bay Pond	Basin, mixed	2.8

16.2 Mangrove Ecosystems, Extent and Distribution

Twenty-one mangrove sites are reported in the three islands, with total coverage 977.8 ha. These are largely saline ponds with a scrubby mangrove fringe.

16.3 Physical Environment

Three main islands with a total area of 345 km^2, with maximum altitude of 474 m. The islands are rocky, with only a narrow coastal plain, but small wetlands are developed at blocked river mouths and around coastal ponds.

16.4 Biological and Ecological Characteristics

There appears to be no comprehensive inventory of USVI wetlands. General site data are available only in Scott and Carbonell (1986). No detailed information was located on mangrove related ecosystems, human habitation and traditional mangrove uses, commercial exploitation and marketing or conversion to other uses.

16.5 Impacts on the Mangrove Environment

There have been minor losses of mangroves due to tourism expansion. Common causes of damage to mangrove ecosystems are dumping and landfill, dredging and marina construction. The socioeconomic implications of these losses are poorly known.

16.6 Research and Training Programs

The Caribbean Natural Resources Institute (CANARI) and the University of the Virgin Islands have conducted research; as formerly did the West Indies Laboratory of Fairleigh Dickinson University on St. Croix. The Virgin Islands National Park has been a major instrument in research and monitoring programmes.

16.8. National Policies and Strategies for Mangrove Management

The legal status of mangroves in the USVI is influenced by the United States environmental protection laws. Locally, the Division of Fish & Wildlife, Department of Conservation & Cultural affairs, USVI Government, has overall regulatory authority. Within the same office there is a Coastal Zone Management Committee with jurisdiction over coastal wetlands.

Influential NGO's are the Island Resources Foundation (IRF) based in St. Thomas, and the Caribbean Natural Resources Institute (CANARI).

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Mangroves of Venezuela

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1. Historical Background

The extent of mangrove forests in western Venezuela, probably triggered important social changes among nomad human groups by inducing an initial settling process of the communities of gatherers, fishermen, and hunters (Sanoja, 1992). Human populations coming from the inner lands of Venezuela, occupied, 6,000 or 5,000 years ago, the mouths of the rivers that descend from the Paria Sierra, and settled in coastal areas, many of them covered by mangroves (Sanoja, 1992) - a process similar to the one hypothesized by Widmer (1988) for the south coast of Florida, USA. Mangroves, as sources of wood, resins, fibers and dyes, and also of proteins of animal origin, provided a spectrum of resources for diverse forms of extraction and spurred some incipient forms of cultivation of native edible plants. Exploitation of mangrove oysters by the native population could have induced seminomad settlements, which can be compared to the use of soil by slash-and-burn farmers (Veloz Maggiolo & Pantel, 1976, cited in Sanoja, 1992).

The migration of human populations to the coastal areas is testified by the presence of archaeological preceramic places of shellfish pickers and fishermen in the Tucacas area, Falcón State, where there is a large extent of mangroves nowadays (Cruxent & Rouse, 1958).

Spanish colonizers were greatly attracted by mangroves, as can be inferred from the words of historian Gonzalo Fernández Oviedo y Valdés, who, in his "Historia General y Natural de las Indias. Islas y Tierra-firme del Mar Oceano", at the beginning of the XVI century, included a whole chapter dedicated to mangroves. This author, who is considered the first to mention American mangroves (Schaeffer-Novelli & Cintrón, 1990; Rodríguez, 1984), notes: the mangrove is " ... a tree of the best that in these places exists, and it is common in these islands ... rare and admirable trees to sight, because of its forms it is not known another being similar". He added an inventory of mangrove uses. In 1595, Sir Walter Raleigh refers to some trees surrounding the channels at the entrance of the Orinoco River, noting that they are capable of living in salty water. This is said to be the first reference to Venezuelan mangroves (Pannier & Pannier, 1989).

The first description of Venezuelan mangrove species was carried out by Adolfo Ernst in 1872 (Pannier & Pannier, 1989). Later, in 1891, the same author published an article where he included considerations about the origin of the word mangle and other denominations that Venezuelan indians give to these plants (Ernst, 1891). Subsequently, Pittier (1926) mentioned the main mangrove areas and included some floristic considerations. Later he made additional considerations on mangroves, pointing that "these roots lodge harmful things..." and "... mangroves, suspended between sea and sky, are depressing with its eternal monotony" (Pittier, 1939); this statement seems to reflect the attitude of the epoch toward mangroves.

The first studies on Venezuelan mangroves ecology and physioecology where carried out by Budowski (1951, 1952), Vareschi (1956) and Pannier (1959).

Environmental impacts on mangroves and associated ecosystems in Venezuela have been documented by Canestri & Ruiz (1973); Pannier (1979); Salm (1980); Delgado (1981) and Díaz & Zelwer (1985). Other aspects have been examined, among others, by Arroyo (1970), Canales & Zelwer (1978), Cannizo *et al.* (1979), Finol (1979), Luna-Lugo (1976) and Rodríguez (1984).

Physiology of several species of mangroves has been studied by Pannier *et al.* (1979) and Mizrachi *et al.* (1980). Other studies of mangrove physiology and their relation to a hemiparasite mistletoe are those of Goldstein *et al.* (1989), Orozco *et al.* (1990), and Rada *et al.* (1989).

Litter decaying processes of several species of mangroves under the influence of oil spills have been described by Bastardo (1988,1993).

Population dynamics and life histories of mangrove crabs have been studied by Conde (1990); Conde & Díaz (1985, 1989 a,b, 1992 a,b); Conde *et al.* (1989); Díaz & Conde (1988, 1989); and Díaz *et al.* (1983). Ecological aspects of the sessile community of red mangrove roots were studied by Sutherland (1980) and Orihuela *et al.* (1991). Díaz *et al.* (1985) catalogued the sponges growing on *Rhizophora mangle* roots. Díaz *et al.* (1983, 1992) and Conde & Díaz (1985) evaluated sampling designs to estimate parameters in populations and communities of organisms associated to mangroves.

General characterization of several mangroves of the Venezuelan coast, including climate, structure, associated fauna and flora, socioeconomy, ecology, impacts, etc., has been made by Ministerio del Ambiente y los Recursos Naturales Renovables (Secretary of the Environment and Renewable Natural Resources) (MARNR, 1986, 1990 a,b,c, 1991 a,b,c,).

Additional references, including thesis, restricted circulation reports and gray literature on mangroves and related marine ecosystems of Venezuela can be found in Pannier (1986) and Rodríguez (1984). Rodríguez (1987) reviewed critically several paradigms about mangroves, including zonation and succession.

2. Species of Mangroves

The more common species of mangrove trees found in Venezuela are: *Rhizophora mangle* L., *Avicennia germinans* L., *Laguncularia racemosa* Gaerth and *Conocarpus erectus* L. also *R. harrisonii* Leechman and *R. racemosa* G.F.W. Meyer, have been reported (MARNR, 1986). *A. schaueriana* Stapf & Leech has been indicated for the San Juan River (MARNR, 1990b); however, there are doubts about its identification (E. Medina, *pers. comm.*).

Other plant species also are known locally as mangroves, but their physiology very different from that of true mangroves. Among them are *Thespesia populnea*, a tree that grows in the supralittoral marine zone (Pittier, 1926; Hoyos, 1983); and *Calliandra riparia*, a scrub found inland surrounding rivers and creeks (Pittier 1939). Goldstein *et al.* (1989) include *Coccoloba uvifera* among the mangrove, but emphasize that this is not a strict mangrove tree.

3. Extent and Distribution of Mangrove Forests

Venezuela is located at the most northern portion of South America. Although the Andes Cordillera extends for about 500 km in its territory and has permanently snow-covered mountains that exceed 5,000 m, the north coast of Venezuela has a tropical semiarid climate, with clear Caribbean affinities, and it is classified, almost totally, as Provincia Caribe Meridional (Southern Caribbean Province) (Fig. 1) (Huber & Alarcón, 1988). The Southern Venezuelan Atlantic coast, in the eastern end of the country, is classified as Provincia Guayana Baja (Low Guiana Province) (Huber & Alarcón, 1988).

Distributed on a narrow latitudinal strip of about 4°, Venezuelan mangrove forests occupy discontinuously about 1,100 km (Pannier & Pannier, 1989) of the 3,300 km of coast line. From west to east, Venezuelan continental mangroves extend from the Cocinetas Lagoon, located at the Guajira Peninsula (42° 20' W), to the lower coastline of the Orinoco River Delta (60° 05' W). The northernmost limit of mangroves are Punta Macoya at the Paraguana Peninsula, Falcón State (12° 05' N); and the southernmost are located close to the Orinoco Delta, near to 8° N (Fig.1). In the insular domain, large mangrove stands are present in the Margarita Island and Los Roques Archipelago.

Different figures were given for the total area of Venezuelan mangroves. Flores (ca. 1979) points close to one million ha. More recently, several authors (MARNR, 1985; Hutchings & Saenger, 1987; Pannier & Pannier, 1989; Bossi & Cintrón, 1990) have given figures close to 650,000 ha, a total that would place Venezuela as fifth in the world, and second in Latin America and the Caribbean. However, this number is probably an overestimation, as a result of the inclusion of the area occupied by the "paramancillo" (*Symphonia globulifera*), a plant whose light spectrum and shape makes it prone to be confused with mangroves in photointerpretation. A number closer to the real extension (Delfina Rodríguez, personal communication) probably is the 250,000 ha reported by MARNR (1986). This could be slightly augmented because some small patches of mangroves, as those of Falcón, were not included. Furtive deforestation, urbanization and other factors probably balance this

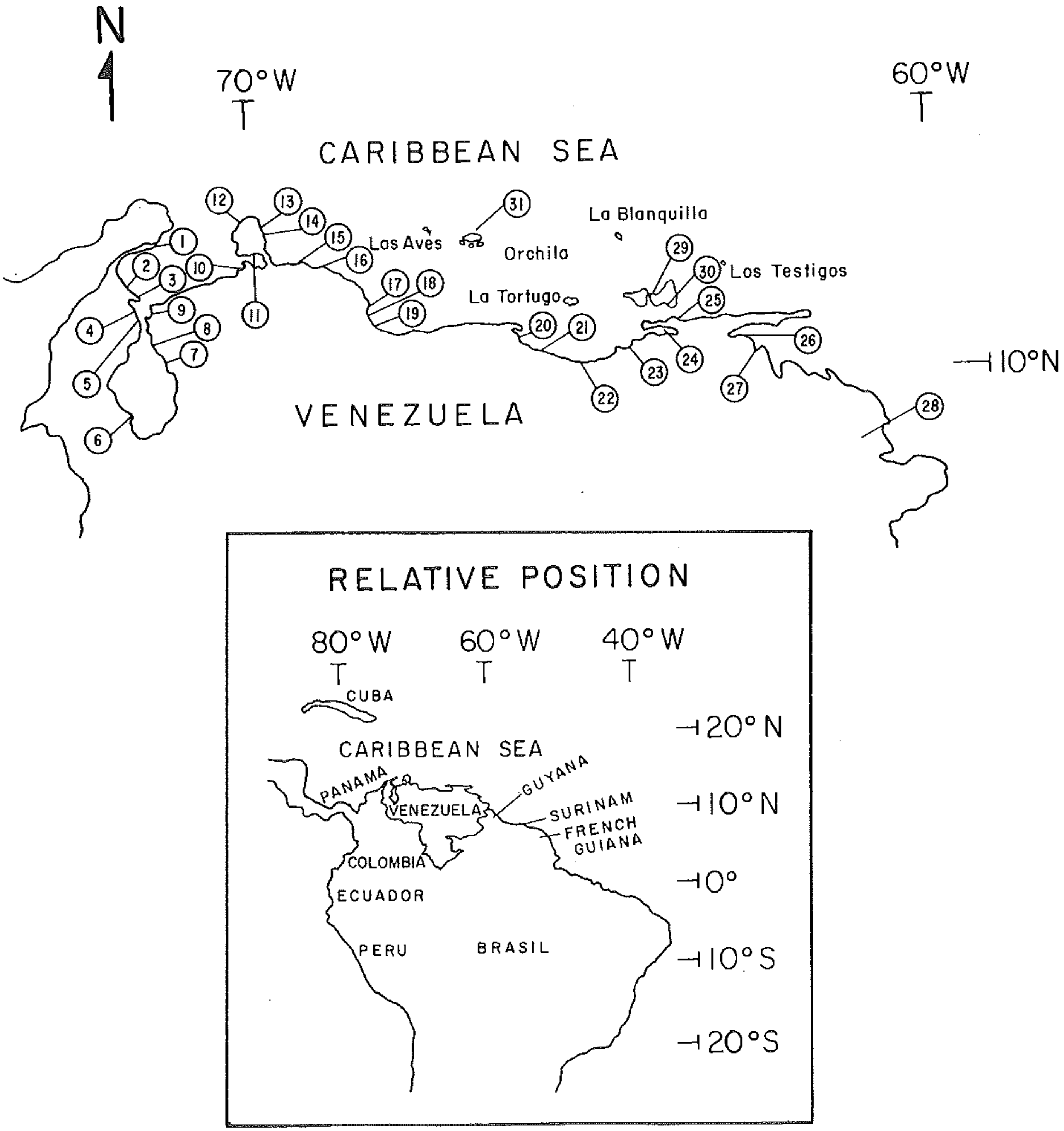

Fig. 1. Map of the Venezuelan coast showing some of the localities where mangroves occur. 1.Cocinetas Lagoon. 2. Gran Eneal Swamp. 3.Limón River-San Carlos Island. 4.Las Peonías Swamp. 5.Punta Capitón Chico. 6. La Concha River-Catatumbo River. 7.Lagunillas. 8. Cabimas. 9. Los Olivitos Swamp. 10. Punta Caimán. 11. Cuara-Prudencio-Tacuato Lagoons. 12.Punta Macolla. 13. Yaima Bay. 14. Boca de Caño Lagoon. 15. Boca de Ricoa. 16. Boca de Hueque-Sauca. 17. Gulf of Cuare. 18. Morrocoy Bay. 19. Yaracuy Delta. 20.Buche-Carenero-La Reina Lagoon. 21.Tacarigua Lagoon. 22. Páritu and Unare Lagoons. 23. Mochima Bay. 24.Gulf of Cariaco. 25.Chacopata Lagoon. 26. Gulf of Paria. 27. San Juan River. 28. Orinoco River Delta. 29.La Restinga Lagoon. 30. Las Marites Lagoon. 31. Los Roques Archipelago.

off and must also be considered. Thus a reasonable estimation of mangrove cover must lay between 200,000 and 300,000 ha, representing less than 1% of the total extension of Venezuelan forests: a number somewhere between 40 and 50 million ha (MARNR, 1985).

Of those 250,000 ha, 183,500 ha (73,4%) are located in the western region of the country, between the Gulf of Paria and the Orinoco Delta. Central western and central-eastern regions include 51,250 ha (20,5%), whereas 9,500 ha (2.3%) are located in the coast of the Gulf of Venezuela (MARNR, 1986). Mangrove extent estimates by federal entities are also variable (Table 1).

Table 1. Extent of mangrove forests in the coastal places and states of Venezuela.

Political Entity	Extension (ha)
Delta Amacuro	96,802-455,298
Falcón	1,500-5,200
Miranda	3,900
Monagas	41,314-55,326
Nueva Esparta	2,340-4,288
Sucre	45,150-94,423
Yaracuy	1,200
Zulia	4,337-22,566

Mangrove areas larger than 4,000 ha are located in the: Orinoco River Delta, Gulf of Paria, San Juan River, Limón River-San Carlos Island, Los Olivitos Swamp, and Tacarigua Lagoon; (Fig. 1, and Table 2). Smaller stands are located in the Maracaibo Strait, Gulf of Cuare-Morrocoy Bay, Buche-Carenero-La Reina Lagoon, Mochima Bay, Cocinetas Lagoon, Punta Caimán, Cuara-Tacuato-Prudencio Lagoons, Boca de Caño Lagoon, Boca de Ricoa, Boca de Hueque-Sauca, Píritu and Unare Lagoons, El Obispo Lagoons, Chacopata Lagoon. In the insular domain, mangroves are found in Los Roques Archipelago, and La Restinga Lagoon and the Marites at the Margarita Island (Fig. 1). Brief descriptions and areas, when the information is available, of some of those localities are given below.

The so-called Maracaibo System (Rodríguez, 1973) comprises three interconnected distinct bodies of water that form a continuum (Rodríguez, 1973). Distributed on a latitudinal band of approximately 300 km the Maracaibo System includes waters typically marine, in the Gulf of Venezuela; limnetic waters of the lake; and the estuarine waters of the Maracaibo Strait and El Tablazo Bay. Characteristic mangroves are associated to this gradient (Pannier & Pannier, 1985). In the vegetation map of the Venezuelan Republic, Hueck (1960) showed mangroves for almost all the Maracaibo Lake perimeter. Nowadays, however, as can be inferred from several sources (Pannier & Pannier, 1985; MARNR, 1985; Huber & Alarcón, 1988; Finita Mayobre, personal communication), mangroves in the Maracaibo System are located at the places indicated below. The littoral hypersaline Cocinetas Lagoon, is located at the north end of the Goajira Peninsula. Although the area occupied by mangroves is relatively small, 274 ha, this lagoon has a remarkable geopolitic importance, given the fact that it is part of the border with Colombia. It includes *Rhizophora mangle,* as dominant, and *Laguncularia racemosa,* at the fringe. *Avicennia germinans* located as following in less flooded ground, reaches a mean height of six meters. Canalization works brought about modifications in the hidrodynamic regime of the lagoon. Sedimentation produced structural changes and affected negatively the stands of *A. germinans* (MARNR, 1991c).

In the southern portion of the Goajira Peninsula, there are several mangrove patches around small littoral lagoons, which totalize 2,032 ha. It includes the Gran Eneal Swamp and the Caños Guaraira and Gualapeña (Pannier & Pannier, 1985). *A. germinans* is the dominant species with a small proportion of *R. mangle.* These stands show major damages, brought about by the hypersalinity conditions derived from the isolation of these lagoons from the open sea, caused the sedimentation that has closed the connecting channels.

The Limón River and San Carlos Island include about 10,900 ha of very dense mangrove forests of *Rhizophora, Avicennia, Laguncularia* and *Conocarpus,* and *Rhizophora-Laguncularia* mixed forests. They exhibit signs of overmaturity and anthropogenic pressure. These areas are exposed to oil spills which could also affect fisheries. There are plans to build, in a nearby zone a deep water harbor which could affect these mangroves that Pannier and Pannier (1989) have catalogued as unstable. Several artificial islands, covered by mangroves, were formed as a consequence of dredging and hydrodynamic modifications of the zone (Pannier & Pannier, 1985).

In the coasts of the Maracaibo strait and close to this city, at the Las Peonías Swamp, which is a littoral lagoon, there is a mangrove patch of about 80 ha, formed mainly by *R. mangle* and *L. racemosa* (Pannier & Pannier, 1985). Downwards, at Punta Capitán Chico, there is a stand of mangroves which has undergone substantial decrease due to the uncontrolled expansion of low-income housing (Gilberto Rodríguez, personal communication).

Following the Maracaibo Lake edge southwards, in a zone of limnetic waters, there are several swamps. Between La Concha River and the Catatumbo River, are Birimbal Lagoon and Madre Vieja Lagoon (Pannier & Pannier, 1985). Alarcón & Huber (1988) report mangroves in La Paloma Lagoon, at the mouth of the Santa Ana River. No information exists about these mangroves that probably are relics of the distribution indicated by Hueck (1960).

South of Lagunillas, on the east coast, there are several *L. racemosa* patches, with an undefined extent (Finita Mayobre, personal communication). Near Cabimas, there are two places where mangroves cover of about 920 ha: at the north, Ciénaga Las Palmeras Swamp (or Los Palmitos Swamp) and the La Telefonica Swamp; these mangroves are surrounded by a belt of the fern *Acrostichum aureum*, with specimens 4-5 m high (Pannier & Pannier, 1985). At the south is located La Yaguasa Park (Finita Mayobre, personal communication). Other mangrove patches occur at the artificial Ana Maria Campos Peninsula created by ground movements made by a branch of Petróleos de Venezuela, S.A. (Gilberto Rodríguez, personal communication).

Los Olivitos Swamp. On this estuary, located at the northeastern coast of the Maracaibo Lake, in front of the Limón River mouth, there are 4,200 ha of mangroves. Toward the northern portion, mangroves are adjacent to psammophilous littoral meadows; toward the south-southwest, they are in touch with xerophilous deciduous forests and an extensive zone of salt flats, now under production. In general, at the margin of the coastal line *Rhizophora* can be found, with *Avicennia* in the inner area; *Rhizophora* forests have heights between 18 to 23m, with high basal area, and very good drainage, resulting in a well developed mangrove. In cleared areas the fern *A. aureum* is found. *Avicennia* specimens have heights up to 20 m and a great basal area (44 m^2 /ha). Decrease of height and basal area seem to be related to the hypersalinization of soils. *Laguncularia* occurs occasionally, it is generally small, and has a small basal area. *Rhizophora-Avicennia* stands are the dominant vegetation type (MARNR, 1990c).

Table 2. Localities and approximate extent of some of the main Venezuelan mangroves.

Locality	Extension (ha)
Orinoco Delta	46,802
Gulf of Paria	45,150
San Juan River	41,314
Limón River-San Carlos Island	9,029
Morrocoy Bay	4,500
Los Olivitos Swamp	4,000
Tacarigua Lagoon	3,900
Margarita Island	2,340
Goajira Peninsula	2,032
Yaracuy Delta	1,500
Maracaibo (Eastern Coast)	921
Puerto Cabello	700
Boca de Aroa	300
Cocinetas Lagoon	274
Maracaibo (Western Coast)	256

Falcón State is one of the areas where mangroves are almost totally unknown (Pannier 1986); the only exceptions are Morrocoy Bay (Alvarez, Undated) and the Gulf of Cuare. However, since 1986 an intense characterization project of the Falcón coast, with visits to more than 70 localities, has been developed (Carmona & Conde, 1989). The more extensive Falcón mangrove stands can be found in: Punta Capana, San Félix, Zazárida, Punta Caiman, Cuara-Prudencio-Tacuato Lagoons, Punta Macolla, Las Cumaraguas, Yaima, Boca de Caño Lagoon (Tiraya), Boca de Ricoa, Sauca-Boca de Hueque, Gulf of Cuare, Morrocoy Bay, coastal belt of Aroa, and Boca de Aroa.

Punta Caimán: a monospecific stand of *A. germinans* with scarce individuals of *R. mangle* which grow on a coastal zone of shallow hypersaline waters. There is no knowledge on this mangrove forest, which is included in the Fisheries Reserve of the Gulf of Coro.

Cuara-Prudencio-Tacuato Lagoons. At the southwest of the Paraguaná Peninsula, there is a group of small coastal hypersaline lagoons surrounded by mangroves, which totalize an approximate area of 200 ha. These are located south of Tacuato (11 41'N - 69 55' W) in an extremely arid zone (annual mean precipitation 256.8 mm). Major areas are located south of Prudencio. Dominant species are *R. mangle* and *A. germinans*. *C. erectus* and *L. racemosa* also are present in this place. The smallest ovigerous females of the mangrove crab *Aratus pisonii* were reported from the Tacuato Lagoon (Conde & Díaz, 1992b).

Punta Macolla. A small *R. mangle* patch that surrounds a lagoon that penetrates landwards, it has the privilege of being the northernmost continental mangrove stand of Venezuela.

Yaima Bay. At the southern portion of this bay there is a mangrove patch, covering two or three ha, with well developed trees, mainly *R. mangle*. Aerial photographs suggest that this mangrove is being encroached upon by urban development and probably is a relic of a more extensive system that formed a continuum from Boca de Caño Lagoon.

Boca de Caño or Tiraya Lagoon. Located at the middle of the oriental coast of Paraguaná Peninsula, is a hypersaline littoral lagoon with 10-20 ha of mangroves, it is probably the larger stand of this arid peninsula. On the lagoon's north edge there is an important mangrove belt, mainly *R. mangle*, with individuals that reach 10 m height. At the eastern border which is separated from the open sea by a sand bar, with an asphalted road and several ground paths and numerous chalets, there are individuals of *R. mangle* and *A. germinans*. In the south end of the bar there is a patch of red mangroves, *R. mangle*, that have important amounts of marine birds.

Boca del Río Ricoa. This locality, sited in the vicinity of Tocópero, 50 km west Coro, is an eminently riverine habitat (S<1ppt) with occasional intrusions of marine water (Conde 1990). *L. racemosa* is the dominant mangrove species. There are some *R. mangle* specimens. At In the bar, west of the mouth, *C. erectus* is the more abundant species.

Boca de Hueque and Sauca salt flats. With an extent of 5,000 ha, this system is sited 80 km west of Coro. Mangroves are at the north side, close to the sea. Along Caños Hueque and Guay there is a belt of about 150 m width; where *R. mangle* and *A. germinans* predominate. There are some isolated individuals of *L. racemosa*.

Gulf of Cuare . A wildlife refuge, created in 1972, and pilot locality for the Ramsar convention, it includes approximately 8,000 ha and is adjacent to the Morrocoy National Park.

Morrocoy Bay, with about 1,900 ha of mangroves. The marine component of this national park, located at the oriental end of Falcón (10° 52'N - 68° 16'W), is formed by an extensive lagoon system, surrounded by mangroves and interconnected by an imbricated network of channels and waterways, and connected to the open sea by several wide mouths. *R. mangle* is the dominant species of mangrove. During the dry period, salinity is typically marine, 36‰, with light fluctuations, ± 2‰ (Díaz *et al.*, 1985). There are no important fluvial tributaries and the rain regime is clearly seasonal, with a peak during the last trimester of the year. Different sedimentary processes can be distinguished in Morrocoy: a continental one, occasionally affected by tides, where *R. mangle* individuals are sparse and small, and *A. germinans* has scarce representation. A sector exposed to tides, constituted by islands, where mangroves are better developed, with a big basal area (66 m^2/ha), can be compared with the ones found in the oriental zone of Venezuela, although their height is less (25m). There are also mixed forests of *Avicennia-Rhizophora-Laguncularia*. The last sector is constituted by small size mangroves with scarce natural regeneration, established on island reefs.

Between Tucacas and Aroa, running parallel to the coast and up to 100 m from the tidal line, there is a strip of *C. erectus*, although there is no information about its extension. These mangroves have suffered as a result of urbanization, farmer's activities, and coconut cultivation. At the Aroa mouth, Ninín (1957) reports 300 ha of mangroves, that include a belt of mangroves along the coast and coconut plantations.

La Reina Lagoon. Located at the oriental end of Miranda State, between the towns of Carenero and Higuerote, this is an artificial lagoon that occupies some old salt flats (Díaz, H. personal communication). It belongs to the Venezuelan system of areas under special administrative regime, as a coastal protected zone. Mangroves cover approximately 370 ha. At the border of the lagoon, *L. racemosa* is dominant, together with *R. mangle*, which predominates on the small cays. On the coastal plain *A. germinans* and *L. racemosa* are abundant. On the flooded plain, are located some ecotones with mixed patterns of vegetation where *A. germinans* and *L. racemosa* can be found, besides *Sporobolus virginicum*, *Sesuvium portulacastrum*, *Batis maritima*, and *Trichilia trifoliata* (Sebastiani *et al.*, 1991). Water movement depends on tides, through the main channel. Soils are loam-sandy salty. Together with Carenero, Los Totumos and Buche they form a littoral belt with some

3,000-4,000 ha of mangroves, which will undergo anthropogenic pressures, due to the explosive urban expansion.

Tacarigua Lagoon. Mangroves are on the alluvial plain forming a belt of *Avicennia-Laguncularia*, adjacent is a xerophilous deciduous forest (MARNR, 1990a). On inner small islands and at the borders *Rhizophora* is dominant. The coastal plain sited on the sandy bar which separates the lagoon from the sea, the four mangrove species characteristic of Venezuela can be found: *R. mangle, A. germinans, L. racemosa* and *C. erectus*. These mangroves are developed on heavy alluvial soils with clay texture. Although they have important influxes of water from sediments of fluvial kind, dominants are *Avicennia* together with *Laguncularia* with 15 m mean height. On the small islands, an active siltation zone, *R. mangle* is dominant. At the inner, end going through permanent flooded zone, can be found juvenile individuals of *A. germinans* and *L. racemosa* (Rodríguez & Alarcón, 1982; MARNR, 1990a).

The Unare Lagoon and the Píritu Lagoon, interconnected by the Unare River, are located in the north-east area of Venezuela. Both lagoons, are belt shaped, and have mangrove vegetation. The Unare Lagoon, with an area of 64 km^2 and depth between 0.5 and 1.5 m, is separated from the sea by a sandy bar, whose width oscillates from 200 to 600 m. Mangrove communities here, are more scarce than in the Píritu lagoon, and are located on the south and west coasts. Patches at the south are exclusively made of *A. germinans*, while in other zones this species is mixed with *R. mangle* (Novo, 1990).

The Píritu Lagoon, topographically similar to Unare, with an extension of 37 km^2, is separated from the sea by a bar, whose width oscillates between 100 and 300 m. Mangroves are located along the inner belt and at the south of the lagoon forming patches on the coast; *A. germinans* and *R. mangle* dominate (Novo, 1990).

At the coastal area of Mochima Bay and in El Obispo lagoons (Sucre State) there are fringe shrubbery mangroves (Flores, 1977). Between CaigÜire y El Peñon, in the same state, there is a belt of more developed mangroves (Flores, 1977).

Gulf of Cariaco, Sucre State constitutes a semi-closed system with an approximate area of 700 km^2. It encloses mangroves adjacent to Santa Fé and the west end of this gulf, near Chiguana and San Antonio del Golfo. These mangroves have arborescent and shrubby forms located on the coastal belt (Flores, 1968).

Chacopata Lagoon. Located approximately 45 km ENE of Cumaná, this is a shallow coastal lagoon, with some 700 ha of fringe mangroves, mainly *R. mangle* (Figueroa & Seijas, 1986).

The most extensive and structurally complex mangrove forests of Venezuela are found along the Atlantic coast. In general, mangroves belonging to the San Juan River, Gulf of Paria and Orinoco Delta are more developed, their heights reach up to 25 to 35-40 m. They form almost continuous belts, interrupted only by streams and rivers that go from Yaguaraparo through Guyana. They have greater diversity of forest types with eight to nine types of distinct forests, while in the western zone can be found a maximum of three distinct types and in the central zone only five to six types. Besides, the highest DBH values correspond to *Rhizophora* specimens located at the Orinoco Delta. The types of forest show a DBH decrease related to the aridity index. In the mixed forests DBH are variable depending on the phytosanitary conditions; *Laguncularia* is the species that shows smaller DBH values (MARNR, 1990b, 1991a,b).

In the southern slope of the Gulf of Paria, which is under marine influence, mixed stands of *Rhizophora-Avicennia* predominate, with similar characteristics to the ones found at the San Juan River, although *Avicennia* specimens show a larger basal area. In the western coast, with fluvio-marine influence, *Avicennia-Rhizophora* also dominate. In the Guariquén and other intermediate channels, with high freshwater input, *Rhizophora-Laguncularia* mixed stands dominate, whereas *Rhizophora-Avicennia-Laguncularia* stands are found in soils with abundant organic accumulation, but whose basal areas are smaller. In the islands with greater marine influence, *Avicennia* forests occur in the higher zones, although herbaceous swampy vegetation is found in depressions (MARNR, 1991b).

There are about 45,000 ha of mangroves in the Forest Reserve of Guarapiche, along a fluvial network of some 100 km in the San Juan River. The main river bed through Gulf of Paria mouth, has strong influence, with major development where pure types of *A. germinans* and mixed of *Rhizophora-Avicennia, Avicennia-Rhizophora* and *Rhizophora-Laguncularia* dominate (MARNR, 1986; Pannier, 1986). At the central part, constituted by islands, surrounded by interconnected streams and waterways, the following associations are found: on marginal areas of islands, *Rhizophora-Avicennia,* next to them and on the neighboring plains, *Rhizophora* and *Laguncularia.* At the inner end of islands can be found swamp forest and several species of palms, also some mixed formations of mangrove forests. A third mangrove zone on higher places of terminal river beds, is formed by a pure forest of *Rhizophora* and a mixed forest of *Rhizophora-Laguncularia* (MARNR, 1990b).

From a structural viewpoint, the *Rhizophora-Avicennia* forest is located on fine texture grounds, permanently flooded. The *Avicennia* forest has an insignificant basal area value. Abundant regeneration of *R. mangle* guarantees dominance of this species in the forest (Pannier, 1986; MARNR, 1986; MARNR, 1990b). *Avicennia* forests reach great heights (40-45 m) and also have high values of basal area and abundant natural regeneration. Where *Avicennia-Rhizophora* forests are on relatively protected ground. *Avicennia* specimens with a large basal area are dominant. For the type *Rhizophora-Laguncularia,* proper of the central sector, in acid soils, *Rhizophora* has intermediate height and density, alternating with *Laguncularia.* These forests are easily attacked by hemiparasites, having also signs of overmaturity, which makes them fragile (MARNR, 190b; Pannier, 1986).

Orinoco Delta. Located at the eastern end of Venezuela, has an area of approximately 25,000 to 40,000 km^2 (Figueroa y Seijas, 1986; Pannier, 1979; MARNR, 1991a), the Orinoco Delta includes about 100,000 ha of mangroves (MARNR, 1991a). The Orinoco Delta hydrographic system comprises three elements: 1) the streams and channels; 2) a river system located at the northwest; and 3) the marine component. This delta constitutes a sedimentary fluvial-marine plain, where, according to geomorphologic characteristics, three sectors can be distinguished the upper, middle and lower delta.

In the upper delta, seasonal deciduous and evergreen formations predominate, following the pluvial regime. At the middle delta, an area with poorly drained soils, muddy and swampy formations can be found depending on the flooding regime. On permanently flooded grounds *Mauritia flexuosa* is dominant, on lower positions are developed herbaceous of hydrophytic type formations and a herbaceous swamp with abundant cyperaceans, gramineans and ferns. There are areas of the middle delta with major marine influence with belts of *R. mangle, R. harrisonii* and *R. racemosa* (MARNR, 1991a).

On the lower delta, where the marine influence is attenuated, the main vegetal formations are swampy forests where species with particular adaptations, as tabular roots or "zancudas" (*Pterocarpus officinalis, Symphonia globulifera, Euterpe oleracea, Roystonea* sp.) predominate. There are also swampy palms (*Mauritia flexuosa*) with peat bog predominance on sites of more recent deposition; mangroves are established, mainly *Rhizophora* (MARNR, 1991a).

In the inner portion of the estuary, on margins more affected by sea currents, are established *Rhizophora,* forming relatively wide belts. On higher ground *Avicennia* is established in the form pure stands or alternating with *Rhizophora.* Contacting the muddy formations, *Rhizophora* is associated with *Pterocarpus officinalis, Symphonia globulifera, Vitex* sp. among other species, and also with some individuals of *Laguncularia racemosa;* the last one also can be found in pure form (MARNR, 1991a). In the island domain, in the Margarita Island, Nueva Esparta State, there are about 2,300 mangrove ha (Rodríguez, 1984), which are mainly located in the La Restinga and Las Marites Lagoons. Cervigón & Gómez (1986) have made a synthesis of a considerable number of thesis, carried out on these lagoons, which covers a comprehensive catalog of biological and ecological aspects.

La Restinga Lagoon, Margarita Island, Nueva Esparta State. With an area of 25 km^2, is the biggest littoral lagoon in this island. The extension of mangroves is somewhere between 500 and 1,000 ha. At the north it is separated from the Caribbean Sea by a large sand bar approximately 20 km long and with variable width that reaches 300 m at the western end. The lagoon is open at the south middle part to the open sea through a mouth about 150-200 m wide and 5 m deep. With the exception of the waters close to the mouth, the rest of the lagoon is hypersaline. The Restinga Lagoon is made up by a complex system of lagoons, channels, mangrove keys, hammock mangrove forests, and salt flats. Dominant mangrove species, with heights that in some places can reach 10 m, are *R. mangle* and *A. germinans;* the last one is found bordering many of the channels, in circumstances where *R. mangle* is usually found in other places. On the bar small individuals of *L. racemosa* are established. This is the only place in

Margarita Island having important extensions of *L. racemosa* and *C. erectus*.

Las Marites Lagoon, Margarita Island, Nueva Esparta State, located southwest of Porlamar, has about 940 ha of mangroves - the second area of mangroves in this island- in an area of 20 km^2. The more common species of mangroves are *R. mangle* and *A. germinans; L. racemosa* and *C. erectus* are also present.

Other localities in the same island where small stands of mangroves have been reported are Boca de Palo Lagoon, Punta de Piedras, Los Caimanes, Juan Benito, Laguna de Raya, Punta de Mangle, Caño El Cardón (also known as Caño El Mangle and Caño La Vega), and three littoral lagoons nearby the Tetas de Maria Guevara, a Natural Monument covering 1,670 ha.

Los Roques Archipelago is a National Park, with an extension of 225,193 ha, located 150 km north of Puerto La Guaira. Fringe mangroves are the dominant community along the coast (Instituto Nacional de Parques, 1982). The dominant species are *R. mangle* and *L. racemosa* (Amend, 1992c). There are also mangroves in Gran Roque, Isla Fernando, Madrizque, Isla de Loco, Crasqui, Espenqui, Isla Larga, Rabusqui, Los Francisquis, and on almost all the belt, from Cayo Sal to Esparky (Amend, 1992 a,b,c).

Besides Los Roques Archipelago, other islands where mangroves have been reported, are Las Aves, La Orchila, La Tortuga, La Blanquilla, Los Hermanos and Los Testigos (Huber & Alarcón, 1988).

4. Physical Setting

4.1 Climate

As seen from Table 3, most of the Venezuelan mangrove forests are located in arid and semiarid zones, a fact that severely limits their structural development. The exceptions are the exuberant mangroves of the Orinoco Delta, and the San Juan River. In some arid and semiarid places, however, freshwater input allows mangroves to reach a greater development, as is the case of the stands sited in the Limón River-San Carlos Island, at Zulia State, and some of the ones sited in the Tacarigua Lagoon. From West to East there is an increase in the mean annual rainfall and in the number of months of rain. The climatic extremes are Cocinetas Lagoon (meteorological station Cojoro), where the most rainy month is October, and the dryer is January with a mean of 85.0 mm. On the contrary, in Orinoco Delta (Curiapo Station), May is the less rainy month, with 98.5 mm, which is much more than the maximum in the Cocinetas Lagoon. In the Orinoco Delta, the maximum monthly precipitation is reached in January with a mean of 330.3 mm; which is much more that the 277.0 mm of rain falling annually in the Cocinetas Lagoon.

4.2 Temperature

Mean annual air temperature varies very little among places, with extremes going from 26.1°C in the San Juan River and Morrocoy Bay, to 28.7°C in the Cocinetas Lagoon and 28.0°C in the Los Olivitos Swamp (MARNR 1986). In the Cocinetas lagoon, at the western end of Venezuela, the temperature varies from 27.1°C during January, to 30.6°C in July; a variation of 12.9% of the minimum. In the Orinoco Delta, at the other end of Venezuela, mean monthly temperature is less variable (7.1%), with the minimum in January (25.4°C) and the maximum (27.2°C) in September.

4.3 Winds

All the Venezuelan coast is influenced by the action of the trade winds with E-NE direction; exceptionally, in the Orinoco Delta and in the San Juan River trade winds come in from NE-SW. In some zones where mangroves are present, winds can reach very high velocities, as for example in the Cocinetas Lagoon, where wind speeds vary from 50 to 65 km/h; in this case trade winds are dominant, in E-NE direction (MARNR, 1991c). In the Zapara Island, at the same Zulia State, in front of the Los Olivitos Swamp, velocities can reach 68.4 km/h in January and 57.6 during the September-November period (MARNR, 1990c). In this swamp, the trade winds blow from northeast in November-April; from May to October, local winds can, occasionally substitute trade winds (MARNR, 1990c). These winds can cause increased sedimentation, as in fact is happening in the Cocinetas Lagoon.

4.4 Geomorphology and Soils

In the continental domain of Venezuela, mangrove areas are circumscribed to two geomorphological unities: coastal lagoons and alluvial plains exposed to tides. In the alluvial plains three units can be distinguished: 1) those with sedimentary marine deposition, as is the case of Los Olivitos Swamp, Morrocoy Bay, and Gulf of Paria; 2) Deltaic swamps with marine-fluvial deposition, as the San Juan River and the Gulf of Paria; 3) Swamp deltas with deposition predominantly alluvial, as is the Orinoco Delta.

Table 3. Rainfall patterns at several localities of the Venezuelan coast near mangrove forests.

Locality (Metereological Station)	Average Annual Rainfall (mm)	Number of Dry Months
Cocinetas Lagoon (Cojoro)	277.0	10
Los Olivitos Swamp (Don Pancho)	511.1	3
Morrocoy Bay (Tocuyo de la Costa)	1,065.4	2
Tacarigua Lagoon (Tacarigua de la Laguna)	990.0	4
Gulf of Paria (Irapa)	958.9	4
San Juan River (Caripito)	2,055.6	2
Orinoco Delta-North (Pedernales)	1,629.3	2
Orinoco Delta-South (Curiapo)	2,289.3	0

The characteristic deltaic plains of the eastern sector have induced a major diversity of landscapes, due to the interaction of microtopographic and pedologic factors, mediated by particular characteristics of each region. Relative velocity of change of habitat of mangrove areas is faster in deltaic zones than in coastal lagoons, which means that the first are more sensitive to changes.

Particularly, at the Orinoco Delta three physiographic landscapes have been recognized: the upper delta, which constitutes the apex where the fluvial processes of sedimentation are predominant; the middle delta corresponding to the central parts, where the muddy fluviomarine plains are predominant; and finally the lower delta, the more extensive part adjoining the sea that includes marismas, estuaries and minor fluviomarine forms highly influenced by tidal action.

Mangroves are located in the muddy plains, in swamps and islands, where immature clay soils, saturated by large periods, are dominant, denominated following the U.S. Soil Taxonomy, as hydraquents clay, associated with superficial tropohemists in the plain depressions; in the rest of the landscape, tropofibrists and clay sulfaquents are associated (MARNR, 1991a).

In the Orinoco Delta, five types of mangrove forests have been recognized, the pure type of *Rhizophora* which is established mainly on flooded acid soils, with high organic matter content and low in salts. Where *Rhizophora* specimens have great vigor and height, the silty-clay-loam textures are dominant with a great abundance of fiber characteristic of tropofibrists. Alternatively, where specimens are more abundant, but with minor development, are located sandy-clay-loam textures, belonging to hydraquents. The mixed types (*Avicennia-Rhizophora-Laguncularia* and *Laguncularia-Avicennia*) are established in hypersaline soils. Finally the transitional forest, constituted by mangrove species and ombrophylous forests or muddy palm, are located on soils with low salt content (MARNR, 1991a).

At the San Juan River, mixed forests of *Rhizophora-Avicennia*, are located on fine texture (silty-clay), with high content of organic matter in the deeper layers (sulfihemists). The type *Rhizophora-Avicennia* on relatively protected ground, of type tropohemists, *Rhizophora-Laguncularia* on acid soils, with low dissolved salt content (MARNR, 1990b). In the peat bogs of the Gulf of Paria and San Juan River, mangroves are developing on deep tropofibrists, where there is development of herbaceous vegetation, the tropohemists are predominant (MARNR, 1991b).

In the Gulf of Paria, the types of mixed forest, where *Laguncularia* is present (*Rhizophora-Laguncularia* and *Rhizophora-Avicennia-Laguncularia*), grow on soils with great accumulation of organic matter down to 1 m depth and high textures (tropofibrists). The *Avicennia* forests are developed on clay soils slightly acid, in contrast with the *Rhizophora-Avicennia* that are developed on silty-slim soils. *Avicennia-Rhizophora* is present on clay-loam soils (tropohemists). In the swamps the mangroves are established on mineral soils (sulfaquents) and organic (deep sulfahemists) (MARNR, 1991b).

In the Tacarigua Lagoon, mangroves that grow in the alluvial plains (*Avicennia-Laguncularia*), are established on acid soils of sandy textures (tropofibrists), with great accumulation of organic matter (Sulfaquents), *Rhizophora* the type that dominates in the small islands, is developed on permanent flooded soils (hydraquents) (MARNR, 1990a).

In the marine valley of Morrocoy, where two geomorphological types of littoral accumulation can be distinguished, the entisols dominate. In the continental subsector the type of *Rhizophora*, with little presence of *Avicennia*, is enhanced, they are soils of high salinity, with pH going from slightly acid to alcaline; where they border xerophilous low semideciduous forests, vary from psammaquents to sulfaquents. In the protected islands, can be found saturated soils (hydraquents), if with major organic matter content they are sulfaquents.

Finally, in the Zulia State, at the western end of Venezuela, mangroves are established in soils with loam textures, with high content of organic matter, to clay texture in the Los Olivitos Swamp (typic torripsaments), and of loamy-sand texture to loamy-clay in Cocinetas Lagoon; soils are from typic torripsaments to sulphic-hydraquents (MARNR, 1990c, 1991c).

4.5 Marine currents and tides

The main direction of the surface marine currents of the Venezuelan coast is from East to West. In some localities adjacent to the coast, due to topographic factors, modifications of the general pattern can occur, as in the Gulf of Paria where the closeness of the Orinoco River discharge creates idiosyncratic hydrodynamics. The velocity of the marine currents is, in general very low oscillating between 0.1 and 0.7 knots (5-36 cm/s) (Ginés *et al.*, 1972, 1982). The action of marine currents on the coast can cause intense deposition processes. Although the effect has not been evaluated, the complexity of this process can be accentuated in the eastern coastal zone, where the fluvial influx from the eastern Orinoco and San Juan rivers is enormous.

In general, in the western Caribbean coast of Venezuela daily tides dominate; while in the far east semidaily components are prevalent (Herrera *et al.*, 1981). There are exceptions produced by local phenomena, as is the case of the Gulf of Venezuela (Herrera *et al.*, 1981). On the Atlantic coast, semidaily tides are prevalent, with a high tide and a low tide every 12 hours and 25 minutes in the Orinoco Delta (Herrera *et al.*, 1981). The maximum variations of the height of tides are reached in Punta Gorda, with 1.8 m, and at Pedernales (Orinoco Delta) with 1.3 m (Herrera *et al.*, 1981). The Caribbean coast shows mean variations of about 20 cm. During the period of spring tides, in Punta Gorda are shown 2.16 m of variation (Herrera *et al.*, 1981). In the Maracaibo Strait (Zapara Island), tides are of mixed semidaily type with a variation about four times greater than the ones of Amuay in the Gulf of Venezuela; which could be a consequence of the amplification of diurnal components (Redfield, 1961).

4.6 Salinity

Salinity of the oceanic waters of the Venezuelan coast oscillates slightly around 36‰. In coastal lagoons, where mangroves are present, however, this number can be substantially modified, depending on the presence or absence of fresh water inputs, and on precipitation. In many of those lagoons salinity can be particularly high, at some places higher than 40‰, although after torrential rains this can go down to 16 ‰ (Conde, 1990). In some places of La Restinga Lagoon, in Margarita Island, salinity can reach values of 92‰, although in most of it salinity is between 40 and 50‰, with the exception of the mouth, where it is close to 36‰ (Monente, 1978). In the Tacarigua Lagoon salinity goes from hypersaline extremes at the eastern end to salinities typically limnetic at the mouth of the Guapo River.

4.7 Fluvial discharges

In most of the coastal lagoons fluvial discharge is low. The Tacarigua Lagoon, which counts with the fluvial subsidy of the Guapo River and of several creeks, is one exception. The sedimentary input to this coastal lagoon is 150 m^3/year. In the oriental zone of Venezuela the fluvial apportion varies from moderate to high, with values that range between 14 and 30,000 m^3/s. The mean annual discharge of the Orinoco River is 36,000 m^3/s and 200,000 ton/year of sediment transported (Vázquez, 1989).

5. Biological and Ecological Characteristics

5.1 Fauna

The inventory of animal species that live permanently or are associated with Venezuelan mangroves is far from completed. Comprehensive contributions, however, are by MARNR (1986) and the reference to wetlands, emphasizing the avifauna, by Figueroa & Seijas (1986).

Among the animal species that have been reported as typical of Venezuelan mangroves are the yellow warbler (*Dendroica petechia*), the bicolored conebill (*Conirostrum bicolor*), the clapper rail (*Rallus longirostris*), the great-tailed grackle (*Cassidix mexicanus*), the spotted tody-flycatcher (*Todirostrum maculatum*), the rufous crab-hawk (*Buteogallus aequinoctialis*), the crab-eating raccoon (*Procyon cancrivorus*), the American crocodile (*Crocodilus acutus*) and the arboreal snake *Corallus hortulanus* (Salvatierra, 1983a). Some of those species, however, have also been reported for other habitats, as is the case of *Procyon cancrivorus*, which is common in savanna forests (Gremone *et al.*, Undated), hundreds of km from the closest mangroves. Some invertebrates, though, are more restricted to mangroves and therefore could be regarded as typical, for example the mangrove crabs *Aratus pisonii*, *Ucides cordatus* and *Goniopsis cruentata*, the bivalve *Crassostrea rhizophorae* and a great number of sponges and fishes.

The avifauna is the best group studied. In seven mangrove areas where inventories have been accomplished, 141 bird species have been counted, although only four of them are reported for all these localities: the common egret (*Casmerodius albus*), the black vulture (*Coragyps atratus*), the scarlet ibis (*Eudocimus ruber*), and the brown pelican (*Pelecanus occidentalis*) (MARNR, 1986). *Eudocimus ruber*, an endangered or vulnerable species in many places of the world, is very common in Venezuelan mangroves. Venezuela seems to be the only country where there are still considerable reproductive colonies of this bird (Gremone *et al.*, Undated).

In the Cocinetas Lagoon, 26 species of birds have been reported (MARNR, 1986). The more common species are *Pelecanus occidentalis*, the magnificent frigatebird (*Fregata magnificens*), the great-tailed grackle (*Cassidix mexicanus*), the tricolored or Louisiana heron (*Hidranassa tricolor*), *Casmerodius albus*, *Ardea cocoi*, *Bubulcus ibis*, *Egretta tricolor* and *Egretta alba* (Salvatierra, 1983a; Figueroa & Seijas, 1986). Less abundant are the yellow-crowned night heron (*Nyctanassa violacea*), *Eudocimus ruber*, the roseate spoonbill (*Ajaja ajaja*), the black-bellied whistling duck (*Dendrocygna autumnalis*), *Haemantopus palliatus*, and also several species of Neartic Limicolae (Figueroa & Seijas, 1986). The osprey (*Pandion haliaetus*), a migratory species (Gremone *et al.*, undated), has also been observed (Figueroa & Seijas, 1986). Among the mammals, the most common are the crab-eating raccoon (*Procyon cancrivorus*), several species of bats, and various visitors of the neighboring zones, including the crab-eating fox (*Cerdocyon thous*) and the cottontail rabbit (*Sylvilagus floridanus*) (Salvatierra, 1983a). A population of the American crocodile (*Crocodilus acutus*) was present until a few years ago (MARNR, 1991c). Among the invertebrates must be pointed point out the exceptional presence of the mangrove oyster *Crassostrea virginica* (MARNR, 1991c); whereas in other localities the species found is *C. rhizophorae*.

El Gran Eneal Swamp. Among the resident species of birds the most common are the anhinga (*Anhinga anhinga*), *Egretta caerulea*, *E. tricolor*, the american wood ibis (*Mycteria americana*), the glossy ibis (*Plegadis falcinellus*), the limpkin (*Aramus guarauna*), the wattled jacana (*Jacana jacana*), the collared plover (*Charadrius collaris*) and the common stilt (*Himantopus himantopus*) (Figueroa & Seijas, 1986). Non-reproductive visitors are: *Egretta rufescens*, the great blue heron (*Ardea herodias*), *Eudocimus ruber*, the flamingo (*Phoenicopterus ruber*), *Anas discors*, numerous species of Limicolae, the laughing gull (*Larus atricilla*), the gull billed tern (*Gelochelidon nilotica*) and the Caspian tern (*Hydroprogne caspia*) (Figueroa & Seijas, 1986). This zone is also important because of the hibernating *Calidris mauri* and *Micropalama himantopus*; the osprey (*Pandion haliaetus*) has also been pointed out as a winter visitor (Figueroa & Seijas, 1986). The manatee (*Trichechus manatus*) and the river otter (*Lutra* sp.) have also been observed (Figueroa & Seijas, 1986).

In Los Olivitos Swamp 53 species of birds have been reported (MARNR, 1986). This is one of the four Caribbean sites where *Phoenicopterus ruber* nests (Sociedad Conservacionista Audubon de Venezuela, undated). Substantial abundances of this species have been registered: 4,700 in 1983; more than 8,000 in 1986, 1987 and 1988; 15,000 in 1990; and between 6,000 and 7,000 in 1992 (Figueroa & Seijas, 1986; Rodner, 1992). *Eudocimus ruber* and the white ibis (*Eudocimus albus*) are also abundant in Los Olivitos. *Cassidix mexicanus*, a bird whose distribution area in Venezuela is very small, being restricted to the northwestern zone, also is present.

Among the resident species are *Pelecanus occidentalis*, *Phalacrocorax olivaceus*, *Nycticorax nycticorax*, *Butorides virescens*, *Egretta caerulea*, *E. tricolor*, *E. alba*, *E. thula*, *Ardea cocoi*, *Mycteria americana*, *Ajaja ajaja*, *Aramides axillaris* and *Rynchops niger* (Figueroa & Seijas, 1986). The Neartic migratory species include *Egretta rufescens*, *Butorides virscens virescens*, *Anas discors*, *Pluvialis squatarola*, *Numenius phaeopus*, *Tringa melanoleuca*, *T. flavipes*, *Actitis macularia*, *Catoptrophorus semipalmatus*, *Arenaria interpres*, *Limnodromus griseus*, *Calidris canutus*, *C. alba*, *C. mauri*, *C. minutilla*, *Larus atricilla*, and several species of *Gelochelidon, Hydroprogne* and *Sterna*, among them *Hydroprogne caspia* and *Sterna maxima* (Figueroa & Seijas, 1986). *Trichechus manatus* and the American crocodile (*Crocodilus acutus*) have been reported in this locality (Figueroa & Seijas, 1986).

Boca de Caño Lagoon. The mangrove forests that surround this hypersaline coastal lagoon shelter big numbers of *Zenaida auriculata*; 60,000 individuals were estimated in 1983 (Figueroa & Seijas, 1986). *Pandion haliaetus* is a boreal winter visitor (Figueroa & Seijas, 1986). *Eudocimus ruber* and *Phoenicopterus ruber* are also common. A detailed inventory of the lagoon should be carried out; at the southeast extreme great quantities of birds can be sighted regularly over very developed mangroves.

In the Gulf of Cuare, a wildlife refuge, more than 85 species of aquatic birds have been registered (Figueroa & Seijas, 1986). The more common are: *Pelecanus occidentalis, Podilymbus podiceps, Phalacrocorax olivaceus, Bubulcus ibis, Egretta caerulea, E. tricolor, E. alba, E. thula, Mycteria americana, Eudocimus ruber, Plegadis falcinellus, Anas americana, A. discors, A. clypeata, Pluvialis squatarola, Charadrius semipalmatus, Tringa melanoleuca, T. flavipes, Calindris pusilla, C. mauri, C. minutilla, Micropalama himantopus, Himantopus himantopus, Chlidonias nigra, Gelochelidon nilotica* and *Rynchops niger* (Figueroa & Seijas, 1986). Thousands of flamingos visit the zone regularly. Other species sighted in the area are *Egretta rufescens, Cochlearius cochlearius, Ajaia ajaja, Aramides axillaris, Aramus guarauna, Rallus wetmorei, Porzana flaviventer, Fulica caribaea* and *Burhinus bistratus* (Figueroa & Seijas, 1986). Specimens of *Crocodilus acutus*, have been frequently observed (Figueroa & Seijas, 1986).

In the Yaracuy River Delta, *Tigrisoma lineatum, Nyctanassa violacea, Cochlearius cochlearius, Ajaja ajaja, Phimosus infuscatus, Anhima cornuta, Dendrocygna autumnalis, Cairina moschata* and *Aramus guarauna* have been reported (Figueroa & Seijas, 1986). There are dense populations of the macaws *Ara chloroptera* and *A. severa* and the yellow-headed parrot *Amazona ochrocephala* (Figueroa & Seijas, 1986). High densities of *Crocodilus acutus* has been estimated in this site (Figueroa & Seijas, 1986). Among the big mammals, the jaguar, *Panthera onca*, and the South American tapir, *Tapirus terrestris*, (Figueroa & Seijas, 1986), and the ocelot (*Felis pardalis*) (Bisbal, 1989) have been sighted.

In Morrocoy Bay, 39 bird species have been counted (MARNR, 1986). Many of them are concentrated in the Pajaros Island, a small mangrove key sited in the central part of the park. Marine birds are abundant, the more common being the snowy egret (*Egretta thula*) and *Fregata magnificens*, this one with a very important reproductive population (Figueroa & Seijas, 1986), the cattle egret (*Bubulcus ibis*), the tricolored heron (*Hydranassa tricolor*), and the great or common egret *Casmerodius albus*. Other non-aquatic common species are the orange-winged parrot (*Amazona amazonica*), which forms great groups, and the pale-vented pigeon (*Columba cayennensis*). Among the nesting species are: *Bubulcus ibis, Egretta tricolor, Egretta thula*, and *Egretta alba*. *Eudocimus ruber* is present around the year (Figueroa & Seijas, 1986). Non-reproductive visitors are *Euxenura maguari, Jabiru mycteria, Ajaja ajaja* and *Phoenicopterus ruber* (Figueroa & Seijas, 1986). Specimens of *Crocodilus acutus* and of several marine turtles, including the green turtle (*Chelonia mydas*), have been also observed. The roots of the red mangrove support a highly diverse community of invertebrates, including the mangrove oyster, *Crassostrea rhizophorae*, a commercial species almost extinct nowadays, due to overexploitation.

Turiamo Lagoon. Access to this lagoon is restricted because it is near a navy basis. Among birds sighted are: *Pelecanus occidentalis, Nyctanassa violacea, Ajaja ajaja, Egretta caerulea, E. tricolor, Ardea cocoi, Mycteria americana, Eudocimus ruber, Anas bahamensis, Himantopus himantopus* (nesting), and several Neartic Limicolae species (Figueroa & Seijas, 1986). Also *Netta erythrophtalma erythrophtalma* is registered (Figueroa & Seijas, 1986). There is a small population of *Crocodilus acutus* (Figueroa & Seijas, 1986).

The variety and densities of birds in the Tacarigua Lagoon are particularly large; about 135 species have been reported (Lentino, 1989). The most characteristic species are the cormorants (*Phalacrocorax olivaceus*), *Eudocimus ruber, Eudocimus albus, Ajaja ajaja, Ardea cocoi*, the sooty tern (*Sterna fuscata*), the brown noddy (*Anous stolidus*), *Larus atricilla, Anhinga anhinga, Nyctanassa violacea, Cochlearius cochlearius, Egretta caerulea, E. tricolor, Mycteria americana, Rallus longirostris, Aramides axillaris, Phaetusa simplex, Himantopus himantopus, Rynchops niger* and several Neartic Limicolae (Salvatierra, 1983a; Figueroa & Seijas, 1986). *Pelecanus occidentalis* is also abundant, with one of the few reproductive colonies that remains in Venezuela (Lentino, 1989). In 1983 existed a population of flamingos (Salvatierra, 1983a), that was estimated in more than 2,000 individuals (Figueroa & Seijas, 1986); nowadays, only 200 specimens are left (Lentino, 1989). There is also a small population of *Crocodilus acutus* (Figueroa & Seijas, 1986); a species that sustained an intense exploitation by French and English companies from 1940 to 1960 (Boede, 1982).

In the more developed and pristine mangroves of Venezuela, those sited at the northeastern end, Gulf of Paria, San Juan River, and the Orinoco Delta, several avifauna elements are considered as typical of mangroves: *Buteogallus aequinoctialis, Todirostrum maculatum,* and *Coccizus melacoriphus* (Salvatierra, 1983a), a species that has been reported in Venezuela only from the Orinoco Delta (MARNR, 1991a). Among the more common species are *Todirostrum maculatum, Ara araruna, Buteogallus aequinoctialis, Eudocimus ruber* and *Eudocimus albus* (MARNR, 1991a). There are elements typically terrestrial, including the tapir (*Tapirus terrestris*), *Panthera onca, Felis pardalis,* and the giant anteater (*Myrmecophaga tridactyla*) (Salvatierra, 1983a). Also, the howler monkey (*Alouatta seniculus*) and the capuchin or ringtail monkey (*Cebus* sp.) have been observed (Salvatierra, 1983a). In the waterways, some aquatic mammals can be seen occasionally, including *Trichechus manatus,* the river dolphin, *Sotalia guianensis,* and the Amazon dolphin, *Ina geoffrensis.* In the San Juan River, the spectacled caiman (*Caiman crocodilus*) is very common and so is the tegus (*Tupinambis nigropunctatus*). The more abundant reptiles are the turtles *Podocnemis unifilis,* and marine turtles as *Chelonia mydas.* Among terrestrial mammals diverse species of bats, the paca (*Agouti paca*), the kinkajou (*Potos flavus*), and agouti (*Dasyprocta guamara*) are common. Other reptiles occasionally sighted is the turtle (*Phrynus gibbus*).

Many mangroves of the Venezuelan coast are associated with extensive coral reefs. In Morrocoy Bay, for example, there are important formations of this community, the more common species are the corals: *Acropora palmata, A. cervicornis, Diploria labyrinthiformis, Eusmilia fastigiata, Montrastea annularis, Mussa angulosa;* the pseudocoral *Millepora alcicornis;* and the alcionaries: *Gorgonia flabellum, Muricia muricata, Pseudopterogorgia rigida,* and species of the genera *Eunicea* and *Plexaura.*

Some of the fishes associated with mangroves are given below in the Fisheries section.

5.2 Vegetation units associated with mangroves.

Mangroves located in arid and semiarid zones of the Caribbean coast are associated mainly xerophilous littoral scrub and halophilous or psammophilous with littoral meadows (Huber & Alarcón, 1988).

Xerophilous littoral scrub communities are characterized by low to middle height (0.5-5m), of variable density, sometimes with columnar cactus. The most conspicuous species are: *Acacia tortuosa, Acrostichum aureum, Bourreria cumanensis, Cercidium praecox, Coccoloba uvifera, Conocarpus erectus,Hibiscus tiliaceus, Opuntia caribea, Prosopis juliflora, Ritterocereus griseus,* and *Terminalia catappa* (Huber & Alarcón, 1988; Pannier, 1989).

On the contrary, littoral meadows are low communities, from open to dense and floristically very poor. The halophilous are found in brackish depressions of coastal areas and the psammophilous on sandy dunes, normally not flooded by sea. In the first type, among other species, can be found: *Atriplex pentandra, Batis maritima, Heterostachya ritteriana, Salicornia fruticosa,* and *Sesuvium portulacastrum.* In the second are distinguished: *Cakile lanceolata, Egletes postrata, Ipomea pes-caprae, Scaevola plumieri, Spartina patens, Sporobolus pyramidatum* and *S. virginicum* (Huber & Alarcón, 1988).

Mangrove areas located at the southern portion of the Maracaibo Lake are found inside ombrophilous evergreen forests (Huber & Alarcón, 1988), named by Pannier & Pannier (1985) tropical rain forest. This formation is characterized by great height (30-40 m), with several strata and emergents up to 60 m. They are partially flooded, with few endemic species, and related to the Amazonic flora (Huber & Alarcón, 1988). *Anacardium excelsum, Cariniana pyriformis, Ceiba pentandra, Faramea capillipes, Gustavia hexapetala, Sterculia apetala, Trichilia maynasiana,* and *T. pleeana* are characteristic species; among the endemic species are *Rhodospatha perezii* and *Spathiphyllum perezii.*

In the Morrocoy National Park more than 300 species of phanerogams and ferns have been collected (Instituto Nacional de Parques, 1982). This high number is probably due to the fact that this park has a substantial terrestrial component, where a tropophilous semi-deciduous seasonal forest is developed, which may be very dense, and is characterized by one or two strata, and height from 5 to 8 m, with some emergent individuals up to 10-12 m. The understory is relatively dense, the armed species are absent or are very scarce. The most characteristic are *Apoplanesia cryptantha*, an endemic species, *Capparis coccolobifolia, C. tenuisilique, Guapira sp., Machaerium robiniaefolium, Morisonia americana, Talisia olivaeformis* and several species of *Eugenia* and *Zanthoxylum* (Huber & Alarcón, 1988). In the marine environment, besides mangroves, occur important extensions of the submarine phanerogam *Thalassia testudinum*, considered as food and refuge for turtles.

In the Tacarigua Lagoon, besides arid and semi-arid littoral formations, where the xerophilous scrubs and the psammophilous or halophilous meadows are predominant, mangroves are adjacent to tropophilous basimontane deciduous forests (Huber & Alarcón, 1988), also named dry tropical forest (MARNR,1990a). These forests are characterized by heights going from low to middle (10-15 m), with emergents to 20 m. There is one or two strata and a very dense understory. Among the more common species are *Bauhinia megalandra, Bourreria cumanensis, Calliandra caracasana, Cassia marginata, Cecropia sp., Erythrina poeppigiana, Hura crepitans, Inga punctata, Ritterocereus griseus, Tabebuia billbergii* and *T. rosea*. There is also muddy vegetation in areas very close to mangroves, where slope is less that 1%, soils are clay and poorly drained (MARNR, 1990a). In this areas are distinguished *Roystonea regia* and some hydrophilous herbs of great development, mainly grass and forbs, and musaceae (*Heliconia latispatha*) (MARNR, 1990a).

In the mangrove forests located on the Atlantic coast, diversity of the physiographic forms has strongly conditioned the vegetation. Tropophilous basimontane deciduous forests are found in the Gulf of Paria (Huber & Alarcón, 1988) or seasonal forest (MARNR, 1986), which are characterized by heights going from low to middle, not very dense, with a relatively well developed understory. The more common species are *Capparis coccolobifolia, Diospyros inconstans, Jacquinia revoluta* and *Maytenus officinale* (Huber & Alarcón, 1988).

Herbaceous muddy vegetation, or muddy meadows, has been recognized in the Orinoco Delta, in the Gulf of Paria and in the San Juan River. These communities characteristically grow in permanently flooded areas. Many times is floating vegetation. It is formed by *Costus arabicus, Cyperus giganteus, Eichornia crassipes, Heliconia psittacorum, Mauritia flexuosa, Montrichardia arborescens, Paspalum fasciculatum, Renealmia alpinia, Thalia* sp. and *Typha domingensis* (Huber & Alarcón, 1988).

The muddy forests (MARNR, 1986), or ombrophilous forests and muddy palms, according to Huber & Alarcón (1988), common to the three areas indicated above, are constituted by forests from low to middle height (from 15 to 20m), with only one arboreous stratum, dense, on ground almost permanently flooded, where *Pterocarpus officinalis, Symphonia globulifera* and *Tabebuia aquatilis*, an endemic species of the coastal zone, ranging between the Amazon River to the Orinoco River dominate.

In the middle of the Orinoco Delta and the San Juan River there are extense muddy forests (MARNR, 1986), named ombrophilous forests and muddy palms by Huber & Alarcón (1988), they are formed by forests of middle height (to 25 m), evergreens, on periodically flooded ground. Finally in the same localities can be found the morichales. The more common species are *Carappa guianensis, Mora excelsa, Pachira aquatica, Pterocarpus officinalis, Symphonia globulifera* and *Virola surianensis*. In the muddy morichales or palms the most remarkable species are *Bactris* sp., *Euterpe oleracea, Manilkara saccifera, Mauritia flexuosa*, and *Phenakospermum guyanense*.

5.3 Sessile community on the red mangrove roots

In some localities where waters are very transparent, as in the Morrocoy National Park, Bahia of Buche, Mochima National Park and the La Restinga Lagoon, a very diverse community of algae and invertebrates can be found sessile on the submerged roots of the red mangrove, *Rhizophora mangle*; sponges, bivalves, and algae predominate. One of the more common species of this community is the mangrove oyster *Crassostrea rhizophorae*, which is a substantial staple of the mangrove forest villagers.

This is a highly diverse and colorful community, where many species and taxa are represented; on some roots this community can reach a huge biomass. Several authors have studied this community, in various localities of the Venezuelan coast (Sutherland, 1980; Díaz *et al.*, 1985; Orihuela *et al.*, 1991). Among the sponges of the sessile community are *Adocia sp., Aplysina fistularis, Bienna microstyla, Cliona rhaphida, Desmacellia jania, D. meliorata, Halichondria sigmadocia, Halichondria magniconulosa, Halichondria melanodocia, Haliclona permollis, H. crassiloba, H. viridis, H. variabilis, H. hogarthii, Ircinia fasciculata, Fibularia ramosa, Geodia papyracea, Geodia gibberosa, Lissodendoryx isodictyalis, Lissodendoryx sp., Liosina monticulosa, Microciona sp., Microciona microchela, Mycale microsigmatosa, Mycale sp., Pellina nodosa, Sigmadocia caerulea, Spongia zimocca, Tedania ignis, Terpios* *zeteki, T. fugax, Thalyseurypon conulosa* and *Toxadocia sp.* The algae include *Acanthophora spicifera, Bryopsis plumosa, Caulerpa verticillata, C. racemosa, Cladophora fascicularis, Dyctyota bartayresii, Spermothamnion investiens* and *Ulva lactuca.* The tunicates are: *Botrylloides nigrum, Botryllus niger, Didemnum* sp., *Diplosoma listerianus, Ecteinascidia conklini, E. turbinata, Microcosmus exasperatus, Phallusia nigra, Polyclinum constellatum, Pyura momus, Styela canopus* and *Symplegma viridae.* Other organisms present are the octocoral *Telesto riisei;* the bivalves *Brachydontes* sp., *Crassostrea rhizophorae* and *Isognomon alatus;* the cirriped *Balanus eburneus;* the annelid *Spirorbis* sp; the bryozoan *Schizoporella* sp., and *Bugula* sp.; the polychaete *Sabellastarte magnifica;* and the actinid *Aiptasia pallida.*

The mangrove oyster *Crassostrea virginica,* a larger species than *C. rhizophorae* and apparently more tolerant of salinity extremes, occurs in some localities (for example, Cocinetas Lagoon) (MARNR, 1991c). Where great amounts of sediments are in suspension, the sessile community of the mangrove roots is very poor, and only represented by a few specimens of *C. rhizophorae* and other bivalves, algae with scant cover, and isolated and poorly developed sponges.

5.4 Massive mortality of the sessile community of mangrove roots

Venezuela is out of the track of hurricanes, and thus is not directly subject to the dramatic consequences observed in other Caribbean localities. However, hurricanes exceptionally can produce stormy winds and torrential rains, as it happened with Gilbert in 1988 and Hugo in 1989. The effect that such meteorological circumstances can have on the communities and marine ecosystems of the Venezuelan coast has not been evaluated. The only exceptions - as far as we know - are the publications of Conde (1990) and Orihuela *et al.* (1991).

Orihuela *et al.* (1991) found that the sessile community of the mangrove roots, considered as very stable (Sutherland, 1980), can be eliminated almost totally by resuspension of sediments and salinity changes produced by the passage of hurricanes or unusual torrential rains. Recuperation of biodiversity in such community was slow; after twenty months it had not reached the original structure and only 45% of the species that originally grew on the red mangrove roots had recolonized the habitat (Orihuela *et al.*, 1991). Frequency and seasonality of such events have not been determined.

Conde (1990) has found that the high tides produced by hurricanes is a recolonization vehicle for isolated, declining populations of the mangrove crab *Aratus pisonii* on the verge of local extinction.

5.5 Consequences of mangrove productivity on the fauna of mangroves

One of the few species that really could be considered as typical of mangroves is the arboreal crab *Aratus pisonii.* For the mangroves of the Venezuelan coast, Conde & Díaz (1989b, 1992a) have found that there is a close relation among some of the biometric and life history characteristics of this crab and a mangrove productivity gradient. To determine if this pattern is present in other species associated with mangroves would be of great practical interest. Consequences of that pattern on the trophic chains culminating in species exploited commercially, are useful in mangrove management.

6. Products, Uses and Exploitation of Mangroves

The benefits of American mangroves were recognized by Spanish colonizerss almost immediately after their arrival to the New World. At the beginning of the XVI Century, the historian Gonzalo Fernández Oviedo y Valdés described the range of uses of mangroves by the indians, including for the construction of shelters, for food, as firewood, etc. The indians of Puerto Rico (probably the arawaks) occasionally ingested the red mangrove seedlings; this is a custom observed nowadays among the fishermen, who say that it helps them to quench their thirst during their prolonged fishing journeys (Carrera, 1975). This could be a current practice among the Caribbean indians.

In the Roques Archipelago, 100 km north of the Venezuelan coast, mangroves were exploited extensively by the indians, up to the point of disappearing almost completely on some of the islands (Antczak & Antczak, 1987). Almost five centuries later, mangrove products still occupy a very important rank in the indians economy; in the Delta Amacuro State, they use mangrove wood for poles on which they build their houses (Flores, 1977). They also exploit heavily some species found in the mangroves, such as the crab *Ucides cordatus* (Flores, ca. 1979).

During the XIX Century's second half, the Curazao people exploited the mangroves - especially *Rhizophora mangle* - of the Los Roques Archipelago, using it as firewood for the furnaces of steamships; as a residual product, tannins were extracted from the bark (Amend, 1992a).

Pittier (1926) writes that the wood of *Laguncularia racemosa* is good for carpentry and also can be used as firewood; *R. mangle* wood is locally consumed in the construction of houses and boats, also as firewood and charcoal; *Avicennia germinans* wood is also used in construction, in carpentry and as firewood; leaves are used in tannery (Pittier, 1926). The bark, fruits, and the leaves of *R. mangle* are used in tannery, on which a substantial export is based (Pittier, 1926).

Traditional medicinal uses of mangroves are worthwhile mentioning, given their potential role in sustainable development schemes. *L. racemosa* has astringent and antidisenteric properties (Pittier, 1926). *R. mangle* is used domestically for the treatment of hemorrhages and angina and has been considered specific against leprosy (Pittier, 1926). Infusion of *R. mangle* fruits in water, after fermentation, is an appreciated beverage in some places (Pittier, 1926). After being cooked, the bark of *A. germinans* is used as gargle to soothe throat pain and for ulcers in the mouth (Delascio, 1985). Flores (1977) reports, with no additional details, that dyeing substances and medicines against leprosy have been extracted from the bark of the red mangrove, *R. mangle*. Pannier & Pannier (1989) point out that the bark of mangroves has been used medically. Spite of these utilizations, species of mangroves do not appear in the catalog of popular medicines by Rodríguez (undated), which includes 226 plant species.

In some regions of Venezuela, fishermen used to impregnate nets with the bark of mangrove to increase their durability (Pannier & Pannier, 1989). Ninin (1957) reports that in Zulia State *R. mangle* was used to reforestate some zones to protect coconut and other plantations from wind and rain. Before the Second World War, in the lower course of the Escalante River (Maracaibo Lake), mangroves were commercially exploited for extraction of tannins (Pannier & Pannier, 1989). More recently, mangroves have been used in commercial scale in making poles for electric and telephonic lines, piles, shelves, parquetry, charcoal, tannins, etc. Apiculture industries, as the ones existing in several localities of the Caribbean - Florida, Dominican Republic, Cuba - and in Suriname, where mangroves can sustain an annual production of 1,000 tons of honey, as is the case of Cuba (Bossy & Cintron, 1990), have not been reported from Venezuela.

Currently, mangrove wood, mixed with the wood of tamiche (*Manilkara saccifera*), is used by indigenous groups, especially waraos, for homes's construction. Farmers employ it, mixed with the "purgüo" *Mimusops balata*, for construction of fences. Other uses of mangroves are given in Table 4.

In the 70's, a silvicultural experience was carried out in the Forestal Reserve of Guarapiche. Concessions were granted to extract wood under a management plan (Luna Lugo, 1976), which considered an area of 21,268 ha of mangrove forest; 5,613 ha would be submitted to rational use. This was considered important for the depressed economies of these populations. Each year, management and exploitation of mangrove areas would generate: 11,636 m^3 of wood; 51,633 poles; 5,633 railway sleepers, 71,086 sticks; and 3,176 m^3 of bark (MARNR, 1990b). However, 15 years after the beginning of activities, the plans have not been developed and annual quota of profits did not go beyond 30% of the initially planned level (MARNR, 1986). Indians of the region were hired, but the wages were very low.

Pannier & Pannier (1989) consider that the results of the exploitation are disappointing, mainly due to the many technical and administrative problems encountered. Of a total of 125 plots given in concession, only 25 were exploited (Pannier & Pannier, 1989). Numerous harvested trees are abandoned, apparently due to the inexistence of sawmills and absence of workers (Ernesto Medina, personal communication).

7. Fisheries

The two main fisheries carried out in the Gulf of Venezuela and in the neighboring Sucre State, depend on the activity of trawlers. Compared to these highly technical and capitalized fisheries, the catches in mangrove lagoons, where fishermen use casting nets and small boats with outboard engines, are small. However, fishing in these lagoons can not be regarded as insignificant, due to its importance for small-scale fishermen, whose income can depend, almost totally, on this activity. Besides, many of the open sea commercial species have phases of their life cycles associated to mangrove lagoons. Quantification of this type of relationship has not been done yet in Venezuela.

Table 4. Mangrove products and industries in Venezuela.

Products	Users and Industries
Railroad girders	National Institute of Railways
Poles for telephonic and electric lines	Electric and telephonic companies (CADAFE, EDELCA, CANTV)
Shelves	
Wood conglomerates	Furniture companies
Other timber products	National Institute of Ports
	Ministry of Transport and Communications Naval industry (ASTINAVE)
Tannins	Tanneries
	Petrochemical industry
Vitamins	Pharmacological companies
Cellulose	Paper and textile industries
Charcoal, Activated coal	Metallurgy, Sugar refinery
	Water treatment, Tires, Bottling industry

Most of the small-scale fisheries are based on a few species. For example, in the mangrove lagoons located in eastern Venezuela, the more commonly captured species are: the catfish *Arius herzbergii*; the snooks, *Centropomus undecimalis, C. ensiferus, C. parallelus*; the mullets *Mugil brasiliensis, M. curema*; the mojarras *Eugerres plumieri, Gerres cinereus* and *Diapterus rhombeus* (Ginés *et al.*, 1972). Catches of *Mugil, Centropomus* and *Eugerres* in these lagoons was almost 2,000 tons in 1970 (Ginés *et al.*, 1972). These species are not represented in all lagoons in quantities large enough for commercial exploitation; in the lagoons of Margarita Island, the commercial species are *M. curema, M. liza, C. undecimalis, D. plumieri,* and *A. herzbergii* (Cervigón & Gómez, 1986).

In the Tacarigua Lagoon, small-scale fisheries are very important and go beyond the subsistence level, reaching about 500,000 kg yearly (Pagavino, 1983). These fisheries are seasonal, the major catches are obtained between June and October. The more abundant species is *M. brasiliensis*, which represents around 30% of total capture in the area. Following in importance are *M. curema*, with 17%; *C. ensiferus* (9%), and finally shrimps (*Penaeus* sp.), which represent 5.45% of total captures (Ginés *et al.*, 1972), although lower percentual values have been registered by Pagavino (1983). Besides, these relatively small-scale fisheries, there are shrimp companies, which use regional manpower.

Nearby, in the Unare and Píritu lagoons: the species exploited more intensively are: *M. liza, M. curema, Penaeus schmitti, C. undecimalis, C. pectinatus, C. ensiferus, E. plumieri, D. rhombeus*, the gray snapper (*Lutjanus griseus*), catfishes (*A. herzbergii, Cathorops spixii*). The Atlantic tarpon (*Tarpon atlanticus*) is also exploitated but to a less degree (Pagavino, 1983). This author (Pagavino, 1983) also identified juveniles of the crevalle jack (*Caranx hippos*), the ladyfish (*Elops saurus*) and the hogchoker (*Trinectes maculatus brownii*). Also with commercial value, but more scarce, are *Bairdiella ronchus, Ophioscion* sp., and *Umbrina* sp. (Pagavino, 1983). The major contributions to capture were: mullets (68%), snooks (12%), and mojarras (11%); shrimps represented less than 2% (Pagavino, 1983).

Production in 1982 (probably subestimated) in the Unare Lagoon was 48,609 kg (Pagavino, 1983). Contributions of species, in decreasing order were: shrimps (53%), mullets (29.6%), mojarras (5.8%), and snooks (5.7%); shrimps did not appear in June and July captures, but were dominant between January and May (Pagavino, 1983).

In the Píritu Lagoon 50,236 kg of fish were captured in the same period (Pagavino, 1983); being the major contributions the mullets (88%), and shrimps (7%). Although, the total unloading on these zones could seem insignificant if compared to the national total - close to 150 millions of kg harvested annualy at the end of the 70's (Ginés *et al.*, 1982) - these fisheries have an enormous importance for these places, where the economies are constantly depressed; for example, in the Tacarigua Lagoon 117 fishing boats were registered in the Inspectoría de Pesca (Fisheries

Inspection Bureau) for September, 1982 (Pagavino, 1983).

Due to its hydrodynamic characteristics, the fisheries in the San Juan River are not commercially important. However, the fisheries around the mouth of the river, reflect the importance of the mangrove zones of this system. *M. brasiliensis* and *M. curema*, are the species more frequently caught, representing 57.6% of total captures that surpass 272,360 kg (MARNR, 1986).

For the inhabitants of the Orinoco Delta the fisheries activity is of seminal importance. The main ports of the zone are: Tucupita, Curiapo, Isla Misteriosa and Pedernales, the latter monopolized more than half of fisheries production between 1980 and 1982, reaching almost 2,000 ton of fishes annually. The catfishes *A. herzbergii* and *C. spixii* represented 45% of total catches, followed by *M. brasiliensis*, *M. curema* and *C. ensiferus*, which comprised 36%. These species are generally found in littoral lagoons and estuaries. In 1978, fisheries of the Orinoco River were equivalent, in volume, to the north eastern open sea fisheries (Novoa & Ramos, 1978), which, together with the ones of the Gulf of Venezuela, are the more important of the country. More than half of the harvest of the Orinoco River is accomplished in the Delta zone, where large extensions of mangroves occur.

Between 1971 and 1976, the percentage of catches in Tucupita and Barrancas, both ranged in the Orinoco Delta, between 58.5 and 85.1% of the total amount for the Orinoco River. The absolute landing values ranged between 1,204 and 3,584 tons (Novoa & Ramos, 1978). It has not been established how much of this volume depends on mangroves; although in the lower delta, according to Novoa & Ramos (1978), an important fraction of total catches is constituted by fishes of marine origin. Probably volumes of mangrove fishes associated would be high as has been suggested for other localities (Bossi & Cintrón, 1990).

In the representative port of the Maracaibo System (Puertos de Altagracia), in 1982 were unloaded 36,815,226 kg (MARNR, 1990c). The major productivity of the area is between January and July, decreasing towards the end of year. The most abundant species are *Cynoscion maracaiboensis* and *C. virescens*, locally known as curvinas, which represented the 96.24% of volume of species captured in the area (MARNR, 1990c). Other important species are the shrimp *P. schmitti* and the blue crab *Callinectes sapidus*, which completes its biological cycle in the estuarine zone of the Maracaibo Lake. During the last years the fisheries have decreased as the destruction of mangrove areas progresses, a fact that has originated massive migrations of fishermen towards more productive areas (MARNR, 1990c).

8. Socioeconomy

Traditionally, the main activities of inhabitants of zones near mangrove areas have been small-scale fisheries and farming. The vigorous development of tourism during the last years, however, has introduced changes in these occupational patterns. Nowadays, many fishermen - characterized by low percapita income and also low scholarity indexes - are dedicated to activities related to tourism.

In Agua Salobre, a town of fishermen and farmers in Morrocoy Bay, Falcón State, the traditional occupation patterns were centered in fisheries and farming until 1965, when tourism started in the zone; it opened a labour market for a population related to tourism (Scorza, 1978). Later, in 1975, after the creation of the Morrocoy National Park and the banning of poles, tourism decreased, and the population returned to traditional activities and the migratory flow of young people towards the cities was increased (Scorza, 1978). Today, the vigorous touristic activity probably has induced a shift in the labour patterns again.

Artisan fishermen occasionally get very high incomes, due to the high prices that some fishes have reached in the market; however, the economic level of fishermen is very low, because they do not own their boats, outboard motors, and fishing gear. Their profits end up with the pawnbrokers and fisheries companies (Suárez & Bermúdez, 1988), who control the last links of the commercialization chains.

Cocinetas Lagoon. In the high Goajira, where this lagoon is located, there were 1,307 persons, in 1977, which represented a low density of 0.56 inh/km^2, with a relation inh/house of 6.8. This marked dispersion is probably due to the almost total absence of fresh water in this region. The economy of villagers, fundamentally seminomad, is based on pastoral activity, reaching a 60% of land usage (MARNR, 1991C).

Limón River-San Carlos Island. People of this area extract wood in an artisanal manner. During the last years feasibility studies to define the adequacy of the zone for forestry exploitation have been made. Concurrently with the forestal reserve of Guarapiche, the Limón River-San Carlos Island area is considered as one of zones whose mangroves have a tangible silvicultural potential (Rodríguez, 1984).

Los Olivitos Swamp. The human population density in the area is about 20 inh/km^2. The land is mainly dedicated to farming. The economy is diversified. The fisheries resource is exposed to contamination and impacts generated by other activities.

Paraguaná Peninsula. Populations adjacent to mangrove zones are traditionally artisan fishermen with craft level gear. At present, the possibility of including all the mangrove area of Golfete de Coro inside of the Medanos de Coro National Park is being studied; although allowing fishermen the use, with freedom, of the traditional fisheries arts (Alarcón *et al.*, 1993).

Morrocoy Bay. The area includes a great number of explosively growing urban centers, whose inhabitats were traditionally dedicated to fisheries and farming. With the arrival of big touristic currents, in the seventies, and the construction of numerous houses on stilts, the autochtonous population abandoned the fisheries in order to service tourists - among them taking care of houses during the week and guiding tourists to the keys and beaches. With the creation of the park, in 1974, and the elimination of private houses, the economic income of the population was changed. Today, the adjacent zones to the Morrocoy National Park have suffered a strong urbanistic-touristic development which has generated a great number of employments.

Tacarigua Lagoon. Inhabitants, organized in cooperatives, are mostly dedicated to fisheries. The population density of the surrounding area of the park is around 20 inh/km^2 (MARNR, 1990a). Outside the park area, 35% of the land is for farming; a 45% is natural or idle secondary vegetation, and a 20% is dedicated to other uses, as sand extraction (MARNR, 1990a).

Gulf of Paria. Population density for 1981 was estimated to be 43.31 in h/km^2 with a mean of 9.05 inh/house, suggesting a certain degree of overcrowding, and relatively high if compared with the mean value of 5.28 inh/house for Venezuela (MARNR, 1991b). In this zone is found part of the Forestry Reserve of Guarapiche, where according to the management plan of 1971 of the company TAMAVENCA (Luna-Lugo, 1976), forest use would be carried out in the sectors of Turuépano and Antica Islands and Caño Guariquén. However, this never was done (MARNR, 1991b). Until present, intensive use has been for construction of houses for the population, although in the past, mangroves were exploited for tannin extraction. In zones adjacent to mangrove forests can be found human establishments dedicated to few intensive activities, which with good management are not conflicting with the conservation of resources, thus permanently irrigated agriculture, developed on consolidated ground with cultures of coffee, cacao, coconut, fruits, etc., which represents 31.6% of land usage, meanwhile the annual semipermanent cultures occupy only 5%; 33.32% is for pastures, 54.5% are for to intensive and semiintensive farming (MARNR, 1991b). In this zone, there are cyclic population explosions of the plague insect *Hylesia urticans*, commonly known as "palometa peluda", which can produce allergic reactions and disarrangements in the immunological system of humans, that inhabit close to these ecosystems. For this reason, neighboring populations value lowly these mangroves. The MARNR (1986) has pledged the implementation of campaigns of environmental education.

Orinoco Delta. The population density in the Delta Amacuro State is low: 1,71 inh/km^2, according to the 1981 census. The percentage of rural population, 65%, is high if compared to the national average. The relation inh/house is very low, 2.82. In the Orinoco Delta, three main ethnic groups can be distinguished: the indigenous groups constituted by Waraos, Arawaks and Caribes; the inhabitants coming from Nueva Esparta State; and immigrants coming from the nearby country, Guyana (MARNR, 1991a). The aboriginal populations, dispersed throughout the intricate system of channels of this Delta, are nomadic groups, living in precarious conditions. A 61% of the land is dedicated to some kind of permanent or semipermanent culture: 45% are pastures and the rest remains as forest or dedicated to other usages (MARNR, 1991a). The indigenous groups exploit mangrove wood for their needs and also participate in the extraction of the palm tree (*Eutherpe oleracea*).

9. Pressures and Anthropogenic Impacts

Careful monitoring of mangrove areas in Venezuela has not been carried out, so it is not easy to establish the percentage of mangrove areas that have been lost; however, some evidence suggest dramatic proportions. The historian Esteves (1980), reports that during the conquest of Venezuela by the Spaniards, the French pirate Juan de Buen Tiempo, used the Adicora Bay (Falcón State), as a hiding place, due to the protection offered by "dense mangroves". The place where those mangroves were, today is occupied by umerous restaurants and chalets. Beyond this remark, there are other sources that confirm the proportions of the diminishing mangrove forests. Flores (*ca.* 1979) indicates a mangrove coverage of one million ha; an amount four times the present day coverage. Another hint of substantial deforestation is the information included by Hueck (1960) in his Vegetation Map of Venezuela. He points mangroves for most of the Maracaibo Lake perimeter (Fig. 2).

Present distribution, according to the inventory made in this project, is more restricted and, *grosso modo*, a tenth of the extent given by Hueck (1960). In 1926, Pittier, in the inventory of the zones of Venezuela with major mangroves, pointed out some places where today there are only some patches, including Cumaná, and Píritu and Unare Lagoons, and the coasts of the Carabobo State. The causes of such a deforestation are unknown; however, it is probable that in some of those areas important semiindustrial exploitations were held, or that small-scale exploitation levels, were continued for decades.

There are many historical instances of mangrove exploitation in Venezuela. One of the first registered deforestation cases of Venezuelan mangroves occurred in 1930, when, in the region close to Tucacas, Falcón State, the English company Bolivar Mining Association extracted mangrove wood to be used in the copper mines of Aroa (Pannier & Pannier, 1989).

During the second half of the XIX Century, the Curazoleans began the exploitation of the Roques Archipelago mangroves, especially *Rhizophora mangle*, which were used as charcoal in steamships furnaces; tannins were extracted from the bark. The exploitation volume was such that big charcoal industries were installed in several islands of the archipelago (Amend, 1992d).

Before the Second World War, in the southern zone of the Maracaibo Lake, mangroves were exploited in great scale for exportation to Germany and USA (Pannier & Pannier, 1989). Number, intensity and consequences of these exploitations are unknown.

During the second half of this Century, coconut plantations and petroleum exploitation affected the Maracaibo Lake mangroves, although the extension of this impact is not precise (Ninin, 1957). In the Limón River, the exploitation of mangroves, for production of firewood and charcoal was considered to exceed artisanal levels (Ninin, 1957). According to Marín (1980), cutting, farming and oil spills, have caused mortalities over 50% in some mangrove forests in the Limón River-San Carlos Island.

According to Aristiguieta (1980), the main impact on mangroves comes from touristic and urbanistic developments. At present, two are the main factors jeopardizing mangroves: urbanistic developments, essentially those with touristic purposes and furtive deforestation. A variation of the second factor is deforestation of heads of rivers feeding some estuaries (the Tacarigua Lagoon, for example). Other kind of impacts, that could represent a major menace in the future, are the creation and expansion of salt pans, shrimp ponds, and pollution.

One of the best studied and documented examples of impact on mangroves is the Tacarigua Lagoon (Salm, 1980; Delgado, 1981; Díaz & Zelwer, 1985). This is an estuarine lagoon, bordered by mangroves, now protected by a National Park regime. The mangroves in this lagoon sustained massive deforestations during 1920, 1927-1931 and 1953-1957 (Delgado, 1981); during the first period 60 MT of wood were extracted. During the last period, the material extracted was used to build the skyscrapers of the Centro Simón Bolívar in Caracas (Salvatierra, 1983b). A very important impact was the deviation of the original course of the Guapo River, by means of Madre Casaña canal in 1964. These works caused an increase of erosion and sediment transport towards the lagoon, causing a progradation of around 225 ha and, as a consequence, a decrease in fish catches (Salm, 1980). Delgado (1981) offers a catalog of the impacts on this lagoon until 1980; this list includes massive deforestation; accumulation of tannins due to changes in the hydrologic regime; progradation of sedimentation; dredging operations with alteration of natural opening and closing of the mouth of the lagoon, with a consequent change of tide rhythms; overexploitation of commercial species, as crocodiles and turtles; overfishing with illegal means; and urban invasion.

Recently, Díaz & Zelwer (1985) established a chronology of more recent impacts and, the laxity of several government organisms to stop intervention

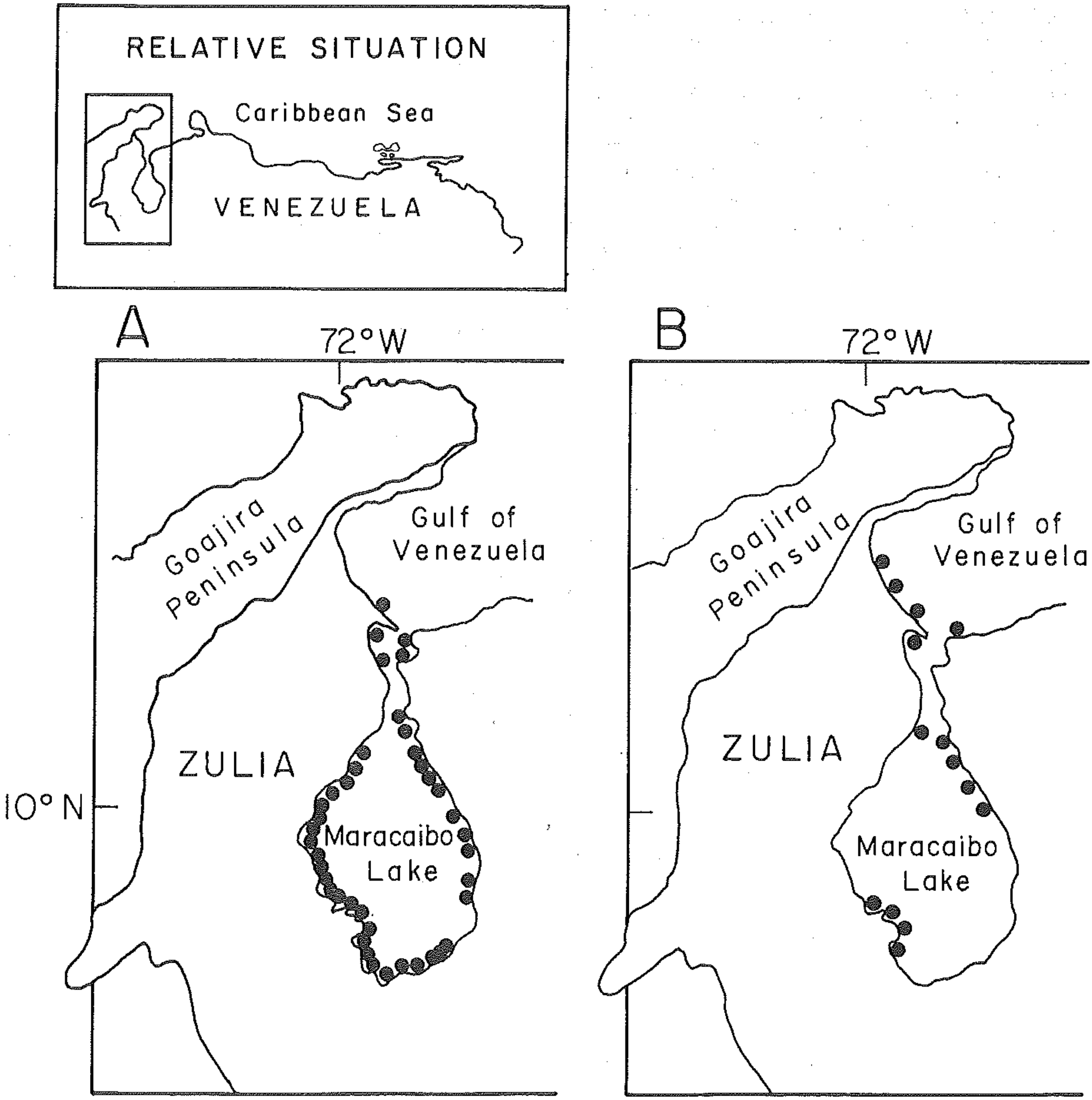

Fig. 2. Map of the Maracaibo System, Zulia State, indicating mangrove forests according to: A. Hueck in 1960; B. this survey, 1993.

to build a resort. Starting with the intervention of river's heads that feed the lagoon and the mouth that communicates with the sea; exclusion of the western bar of the legal protection regime; probable use of defoliants of phenoaxiacetic type; and, according to the words of Díaz & Zelwer (1985), the scarce interest of the MARNR to fulfill its functions, the Tacarigua Lagoon case can be seen as the *summum* of the problems that can affect a mangrove forest. Nowadays, pressures should be subdued, due to the Tacarigua Lagoon National Park status (MARNR, 1990a); however, during the 80's in the neighboring areas, many touristic and urbanistic complexes were built.

Another well documented case is the Orinoco Delta mangroves (Pannier, 1979). As early as 1926, Pittier (1926) pointed out that the mangrove exploitation was very active in the Orinoco Delta and that it was desirable to adopt effective measurements to balance exploitation and stocking. During the 70's, the Venezuelan Corporation for Guayana Development (CVG) carried out several hydraulic works to gain flooded grounds for agriculture, although according to another information the real purpose was related to the export of minerals. Engineering works were not very effective due to the complex imbrication and hydrodynamics of the Orinoco Delta waterways. Additional works solved such a problem; however, soils have been modified to such an extent that it is impossible to use them for agricultural purposes. According to Pannier (1979), the present hydrographical regime could have a predictable deleterious effects on mangroves. Figueroa & Seijas (1986) consider that in the future, oil prospecting could constitute the main hazard for those mangroves, alongside hidden cuttings.

A very important impact case, whose ecological consequences have not been evaluated, is the Guarapiche Forest Reserve, in the San Juan River, north of the Orinoco Delta. This mangrove exploitation has been considered a well planned silvicultural enterprise. Other opinions, however, are not so optimistic. Ernesto Medina (personal communication) estimates that in the exploited parcels, mangroves have reached between 40% and 60% height as compared to the ones not exploited, but the community structure is far from recovering. In the 70's, it was given in concession to the TAMAVENCA company, and what remains is a desolate landscape and tons of mangrove timber, that probably will end rotting (Ernesto Medina, personal communication). Nowadays, a new by company is using the installations and equipment to process pine wood (Ernesto Medina, personal communication).

Rio Hueque-Sauca, Falcón State. Several years ago the development of a shrimp company was planned in the zone, but due to problems of subcapitalization, it disappeared. Recently, a dam is being built upriver. A modification of the hydrodynamics of the zone with unsettling results must not be excluded, as it happened in Caño Mánamo, in the Orinoco Delta. There is also a project of installing a new shrimp company (Delfina Rodríguez, personal communication; Hidroimpacto, 1991).

Gulf of Cuare. Created in 1972 for protecting and conserving endangered species and fragile ecosystems, the fauna refuge of Cuare is, since 1988, the pilot locality for the adhesion of Venezuela to the Ramsar Convention; it is sited in the eastern coast of Falcón State. Figueroa & Seijas (1986) considered this refuge as one of the most important coastal environments of Venezuela and they emphasized that its integrity must be maintained. They point out that the main hazard is the rapid urban expansion of Chichiriviche, a coastal town with an explosive and chaotic urban development, that lead, among other things, to illegal urbanization inside the limits of the reserve, and the construction of big hotels in the surroundings (Figueroa & Seijas, 1986).

Morrocoy Bay. Garish beauty of this place, make this locality an ideal place for recreation, a fact that has spurred a chaotic influx of tourists. As a consequence of the excesses of tourism at the beginning of the 70's, particularly the indiscriminate construction of houses on stilts in the mangrove lagoons, on coral reefs and *Thalassia* beds, the area was declared a National Park in 1974, and to the promulgation of a specific Presidential Decree to protect mangroves throughout Venezuela.

Unare Lagoon. The artisanal fishermen of this place interrupted the construction of a shrimp company, that would function near the mouth of the Unare River. Fishermen argued that the construction works of the company would modify the fishing places, the breeding of larvae and alevins, and navigation routes. The company had among its plans to dredge a channel at the mouth of the Unare River, that would induce a decrease in the number of shrimp larvae recruited into Unare and Píritu Lagoons; with unpredictable consequences on the resources traditionally exploited by artisanal fishermen (Sebastiani *et al.*, 1991). Until 1990, and after the reinitiation of works in two opportunities, the project was suspended (Novo, 1990). The construction of a coastal highway has also diminished the extension of mangroves.

Margarita Island. The advance of urban areas and explosion of resorts and touristic buildings construction, that began during the past decade, are the main menaces for mangroves in this Caribbean island. Figueroa & Seijas (1986) add illegal timber extraction as another important impact. However, it looks like a process of awareness about the importance of mangroves, is emerging among the community. Boatmen of La Restinga Lagoon, a National Park, who transport tourists around it and through its waterways, are very sensitive to the possibility of these mangroves being damaged, and they avoid visitors cutting branches (J.E. Conde, personal observation). In this lagoon solid waste dumpings have been carried out to recover lands in mangrove area. The avifauna is perturbed by recreative activities with motor vehicles (Figueroa & Seijas, 1986).

10. Legislation and Management Policy of Mangrove Forests

Venezuela is one of the South American countries with the highest number of protected areas and conservation units. More than 30 million ha, 33.7% of its territory, are protected; being this the major percentage of South American countries, which have a mean of 6.2%. By the end of the 80's, there were 629 conservation areas in the subcontinent; 104 corresponded to Venezuela. Thus it is not surprising that many of the mangrove areas are contained in conservation units.

Venezuela has a prolific environmental legislation. There are more than 200 regulations, ordinances, laws, presidential decrees, and other legal instruments that deal with environmental matters (Barrios, 1991). A large number of mangroves are legally protected by being included in conservation units and protected areas under the ABRAE System (Areas Bajo Régimen de Administración Especial: Areas under Special Administrative Regime). The legal frame sustaining ABRAE includes the Washington Convention of 1940 on Protection of Flora, Fauna and Scenic Natural Landscapes of America, the Forest Law of Soils and Waters, the law of Wildlife Protection, the Organic Law of the Environment, Organic Law for Ordination of the Territory; plus a large number of decrees, approbatory laws of treaties and agreements, resolutions, rules, designations and other specific laws (Gondelles, 1992). The ABRAE includes 19 categories or figures (Gondelles, 1992). Among them are National Parks, of which Venezuela counts 39, the largest number in South America. The localities protected by ABRAE that include mangrove areas are shown on Table 5.

In 1974, through the promulgation of Presidential Decree N 110 (Gaceta Oficial de la República de Venezuela N 30.408 of May 27, 1974), unconditional protection of mangroves was established. This decree banned the direct destruction of mangroves, the implementation of activities that could jeopardize their existence, including discharges of waste waters, dredging of marine bottoms, and dumping of residue in mangroves and coral reefs. However, during Carlos Andrés Pérez second presidential term, decree 110 was substituted by Presidential decree N 1843 (Gaceta Oficial de la República de Venezuela N 34.819, October 14, 1991). In this second decree the possibility of intervention of mangroves, with the administrative authorization of MARNR as the only requisite, is open and the need for an Environmental Impact Assesment (EIA) is discretional.

This decree offers alternatives that were absent in decree 110, which practically prohibited any intervention in mangroves. Now, the MARNR is the governmental organism deciding if the intervention must be allowed. As the case of Tacarigua Lagoon has shown (Díaz & Zelwer, 1985), there are reasons to worry. Additionally, this is the same body that decides in each case if it is to carry out an EIA to allow the occupation of the territory. It is important to mention that in Venezuela, an EIA must be carried out when the intervention of nature is considered necessary. The new decree is, in our opinion, a backward step in the protection of mangroves.

Recently was passed the Ley Penal del Ambiente (Environmental Penal Law), a law that could amend this situation. This law contemplates fines and prison up to 10 years for those damaging or impairing nature and also includes the obligation of performing an EIA. However, if this is not done for those activities required by the rule on this matter, the maximum fines are equivalent to less than USA $ 2,000 and six months in prison. This amount is a trifle, if compared to the capitals of millions of dollars that a project of resort development for five or four star tourism usually boasts. Besides, this law has its gaps. For example, Article 15 establishes attenuations

Table 5. Some conservation units that include mangrove stands. Areas of mangroves are approximate.

Locality (Figure)	Unit Area	Mangrove Area (ha)
Mádanos de Coro (National Park)	91,280	(1,000)
Morrocoy Bay (National Park)	32,090	(4,500)
Los Roques Archipelago (National Park)	225,153	(4,000)
Tacarigua Lagoon (National Park)	18,400	(4,000)
La Restinga Lagoon (National Park)	10,700	(1,000)
Mochima Bay (National Park)	94,935	(500)
Guarapiche (Forest Reserve)	370,000	(30,117)
Las Marites Lagoon	3,674	(1,000)
Gulf of Cuare (Fauna Refuge)	11,825	(1,500)
Los Olivitos Swamp (Fauna Refuge)		(4,063)

when the penal act is transgressed for personal or familiar subsistence.

In Venezuela, there are no figures that could be defined or equated to national strategies, national board, or high policies for management of mangroves. Some personalities and institutions, individually, have made recommendations in that sense. Federico Pannier, a well known specialist on mangroves, has pushed the creation of a high level committee that should have paramount authority. Other persons and entities (Arroyo, 1970; Rodríguez, 1984; Sociedad Venezolana de Ciencias Naturales, 1985) have made similar recommendations.

11. Community Participation and Training Programs

The laws and good wishes of those who know the immense value of mangroves are not enough to accomplish their preservation and best use. The incorporation of communities in mangrove rational management and sustainable development is a more promising way. One of the first attempts to promote awareness and education for rational management of mangroves was carried out in the frame of the International Project of Conservation and Management of Mangroves, that was sponsored by several organizations, and was started in 1982 by the Direction of Environmental Education of the MARNR (Salvatierra, 1983c). In some localities, as the Guf of Cuare and Los Olivitos Swamp, official and private organizations have developed programs of community promotion in order to try to integrate them into the management of the coastal zone.

A recent experiment, now in progress, is the one carried out in the Gulf of Cuare. Beginning in 1989, FUDENA (Fundación para la Defensa de la Naturaleza: Foundation for the Defense of Nature), a non-governmental organization, initiated an interesting program for conservation and rational use of mangroves of the zone. In this program, the stimulation of the environmental awareness and active participation of neighbors play seminal roles; emphasis is put on low-income families (Díaz-Martín, 1992; Díaz-Martín *et al.*, 1992). So far, the program is considered to be successful. The participants-many of them children and teenagers - are engaged in promoting the proper management and preservation of nature as a scenic resource and, concurrently, as a source of jobs and income for them. Some of the fishermen of the zone have also begun to understand the importance of the right selection of their fishing gear and of conservation of mangroves, on whose roots grows *Crassostrea rhizophorae,* a key staple of their income. Other segments of the community are participating in this program: the oyster collectors, the boatmen, and neighbor associations (Díaz-Martín, 1992; Díaz-Martín *et al.*, 1992). This way, the villagers are converted into beneficiaries and guards. Cuare is, since 1988, the pilot locality for the adhesion of Venezuela to the Ramsar Convention, this experience must be observed with attention, due to its possibilities for serving as a model in the future.

In Los Olivitos Swamp a program of environmental activism is also being developed by the Sociedad Conservacionista Audubon de Venezuela and PROFAUNA (MARNR).

12. Research and Information Needs

The large volume of information about mangroves and associated ecosystems defies the most vehement attempts of synthesis. For instance, Rodríguez (1987) pointed out that for 1975 there were close to 6,000 available papers on mangroves; recently there seems to be an enhanced interest in mangroves. Only for Brazil, Schaeffer-Novelli (1986) catalogued, 568 sources, starting back in 1614. For Colombia, Alvarez-León (1992) reports more than 400 publications.

Production of Venezuelan researchers does not seem to be so prolific, which probably allows to make a good assessment of the research topics and information output, and also to estimate the research needs for the next years. There is a conspicuous absence of interdisciplinary teams carrying out projects continuously. Most of the efforts have their genesis in individual initiatives. One noteworthy effort is that of Federico Pannier and Rosario Fraino de Pannier, who, during almost four decades, have produced a large amount of information, that has appeared in articles going from ecology and physiology to environmental management and popularization.

A large amount of valuable information came from a project with an interdisciplinary vocation that was originated at the beginning of the 80's by the MARNR, the Program of United Nations for the Environment (PNUMA), the Sierra Club International Earth Care Center of USA, and the Institute of Marine Affairs of Trinidad and Tobago, to study the mangroves of Venezuela and Trinidad-Tobago. The large amount of information produced in this project is found in several restricted circulation, technical reports (MARNR, 1986, 1990a,b,c, 1991a,b,c).

During the same project a Delphi process was administered to a panel of mangrove experts from Venezuela and Trinidad-Tobago (MARNR, 1986). According to the results of this questionnaire the top five research needs were: 1. Evaluation of the contribution of mangrove forests to the productivity of commercially important fishes; 2. Determination and quantification of the main factors that affect primary productivity in mangroves, with emphasis on those factors sensible to management; 3. Long-term effects of oil spills on structure, function, and economical values of mangroves; 4. Evaluation of mangrove cutting, extraction, and strategies for regeneration induction; and 5. Determination of strategies for optimal mangrove management in small communities (MARNR, 1986). Most of, if not all, these needs remain unfulfilled.

In spite of the unfortunate -according to some opinions-, experience in mangrove silviculture, forest and silvicultural approaches have not been absent. Many of those works come from the Facultad de Ciencias Forestales, Universidad de los Andes (Mérida, Venezuela). Rodríguez (1984) included an important amount of references relative to mangrove conservation and forest aspects.

Another group has directed its interest mainly to the sessile community of roots of the red mangrove, *Rhizophora mangle*, (Díaz *et al.*, 1985; Orihuela *et al.*, 1991) and mangrove Crustacea, especially the mangrove crab, *Aratus pisonii*. The population dynamics and life histories of this crab have been studied in a gradient of several habitats and types of mangroves (Conde, 1990; Conde & Díaz, 1985; 1989a,b, 1992a,b, Conde et al., 1989).

In spite of efforts and recommendations, the amount of information necessary for a complete comprehension of Venezuelan mangroves is enormous. Information about phenological data, growth rates, biomass and other basic data needed for an understanding of the dynamics of this ecosystems is scant or completely lacking. Fauna inventories are not complete, neither are the population dynamics of many commercial species.

Courses that deal exclusively with mangroves have not been common in Venezuela. In 1989 Yara Schaeffer-Novelli and Gilberto Cintrón-Molero, gave a very succesful course of two months on mangroves, sponsored by the Universidad Central de Venezuela.

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Federico Pannier, has been a true pioneer in the study of mangroves of Venezuela. His contributions are many and valuable, and range through a wide spectrum of interests. We profited from that corpus of knowledge.

As far as we could, we have tried to review and cite most of the literature on mangroves that has been produced in or about Venezuela. It is obvious that it was not possible to cover all entries, due to the constraints of space available for the chapter. Similarly, a large number of reports and theses was left out. The exclusion was not a matter of quality, but of difficulties and cost to obtain them.

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Mangroves of Brazil

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1. Historical Background

Mangroves are both of great importance and value in Brazil, although they are used to a much lesser extent than mangroves in Asia or Central America. Historically, Brazilian mangroves were exploited for wood and considered an area for urbanization. However, concern for sustainable exploitation of mangrove resources already existed in colonial times. In July 1760, Dom José, king of Portugal, issued an edict, making it unlawful to cut mangrove trees for fuel wood without also utilizing the bark of the trees (Maciel, 1989; Schaeffer-Novelli & Cintrón, 1990). The edict was issued in response to widespread cutting of trees for firewood along both the northeastern and southeastern coasts of Brazil, and the worry that mangrove tree bark would soon become unavailable. Mangrove bark, which was used to extract tannin and alkaloids, had increased drastically in price prior to the issue of the royal Portuguese edict. This act of protection of mangroves was one of the first, if not the very first, legislation recognizing the value of mangroves for sustainable utilization.

Mangroves form a strip along a large portion of the Brazil coast from Amapa in the north to Santa Catarina in the south and constitute an invaluable ecological unit of the coastal zone. Stabilization of the mangrove resource and rational utilization of mangrove areas for aquaculture and other uses are desirable. Creation of protected coastal mangrove areas for the sake of conservation is an important form of stabilization. Stability in this context means preservation of the ecosystem for sustainable development of the coastal zone. As an example of the economic benefits derived from Brazilian mangroves, the relatively small 4,370 ha mangrove system in the Rio Paraíba estuary in Piauí sustains more than 10,000 persons, who depend on the abundant mangrove crab fishery.

Artisanal crab fishery is probably the most important economic activity in mangrove systems on a commercial scale along the entire Brazil coast. Canoes in the northern coastal states are in many places made from mangrove wood. Likewise fishing tools and the masts of simple northeastern ocean fishing boats (jangadas) are commonly made from mangrove trees. Also, tannin is still extracted from the bark of mangrove trees. Otherwise, a lack of exploitation is characteristic of the mangrove ecosystems in Brazil, especially when compared to Central America and Asia. Still, mangroves in Brazil are subject to intense pressures from development projects. In some places, especially in southeastern Brazil, urban centers, airports, ports, and shopping centers occupy the space where mangroves once grew.

Similar to the Mata Atlântica, the once magnificent coastal forest that stretched from Santa Catarina to Bahia, Brazilian mangroves have been subjected to cutting and destruction to give place for industry and development. Mangrove reforestation is largely not taking place in Brazil. Inaccessibility and low population density are the main reasons why the spectacular mangrove wetland forests of the northern states of Amapá, Pará, and Maranhão remain for the most part intact. Cheap and ample electricity in Brazil is another reason why mangroves have not been cut for fuel, as is the case in West Africa. Also, since no salt-tolerant species of rice are grown in Brazil, the pressure to convert mangrove areas to rice fields has not been an issue of significance in Brazil.

There exists a very rich body of knowledge about mangroves in Brazil and an impressive number of completed mangrove studies, covering a diverse set of topics. Schaeffer-Novelli (1986) listed more than 560 references on Brazilian mangroves up until 1985. Unfortunately, much of this information is unpublished or "lost" in technical reports or student theses and dissertations.

Brazilian mangroves have been the subject of scientific studies since colonial times. In the earliest phase, most studies described the fauna, flora, and

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traditional uses of mangroves by the local population. Most educated travellers of the 16th, 17th, and 18th centuries included descriptions of mangroves in their travel journals. Typical examples of such literature are the descriptions of mangroves in Anchieta (1554-1594), Abreville (1619), and Almeida Pinto (1698). Also, Darwin (1845) described briefly the mangroves and mangrove creeks near Recife during his journey on the Beagle.

Nineteenth and early twentieth century studies on mangroves were most frequently undertaken by professional scientists, and most of these accounts still serve as important sources of information on Brazilian mangroves. Most significant is maybe the description of the coastal vegetation of Rio de Janeiro by Ule (1901); the pioneering work of Luderwaldt (1919) with a detailed description of the mangroves of Santos, São Paulo; the comprehensive monographs of Silveira (1937) and Pedrosa (1950); and the first treatises on phytogeography of Brazil by Fróis-Abren (1931) and Sampaio (1934). Also important is the contribution by Freise (1938), who was the first person to study sedimentation and geomorphology of Brazilian mangrove areas.

Simultaneously with these early descriptive studies, the importance of mangroves as useful plants and as sources of tannin and timber was acknowledged by Correa (1909), Brocadet (1921), Fróis-Abreu (1926), Freise (1933-34), and Horn (1946). Horn (1946) focused on tannin production and extraction procedures from *Rhizophora mangle*; and Freise (1933-34) and Horn (1948) focused on the durability and uses of Brazilian mangrove timber. The importance of mangroves for fisheries was recognized relatively early by Freise (1931, 1932), and Góes (1942). Gonçalves (1934) was the first person to evaluate mangrove dominated coasts as a potential site for mariculture.

After 1950, detailed ecological studies begun in many mangrove systems along the Brazilian coast. Dansereau (1947, 1950) proposed a succession and zonation pattern for the mangroves of Rio de Janeiro, which has been reproduced in many text books to date. Detailed descriptions of mangrove associated fauna and flora became abundant in the literature. Mangrove algae and fungi were reviewed by Mitchell (1974), Rehm (1901), and Braga (1970 a,b). Higher plants were described by Dias-Brito & Zaninetti (1979), Barth & Silva (1965), Lutz (1938), Coimbra-Filho & Magnanini (1961), Reits (1961), and Lamberti (1979). Birds were studied by Brito (1950), Mitchell (1957), Berla (1944), Novaes (1950), and Silveira (1965). Crustaceans and molluscs were studied by Oliveira (1940, 1950), Castro (1962), and Klappenbach (1965). Insects, in particular those of public health importance, were reviewed by Castro (1932) and Lutz (1912, 1913). Foraminifera were described by Zaninetti (1979).

Pre-historic utilization of mangroves and the anthropology of coastal pre-historic human groups were the focus of investigations by Beltrão (1976), Clerot (1928), Cunha (1965), and Emperaire & Lamig (1956). Anthropogenic impacts on mangroves were intensively studied after World War II, as the Brazil coast increasingly was becoming urbanized. This lead to detrimental impacts associated with increasing sedimentation (Ruellan, 1944; Rocabati & Neves, 1976; Amador, 1980), industrialization (Oliveira 1958, 1975; Lacerda & Hay, 1982; Oliveira & Krau, 1976), and oil spills (Jacobi & Schaeffer-Novelli, 1990).

In the 1960s and 1970s, mangrove research in Brazil already involved many research groups. However, it was scientists at the Universidade de São Paulo (USP) who established a pioneering group to study mangrove waters, productivity, and plankton ecology (Teixeira *et al.*, 1965; Tundisi, 1969, 1981; Tundisi & Tundisi, 1968, Tundisi *et al.*, 1973, 1978; Kutner, 1975). Another research program at USP under the direction of Schaeffer-Novelli, resulted in the first comprehensive review of mangrove research in Brazil (Schaeffer-Novelli, 1982, 1986, 1989, 1990).

Starting in the late 1970's, scientists began using mangroves as models for ecosystem studies. This included nutrient cycling (Adaime, 1987; Schmidt, 1988; Ovalle *et al.*, 1990; Ovalle, 1992); evolution of depositional coastal environments (Dias-Brito & Zaninetti, 1979; Bronimann *et al.*, 1981 a,b; and Moura *et al.*, 1982); and pollutant biogeochemistry (Japenga *et al.*, 1988; Lacerda *et al.*, 1988 b; Rezende, 1988; Rezende *et al.*, 1990). Herz *et al.* (1984) and Pires (1986) developed model algorithms to detect and map mangrove systems by use of satellite remote sensing and image analysis. Also, more comprehensive reviews of mangrove flora, fauna, and ecology were concluded (Aveline, 1980; Araújo & Maciel, 1979; Sant'Anna & Whately, 1981; Schaeffer-Novelli, 1989; Maciel, 1989; Cintrón & Schaeffer-Novelli, 1983, 1992; Cordeiro-Marino *et al.*, 1992).

2. Mangroves Along the Coast of Brazil

2.1 Extent and Distribution

Mangrove forests are distributed in a patchy fashion along 6,800 km of the coast of Brazil, or 92% of the entire length of the coastline. They reach from Oiapoque, Amapá, in the north at lat. N 4°30' to Praia do Sonho, Santa Catarina, in the south at lat. S 28°53' (Schaeffer-Novelli, 1989). The only coastal state without mangroves is Rio Grande do Sul in the far south. The eastern-most limit for mangroves in Brazil is the offshore island, Ilha Fernando de Noronha (long. W 32°24' and lat. S 3°50'), where a small (0.15 ha) monospecific stand of black mangroves (*Laguncularia racemosa*) borders the estuary of the river Maceió (Herz, 1991).

There are many very different estimates of the area of coverage of mangroves in Brazil. It is our judgment that the most accurate area estimate is 1.38 million hectares (Table 1). Saenger *et al.* (1983) reported Brazil to be the country in the world with the most extensive mangrove coverage with 2.5 million hectares of mangroves, followed by Indonesia with 2.1 million hectares. However, Saenger *et al.* (1983) did not report the sources for their data figures, and their appraisal for Brazil is certainly a gross overestimate. The most recent, independent estimate for the area covered by mangroves in Brazil is $1.01.10^6$ ha (Herz 1991), and was based on detailed measurements from satellite images. However, the estimate by Herz (1991) appears to be a 16% underestimate as compared to a summation of estimates by scientists having worked on mangroves in parts of the country.

Although Herz' (1991) estimate of mangrove areas in Brazil as a whole is the result of the best survey ever done, detailed local studies generally yield larger estimates for the same areas. For example, a study in Baía de Sepetiba, RJ, (Ovalle, 1992) indicated that the mangrove area measures 2,800 ha, while Herz (1991) reported 1,100 ha. In other instances, there exist even larger discrepancies. Lana & Sessegolo (1993) estimated that mangroves cover an area of 51,000 ha in the state of Paraná, whereas Herz' (1991) estimate is only 20,800 ha (Table 1). The RADAN (1983) study also used aerial mapping to assess the area of mangroves in Brazil, but there still is disagreement. Herz' (1991) estimate for the joint mangrove areas of the states of Espírito Santo and Rio de Janeiro is 17,800 ha as compared to 35,500 ha in the RADAN (1983) study (Table 1). The delta of the Paraiba do Sul, RJ, contains 800 ha of mangroves but has been completely left out in Herz' (1991) inventory.

Herz' (1991) area estimate was based on interpretation of satellite imagery for the entire length of the coast of Brazil. The discrepancy between his and other estimates is in all likelihood at least partially due to the fact that Herz (1991) considered only mangroves proper, excluding adjacent waterways, mudflats, salt flats, and marginal plant communities. As long as waterways, mudflats, and salt flats are small relative to areas covered by mangroves, other studies usually include these areas in mangrove cover estimates. Marginal plant communities adjacent to or within mangrove systems, e.g. salt marshes, are also usually grouped together with mangrove systems in southern Brazil in most studies but apparently not in the Herz (1991) study.

Another explanation for the rather considerable area differences can be found in the size of pixels associated with x-band radar and Landsat and SPOT multispectral determination of mangrove areas. Mixed pixels in the Herz (1991) study were most likely not included in mangrove area estimates and help to explain the large differences in area estimates, especially for small mangrove areas in southeastern and southern Brazil. For the large mangrove systems in Maranhão and Amapá, Herz' (1991) mangrove area estimates are much closer to other estimates. The large discrepancy in the Pará estimates may be due to the fact that reflectance characteristics of hardwoods and mangroves are quite similar, and thus difficult to distinguish.

Area estimates of mangroves vary with methodology, season of measurement, stage of the tide, and also depend on what has been considered to be mangroves and what has not been included in the mangrove inventory. Because Herz (1991) only considered mangrove forests proper, his estimate of mangrove area in Brazil can with advantage be used to calculate timber volume, estimate biomass, and for other ecological measurements and purposes. However, when considering mangrove vegetation forms, geographical systems, and interactions between mangroves and adjacent marine and terrestrial systems, Hertz (1991) calculated area is clearly an underestimate. We propose, based on this review of the local mangrove surveys along the coast of Brazil, that mangrove areas cover $1.38, 10^6$ ha in Brazil (*sensu latu*) (Table 1).

Table 1. Estimates of mangrove cover in Brazil by state.

State	Coastline (km)	Area (ha) Herz (1991)	Area (ha)	Reference
Amapá	598	162,270	182,300	Fearnside (1990)
Pará	582	181,972	389,400	Fearnside (1990)
Maranhão	640	492,310	500,000	Sant'Ana & Whately (1981); Mochel (1993)
Piauí	66	6,233	4,370	Freire & Oliveira (1993)
Ceará	573	11,011	22,940	Freire & Oliveira (1993)
Rio Grande do Norte	399	14,181	6,990	Freire & Oliveira (1993)
Paraíba	117	7,397	10,080	Freire & Oliveira (1993)
Pernambuco	228	6,555	7,810	Freire & Oliveira (1993)
Alagoas	229	5,685	3,565	Freire & Oliveira (1993)
Sergipe	163	16,772	26,200	ADEMA (1984)
Bahia	932	44,537	110,000	CEPLAC (1976)
Espírito Santo	392	8,951	19,500	RADAN (1983)
Rio de Janeiro	636	8,994	16,000	Lacerda & Rezende (1993)
São Paulo	622	13,994	23,100	Herz (1987)
Paraná	98	20,825	51,000	Lana & Sessegola (1993)
Santa Catarina	531	8,313	3,000	Panitz (1993)
Total:	6,806	1,010,000	1,376,255	

2.2 Characterization of Brazilian Mangroves

The coastline of Brazil is shown in Fig. 1, emphasizing the distribution of mangroves according to state, and showing major cities, and salient coastal features. Eighty-five percent of Brazilian mangroves occur along the 1,800 km long coast of Amapá, Pará, and Maranhão, in northern Brazil, especially between Belém, Pará, and São Luís, Maranhão. The state of Maranhão, with 0.5, 10^6 ha of mangroves, embodies nearly half of the total area of mangroves in Brazil. Maranhão is the state with the most extensive structurally complex mangrove forests.

Along the north coast of Brazil, the extensive mangrove systems reflect hydrological topographical characteristics of the coast. The semidiurnal tide has a range, which in places exceeds 8 m. As the coast generally consists of extensive flat quaternary plains, huge coastal areas are flooded during high tides and during the rainy season. Along the north coast of Maranhão, rainfall exceeds 2,000 mm yr^{-1}, which is a major factor enhancing mangrove growth and producing the most extensive and spectacular mangrove systems of Brazil. As a result of the large tidal range and the ample rainfall, mangrove systems extend more than 40 km inland following the course of estuaries and rivers in Pará and Maranhão.

In the north, *Avicennia* trees are particularly well developed and most frequently occurring. The trees reach more than 1 m in diameter and are in places 40-45 m tall (Sant'Anna and Whately, 1981). *Rhizophora* trees occur only very close to the coast (Sant'Anna and Whately, 1981). *Spartina alterniflora* grows as seaward fringes along the north coast, and *Hibiscus tiliaceus* typically dominates the landward margins of mangrove systems (Damasio, 1979/80 a,b).

The mangroves in the Amazon estuarine area are quite different, because they contain typical Amazon freshwater hardwoods. Although well developed, mangrove trees in this area have a relatively restricted distribution due to the enormous rate of freshwater input and competition from freshwater macrophytes.

The northeast coast from Rio Grande do Norte to Rio de Janeiro extends for 4,000 km, but contains only 10% of the total mangrove area in Brazil. This coast is characterized by micro or meso-tidal regimes, and narrow quaternary coastal plains with rocky outcrops. The tertiary "Barreiras" formation frequently extends to the coast and limits the inland distribution of mangroves. The northeastern climate is mostly semi-arid with low precipitation restricted to a few months of the year north of southern Bahia. However, humid climates dominate the remainder of the northeastern coast with exception of the Cabo Frio, RJ, region with annual precipitation equal or greater than 1,500 mm per year. This more humid climate allows the development of extensive mangroves inside bays and along estuaries of major rivers, especially in southern Bahia with more than 100,000 ha of mangroves.

The northeastern mangroves are less tall than along the north coast. *Rhizophora mangle* is the most conspicuous vegetation and reaches 10-20 m height (Hueck, 1972). Narrow fringes of mangroves border deltas, lagoons, and estuaries with heights that seldom exceed 15 m. In the inner part of bays with high freshwater supply, and where the climate is humid, mangrove systems can be quite extensive.

The southeastern coast of from Rio de Janeiro to Santa Catarina extends for 1,250 km and contains only 5% of the total mangrove area in the country. The coast brakes into distinct ecological units at the city of Rio de Janeiro. The coast is impinged by the Serra do Mar mountain chain, which in many places enters the sea. This is a pre-Cambrian shield area, which extends along the length of the southeastern coast. Mangroves are restricted to protected coastal shores and bays, but are in places more abundant and better developed than along the northeast coast. Coastal plains are narrow, inundated by the tide only occasionally. The tidal range is low, approximately 1 m, and mangroves, particularly *Rhizophora* trees do not extend far inland. Mangroves are mostly restricted to the delta of rivers, coastal lagoons, and interior parts of bays. The forest consists of trees mostly less than 10 m in height, dominated by *Rhizophora mangle*, but far less diversified than the mangroves along the northeastern and north coasts.

3. Mangrove Flora

3.1 Mangrove tree dlora

Brazilian mangroves are composed of "true" mangrove trees and a diversified flora of mangrove associates from both terrestrial and aquatic habitats. True mangroves are dominated by the genus *Rhizophora* (Rhizophoraceae) with three species, the genus *Avicennia* (Avicenniaceae) with two species, and the genera *Laguncularia* and *Conocarpus* (Combretaceae) with one species each (Table 2).

Rhizophora mangle is the most widespread of the mangrove species and occurs along a gradient of environmental conditions along the tropical and subtropical coasts of Brazil where mangroves are found (Schaeffer-Novelli, 1989). This species presents great phenological variability. Depending on environmental conditions, *R. mangle* can grow 25 m tall in humid climates with abundant freshwater and

Table 2. Mangrove tree species and their south distribution limit along the coast of Brazil. All tree species have their Brazilian north limit in the state of Amapá lat. N 4°30'.

Species	Southern Limit	Reference
Family Rhizophoraceae		
Rhizophora mangle L.	Praia do Sonho, SC, 27°53' S	Cintrón & Schaeffer-Novelli (1992)
Rhizophora harrisonii Leechman	Rio Preguiças, MA, 2°40' S	Santos (1986)
Rhizophora racemosa G.F.W. Meyer	Rio Preguiças, MA, 2°40' S	Santos (1986)
Family Avicenniaceae		
Avicennia schaueriana Stapf. & Leech	Laguna, SC, 28°30' S	Cintrón & Schaeffer-Novelli (1992)
Avicennia germinans L.	Atafona, RJ, 21°37' S	Lacerda & Rezende (1993)
Family Combretaceae		
Laguncularia racemosa (L.) Gaertn.	Laguna, SC, 28°30' S	Cintrón & Schaeffer-Novelli (1992)
Conocarpus erectus L.	Lagoa de Araruama, RJ, 22°35' S	Araújo & Maciel (1979)

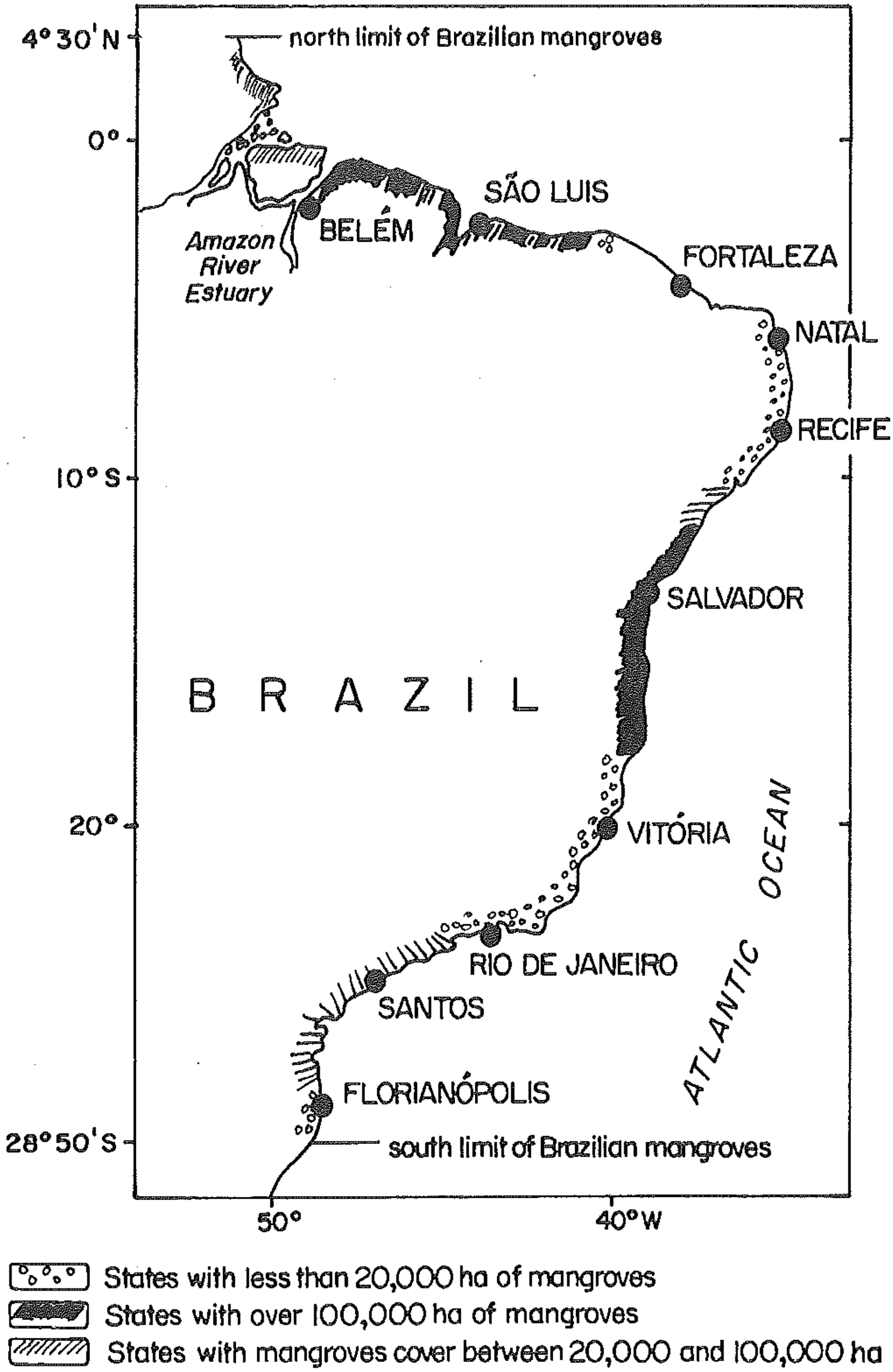

Fig. 1. Map of coastal Brazil showing major areas of mangroves and principal geographical features.

nutrient supplies. In hot, arid climates, *R. mangle* often grow only as dwarf trees less than 1 m tall (Prance *et al.*, 1975). *R. racemosa* and *R. harrisonii* have a much more restricted distribution and less phenological variability. They are only found along the humid north coast, where they generally exist as trees with heights up to 20 m growing as fringes landward of the *R. mangle* belts (Santos, 1986).

The two *Avicennia* species and the two species of the family Combretaceae (Table 2) have a similar distribution. *A. germinans* and *C. erectus* have their southern limit along the coast of Rio de Janeiro (Araújo & Maciel, 1979). In contrast, *A. schaueriana* and *L. racemosa* have a distribution similar to *R. mangle* and extend to the south coast of Santa Catarina (Table 2). Both species occur as shrub patches at their southern limit. However, along the north coast, *Avicennia* trees can reach 1 m in diameter (Schaeffer-Novelli, 1989).

Nypa palms, also a "true" mangrove species, are very abundant in Asian mangrove ecosystems, and have been present in northeastern Brazil during the Paleocene. However, it disappeared from the pollen record after this age (Dolianiti, 1955). Similar to *Pelliciera rhizophorae*, *Nypa fruticans* disappeared from the Brazilian mangroves, probably in response to arid conditions during the Holocene (Jimenez, 1984).

3.2 Associated mangrove flora

Many plant species occur associated with mangrove systems in Brazil. Their diversity seems to be a reflection of climatic conditions and the proximity of other ecosystems. This flora is highly variable from region to region and even from one system to the next within a region. A few species, however, seem to be associated with the "true" mangroves throughout their range in Brazil, and have even been considered as "true" mangrove species. The most wide-spread such species are the fern, *Acrostichum aureum* L, and Malvaceae *Hibiscus tiliaceus* L., which frequently form dense belts along the landward edges of mangrove systems, on elevated sites, and around dry and saline areas inside mangrove systems. In spite of their widespread distribution, their biology and ecology remain poorly known.

Along the humid north coast of Brazil, a number of tropical forest species invade the mangroves. These include the Leguminosae vine, *Dalbergia brownei* (Jacq) Urban, and the Apocynaceae liana, *Rhabdadenia biflora* (Jacq) Hull (Pantoja, 1993). From the estuary of the Amazon to Baía de São Marcos, Maranhão, where abundant rainfall protects mangroves from inundation by high salinity waters, assorted freshwater macrophytes occur in association with mangrove systems, e.g. the Araceae *Montrichardia arborescens* Schott and the Leguminosae *Mora oleifera* (Triana) Duke (Pantoja, 1993; Mochel, 1993). Also, a variety of palm species, e.g. *Euterpe oleracea* Mart., are typical of the north coast mangrove systems.

Along the south Brazil coast from Rio de Janeiro to Santa Catarina, where mangroves exist as narrow fringes between estuarine systems and mountain rain forests, epiphytes of the Bromeliaceae and Orchidaceae families pervade the canopy of mangrove trees, including particularly *Tillandsia usneoides* L., *T. stricta* Solander, *Vrizia* and *Epidendrum* spp. (Lacerda, 1984).

A number of salt marsh grass species occur as seaward fringes, as fringes along creeks and channels, and in gaps under tree canopies in the mangrove systems in southern Brazil, particularly in Paraná and Santa Catarina. This marginal distribution of the salt marsh grasses is due to the light limitation induced by the canopy of the mangrove trees (Santos, 1989; Costa & Davy, 1992). The most common salt marsh grass is *Spartina alterniflora* Loisel, which can be found as fringe environments associated with all Brazilian mangrove systems. This species may play an important role in mangrove systems by increasing the trapping capacity of sediments and chemical elements (Lacerda & Abrão, 1984; Costa & Davy, 1992). Other salt marsh grass species appear to colonize disturbed areas in mangrove systems. For example, *Sesuvium portulacastrum* L., Aizoaceae, and *Blutaparon vermiculare* L. Mears Amaranthaceae, form dense communities in disturbed mangrove areas, especially oil impacted areas such as Baía da Guanabara, Rio de Janeiro (Lacerda & Hay, 1982). Other salt marsh grass species that commonly are associated with mangroves include Batidaceae, *Batis maritima* L., the Chenopodiaceae *Salicornia ambigua* Michx., which together with *B. vermiculare* and *S. portulacastrum* occupy high salinity areas inside mangrove systems. In contrast, the Gramineae *Sporobolus virginicus* L. Kunth and *Paspalum vaginatum* Swartz frequently occur in more sandy soils within mangrove systems.

Submerged macrophytes are also commonly associated with mangroves, including higher plants (sea grasses), lower plants (macroalgae), and fungi. Among the seagrasses, *Holodule wrightii* Aschers.

(Potamogetonaceae) and *Ruppia maritima* L. (Zannicheliaceae) frequently grow associated with mangroves along the northeastern coast of Brazil.

Mangrove macroalgae are mostly found on the roots of mangrove trees and constitute the substratum of more than 50% of all macroalgae species. Other hard substrates, e.g. rocks, stones, and large shell fragments, serve as the substratum for nearly 30% of the species, while soft mud and sandy substrates account for the remaining 20% (Cordeiro-Marino *et al.*, 1992).

In most mangrove systems, the macroalgal community on trunks and aerial roots, is dominated by the Bostrichietum association, which includes the genera *Bostrichia, Caloglossa* and *Catenella*. These include 12 typical species with year-round reproduction (Braga *et al.*, 1990). Another typical association exists in mangrove sediments, the so called Rhizoclonietum association, formed by over 10 species of green algae of the genera *Rhizoclonium, Enteromorpha* and *Cladophora* (Pedrini, 1980).

Lichens are also abundant in mangrove systems. Marcelli (1990) lists more than 150 species of lichens for the Ilha do Cardoso mangroves in a state reserve along the São Paulo coast. Important genera include *Panmaria, Physma, Leptogun, Erioderma, Usnea,* and *Ranaline.*

The microflora of mangrove trees is determined by the submergence in sea water of the part of the tree infested by fungi. In general, submerged tree parts contain a completely different microflora as compared to non-submerged parts. However, near the high tide level, marine and terrestrial fungi overlap. A few host-specific species are rather restricted in their distribution, whereas the more common omnivorous species tend to have a pan-tropical distribution (Kohlmeyer, 1969). A recent survey of the mangrove fungi of the mangroves of Ilha de Maracá, Amapá, showed 32 species of macroscopic Basidiomycetes, the major organism responsible for wood decomposition, occurring in decomposing trunks, branches, and roots of *Avicennia* and *Rhizophora*. The dominant species was *Tyromyces chioneus* (Fr.) Karst., which occurred throughout the year in periodically inundated substrata with salinities less than 14‰ (Sotão *et al.*, 1991).

Various studies on phytoplankton composition and productivity of mangrove areas in Brazil have been undertaken, mostly along the southeastern and southern coasts of the country. In the Cananeia region of São Paulo, mangrove phytoplankton are dominated by the diatom, *Skeletonema costatum*, which comprises more than 80% of the phytoplankton. Other commonly occurring phytoplankton species include other diatoms, cyanophytes, and dinoflagellates. Maximum densities occur in the austral summer and minimum densities in the austral winter (Kutner, 1975; Tundisi *et al.*, 1973). Phytoplankton densities in mangrove waters are one order of magnitude higher than in adjacent coastal waters (Teixeira *et al.*, 1965). In the mangroves of Paraná, diatoms dominate the phytoplankton, but nanoflagellates are also abundant throughout the year (Knoppers & Opitz, 1984). Bacterial plankton is also abundant in the mangrove systems of southeastern Brazil. Watanabe & Kutner (1965 a,b) found densities of 21 to 132, 10^3 cells ml^{-1} and 6 to 316, 10^3 cells ml^{-1}. Major bacterial plankton forms were *Pseudomonas* and *Achromobacter*. Phytoplankton productivity reached a maximum of 1 g C m^{-2} d^{-1} in summer, and cells less than 50 μ in diameter were responsible for the major part of the production (Tundisi, 1981).

4. Mangrove Fauna

As in most New World mangroves, it is very difficult to identify an exclusive mangrove fauna. As a rule, mangrove animals also occur in other coastal habitats such as coastal lagoons, bays, and estuaries. However, many animal species characteristically occur in mangrove wetlands, and have their greatest populations in this habitat. Notwithstanding the hundreds of animal species that are found in Brazilian mangrove ecosystems or associated with such systems, this component of mangrove biocoenosis is the least well studied in Brazil. However, a few detailed local studies do exist and have been published (Araújo & Maciel, 1979). A number of species are threatened with extinction in mangroves in Brazil, including the red ibis, *Eudocimus ruber*, the monkey, *Chipotes satanas*, and the manatee, *Trichecus manatus*.

Among the most comprehensive surveys of Brazilian mangrove fauna are the pioneering work by Luderwaldt (1919) on the mangroves of Santos in São Paulo, and the mangrove inventories of Oliveira (1940, 1947, 1950), Oliveira and Krau (1953), and Araújo and Maciel (1979) on the fauna of the mangroves of Baía da Guanabara, one of the largest mangrove areas in Southeastern Brazil. Also noteworthy are the surveys of mangrove crustaceans of Pernambuco in northeastern Brazil (Coelho, 1963/64, 1965/66, 1966). However, by far the most complete survey of Brazilian mangrove fauna as a whole was undertaken by Aveline (1980).

The majority of mangrove fauna studies have focused on a few species of economic importance such as cockles and mussels (Paranaguá & Carvalheira, 1972; Pereira Barros and Macedo, 1967; SUDAM/UFMA, 1983), shrimps and crabs (Silva, 1977; Ramos, 1971; Fausto F, 1966; SUDAM/UFMA, 1983), and fish (Menezes, 1968; Eskinazi-Oliveira, 1972, 1974; SUDAM/UFMA, 1983).

The most recent and complete account of Brazilian mangrove fauna (Aveline, 1980) reported 363 species of mangrove animals, excluding mammals and insects. Birds were represented by 86 species, crustaceans by 51, molluscs by 33 and fish, the largest group, by 185 species, including resident, transient and migratory species. Although mammals were not included in this survey, other authors have reported more than ten species frequently found in mangroves, including raccoons (*Procyon cancrivorus*) and otters (*Lutra enudris* and *L. platensis*) (Araújo & Maciel, 1979; Maciel, 1984; Maciel & Magnanini, 1989). With respect to reptiles, the yellow crocodile, *Caiman latirostris*, has been reported to occupy the mangrove-fringed lagoons in Rio de Janeiro (Maciel, 1984).

Zooplankton in Brazilian mangroves are dominated by copepods with maximum densities occurring in the austral summer and minimum densities in the austral winter. Major species are *Euterpina acutifrons, Acartia lilijaborghi, Oithona ovalis,* and *Pseudodiatomus acutus*. Other commonly occurring organisms include *Tintinnidae, Appendicularia, Chaetognatha,* and medusae (Tundisi, 1969; Tundisi *et al.*, 1965). Tundisi & Tundisi (1968 found that copepods migrate toward the bottom during high tide as the light intensity in mangrove creek waters increases, and that they are carried landward in the presence of a gravitational estuarine circulation. Benthic copepods occupy decaying mangrove leaves, and are also abundant in Brazilian mangrove waters, particularly the Harpacticoida of the family Darcythompsoniidae, which are distributed throughout the Brazilian mangroves (Por, 1983).

The composition of mangrove fauna in Brazil is summarized in Table 3, according to Aveline (1980). The fauna can be grouped into four functional classes. (1) Species that occur directly associated with the aerial structures of mangrove trees.

Table 3. Fauna composition of Brazilian mangroves according to Aveline (1980).

Animal Groups	Number of Families	Number of Species
Birds	35	86
Crustaceans	16	59
Molluscs	16	33
Fish	60	185

Examples of this class are the tree-crab *Aratus pisonii*, the leaf snail *Littorina angulifera*, and the mangrove oyster *Crassostraea rhizophorae*, which colonizes the aerial roots of mangroves. Among the vertebrates, the mangrove bird *Conirostrum bicolor* is a permanent dweller of the mangrove canopy. (2) Species that live in terrestrial habitats but periodically migrate into mangroves. This class is represented by mammals, such as the crab-eating raccoon *Procyon cancrivorus* and otters; and reptiles such as crocodiles, and birds such as many members of the Falconidae (Maciel, 1984; Maciel & Magnanini, 1989). (3) Species that live in mangrove sediments and on adjacent mud flats. This class includes the largest number of species, in particular crustaceans and molluscs. Typical representatives are the crabs *Cardisoma guanhumi, Ucides cordatus*, the mussel *Mytella guyanensis* and *M. falcata*; the cockles *Anomalocardia brasiliana* and *Iphigenia brasiliensis*, and the snail *Mellanpus cofeus*. (4) Species which live in the marine habitat but spend part of their life cycles in the mangroves. The most conspicuous species in this class are shrimps, *Penaeus schimitii* and *P. brasiliensis*. Most fishes belong to this class, in particular mullets (*Mugil* spp.) and anchovies (Engraulidae).

A detailed accounting of the fauna of a small, 9 km long, mangrove creek on Ilha de São Luís, Maranhão, serves as a good example of the richness of the fauna supported by the adjacent mangroves (SUDAM/UFMA, 1983). More than 45 species of fish exist permanently or occasionally in the creek with mullet, *Mugil* spp., being most common and making up for 11% of all catches. The creek, Rio Cururucu, abounds with shrimp. The red shrimp, *Penaeus subtilis*, accounts for 43% of the catch, the white shrimp *P. schmittii*, accounts for 30%, and *P. notialis* and *P. brasiliensis* account for 14% and 13%, respectively. The creek also supports the benthic mollusc known locally as "sururu", *Mytella falcata* or *guyanensis*, with population densities of 6-10 g m^{-2} in creek muds. The cockle, *Anomalocardia brasiliana*, locally known as "sarnambi", is even more plentiful with population densities of 600-3,000 g m^{-2} where it exists in the creek. Rio Cururucu also supports the mangrove oyster, *Crassostrea rhizophorae*, the fiddler crab, *Ucides cordatus* (Linnaeus), and swimming crabs, *Callinectes bocourti* and *C. danae*.

5. Mangrove Structure and Ecology

Tropical depositional environments along coastlines with low wave energy are most frequently colonized by salt-tolerant trees and bushes, and the communities are collectively referred to as mangroves. In Brazil and elsewhere, these environments are most prolific in humid settings with ample river discharge, especially in river deltas and along shores of gulfs, estuaries, and lagoons, which are protected against significant ocean swells. Where the tidal range is great as in the case of the northern Brazilian coast from Amapá to southern Maranhão (mean tidal range 3-6 m and spring tidal range 4-8 m), the mangrove systems become particularly extensive because of regular tidal inundation by brackish and marine waters and also episodic flooding by rivers. In general, mangroves have been divided into (a) true mangroves, (b) minor elements, and (c) mangrove associates (Tomlinson, 1986).

True mangroves are salt tolerant floristic species, taxonomically distinct from terrestrial species, which are specially adapted to colonize and dominate the coastal environment, whereas minor mangroves occupy peripheral habitats and seldom form dominant communities (Cintrón-Molero & Schaeffer-Novelli, 1992). Mangrove associates consist of invading and transitional plants from adjacent fresh water and hypersaline environments (Cintrón-Molero & Schaeffer-Novelli, 1992). The mangroves of Pará are particularly diverse due to the fact that plant species transit from true mangroves to include many freshwater species from the Amazon floodplain (*varzea*) environment.

The distribution of mangroves is limited by low temperature, hyper-salinity, high wave energy, and lack of freshwater. The distribution of mangrove species with latitude along the Brazilian coast is a direct function of the influence of temperature. Mangroves extend much further to the south along the Brazilian coast, lat. S 34°, as can be expected solely based on latitude limits. The reason is the presence of warm coastal water temperatures due to the proximity of the southward flowing warm water Brazil western boundary current, and also the protection afforded to the mangroves along the southern Brazilian coast against chilly continental air masses by the coast-parallel mountain range, Serra do Mar. In contrast, mangroves only extend to lat. S 5° along the west coast of South America because of the proximity of the northward flowing cold water Perú eastern boundary current and also the persistent and extensive La Ninã near-shore upwelling system, which brings cold deep water onto the ocean surface along the Pacific coast of South America. For most parts, mangroves require that the sustained low winter air temperature exceeds 18°C, and mangrove distribution thus closely resembles the generic distribution of coral reefs. Since coral reefs are limited in their distribution along the Brazilian coast because of high sediment loads and mobile sand banks, the association of mangroves and coral reefs, which is very common in the Caribbean and the Pacific, does not hold true in Brazil.

Mangrove communities in most parts of the world are subject to episodic and sometimes frequent destructive impacts by tropical storms, which when fully developed are referred to as hurricanes in the North Atlantic, typhoons in the Pacific, and cyclones in the Indian Ocean. However, the northern South Atlantic Ocean exhibits slightly lower surface temperatures (only a relatively small area has surface temperatures in excess of 25°C) than surface water masses elsewhere in the tropics. This is one factor contributing to explain why tropical storms do not form or propagate across the South Atlantic. As a result, the coast of Brazil and its mangrove communities are spared the potentially destructive powers of tropical storms. Tropical storms affect mangroves most seriously when a combination of wind gusts from the ocean, flooding, and storm wave impact a mangrove coast. Stoddart (1971) found serious defoliation of several mangrove species in Belize subsequent to hurricane passage. However, Jennings & Coventry (1973) and Chapman (1976) found *Rhizophora* to be highly resistant to tropical storm damage. Whereas tropical storms do not impact Brazilian mangroves, prolonged periods of drought can be equally damaging, as in the recent case of mangroves in Sepetiba Bay (Ovalle, 1992). The construction of shallow grow-out ponds for *Penaeus* shrimp culture constitutes another serious stressor to mangrove systems, since ponds in many places in Latin America and elsewhere are constructed in mangrove areas. Once the mangroves have been cleared, the soil is exposed, organic matter oxidized and sulfides produced, reducing the soil pH, often well below 5, which is too acidic for shrimp rearing. The ponds are often abandoned after a few years but mangroves do not recolonize the area because of the high sulfide content in the soils.

Although many earlier studies emphasized the role of succession in mangrove distribution and development (cf. Oliveira, 1947, 1950; Chapman, 1976), it now appears that there exist few general patterns of mangrove distribution within a particular mangrove wetland and no clear patterns of succession. Rather, extreme local and regional variability is common as a result of physical-chemical variability and hydrological forcing. Instead of linear succession, mangroves consist of a mosaic of species, in general influenced and distributed as a result of physical and chemical characteristics of the sediments, microtopography, and magnitude and frequency of tidal and freshwater inundation (Reits, 1961; Ovalle *et al.*, 1990; Ovalle, 1992; Kjerfve *et al.*, 1993).

Structural development of mangroves in Brazil and elsewhere is optimum along (a) low relief coast, especially deltaic plains, with extensive estuaries and tidal creeks; (b) coasts with macrotides which provide regular and extensive flooding and dispersion of propagules, seeds, sediments, nutrients, and salts; (c) coasts with large freshwater discharge and high sediment load and adsorbed nutrients, experiencing episodic seasonal flooding of mangrove communities, transport and deposition of sediments onto mangrove-occupied tidal flats, and washing away of leached salts; (d) coasts with high rainfall, preferably in excess of 2,000 mm annually, where the seasonal signature is minimal and humidity remains high during the entire year; (e) low energy coasts where the wave power is dissipated by the time waves that reach the shoreline so that propagules may settle grow; and (f) prograding coasts with a voluminous fine-grained sediment supply and associated terrestrially derived nutrients as in the case of river deltas (Cintrón-Molero & Schaeffer-Novelli, 1992).

In Brazil, these conditions are most closely met in the northern states and territories, particularly Maranhão, which contains 36% of all mangrove wetlands of Brazil (Table 1). In places along the Maranhão coast, mangrove trees may be as tall as 45 m, and have DBH exceeding 0.8 m, and above-ground forest biomass of 280 ton/ha (Lacerda & Schaeffer-Novelli, 1992). The structural values for Maranhão are very close to the upper limits for mangrove trees anywhere in the world (Cintrón & Schaeffer-Novelli, 1983).

The mangroves of Sepetiba Bay, in the state of Rio de Janeiro, have been intensely studied by Silva (1988) and Silva *et al.* (1991), who found mangrove trees to have a height of 6.1 m, DBH of 8 cm, basal area of 21.6 m^2/ha, tree density of 4,510 trunks/ha, above ground biomass of 65.3 ton/ha (80%), below ground biomass of 16.3 ton/ha (20%), and total mangrove tree biomass of 81.6 ton/ha. Although there are only few data on below ground biomass for mangrove trees in Brazil, limited data from various locations around the world indicate that approximately 58% of the total mangrove tree biomass is above ground and 42% is below ground, and that the trunk accounts for 65% of the above ground biomass in *Rhizophora mangle* and 86 % in *Laguncularia racemosa* (Cintrón & Schaeffer-Novelli, 1983).

Cintrón & Schaeffer-Novelli (1983) also listed modest values for structural parameters of the mangrove trees of Cananeia, São Paulo (lat. S 25°) compared to the Maranhão data. Cananeia mangroves have an average height of 4-5 m, an average DBH of 8.1-10.1 cm, a density of 3,500-3,600 trunks/ha with a DBH diameter of at least 2.5 cm, and a basal area of 18.4-27.9 m^2/ha (Cintrón & Schaeffer-Novelli, 1983). Adaime (1987) also reported on mangroves from Meio River near Cananeia. She measured canopy heights of 9.2 m, basal area of 36.9 m^2/ha, and tree density of 3,700 trunks/ha. In Paranaguá Bay, Paraná, further to the south, Lana & Sesegolo (1993) reported canopy heights of 8-17 m for *Laguncularia racemosa* stands, and DBH of up to 50 cm.

Maybe the key ecological measure in ecosystems is the ability for plants to fix atmospheric carbon through photosynthesis, which is referred to as productivity. *Net productivity* is the portion of the gross production converted into carbon, which together with plant respiration make up the *gross production.* Mangrove ecosystems typically exhibit among the highest production rates of any aquatic ecosystem with rates varying from 1 to 5 g C/m^2/day when extrapolated for a year (Lacerda & Rezende, 1990). In mangroves, productivity is often measured by measuring litter fall from mangrove trees at forest sites, Lana & Sessegolo (1993) measured litter fall in Paranaguá Bay. They measured exceptionally high litter fall rates equivalent to a net production of 22.3 g C/m^2/day below *Laguncularia racemosa* and *Rhizophora mangle* trees, and 45.9 g C/m^2/day below *Laguncularia racemosa* and *Avicennia schaueriana* trees with summer litter fall rates six times greater than winter values and with leaf litter accounting for 79% of the total litter fall. These very high rates are presumably for a short time span rather than for a prolonged period. The half-life litter decomposition rate measured 10.5 days for *A. schaueriana* constantly submerged to 249 days for *R. mangle* on supratidal flats (Lana & Sessegolo, 1993), Silva (1988) and Silva *et al.* (1992) measured sustained litter fall rates of 2.6 g $C/m^2/day$ in the mangroves of Sepetiba Bay Rio de Janeiro, with leaf litter measuring 1.9 g $C/m^2/day$ or 73% of total net production. Because of reduced structural development of the mangroves in the Cananeia area, Adaime (1985) measured only 0.8 g $C/m^2/day$ litter fall of which the leaf litter made up for 63%.

Organic carbon in mangrove systems is either supplied via river drainage or via in situ mangrove production through photosynthesis. Mangrove wetlands typically export substantial amounts of organic carbon to the coastal ocean and this transport increases dramatically during spring tides (Ovalle *et al.*, 1990). Approximately 5% of the mangrove carbon production can be accounted for by herbivory by insects (Lacerda *et al.*, 1986; Lacerda & Rezende, 1990), who transmit the carbon to terrestrial food chains. Another 20% of the total litter fall is likely to be broken down and consumed by mangrove crabs and other animals within the mangrove wetland (Lacerda & Rezende, 1990). The remaining organic carbon in the form of litter fall or detritus, which can be more than 50% of the totals, is buried within the mangrove sediments. On a global basis, this may account for 30% of the total carbon burial (Lacerda, 1990). Mangroves and the size of mangrove areas indeed appear to be extremely important for secondary production in coastal and estuarine waters as documented in Indonesia (Macnae, 1974; Martusubroto & Naamin, 1977; Turner, 1980).

In general, ecological studies constitute the basis for rational management of mangrove and other ecosystems. Unless we have access to local structural and ecological data and have already developed a sound understanding of ecological relationships and dynamics, we cannot hope to manage mangrove ecosystems well. This both justifies and call for the continued measurement of structural mangrove parameters and the execution of ecological studies experiments, and modeling exercises.

6. Uses of Brazilian Mangrove Areas and Resources

6.1 Geographical variability

Most of, the Brazilian mangrove systems are intact, especially the extensive mangrove wetlands in the northern states, where the population density is low. Here, mangroves exist with minimal anthropogenic impact, and the mangrove ecosystems support rich populations of fish and shellfish. This is quite different from southeastern Brazil, where the mangrove areas have been cleared for coastal urban and industrial developments. Mangroves often serve as dumping sites for human trash and sediments from dredging. On a very limited scale, they were until recently cut down for fuel wood and pulp. This practice has now disappeared for all practical purposes with the increase in forest replanting of fast-growing species such as *Eucalyptus* and *Pinus*, which exceeded 6 million hectares in 1985 (Bacha, 1992). Harvesting of mangrove trees and use of the bark as a preservative of fishing nets is still practiced in some traditional fishing villages (Andrade, 1984; Diegues, 1990).

In the south of Bahia, the largest mangrove forests south of Maranhão, the mangroves are not utilized to any direct extent. On a limited scale, mangrove wood is used to build fishing gear and construct housing. Tannins extracted by boiling mangrove bark is used as a preservative of fishing nets. In Alagoas, mangroves are also used for house construction and fishing gear (Viegas & Esteves, 1987). In Rio de Janeiro, 40% of the mangroves in Baía de Guanabara have been cut down as the shores became urbanized, whereas only 10-15% of the mangroves have met the same fate in Baía de Sepetiba to the south.

During the 1970's, the tourism boom along the shores and on the islands of Baía a Ilha Grande near the border between the states of Rio de Janeiro and São Paulo, resulted in extensive reclamation of mangrove areas for building of marinas and condominiums. This, in turn, led to the complete disappearance of mangroves in many localities in this region. More than 50% (ca. 2,000 ha) of mangroves in Baía da Ilha Grande were lost due to reclamation.

6.2 Historical uses of mangroves

Evidence of utilization of mangrove resources by pre-historic human nomads is well documented at many sites along the Brazilian coast. Examination of shell mounds have yielded much information on the very early use of mangrove resources. These shell mounds are called *sambaquís* and have largely been found along the coast where the remains of shellfish and finfish from mangrove environments are abundant (Beltrão, 1976; Kneip, 1977). These huge shell mounds were for the most part generated between 7,000 and 2,000 years BP.

Pre-colonial indians, in contrast, seem to have utilized mangrove resources to a much lesser extent. One explanation for this is the defeat of the littoral indians by the major Tupi-Guarani indian groups. These indians came from the tropical forests of the interior of the country and had little use for mangrove wood or other mangrove resources. After the discovery of South America by Europeans, use of mangrove resources increased dramatically. This was both the result of Portuguese travelers, who already knew of mangroves and their many uses from Africa and south and southeast Asia, and also due to the influx of some 4,000,000 African slaves to Brazil, many of whom came from mangrove-rich coastal areas in west Africa, specially Nigeria. One of the uses of mangroves, was the boiling of mangrove bark for tannin production, which the Portuguese Crown attempted to regulate in the eighteenth century because of the importance of tannin to produce good parchment.

Presently, intensive use of mangrove resources in Brazil is limited to only parts of the coast. Traditional human societies in mangrove wetlands can be found along the sparsely populated north coast of Brazil in the states of Pará and Maranhão. These traditional societies still depend on mangrove resources, in particular mangrove fisheries (Andrade, 1984). They collect crabs, fish, oysters, and molluscs intensively, however, their fishing practices are environmentally sound. For example, crab gatherers in Pará use only their hands to avoid significant injuries to the animal. Also, they only collect male animals and return female animals intact to the environment. In another practice, they "rear" teredinid (*Teredo* spp.) bivalves by felling mangrove trees and leaving the trunk to rot in the forest (Andrade, 1984).

6.3 Fisheries

Although studies in Asia clearly demonstrate the strong positive correlation between shrimp catch and area of mangrove ecosystems, such definitive studies do not exist for Brazil, but, it is believed that mangroves support fisheries by either providing food, nursery areas, or protection against predation. Inventories of specific mangrove habitats indicate that mangrove areas in Brazil are rich in fish and shellfish resources. For example, the mangrove ecosystem of Tutóia, Maranhão, near the Piauí border supports 1,800 mostly artisanal fishermen, who caught 1,162 tons of *Penaeus* shrimp in 1977 (SUDAM/UFMA, 1981). Another example is Baía de Sepetiba, Rio de Janeiro, where 3,200 ha of mangrove wetlands yields between 100 and 200 tons of shrimp annually. In addition, Baía de Sepetiba yields between 200 and 400 tons of finfish and more than 10 tons of shellfish (besides shrimp) annually (Lacerda *et al.*, 1988).

6.4 Mariculture

Whereas the mangroves of other Latin American countries such as Ecuador were severely impacted by shrimp aquaculture operations, this is still a small-scale business in Brazil. Brazil only produces 2% of the shrimp mariculture production of the Americas as compared to 76% in Ecuador (Tecnarão, 1993). Brazil produces less than 2,000 tons of shrimp in ponds excavated in less than 3,000 ha of mangrove wetlands (Table 4). Thus, in Brazil, the conversion of mangroves to shrimp aquaculture ponds is a very small business in comparison to the 100,500 ha of aquaculture ponds in Ecuador. Although, there presently is a trend in Brazil to expand shrimp farming, the legal necessity for environmental impact studies prior to construction and operation of shrimp farms will hopefully prevent major adverse impact on mangroves from mariculture.

6.5 Agriculture and cattle farming

There is ample land in Brazil with far better soil for agriculture and cattle farming than mangrove soils. Contrary to other countries, agriculture and cattle farming has negligible impact on mangrove ecosystems. In a few areas, in the watersheds of Baía de Sepetiba and Baía da Guanabara in southeastern Brazil, extensive cattle farming and vegetables production occur in non-wetland areas adjacent to mangroves. The impact of these activities on the mangrove wetlands are however not known, although relatively high levels of pesticides (DDT, DDE, and DDD) have been measured in some mangrove areas in these bays (Japenga *et al.*, 1988)

6.6 Salt production

Conversion of mangrove wetlands into salt pans for commercial salt production has changed permanently thousands of acres of mangrove areas along the arid northeastern coast, especially in Rio Grande do Norte. However, the ecological and economical costs and socio-economic constraints of such conversion has hampered its expansion to other areas and

Table 4. Shrimp production and area of shrimp mariculture projects in Brazil located in previous mangrove systems according to DEPAQ/IBAMA (Tecnarão, 1993).

State	Shrimp Production (tons)	Shrimp Mariculture Facilities (ha)	Number of Companies
Maranhão	138	230	1
Piauí	146	338	4
Ceará	202	430	2
Rio Grande do Norte	113	150	5
Pernambuco	110	172	2
Bahia	760	700	4
Santa Catarina	183	161	1
Total:	1,652	2,181	19

led to a total prohibition of the practice of constructing salt pans (*salinas*) elsewhere. The production cost of salt from converted mangrove areas is generally much greater than the cost of salt production in naturally hypersaline lagoons, usually US$ 20 vs. US$ 5 per ton. Salt production companies, which have converted mangrove areas, are now obliged to replant the original mangrove forest, and a number of these companies have become bankrupt.

6.7 Anthropogenic impacts due to urbanization

The expansion of urban areas as a result of housing, industrial, harbor, and tourism development represents the major anthropogenic activity which causes reclamation of mangrove areas. We estimate that at least 20% of the original mangrove cover has disappeared because of major anthropogenic impact on mangrove systems along the coast of Brazil.

Reclamation of mangrove areas for housing is a major problem along the more developed southeastern coast. Particularly valuable coastal sites have been turned into large condominia where remaining stands of mangroves are left as gardens (Fig. 2). However, not only upper class housing developments impact mangroves. During the last decade, following the economic crises, Brazil has witnessed a rapid increase of human population in coastal areas due to internal migration. People congregate around the perimeter of large coastal cities and towns, where they exploit any available natural resource, including mangroves. Examples of such typical settlements in mangrove areas north of Rio de Janeiro are shown on Figs. 3, 4.

The necessity to pump increasing volumes of freshwater to coastal towns has forced the construction of numerous dams on rivers. The dams serve not only for water storage but also as sediment sinks, these otherwise would be transported to the river estuaries and deltas where mangroves flourish. As a result, many coastal areas have been starved of sediments and become highly erosive. Some important mangrove areas, such as the 800 ha mangrove forest in the Rio Paraiba do Sul estuary (Fig. 5), have been severely impacted by erosion.

Industrialization has likewise caused major local impact on mangroves, particularly along the southeastern coast of Brazil. Oil spills have adversely affected mangrove areas in the Santos Bay region with significant destruction of mangroves as the end result (Lamparelli *et al.*, 1993). Trace metals have also contaminated many Brazilian mangrove resources along the coasts of Rio de Janeiro, São Paulo, and Bahia, in particular toxic elements such as lead, zinc, and cadmium. Although with only minor direct effect on the mangrove biota, contamination of mangrove resources, in particular shellfish, is a major concern of human public health authorities (Lacerda *et al.*, 1983; Pfeiffer *et al.*, 1985.

7. Laws and Legislation

A number of laws exist that protect mangroves and mangrove resources in Brazil, but unfortunately enforcement of these laws is at best only spotty. The most important laws relative to mangrove protection and regulation are Federal Decree 3.438 passed on 17 July 1941; Federal Decree 4.771, passed on 15 September 1965, together with Federal Law 6.535, passed on 15 June 1978, establishing *codigo florestal* for preservation of vegetation and forests, including mangroves; Federal Law 5.197 passed, on 3 January 1967, with provisions for the protection of mangrove fauna; and Federal Law 6.902, passed on 27 April 1981, relating to the creation of environmental protection areas (Maciel, 1989). In addition, coastal state government agencies have issued various decrees and regulations to serve as guidelines for coastal development activities while at the same time protecting local mangrove resources.

A national coastal zone management plan (PGNC) was passed into Federal Law 7.661 on 16 May 1988 to control coastal pollution, degradation of coastal habitats, decreased fisheries catches, and tourism (Herz, 1990). However, the law has not yet been implemented. The law defined the boundaries of the coastal zone as stretching from 2 km inland until 12 nautical miles seaward relative to the mean high tide line. The coastal zone, thus defined, measures 200,000 km^2 and includes all of the Brazilian mangrove areas. The Comissão Interministerial de Recursos da Marinha (CIRM) was responsible for preparing and implementing the management plan and for providing financial and technical aid to coastal state governments for the creation of optimum management plans (Herz, 1990).

A geographical information system (GIS) database was used for macro-zoning of the entire coast of Brazil, i.e. the division of the coast into areas with the highest potential for ecological conservation, port facilities, urban growth, industrial expansion, recreation and tourism, exploitation of minerals and hydrocarbons, agriculture and silviculture activities, and preservation of historical, cultural, and aesthetic assets. A series of thematic maps were over-laid to classify the coastal zone of Brazil, using 280 cells, each measuring 30 minutes latitude by 30 minutes longitude (Herz, 1990). With collaboration from the federal government and a variety of organizations with an interest in coastal areas, the department of environment (meio ambiente) in each coastal state is currently in the process of micro-zoning the coastal resources, based on maps to the scale 1:12,500 and 1:25,000 (Herz, 1990).

8. Management of Mangrove Areas and Resources

A summary of management units for the mangroves of Brazil is presented in Table 5. Brazilian mangroves are quite diverse in terms of structure and biodiversity, which vary from site to site. This site specific variability should always be considered whenever management policies are to be applied. Notwithstanding, this we suggest a general but preliminary classification of management categories for Brazilian mangroves.

When considering rational management guidelines, we propose a division into the following general categories: (A) mangrove conservation reserves, (B) mangrove forest reserves, (C) mangrove fisheries areas, and (D) damaged mangrove areas (Table 5). Guidelines may additionally be needed for mangrove areas that due to their small size or high degree of degradation, or any other reason which impoverish their ecological and biological characteristics, are subject for conversion to other uses, e.g. agriculture, aquaculture, and urbanization. However, such a category is in theory not necessary as Brazilian legislation considers mangroves as permanent conservation areas. It is our view that socio-economic and geographical characteristics of Brazil strongly implies that conversion of mangrove areas for other uses is neither economically nor ecologically sound. Mangroves provide many direct and indirect benefits to coastal populations, and conversion of mangrove systems should be avoided. Rather, it would be better to recuperate "poor" mangroves and return them to serve their inherent ecological role.

Mangrove conservation reserves (MCR) include those forests designated for conservation, tourism, recreation, and scientific studies. Included are also fragile mangrove areas of significant scientific interest, e.g. the *Laguncularia racemosa* forest of the Maceio River estuary on Ilha Fernando de Noronha (Herz, 1991), which thrives under unique oceanic conditions. High biodiversity sites comprise another type of MCR due to the inherent biological significance of rich biodiversity forests and their potential as refuge of endangered species. Examples of high diversity systems include the extensive mangroves along the coast of Pará and the unique Amazon River estuary mangroves, where freshwater macrophytes mix with "true" mangrove species (Pantoja, 1993). Included among MCR are mangroves of particular importance in providing indirect benefits to coastal areas, such as maintaining water quality, providing protection against erosion and storms, and stabilization and building of coastlines and islands. Examples include the mangroves of certain southeastern mangrove sites, e.g. in Baía Todos os Santos, in Baía da Guanabara, and the Santos-Bertioga region, where intensive industrialization and harbor activities have led to a decrease in coastal water quality. Included

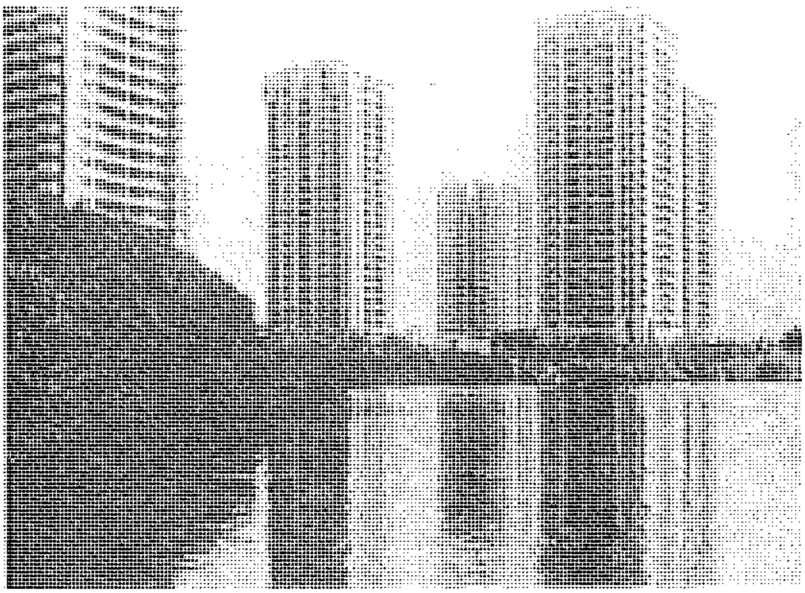

Fig. 2. High rise condominia tower over Lagoa de Marenpendi in Rio de Janeiro and remnant stands of mangroves are left as decorative gardens.

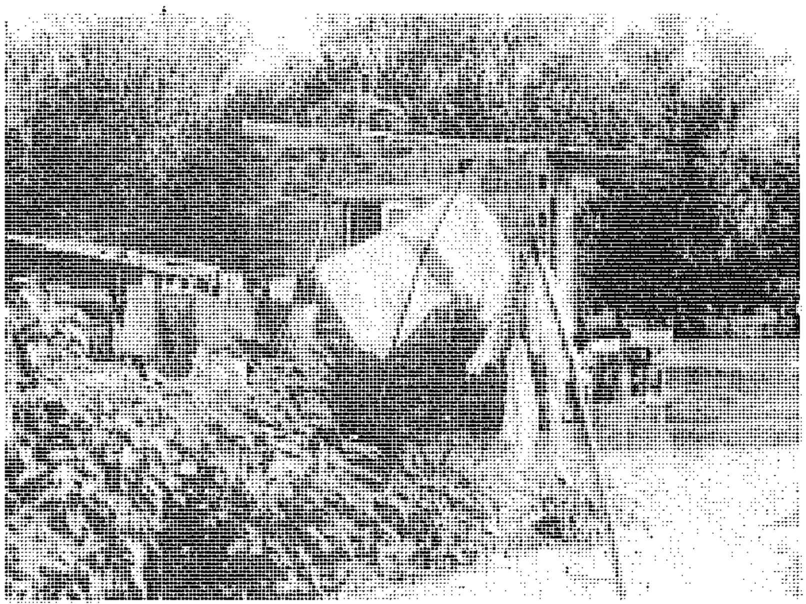

Fig. 3. Low-income housing developments (favelas) encroach upon mangroves along the north coast of Rio de Janeiro, representing a major form of anthropogenic impact on mangrove systems.

Fig. 4. Low-income housing developments (favelas) encroach upon mangroves along the north coast of Rio de Janeiro, representing a major form of anthropogenic impact on mangrove systems.

Fig. 5. Sediment starvation and rising relative sea level in the delta of the Rio Paraiba do Sul in the northern part of Rio de Janeiro have resulted in severe shoreline retreat and erosion of mangrove areas.

among MCR are the fringe mangroves, which provide effective protection to shorelines and coastal ecosystems. Examples include the mangroves of São Luís, Maranhão and the south of Bahia, where the mangroves help trap huge amounts of terrestrial sediments, and thereby protect the offshore coral reefs of Parcel Manuel Luiz and the Abrolhos archipelago, respectively, from excessive siltation.

Mangrove forest reserves (MFR) is a management category which includes those mangroves designated for sustainable production of timber and other forest products. MFR include extensive mangrove stands with high structural development and biomass, allowing for economically viable exploitation with conservation of the many ecological properties of the mangroves. Multiple sustainable utilization of other mangrove resources should be encouraged in MFR. Examples of mangrove systems in this category are the extensive forests along the coast of Amapá and Maranhão in northern Brazil, which comprise over 60% of all Brazilian mangrove areas, and where forests frequently are taller than 40m.

Mangrove fisheries areas (MFA) is a category which includes mangroves associated with extensive waterways or coastal waters, with high productivity of fish and shellfish species that spend at least part of their life cycles in mangrove areas, and use them for food, nursery, or shelter. Such systems include areas where catches consist mostly of mangrove species, and do not involve activities in adjacent coastal waters. Examples are the mangrove crab fisheries in Piauí and other sites along the coast of northeastern Brazil and the harvesting of mangrove oysters along the coast of São Paulo. More than 30,000 persons depend directly on these fishing and harvest activities. MFA also include those areas where large catches of mangrove-dependent estuarine species of fish and shellfish are harvested, and protection and restriction of activities in adjacent coastal waters are necessary. Examples include shrimp fishing in mangrove waterways and coastal waters along the coasts of Pará, Maranhão, and the Baía de Tacama in southern Bahia. In these areas, it is logical to expect a direct relationship between catch and the area of mangroves.

Table 5. Management categories and examples of mangrove systems in Brazil.

Management Category	Sub-Category	Example
A. Mangrove Conservation Reserves	Fragile mangrove systems for conservation and scientific study	Maceio River estuary, Ilha Fernando de Noronha
	Mangrove systems with high biodiversity	Mangroves of the coasts of Pará and Maranhão
	Mangrove systems with specialized ecological function	The efficient sediment trapping mangroves of Baía São Marcos, Maranhão and southern Bahia
B. Mangrove Forest Reserves	Mangrove systems with sustainable utilization of forest products	Mangrove systems in Amapa and Maranhão
C. Mangrove Fisheries Areas	Crab fishing	Mangrove wetlands in northern and northeastern Brazil
	Oyster harvesting	Coast of São Paulo
	Shrimp fishing	Coastal and estuarine waters off Maranhão and southern Bahia
D. Damaged Mangrove Areas	Mangrove systems converted for other uses	Abandoned shrimp and salt ponds in northeastern Brazil
	Construction of tourism and resort areas	Southeastern Brazil
	Oil impacted mangroves	Bertioga and Santos, São Paulo, and other industrialized areas

Damaged mangrove areas (DMA) are those which have been converted to non-sustainable uses, submitted to ecologically unsound management practices at the expense of mangroves, and impacted by anthropogenic activities with detrimental effects on the functioning of the mangrove ecosystem. Examples include abandoned shrimp ponds and non-productive salt pans in converted mangrove areas along the northeastern coast of Brazil, and bankrupted tourism projects that deforested mangrove forests along Ilha Grande Bay in southeastern Brazil. Also, DMA are those impacted by oil spills, e.g. mangroves of the Santos-Bertioga coast of São Paulo, and the chronically impacted mangroves of the industrialized south Brazil coast, where pollutants are constantly being discharged into mangrove wetlands (Lacerda, 1984).

In conclusion, a detailed survey to classify the mangrove areas of Brazil into the above four categories is far from complete. It is likely that different and more detailed mangrove management categories would be even more useful due to the high diversity of mangrove habitats along the coast of Brazil. Any management strategy for the country's mangroves should be kept flexible and be allowed to evolve as necessary.

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