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Conservation of coastal marine environments

by

Robert C. West *

Abstract: The intertidal zones of the Central American coasts are here classified as 1) cliffed or rocky headlands, 2) sandy beaches and 3) low-lying alluvial coasts. The ecosystems associated with these zones are among the most complex and biologically productive, but least understood, of the biosphere. Emphasis is placed on the importance of estuarine alluvial coasts with tidal, or mangrove, forests, which comprise approximately 30 percent of the Central American coastline. As demonstrated by studies in southern Florida, estuarine mangroves play a key role in the maintenance of juvenile forms of marine life by controlling the availability of nutrients through the accumulation of decaying detritus and the growth of organisms on the stilt roots. Thus the preservation of mangrove is essential for the maintenance of much of the offshore fishing resources. But in various parts of the Central American coast, mangrove is endangered by overcutting, industrial pollution, and urban resort development. Although less vulnerable than the mangrove coast, sand beaches and cliffed headlands deserve conservational consideration because of both their biologic and touristic value. The establishment of national parks and wildlife refuges along various parts of the Central American littoral may be a first step in the conservation of that region's coastal resources.

Seacosts have long been important for man's livelihood. With rapidly rising populations in the past half century, and with the movement of large numbers of people to the coasts to engage in agriculture, industry, commerce, and recreation, the significance of the sea margins is rapidly increasing world-wide. Partly in response to the rising economic and political aspects of the sea and its littoral, various governments and scientific institutions have begun intensive studies of the coastal marine environments. Such investigations have sought to understand the complex ecology of seacoasts, to inventory existing coastal marine resources, to point out the magnitude of the destructive exploitation of such resources, and to suggest wiser methods for utulizing them. Most of these investigations, however, have been limited to the seacoasts of the developed countries of Europe, North America, and Australasia. Relatively few studies have been made for the coasts of developing countries, where guidelines for future research development are badly

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needed. For the Central America–Panama area only the coasts of El Salvador have received adequate preliminary study, mainly by German scientists associated with the Instituto Tropical de Investigaciones Científicas of the Universidad de El Salvador during the 1950s* More recently various studies on particular aspects of the biology of Central American seacoasts have been done by both North Americans and nationals under the auspices of the Organization for Tropical Studies, Inc. (OTS) and other scientific bodies. But in general we can say that such investigations are still few in number.

My concern in this presentation lies mainly within the complex geography and ecology of the intertidal zone of the coast. Many biologists have commented that the ecosystems within the intertidal zone are perhaps the most complex, diverse, and biologically productive of the biosphere, and that such ecosystems are among the least understood, because of the complexity of the numerous scientific disciplines involved in their study. For here we are concerned with the interface of ocean and land, of salt and freshwater habitats, of tidal and fluvial fluctuations, and many other interfacial parameters.

Because they are so complex in a natural state, only a slight interference by man can easily upset these delicately balanced intertidal ecosystems, leading to a rapid decrease in biological productivity. A prime prerequisite, of course, is a greater knowledge of the nature of the intertidal zone along the Central America-Panama coasts, and how their resources are being exploited by man, before effective measures can be suggested for their conservation. Ideally, we need something like **Ricketts'** and **Calvin's** (13) *Between Pacific Tides,* but the research needed for such a compendium has barely started.

For the purpose of this report the Central America-Panama coast has been classified into three different types: (I) cliffed or rocky headlands; (II) sandy beaches; and (III) low-lying alluvial coasts. The intertidal portions of these types will be considered briefly in terms of their respective ecosystems, exploitation by man, and possible conservation measures desirable to maintain environmental quality. Because they are largely subtidal, coral reefs and meadows of shallow-water sea grasses off coasts have been excluded from this discussion.

ALLUVIAL COASTS AND MANGROVE FORESTS

Emphasis is placed on the importance of alluvial coasts with tidal forests, or mangroves, which comprise approximately 30 percent of the Central America-Panama coastline (Fig. 1). Mangrove woodland and patches of salt marsh occur in the tropics mainly in saline tidal areas that receive little wave action and where alluvium is abundant. Protected by offshore coral-sand islands and a long barrier reef, the coast of Belize presents the longest nearly continuous stretch of mangrove woodland in Central America. Deeply indented bays, such as the Gulf of Fonseca, the Gulf of Nicoya and the Gulf of San Miguel along the Pacific, where tidal range is high, contain large areas of tidal forest; mangrove may extend up river courses as far as brackish water is carried by the tide (Fig. 2). Perhaps the most common occurrence of mangrove and marsh is along muddy lagoonal shores that lie

* The results of these studies were published in the *Comunicaciones* of the Instituto and in special publications in German, such as H. G. Gierloff–Emden's monograph, Die Küste von El Salvador, *Acta Humboldtiana,* Ser. Geographica et Ethnographica, no.2, 1959, 183 p.

behind barrier sand beaches, as illustrated by the Estero de Jaltepeque in El Salvador (Fig. 3). Such are found in places along the entire Pacific coast of Central America and Panama and along much of the Atlantic coast. Finally, within their intertidal zones, river deltas afford excellent conditions for the formation of mangrove forests, mainly because of the abundance of silt. The Térraba-Sierpe delta system of southwestern Costa Rica is one of the best examples of this mangrove habitat in Central America (Fig. 4).

Most of the low-lying, mangrove-lined coastal forms described above exhibit estuarine characteristics. Estuaries have been variously defined, but most definitions include deeply indented bays, lagoons, or wide, shallow river mouths that have a free connection with the open sea and within which sea water is diluted with freshwater from land drainage. Thus, a marked salinity and turbidity gradient, which may vary seasonably, is characteristic from the landward toward the seaward portion of the estuary, providing desirable habitats for several species of aquatic life. Moreover, river inflow not only supports the gradient, but also provides nutrients, both in dissolved and suspended forms, necessary for the growth of organisms.

It is well known that estuaries in many parts of the world serve as spawning grounds and nurseries for many species of offshore marine life (**Hedgpeth,** 9). This is especially true in the warm waters of tropical and subtropical coasts. In his study on the ecology of the ichthyofauna in the Gulf of Nicoya, **León** (11) indicated the large population of juvenile forms of various oceanic fish, such as drumfishes (Sciaenidae) and sea catfishes (Ariidae), that utilize this large estuary as a nursery. Other studies have shown that many lagoons and bays along the Central American coast serve a similar function in the life cycle of the peneid shrimp, whose exploitation has become so important in the national economy of many isthmian countries.

It may be less well known that the tidal channels within the mangrove that occurs along the shores of estuaries possibly play a key role in the maintenance of the juvenile forms of marine life. In their studies of the estuaries in southern Florida, **Heald** and **Odum** (8) and **Odum**(12) found that detritus that accumulates within the tangle of stilt roots of the *Rhizophora* mangrove forms the main food source for aquatic species. Within the mangrove swamp *Rhizophora* usually occupies the banks of tidal channels, where fine mud accumulates and water salinity averages between 15 and 20°/oo. Its stilt roots, alternately inundated and exposed by tidal fluctuations, easily entrap floating debris and at high tide are accesible for swimming organisms (Fig. 5). Fallen leaves and other plant material caught in the roots are decomposed by micro-organisms which are consumed along with the converted detritus by omniverous organisms such as juvenile shrimp and midge larvae. These, in turn, are food for larger species; juvenile forms of 60 such species were noted in the Florida studies. Quite probably similar surveys in the mangrove-lined estuaries of Central America and Panama would yield like results.

The stilt roots are also hosts for various algae, sponges, and other small plant life, and when fully developed the roots and underlying mud become the habitat of a number of semi-aquatic organisms, such as various mollusks and crustaceans that furnish food for both man and other animals (**Zilch,** 16). **Glynn** (7) in his study of the Panamanian coasts indicated that, because of the low tidal range, stilt roots of *Rhizophora* on the Caribbean side are often submerged continuously and support a lush growth of small plant and animal life. On the Pacific coast, where tidal range is large, mangrove roots are exposed for several hours at low water, and as a result support a limited epibenthic population. More comparative studies of the Pacific and Caribbean shores of Central America are needed to corroborate Glynn's findings.

Inland from the *Rhizophora* forest, a woodland of black mangrove (*Avicennia*), white mangrove (*Laguncularia*), or a mixture of all three species often occurs on slightly higher ground and more compact soils (Fig. 6). These inland areas are usually completely inundated only by spring tides and consequently do not serve as feeding grounds for aquatic life to the same degree as do the *Rhizophora* fringes along the tidal channels. However, the pencil-like pneumataphores of the *Avicennia* mangrove support algal growth on which feed various snails and crabs. Land crabs, especially the large blue *Cardisoma*, are abundant in the better drained areas of the *Avicennia* and *Laguncularia* woodland near the inner edges of the mangrove. These and other wild-life of the inner mangroves, such as various shellfish, turtles, and iguanas, are avidly sought by people living within or near the swamps for protein-rich foods.

Although relatively depauperate in numbers of species, the wild-life population of the mangrove forest is sufficiently abundant to have attracted human settlement since ancient times. This is indicated by the frequent occurrence of shell mounds and other archaeological sites within or on the edges of the mangrove. Today most of these swamps are still inhabited, chiefly by people who cut certain species of mangrove trees to make charcoal, sold in towns and cities in the interior, or by those who utilize mangrove wood as fuel in manufacturing salt on a small scale (Fig. 7). Others are fishermen who exploit commercially the products of the tidal channels and estuaries. All of these people obtain much of their protein food in the form of fish, crabs, clams and other wildlife in the mangrove.

To date, the exploitation of the mangrove woodland in most of Central America and Panama has not been of sufficient intensity to endanger severly the vegetation or wildlife. However, in El Salvador, where population pressure is reaching intense proportions, there are signs that the mangrove along the coastal lagoons is being overexploited by an increasing swamp population. For example, along the Estero de Jaltepeque large tracts of white mangrove forests have been nearly destroyed by the *carboneros* (Fig. 8). Within these cutover areas the crabs and clams have virtually disappeared due to the lowering of the water table that has resulted from increased evaporation on bare surfaces and because of decreased food supply for these animals. In turn, this has put increasing pressure on the crab populations of uncut mangrove areas in the people's relentless search for protein food. Fortunately, the *Rhizophora* forests along the tidal channels have suffered little destruction as yet, but the wood serves well for charcoal and firewood and the tannin content of the bark (25 percent) could attract exploitation in the future. Once the *Rhizophora* fringe is badly disturbed, the biotic productivity of the estuarine waters will probably decline precipitously; and with the destruction of the interior black and white mangrove areas will be a decline in the numbers of clams, crabs, and other animals–an important source of protein for local people. For such reasons the protection of the mangrove forest from overexploitation would seem to be essential.

Mangrove, particularly the vital outer fringe of *Rhizophora,* can be endangered even more seriously by port, industrial, or recreational developments. For example, in 1968, near the Atlantic entrance to the Panama Canal, a large oil spill from a ruptured tanker caused severe damage to intertidal zones along the coast, including mudflats, mangroves, sand beaches, and rocky headlands. The mangroves suffered most. All red mangrove seedlings and all sedentary life on the stilt roots of mature *Rhizophora* were contaminated with oil and eventually died (**Rützler** and **Sterrer**, 14). Moreover, wholesale destruction of fringing mangrove along the coast of Venezuela by recreational projects (e.g., clearing of the tidal woodland to make room for building summer homes on pilings) has caused environmental agencies to protest further deterioration of the coastal habitat (**Canestri** and **Ruíz**, 2).

A further cause for deterioration of estuarine environments, which has been little studied in Central America or Panama, is the contaminating effect of biocides and agricultural fertilizers carried in solution by rivers into bays, lagoons, and deltas. Such studies should be of prime importance to ascertain the degree of direct toxicity upon organisms within the mangrove swamp, as well as indirect effects, such as the reduction of dissolved oxygen. These investigations would be particularly revealing along the Pacific coast, adjacent to the intensive cotton producing areas of Guatemala, El Salvador, and Nicaragua.

RIVER DELTAS AND RESERVOIRS

Another paper of this symposium deals with the effects of dams on river ecology. I wish to expand this topic to consider the possible effects of water impoundment on the ecology of river deltas in the tropics where mangrove abounds. I take as an example the Térraba-Sierpe delta system in southwestern Costa Rica. The construction of the proposed dam and reservoir on the middle Térraba River will cut off the supply of most of the bed load and much of the suspended load, as well as a large amount of nutrients, that are now carried to the river mouth where they are distributed within the delta by tidal and longshore currents. Moreover, after a period of greatly decreased water discharge while the reservoir is filling, water released for power generation will completely change the normal seasonal regime, on which the present ecology of the active delta is based.

The effects of these changes on deltaic ecology might be predicted by comparing the two sectors of the Térraba-Sierpe system (Fig. 4). The presently active part of the delta is its northern sector, controlled by the Térraba River and its seasonally variable discharge of freshwater into the deltaic distributaries. Both the abundance of fresh water and the active building of natural levees in its lower course appear to have limited tidal saltwater incursion and the growth of mangrove to a band 3 to 5 km wide along the outer delta fringes. The southern sector, on the other hand, is controlled by the Sierpe river, which is now inactive. Formerly the Sierpe appears to have carried the greater part of the Térraba discharge, building the southern sector of the delta. A shift of the main channel to its present northern position may have deprived the Sierpe of its fresh water, reducing it to a tidal stream. It is postulated that the loss of river discharge and active sedimentation resulted in subsidence of the Sierpe delta, permitting the incursion of tidal sea water far inland. This, in turn, may have resulted in the present extensive mangrove forest, a band 10 to 15 km wide, that today covers the Sierpe sector of the delta.

In addition, loss of sediment has made the seaward edge of the Sierpe delta subject to wave erosion, in contrast to the progradation of the active Térraba portion of the coast. Comparison of aerial photographs of the delta taken by the Instituto Geográfico of Costa Rica in 1960 and 1972 show coastal recession of up to 600 m along some portions of the Sierpe coast by wave erosion within 12 years (Fig. 9).

On the basis of these comparisons (and provided the projected dam and reservoir become reality) the following predictions as to the fate of the active Térraba delta are made:

1) Because of river sediment loss, land subsidence likely will permit the penetration of tidal salt water inland, reducing agricultural land and expanding mangrove vegetation.
2) Loss of river sediment supply will also cause increasing wave erosion along the delta front, destroying beaches and the outer fringe of mangrove in the course of coastal recession.
3) The change from a natural seasonal regime of freshwater discharge to an equalized year-round flow from the reservoir may cause repercussions of unknown character to the delta ecosystem.

Before the dam and reservoir are completed, detailed ecological studies of the Térraba-Sierpe delta system should be done to ascertain present conditions. These studies could serve as a base against which to measure the ecological changes induced by the effects of the dam after its completion. The results could serve for planning purposes when other dam projects are contemplated in other parts of Central America and Panama.

OTHER COASTAL TYPES

The remaining coastal types mentioned previously–sandy beaches and rocky headlands– comprise more than two-thirds of the total shores of Central America and Panama. These will be considered briefly. The ecosystems associated with these types are perhaps less complicated than those of the mangrove-lined estuaries. Nonetheless, all are important in terms of their particular vegetation and wildlife assemblages. And in terms of man's present-day use of them, in particular for recreation, they are highly significant. Therein lies their future commercial value to Central America and Panama, but therein lies also the danger of over-exploitation and consequent environmental deterioration.

To illustrate the relative extent of coastal types for a portion of Central America, a chart was prepared showing percentages for Costa Rica (Fig. 10). Sandy beaches alternate with rocky headlands for 84 percent of the length of the country's Pacific coastline. The scenic beauty of this combination helps give the Pacific coast of Costa Rica its well-known potential as a marine playground. Mangrove lines 25 percent of the Pacific coast, including that fronting directly upon the sea, as in the Golfo de Nicoya, and that along estuaries behind barrier beaches. The graphs also indicate percentages by particular regional stretches along the Pacific, emphasizing the beach-headland character of the Nicoya coast, the mangrove shore of the Gulf of Nicoya, and the mixed nature of the southwestern coast. In contrast, the Atlantic coast is fringed by an almost continuous sandy beach, with a long stretch of palm swamp (*Raphia* and *Manicaria*) behind the beach barrier in the Tortuguero area. Every Central American country, of course, will exhibit different proportions of coastal types, but these can be easily mapped and calculated using aerial photographs or modern topographic maps available from the respective national geographical institutes.

SANDY BEACHES AND ROCKY HEADLANDS AS ECOSYSTEMS AND RECREATION SITES

The ecologies of beaches and headlands along the Central American coasts are probably better known than those of other coastal types. Much has been written on the zonation of animal life on both sandy beaches and rocky headlands (**Stephenson** and **Stephenson,** 15; **Dahl,** 4; **Doty,** 6; **Hedgpeth,** 10; **Dexter,** 5). The beach has also been considered as an emigration route for certain animals. For example, in Central America a number of crustaceans, such as land crabs (*Ucides, Cardisoma, Gecracinus*) must return to the sea to spawn, making annual mass migrations to the beach (**Bright** 1). Again, the story of the marine turtles, their use of tropical sandy beaches for breeding and nesting, and their near demise through man's overexploitation for eggs, meat, and shell, is well known (**Carr** and **Giovannoli,** 3). The recent efforts on the part of Costa Rica to control sea turtle exploitation, as well as the effective work of the Caribbean Conservation Corporation under the able direction of Dr. Archie Carr in stemming the reduction of numbers and increasing the range of endangered turtle species, are prime examples of what can be done in wildlife conservation along tropical coasts. However, the increasing use of Central American and Panamanian beaches for recreation helps to deny those areas to their natural plant and animal inhabitants. Decisions must be made as to the relative priority of preserving the natural habitat or disrupting it through human use.

The opening of pristine beaches and rocky headlands to recreational development usually involves the destruction of the natural vegetation and often the filling of small, mangrove-bordered lagoons and tidal streams for the construction of streets and buildings. A case in point is the recent real estate development along the Pacific coast of the Nicoya Peninsula (Fig. 11). Once occupied, the beach resort is confronted with the problem of sewage disposal, often circumvented by dumping into the adjacent sea, causing pollution of the very beach that attracted development. Moreover, the frequent mining of beach sand for both local and inland construction material eventually may cause accelerated wave erosion of the beach. Although property regulations that reserve the immediate coast exclusively for public use (such as Costa Rica's 200 m law), are conservation-oriented, strict government control of coastal resort and urban growth seems necessary to prevent environmental deterioration. Environmental quality of the coasts might also be sustained by the formation of national coastal or marine parks along the more pristine and esthetically attractive parts of the seashore. The combination of barrier beaches and mangrove-lined lagoons, such as the Estero de Jaltepeque in El Salvador, presents a double attraction for tourism. Such areas might be set aside as a combined public park and wildlife refuge. Costa Rica's national park of Tortuguero on the Atlantic and Trinidad's Caroni Swamp National Park and Wildlife Sanctuary are examples that might be adopted for many sections of the Central America-Panama coasts.

CONCLUSIONS

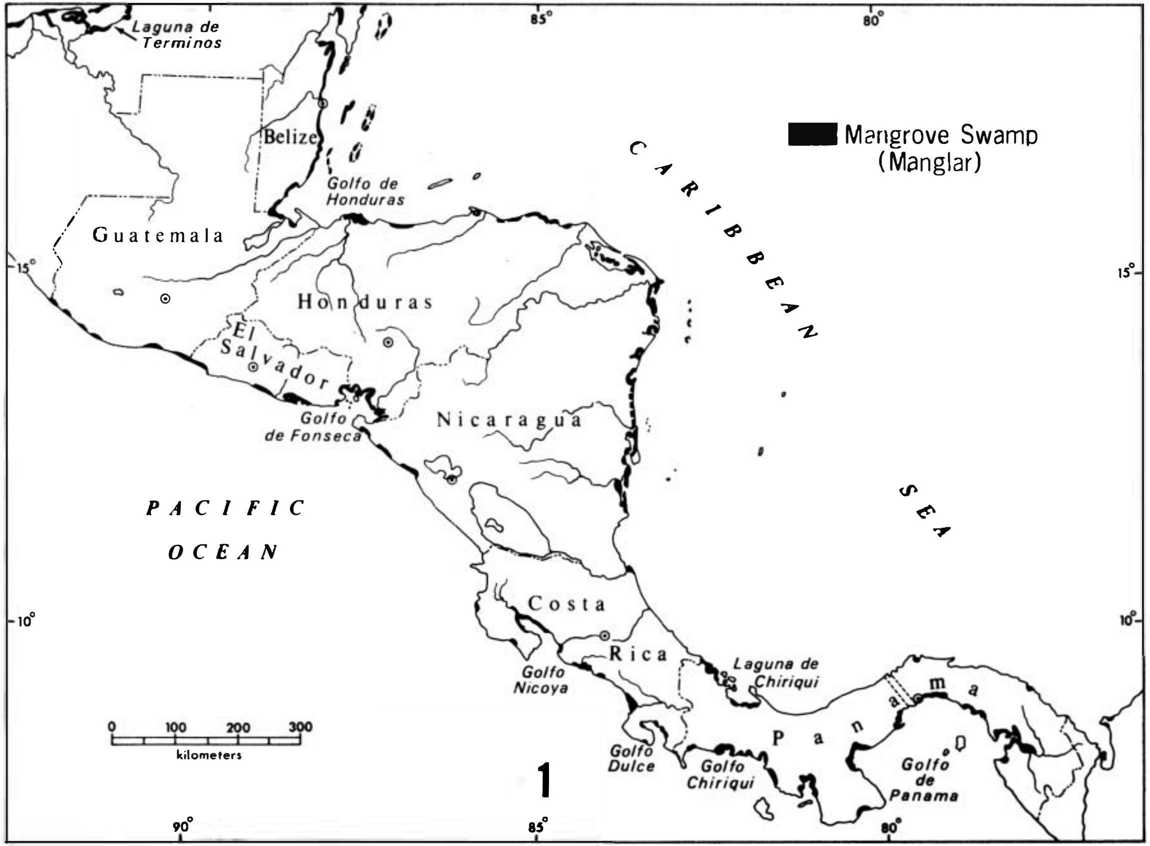
For the conservation of coastal marine environments of Central America-Panama three points are emphasized:

1) One is the role of mangrove-lined estuaries in the maintenance of juvenile forms of oceanic or offshore fish and crustaceans, and the importance of the mangrove as a source of protein food for poverty-stricken coastal people.
2) Sandy beaches and rocky headlands form one of Central America's prime assets for the development of tourism and recreation. The wise development of this asset should be assured by proper national and international planning.
3) Technical knowledge of the coasts of Central America-Panama is in great need of expansion, if proper planning of their uses is to be accomplished. Coordinated efforts to carry out such studies to that end should be encouraged by both governmental agencies and scientific organizations.

RESUMEN

Las zonas entre mareas de las costas Centroamericanas se clasifican como 1) farallones rocosos, 2) playas arenosas, y 3) costas aluviales bajas. Los ecosistemas asociados con estas zonas están entre las más complejas y biológicamente más productivas, a la vez que menos comprendidas de la biosfera. En esta presentación se destaca la importancia que tienen las costas aluviales estuarinas, los manglares y los bosques, que comprenden aproximadamente el 30 por ciento de las costas centroamericanas. Como lo demuestran los estudios en el sur de Florida, los manglares de los estuarios desempeñan un papel clave en la supervivencia de las formas juveniles marinas al acumular en sus raíces aéreas materiasen descomposición que a su vez fomentan el crecimiento de organismos y aseguran asi una fuente alimenticia constante. De manera que es esencial el preservar los manglares para la continuidad de los recursos de pesca en el litoral. En muchas partes de América Central los manglares están en peligro de extinguirse por la explotación excesiva, por la contaminación industrial y por el desarrollo urbanístico y turístico. Aunque menos vulnerables que los manglares, las playas arenosas y los farallones ameritan medidas de conservación por su valor biológico y turístico. El establecimiento de parques nacionales y áreas de refugio para la vida silvestre en varias partes del litoral centroamericano serían los primeros pasos hacia la conservación de los recursos costeros de esta región.

Fig. 1 Distribution of mangrove in Central America and Panama, based on 1:50,000 topographic maps.


Laguna de Terminos
Belize
Golfo de Honduras
Guatemala
Honduras
El Salvador
Golfo de Fonseca
Nicaragua
Costa Rica
Golfo Nicoya
Golfo Dulce
Golfo Chiriqui
Laguna de Chiriqui
Panama
Golfo de Panama
CARIBBEAN SEA
PACIFIC OCEAN
Mangrove Swamp (Manglar)
0 100 200 300
kilometers
85°
80°
90°
15°
10°

1

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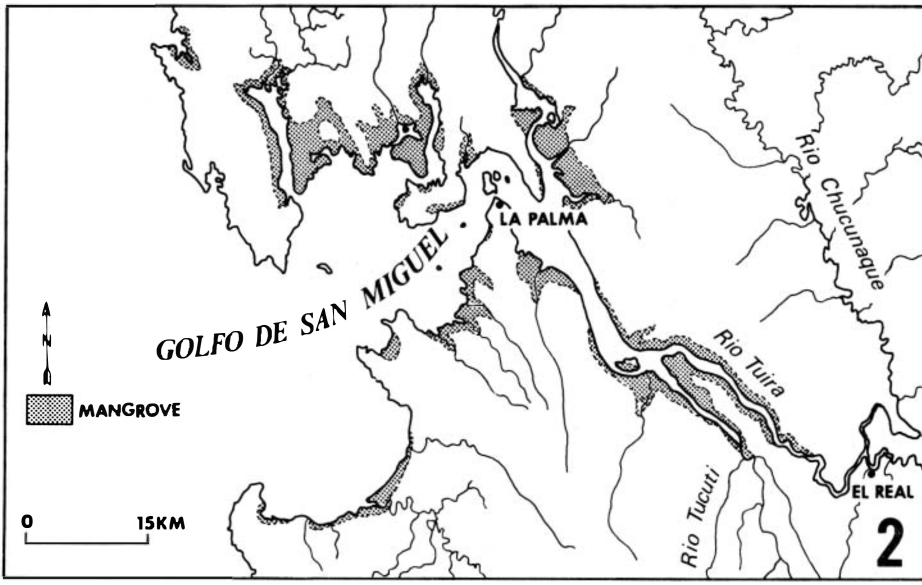
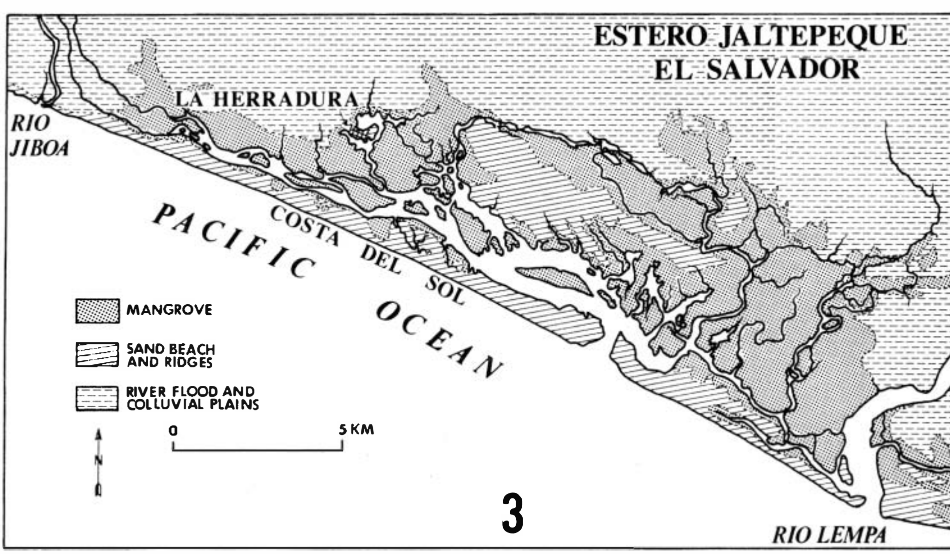
Fig. 2. Distribution of mangrove, Gulf of San Miguel, Panama, based on radar imagery.
Fig. 3. Distribution of mangrove, Estero de Jaltepeque, El Salvador, based on 1:50,000 topographic maps.


GOLFO DE SAN MIGUEL
LA PALMA
Rio Chucunaque
Rio Tuira
Rio Tucuti
EL REAL
MANGROVE
N
0 15KM
2


ESTERO JALTEPEQUE
EL SALVADOR
LA HERRADURA
RIO JIBOA
COSTA DEL SOL
PACIFIC OCEAN
MANGROVE
SAND BEACH AND RIDGES
RIVER FLOOD AND COLLUVIAL PLAINS
N
0 5 KM
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RIO LEMPA

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Fig. 4. Distribution of mangrove, Terraba-Sierpe Delta, Costa Rica, based on 1:50,000 topographic maps.

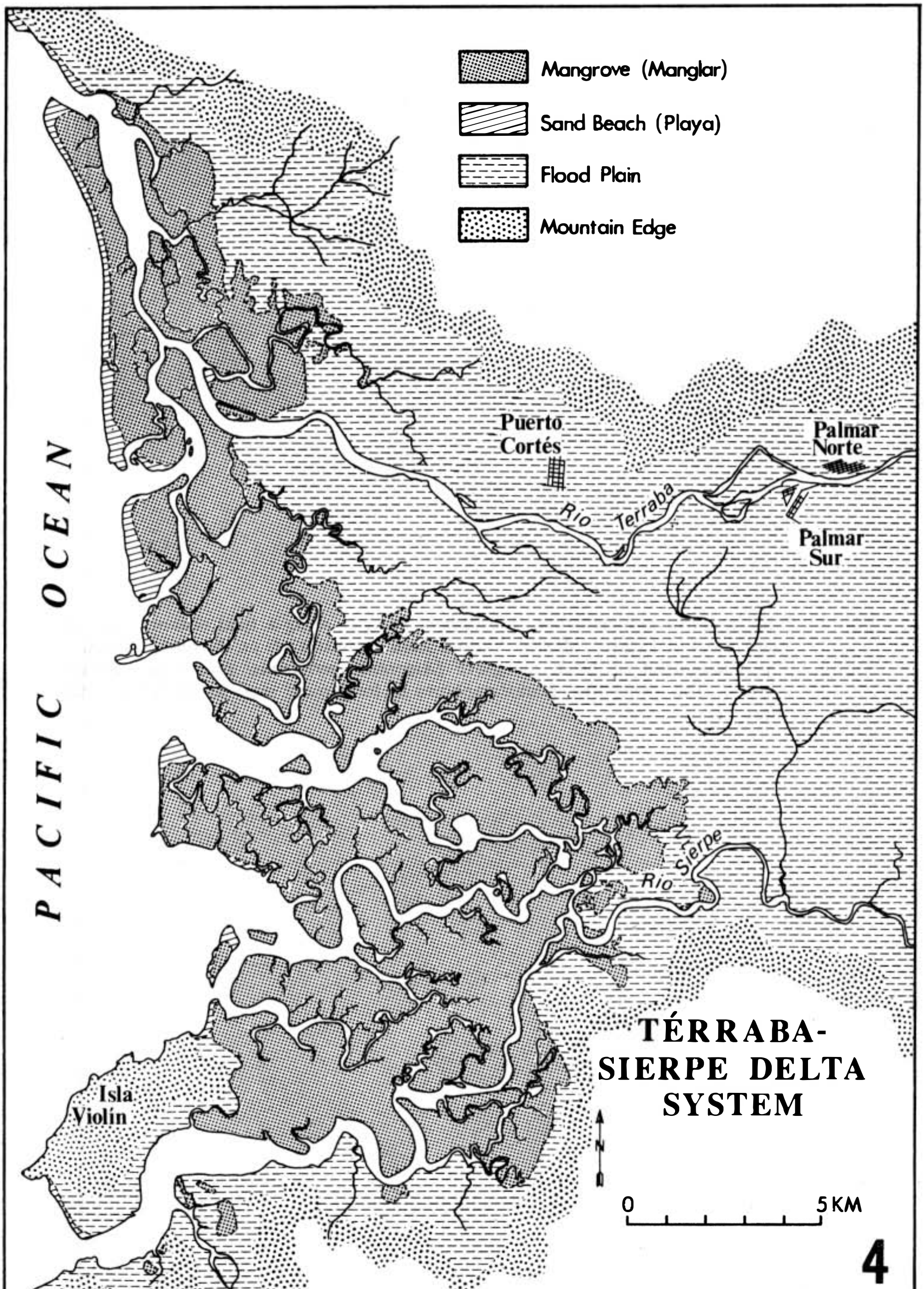
Mangrove (Manglar)
Sand Beach (Playa)
Flood Plain
Mountain Edge
PACIFIC OCEAN
Puerto Cortés
Palmar Norte
Palmar Sur
Río Terraba
Río Sierpe
Isla Violín
TÉRRABA-SIERPE DELTA SYSTEM
N
0
5 KM
4

Fig. 5. Stilt roots of red mangrove *(Rhizophora mangle)* along a tidal channel (near low tide), coast of Tabasco, Mexico. Various small organisms live on the root surfaces.

Fig. 6. Open woodland of black mangrove *(Avicennia germinans)* near coast, Tabasco, Mexico. The pencil-like pneumataphores in foreground serve as hosts for various algae.


5


6

Fig. 7. Charcoal kilns near coast, Tabasco, Mexico. White mangrove *(Laguncularia racemosa)* is the favored wood cut for this operation. Similar *carbonero* camps occur within the mangrove swamps of Central America and Panama.

Fig. 8. A stand of white mangrove badly depleted by *carboneros,* Estero de Jaltepeque, El Salvador.


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Fig. 9. Changes in coastline, Terraba-Sierpe Delta, Costa Rica.

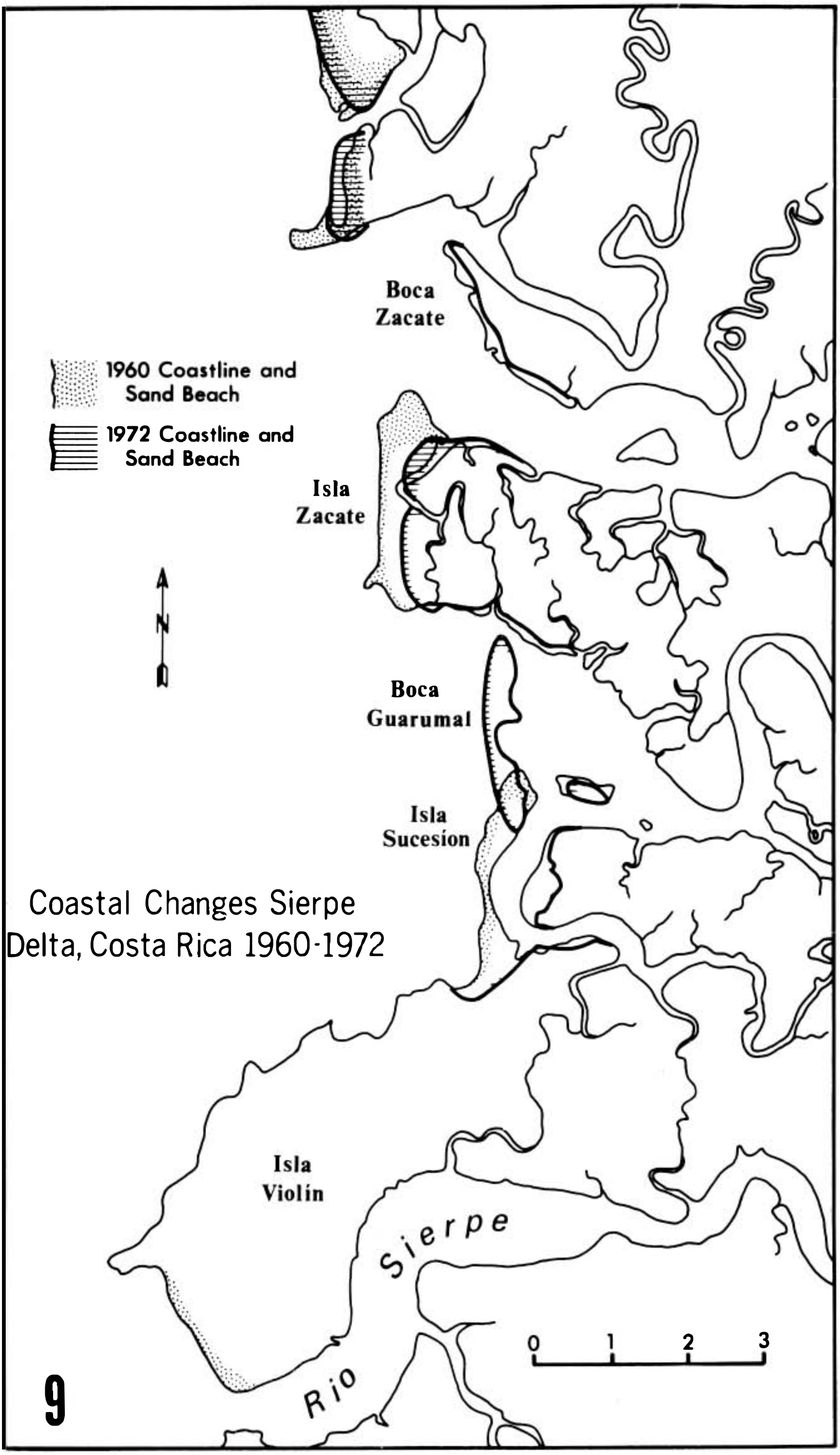
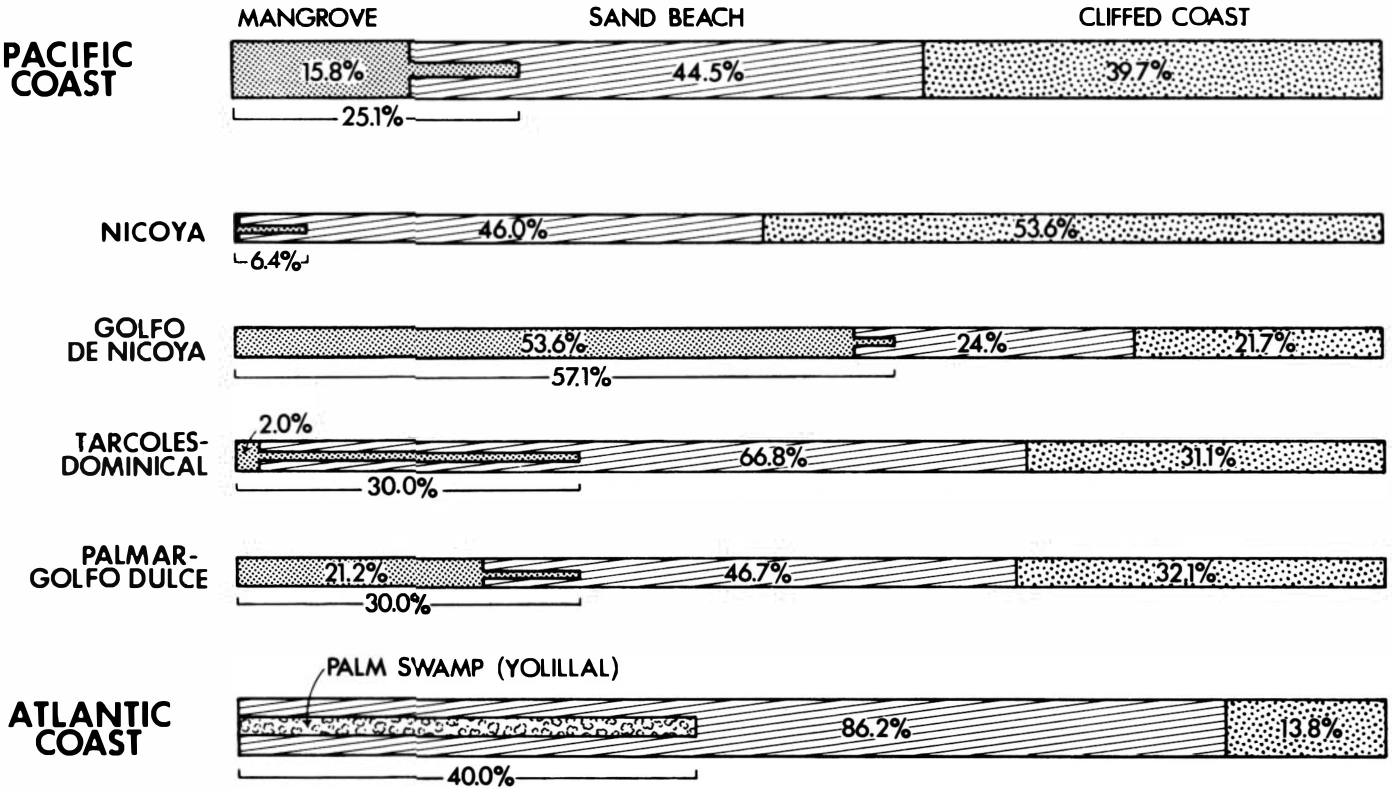
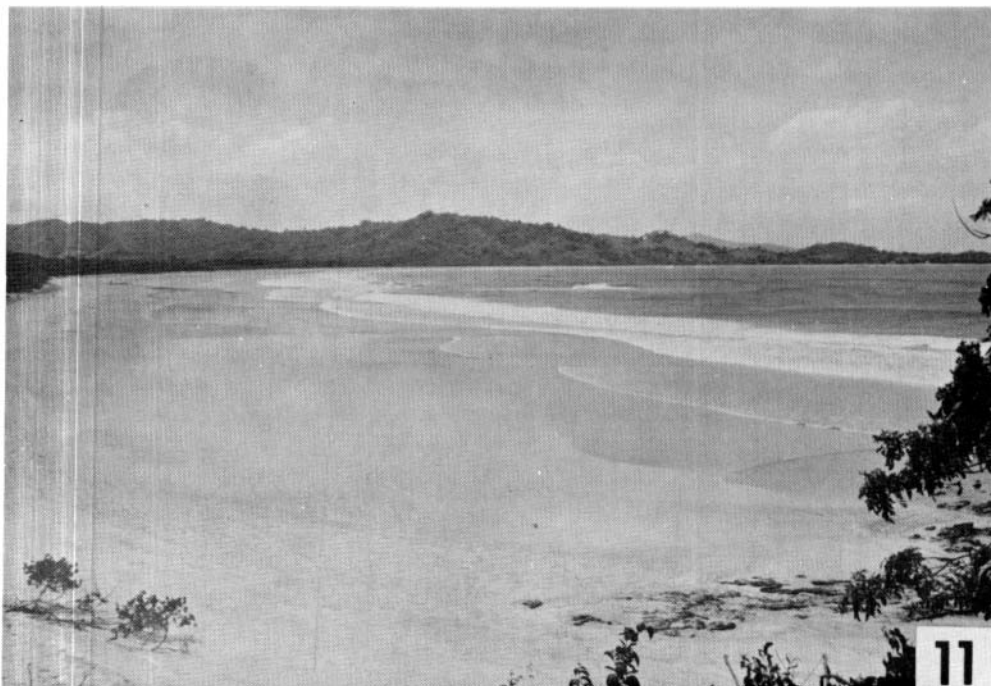

Boca
Zacate
1960 Coastline and
Sand Beach
1972 Coastline and
Sand Beach
Isla
Zacate
N
Boca
Guarumal
Isla
Sucesion
Coastal Changes Sierpe
Delta, Costa Rica 1960-1972
Isla
Violin
Rio Sierpe
0 1 2 3
9

Fig.10. Percentage of coastal types, Costa Rica.


MANGROVE
SAND BEACH
CLIFFED COAST
PACIFIC COAST
15.8%
44.5%
39.7%
25.1%
NICOYA
46.0%
53.6%
6.4%
GOLFO DE NICOYA
53.6%
24%
21.7%
57.1%
TARCOLES-DOMINICAL
2.0%
66.8%
31.1%
30.0%
PALMAR-GOLFO DULCE
21.2%
46.7%
32.1%
30.0%
PALM SWAMP (YOLILLAL)
ATLANTIC COAST
86.2%
13.8%
40.0%

10

Fig.11. Playa Grande, on the Nicoya coast, Costa Rica, now being developed as a seaside residential and resort center.



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