CORINTO COASTAL PROTECTION PROJECT

ENVIRONMENTAL MONITORING

BIOPHYSICAL DIAGNOSIS

CORM-M-94118

September 1994,
National Harbour Enterprise of Nicaragua (ENAP)
Directorate General for Public Works and Water Management (RWS)
Directorate General for International Cooperation of the Netherlands (DGIS)

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This report forms part of a set of five final reports on the Environmental Monitoring Programme of the Coastal Protection Programme of Corinto in Nicaragua, that is to say:

- Environmental evaluation of the coastal protection project
- Socioeconomic diagnosis - Assessment of Socioeconomic environment
- Biophysical diagnosis - Assessment of Biophysical environment
- Morphological diagnosis
- Environmental Managementplan, main report

Besides, the article "Man and the Mangroves" and two maps indicating the landuse have been elaborated on the basis of satellite images.

The reports were presented to:
- the National Harbour Enterprise of Nicaragua (Empresa Nacional de Puertos de Nicaragua, ENAP)
- the Nicaraguan Institute for Natural Resources and the Environment (Instituto Nicaragüense de Recursos Naturales y del Medio Ambiente, IRENA)
- the Ministry of Building and Transport (Ministerio de Construcciones y Transporte, MCT)
- the Directorate General for International Cooperation of the Netherlands (Directoraat-Generaal voor Internationale Samenwerking, DGIS), which financed the programme.

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CONTENTS

1 INTRODUCTION

1.1 Objectives and scope of work

Based on an analysis of the information available and the additional data obtained by means of observations in the field (see Appendix I), it has been possible to identify the main existing environmental impacts in the Corinto area.

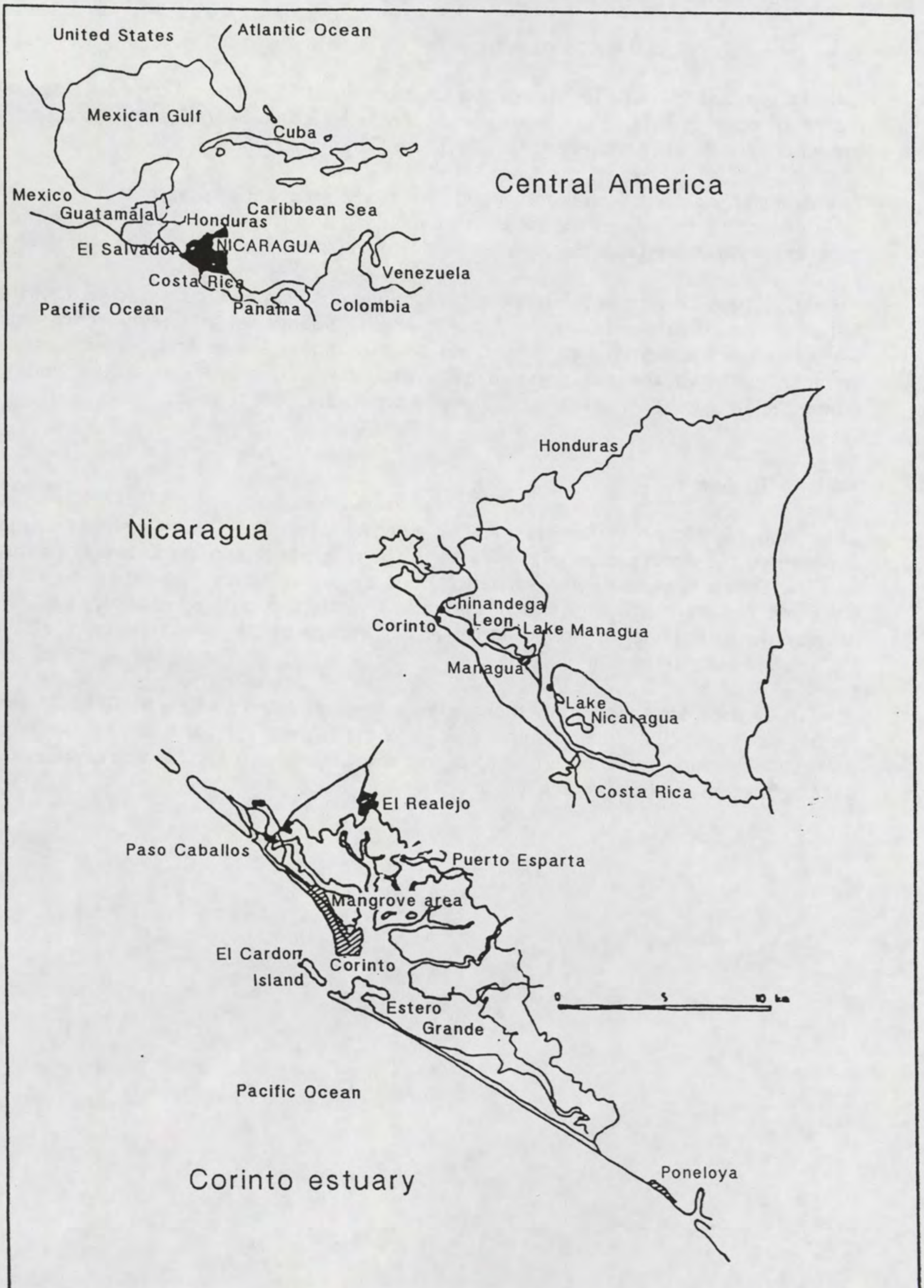
The assessment of the environment in the study area permits both to define the environmental problems under the actual conditions and to predict a future degradation of the environment due to the autonomous development of the Corinto area.

An action plan, called the Environmental Management Plan, will be formulated on the basis of the results obtained by the present biophysical and socioeconomical assessments, the purpose of which will be to mitigate the existing environmental impacts, to avoid the deterioration of environmental conditions in future and to guarantee a sustainable use of natural resources in the Corinto area.

1.2 Study area

The harbour of Corinto is the main and only natural deep water harbour in Nicaragua, situated on the Aserradores Island, close to the union between the Estero El Realejo and the Estero Grande ('estero' means tidal creek). Corinto is situated in Region II, the most important agricultural and agro-industrial production area of Nicaragua. The development of these economic activities depends partly on the availability of the harbour services in the Corinto area.

The study area stretches from the Maderas Negras Island to Salinas Grandes and includes not only the coastal fringe, but also the hydrographical basin upstream of the estuarine zone (the mangrove area and the Corinto estuary), which produces a direct effect on the coastal ecosystems.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El Salvador
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Costa Rica
Venezuela
Pacific Ocean
Panama
Colombia
Honduras
Nicaragua
Chinandega
Corinto
Leon
Lake Managua
Managua
Lake Nicaragua
Costa Rica
El Realejo
Paso Caballos
Puerto Esparta
Mangrove area
El Cardon Island
Corinto
Estero Grande
Pacific Ocean
Poneloya
Corinto estuary

2 CHARACTERISTICS OF THE BIOPHYSICAL ENVIRONMENT

2.1 Climate

With regard to precipitation, during the period from approximately the end of May till October, the Pacific coast is influenced by the approach of the intertopical convergence (ITC).

According to the classification by Koppen, the climate in the study area can be classified as a Tropical Savannah climate. Figure 1 shows the monthly variation in temperature, precipitation and evaporation, all according to the information supplied by the National Hydrometeorological Service.

The seasonal variation in temperature is minimal and the spatial variation of the average year temperature in the study area fluctuates between 24 and 28°C. In April, temperatures are at their maximum and December-January is the coldest period. The climate is characterized by large seasonal variations in precipitation.

Precipitation fluctuates between 1,200 and 2,200 mm a year. The rainy season starts in May, with a maximum in June, and is interrupted by a relatively dry period in July and August; after that, till November there is a second rainy season which has its peak in September. During the rainy season, almost all precipitation is produced by showers. The highest levels of relative humidity of the air are registered in September and October.

From December to April, when the prevailing winds blow from the east and air masses are dry, precipitation is very low, only about 5% of the yearly precipitation. During the rest of the year, the prevailing winds blow from the Pacific Ocean and almost daily measurable precipitations occur.

Nicaragua is frequently affected by tropical depressions and occasionally by hurricanes.

2.2 Geology and geomorphology

Geological formations in western Nicaragua consist mainly of relatively recent volcanic rocks (60 million years or less), and of sediments related to volcanic activity. The active and dormant volcanoes are situated along a line that stretches from the Cosiguina volcano, close to Potosí, towards the south of the southern border of Lake Nicaragua. The rocks on the western slopes of this series of volcanoes, which also includes the mainland adjacent to Corinto Island, consist of a succession of lava, ashes and volcanic waste, and alluvial sediments deposited by currents running from the volcanoes to the Pacific Ocean.

The study area is situated in the geological province of the Coastal Strip of the Pacific; within this province, the Corinto area belongs to the unity named "Nagrandanas Plains", considered as a volcanic plain. The part of the pacific coast included in the Nagrandanas Plains belongs to a sunken coast. The littoral is characterized by the presence of a large number of tidal creeks.

The Nagrandanas Plains consist of pyroclastic material belonging to the volcanic Quaternary. The western part of this unity, that includes the Corinto zone, consists of alluvial material.

At Corinto Island, mainly consisting of alluvial quaternary deposits, locally the Tamarindo Formation outcrops. This is the oldest volcanic formation of the Pacific coast of Nicaragua. The Cardón Island, situated opposite Corinto, consists of volcanic rock.

The plains of Corinto Island or Aserradores Island, formed by alluvial deposits, are situated in a slightly elevated position above the river channels and have a shallow water table. The alluvial plains form the actually urbanized part of the island, because this is where the highest terrains are situated. The maximum natural height of Corinto Island, however, does not exceed 2 metres above mean sea level.

In the area of the tidal creeks, marine deposits formed by coastal currents, fluvial deposits and fluviomarine deposits can be distinguished. In the alluvial deposit of the mangrove area, two main strata can be distinguished: a stratum consisting of mud or organic clay with a density of 0.60 up to 4.50 metres and, underneath, at more than 20 metres, a stratum of fine sand with a density of 1.70 metres.

2.3 Soils

Between León and Chinandega, fluvio-volcanic and volcanic soils, fertile and suitable for agricultural production, prevail. These are soils derived from volvanic ashes, flat and deep, while their texture varies from fine to moderate fine. The soils of the mangrove areas are moderately clayey, with a high concentration of salts and little oxygenation. They are rich in organic material and have a low content of sand.

With regard to the landuse for agricultural purposes in the study area, Table 1 shows the harvested area for various crops over the last decade.

Cycle	Cotton	Sesame	Sugar Cane	Coffee	Banana	Maiz	Rice	Kidney Bean	Sorg-hum
83-84	140,380	21,545	33,728	1,435	3,104	21,630	7,943	1,881	14,800
84-85	134,934	18,545	32,022	927	3,777	23,777	6,114	2,882	15,427
85-86	112,800	9,700	32,022	1,400	3,800	24,200	7,000	8,400	33,000
86-87	78,856	8,751	33,199	1,100	3,400	15,230	10,300	6,345	43,373
87-88	82,500	8,233	33,199	1,400	3,500	36,699	11,200	6,558	44,998
88-89	56,780	12,169	33,457	800	3,178	49,351	18,180	8,558	42,487
89-90	49,512	30,499	31,272	903	3,500	26,438	16,500	10,054	10,881
90-91	61,052	39,477	34,734	829	3,526	18,689	11,229	9,666	8,941
91-92	50,927	19,652	36,128	780	3,526	17,453	13,064	8,022	12,601
92-93	3,294	28,246	36,128	780	3,526	19,421	21,425	6,336	29,215

Table 1: Harvested area (in 'manzanas' (1 manzana = 1.75 acres)) for various crops in Region II during the cycles 1983 to 1993

Source: MAG, Region II

2.4 Hydrography

The tidal creeks form a large hydrographic system that penetrates inland, thus invading the rivers. Twice a day, the area of the mangroves is covered by tidal waters; the amplitude between high tide and low tide varies from approximately 1 to 3 metres. During winter, from June to August, when the southeastern swell comes up, the waves reach their highest level of harshness. These waves are the main cause of littoral dragging. The tidal currents in the Corinto estuary align with the natural channels of the estuary.

In the access channels and in the harbour area, that is to say, in the mouth of the large estuary, strong currents maintain a natural depth of 5 to 9 metres.

Generally, the rivers that drain the area adjacent to the coastal zone of Corinto are rather short and most of them dry out in summer. In the study area, important underground water resources do exist.

2.5 Life zones and vegetation formations

Bio-geographically spoken, the study area forms part of the Pacific Province. The prevailing vegetation in this biogeographical region is the rainforest, which is extremely rich in tree species and in palmaceous. The most important families of plants that are found in the region are the Leguminosae, the Anonaceae, the Bombacaceae, the Burseraceae, the Hypericaceae and the Myristicaceae.

The study area belongs to the life zone of the Humid Warm Suptropical Forest. Almost the whole area between León and Chinandega is used for the cultivation of crops and cattle breeding, so at this moment natural vegetation formations cover only insignificant areas situated around gorges and watercourses.

Remains of natural vegetation do exist, but due to its use for firewood, removal for agricultural purposes and extensive pasturing, a high degree of human intervention can be observed. The most frequent species in the region are: the laurel, Cordia dentata (fam. Boraginaceae), Haematoxilon brasiletto, Luehea candida, the calabash Crescentia alata (fam. Bignoniaceae), Gliricidia sepium, the 'guácimo' Guazuma ulmifolia, the fistel cane Cassia sp. (fam. Caesalpinaceae) and Trema micranta.

Nowadays, the residual dry forest and mangroves are the largest suppliers of forestal products in the study area. With regard to terrestrial vegetation, the species preferred by the users are: the arbutus (Calycophyllum candidissimum), the 'madre cacao' (Gliricidia sepium), the 'guachipilin' (Diphysa robinioides), the 'guácimo' (Guazuma ulmifolia), the laurel (Cordia alliodora), the break ax (Lysiloma seemanii) and the white giant tree (Albizzia caribaea).

The mangrove forests consist of sclerophile sempervirent trees, with stilts or aerial roots. In the mangrove areas on the Nicaraguan Pacific coast the red mangrove, Rhizophora mangle, R. racemosa and R. harrisonii, the white mangrove, Laguncularia racemosa, the black mangrove, Avicenna germinans and A. Bicolor and the tawny mangrove, Conocarpus erecta are found.

2.6 Mangrove forests

2.6.1 Distribution

The mangrove forests of the Nicaraguan Pacific can be found from the Estero Real in the north, to Puerto Sandino in the south. Vast areas of mangrove forests exist along the tidal creeks that form the estuarine zone of Corinto. In the Nicaraguan Pacific, the approximate area covered by mangroves adds up to 39,310 hectares, distributed in the following way:

Location	Area (in hectares)
Estero Real and Gulf of Fonseca	19,410
Estero Padre Ramos	5,590
Estero Aserradores-Corinto-Poneloya	10,700
Las Peñitas-Salinas Grandes	2,420
Salinas Grandes-Puerto Sandino	1,190
Total area	39,310 hectares

Table 2: Area and distribution of mangroves on the Pacific Coast of Nicaragua
Source: DIRENA, 1988

2.6.2 Zonation and succession

The red mangrove, Rhizophora sp., is characterized by stilt roots and is found on unstable (soft mud) substrata along the edges of the tidal creeks. Rhizophora promotes sedimentation so that later on Avicennia can settle, provided that the salinity is locally quite high.
When the salinity level is low, the white mangrove, Laguncularia racemosa, will colonize the old formations of red mangroves. Conocarpus erectus is found in the transition-zone between the real mangrove marsh and the terrestrial vegetation.

Although mangrove trees do grow in a saline environment, they have the same basic needs as other plant species, such as an adequate supply of oxigen, nutrients and fresh water. Although the salinity of the environment demands an energy expense from the mangroves, it also serves to eliminate the competition by non-halophite species.

The saline mud flats form the interior areas of the mangrove marshes and they are only submerged by the highest tides. There is an almost total lack of vegetation due to the high salinity of the sediments in these areas, as a result of the high degree of evaporation and low surface water runoff. Hyper-salinity of the soil limits the settlement of mangroves on the saline mud flats.

The mangrove ecosystem presents vast and extreme ranges of tolerance to salinity, temperature and availability of nutrients. In extreme conditions, a clear zonation occurs, such as can be observed in the mangrove marshes of the Nicaraguan Pacific. This division in zones is mainly determined by the physiological capacities of the different species of mangrove trees.

2.6.3 **Structural aspects**

2.6.3.1 Development of the forests

In the study area, the mangrove forests are dominated by Rhizophora spp. and, according to the classification as proposed by Lugo and Snedaker (1974), from a physiographical point of view these forests correspond to riverine mangrove forests. Other conditions however, such as: very low fluvial influence (intermittent rivers), high salinity levels and structure of the forests, suggest that these forests are more similar to seashore forests.

The mangrove forests in the study area consist of a belt dominated by Rhizophora spp. with the presence of isolated specimens of Laguncularia racemosa, followed by a belt of Avicenna spp. together with Conocarpus erectus.

The structure found is characteristic of a seashore mangrove forest with zones of low precipitation, even when not directly exposed to the effect of the sea. This type of forest is characterized by a poor structural development.
The average height of the trees is low (7 to 11 metres). The climate in the study area is characterized by a low precipitation and warm temperatures, with averages above 26°C. The shortage of the rainy season, practically concentrated in four months a year, followed by a period of drought with temperatures fluctuating between 24 and 40°C are all conditions that create high salinities and anoxia of the soil, which leads to a poor growth of the mangrove forest.

2.6.3.2 Height

Table 3 shows the extension of the different strata of mangrove forests; the low forests are represented by trees < 10 metres; the high forests are represented by trees > 10 metres.

Stratum	**Extension (in hectares)**
RHIZOPHORA Total	7,051
High Forests of Rhizophora	600
Low Forests of Rhizophora	6,451
AVICENNA Total	1,649
High Forests of Avicenna	250
Low Forests of Avicenna	1,399
TOTAL	8,700

Table 3: Strata present and their extension regarding the mangrove marshes in the study area (Region II)
Source: CATIE/IUCN, 1991

The stratum of High Forests has an average height of about 11 metres; the stratum of Low Forests has an average height of 7.5 metres. In total, the strata of Low Forests (7,850 hectares) represent 90% of the total area covered by mangrove forests, while here the red mangrove, Rhizophora spp. prevails.

2.6.3.3 Diameter and density

The mangrove trees in the study area have an average diameter of 5.5 cm. This low diameter indicates that, due to environmental restrictions or because they are cut before reaching larger sizes, the trees are heavily limited in their growth. The development of the mangroves in the study area is being affected by both factors.

In the Corinto-Poneloya sector, a predominance of specimens of the diametrical classes of 2.5 to 7.5 cm is registered, with a density of 399 specimens per hectare. Due to the pressure exercised on the resource, diametrical classes over 7.5 cm present maximum densities not above 53 specimens per hectare (in the diametrical class of 9.5 cm). In Reparto Alemania Federal, which is a zone with a very high activity concerning the extraction of firewood, the diametrical categories with the highest densities are those of 2.5 and 3.5 cm., presenting a density of respectively 929 and 811 specimens per hectare.

When utilizing the density as an index for the intensity of cutting, the following categories regarding the extent of extraction can be established:

1 = 1,800 specimens/ hectare
2 = 1,200-1,800 specimens/ hectare
3 = 900-1,200 specimens/ hectare
4 = 100- 900 specimens/ hectare

In the zone of Venado Island, the majority of the transects in the Low Forests remain within category 4 and a large part of the High Forests within category 2. Because of the heavy pressure exercised on the resource by the firewood-cutters of Reparto Alemania Federal, mangrove forests in the Paredones and Maderas Negras Islands remain within the categories 3 and 4.

2.6.4 **Productivity**

2.6.4.1 General

Mangrove marshes are systems strongly depending on sources of energy from outside the system. The main factors that determine the preservation of this vegetation formation are the following: an adequate supply of nutrients, an adequate water supply and the stability of the substratum.

The development of mangrove forests depends on the equilibrium fresh water - salt water. A high salinity has a negative influence on the metabolic efficiency of the mangrove trees. The erosion of the substratum causes a decline of the mangrove area; on the other hand, processes favouring the deposition of sediments generally lead to an extension of the mangrove forests.

The mangrove vegetation receives the nutrients necessary for its growth, both from the tidal flow and from the floods caused by the rivers.

Generally, mangrove marshes form a system characterized by a high productivity. A part of the organic material produced by the mangrove areas is carried along to the estuary as leaf litter. A process of fragmentation and discomposition of the leaves makes the organic material available for estuarine organisms.

2.6.4.2 Biomass

The biomass of the mangrove as dry weight per cubic metre can be subdivided as follows: 778 g in leaves, 1,274 g in branches, 2,796 g in trunks, 1,437 g in stilt roots and 5,000 g in roots.

The part denominated as "total commercial" forms approximately 44% of the firewood biomass produced by the forest. Bark forms about 5.6% of the firewood material in the mangrove forests.

The total productivity of the mangrove forests consist of:

- leaf litter, including: leaves, flowers, offshoot and "palitos" (= sticks) (usually, an estimate of the total productivity is made on the basis of leaf litter: a relation of 2:1 between Primary Net Production (PNP) and leaf litter is assumed);

- the production of firewood material (an important part of the production, but to be able to measure this production, a sample survey during large periods is required, reason for which this is scarcely being reported);

- production consumed by herbivores (generally ignored, because it forms only a very small part of the total production).

Information about the growth rate of the mangrove forests in the study area is not available. Based on information about the age of certain trees, an increase in the order of 1.5 to 3.5 cubic metres/hectare/year is estimated, low values in comparison with other mangrove forests. The average volume calculated for the High Forest amounts to 37 m^3/ha and for the Low Forest to 32 m^3/ha.

The major part of the firewood is intended for domestic use and the rest is used in small industries, especially in the brickwork, bakery and tortilla industries. The extraction of firewood for the commercial market is mainly carried out by firewood cutters proceeding from Reparto Alemania Federal, close to Corinto, and from the community of Las Peñitas, to the southeast of León. In the remaining places, the extraction of firewood is intended for personal use.

2.6.5 **Fauna**

2.6.5.1 Zonation

There is a well marked stratification in the distribution of the organisms that colonize the mangrove marsh. Clams (Anadara spp.), bivalve filter feeding molluscs, and fiddler-crabs (Ucides occidentalis) live buried in the mud. On the surface of the substratum mainly gastropod molluscs are found. Large oysters (Crassostrea sp.), cirrepod crustaceans (Balanidae) and crabs of the family of the Grapsidae live on the aerial roots of the mangroves. In the branches and the foliage of the trees we find terrestrial life, represented by green iguanas (Iguana iguana) and birds like herons, parrots, blackbirds and various migratory species.

2.6.5.2 Fishery resources

In the mangrove areas, the clams, Anadara tuberculosa and A. similis, both belonging to the family of the Arcidae, are being exploited.
They live in the muddy substrata of the Rhizophora zone, together with the 'miona' shell, Gelonia inflata, and the torch shell, Modiolus polypunctatus. For both species of the Anadara, salinity fluctuates between 16 and 30%.

The average densities and the average size of the shells in the different locations are given in respectively the Tables 4 and 5.

Location	**Density**
A. tuberculosa	
Salinas Grandes	0.66 shells/m²
Corinto	0.15 shells/m²
El Realejo	0.04 shells/m²
RAF	0.64 shells/m²
A. similis	
Salinas Grandes	0.28 shells/m²
Corinto	0.28 shells/m²
El Realejo	0.49 shells/m²
RAF	0.30 shells/m²

Table 4: Average density of the shells at different locations
Source: Hernandez Solís, 1992

Location	L (mm)	L min.-max.
A. tuberculosa (N = 574)		
Salinas Grandes	47.85	(25.0-70.75 mm)
Corinto	51.5	(27.3-75.70 mm)
El Realejo	52.8	(32.6-73.0 mm)
RAF	45.85	(26.4-65.3 mm)
A. similis (N = 1503)		
Salinas Grandes	46.6	(42.4-51 mm)
Corinto	43	(34.2-51.8 mm)
El Realejo	40.7	(27.3-54.1 mm)
RAF	49	(42.1-55.9 mm)

Table 5: Average, minimum and maximum size of the shells at different locations
Source: Hernandez Solís, 1992

The clams are caught the whole year round; in Salinas Grandes, the total catching amounts to 15,840 dozens of clams a year, in Corinto 13,200 dozens a year, in El Realejo 15,840 dozens a year and in Reparto Alemania Federal 21,120 dozens a year.

The fiddler-crab (Ucides occidentalis) is a crab belonging to the family of the Ocypodidae, and the whole year round this species is being submitted to an intense exploitation. This crab makes burrows in the soil of the mangrove areas.

In November, the crabs penetrate deeper into the soil and prior to the preparation for moult, they cover the opening of their burrow. In June, they leave their burrows for reproduction; this is the period of major catches. The fiddler-crab can be found abundantly in muddy substrata, generally in the zone of the red mangrove (Rhizophora). They live at a depth of about 1 m to 1.5 m and share their habitat with the Goniopsis pulchra and Sesarma rhizophora crabs. Their main predator is the raccoon (Procyon loto).

In the Corinto area (Barquito), the density of 'fiddler-crabs' is estimated at 0.30 specimens/m², in the El Realejo area at 0.75 specimens/m² and in the Reparto Alemania Federal area at 0.74 specimens/m². The average catch by man effort in the mangrove areas in Region II (Departments of Chinandega and León) amount to 16 crabs an hour. On the basis of employed time/man/year and the number of crab catchers working, it is estimated that the total catch in Region II amounts to about 1,152,000 crabs a year.

2.7 Estuarine ecosystem

2.7.1 General

In the dry season, the salinities registered during high tide in the tidal creeks of El Realejo, La Chocolata and Esparta are almost equal to those of the sea (Table I.3 of Appendix I). During low tide, only in the Estero El Realejo salinity dropped significantly, namely to 11 ‰.

Due to the supply of fresh water in the Estero El Realejo, both at the surface and near the bottom, in the rainy season a strong decrease in salinity is registered, and salinity drops to no more than 2 ‰ during low tide. In the Estero Esparta, the supply of fresh water from the mainland also significantly affects the salinity during the rainy season (Table I.4 of Appendix I). On the other hand, according to the information obtained in the field, salinity in the Estero La Chocolata is being dominated by the marine influence.

The substratum of the estuary consists mainly of mud and muddy sands. On this type of substratum, algae grow rather infrequently, because of the unstable substrate, and the fauna at the sea-bottom consists mainly of burrowers, such as the Lamellibranchiata and the Polychaeta, and of organisms that can move easily, such as the Crustacea Decapoda.

There does not only exist a close relationship between the estuary and the mangrove areas, but also between the estuarine system and the system of the continental platform (Figure 2). During the early phase of their life cycle, many species of crustaceans and fish living in the zone of the continental platform depend on the estuary/mangrove environment. The continental platform of the Nicaraguan Pacific consists of a coastal strip with an average width of 7 miles, consisting of a rocky and muddy bottom.

2.7.2 Adaptation strategies of the organisms

The organisms that constitute the biota in the estuarine system have developed physiological and behavioural patterns in order to coexist within the high degree of variability of the physio-chemical parameters present in this type of ecosystem. Frequently, estuarine waters are more productive than marine waters or the adjacent fresh waters, reason for which the adaptability to estuarine stress is beneficial for the organisms. The two-directional flow of the water in the estuaries has led to the development of three main categories of organisms:

- species that reproduce in marine waters and that use the estuarine waters as nursery area for the young specimens (for example, the Penaeus trisulcatus shrimp);

- species that complete their whole life cycle within the estuary (for example, the crabs of the genus Callinectes;

- species that reproduce in fresh water, but that during part of their life cycle live in the oligohaline zone of the estuary.

2.7.3 Relation estuary/ mangroves and food web

(i) Primary producers

The estuarine system is characterized by a high rate of primary production, which leads to an elevated secondary production. In view of the fact that productivity of the various primary producers is divided according to the different seasons, a high productivity level is maintained throughout the year. For example, the maximum production of the mangrove forests takes place during the rainy season, when the turbity of the waters prevents the primary production by phytoplankton, and the reverse occurs during the dry season.

(ii) Primary consumers

Among the first-rate consumers a distinction can be made between exclusively herbivores, detritivores and omnivores. This last group comprises the majority of filtering zooplankton, fish like gray mullet, shrimps and 'jaibas'.

(iii) Secondary consumers

This group comprises organisms that consume mainly animals belonging to the above mentioned group, and includes demersal fish like sea catfish, crab and other representatives of the zoobenthos.

(iv) Tertiary consumers (predators)

This group comprises only carnivorous organisms that feed on species belonging to the above mentioned consumer groups.

With regard to the three consumer categories mentioned, frequently it turns out to be difficult to classify an organism within a specific group, while the alimentary habits of a species may change with age, time of the year, place and availability of the food.

(v) Food web

Part of the organic material produced by the mangrove areas is being transferred to the estuary as leaf litter. The decomposition and fragmentation processes of the leaf litter and its conversion into detritus make the organic material produced by the mangroves available to the consumers. During this process of decomposition, the plant material, initially low in proteins is being transformed in detritus particles containing high levels of protein of microbic origin.

As a result of the large diversity of habitats, the estuarine system presents a complex trophic structure with many interconnections (see also Figure 3).

2.7.4 Characteristic species

After larval development, the postlarva of the penaeid shrimp migrates from the sea to the estuary, carried by the tides. The young shrimp stays for some time in the shallow estuarine waters that are rich in nutrients. The more the shrimp grows, its physiology changes, and it becomes less tolerant to reduced salinities. When approaching its sexual maturity, the shrimp starts its migration towards the sea, in order to reproduce. Figure 4 summarizes the phases of the life cycle of the penaeid shrimp and also indicates its relation to shrimp fishery, that exploits adult as well as young shrimps.

The distribution of postlarvas and young shrimps in the estuarine system is not uniform, but remains conditioned by the bottom characteristics, the presence of vegetation, salinity, temperature and the tides.

A close relationship exists between the mangrove marshes and the biology of Penaeidae. After falling and decomposing, the triglycerids that form part of the lipoidal cover of the leaves provide the appropriate food for shrimp in their postlarval phase.

The whole year, the postlarvas of Penaeus vannamei remain in the tidal creeks from Salinas Grandes to the Maderas Negras Island. They have been observed in highly muddy and fetid substrata, at depths between 30 and 50 cm, covered by a thick layer of decomposing mangrove leaves.

P. stylirostris prefer a more sandy substratum and turbid waters. They are more abundant in the R.A.F. and Corinto region. The whole year round, young specimens are present in the tidal creeks from Salinas Grandes to the Maderas Negras Island, which indicates that spawning occurs during the whole year.

The postlarvas of P. occidentalis are concentrated close to El Realejo, Las Penitas and Salinas Grandes, at depths between 10 and 30 cm, in the shadow and on mud/sandy substrata. From August to December densities are at their peak. Spawning occurs only once a year.

The whole year round, postlarvas of P. californiensis can be found close to Salinas Grandes and El Realejo; spawning is continuous and takes place in open sea.

The young specimens of P. californiensis and P. occidentalis, observed in the tidal creeks, do not reach a size of more than 30 mm; these species remain only for a short period in the estuarine environment. The young specimens of P. vannamei and P. stylirostris, on the contrary, remain for a longer period in the tidal creeks, where they can reach a size up to 120 mm; migration to open sea occurs when they have almost reached their adult size.

The catchings of crabs originating from the estuary, consist mainly of the species Callinectes toxotes, the **blue crab** or **'jaiba'**, belonging to the family of the Portunidae. This species abundantly occurs on sandy and muddy bottoms in the shallow waters of the tidal creeks in the mangrove area. Moreover, due to the composition of the substratum, the distribution of the blue crab depends on the salinity in the estuary. For spawning, the oviparous female migrate towards waters with a higher salinity. Blue crabs use the area of the mangroves as their breeding area. The male, that are bigger, are found in waters with a reduced salinity. Figure 5 summarizes the life cycle of the blue crab.

Fish families characteristic for the estuarine environment are the Carangidae (scad), Centropomidae (bass), Lutjanidae (mullet), Sciaenidae (umberfish), Mugilidae (gray mullet) and Ariidae (catfish). The family of the Carangidae is represented by the largest number of species.

2.8 Tidal zones

2.8.1 Colonization of the substratum

The following categories of substratum can be distinguished: rock, shingle with particles from 2 to 64 mm, sand with particles from 0.02 to 2 mm and mud o clay and sludge, with particles < 0.02 mm.

Sessile organisms settle on a generally solid surface; this category includes ascidians, sponges and bryozoans.

Sedentary organisms can move over the substratum, although to a small extent; this category includes an important number of gastropods and echinoderms and some polychaetes.

Free-living organisms, like the majority of the crustaceans, fish and cephalopods can move to a much wider extent.

Burrowers, like the Pelecypoda, Scaphopoda, Polychaeta and some Crustacea and Gasteropoda (Olividae, Naticidae) penetrate into the loose substratum.

2.8.2 Zonation

The **epilittoral** zone: upper zone, without direct influence of the seawater, except for filtrations into the subsoil, conditions that determine a halophilic vegetation and a predominantly terrestrial fauna.

The **supralittoral** zone: in this zone, organisms exist that withstand or require total emersion; there is the influence of salt water through splashing; immersion takes place only during equinoctial tides or during storms.

The **eulittoral** or **mesolittoral** zone (true tidal zone): zone where as a result of the tides, continuous emersions and immersions occur, being the upper limit the high tide and the lower limit the low tide; the organisms that live here are more or less amphibious.

The **infralittoral** zone: is always submerged and rarely emerged, being its lower limit that of the marine phanerogamia and of the photophile algae.

2.8.3 Sandy and muddy littoral

The supralittoral zone is the home of the Ocypodidae (Crustacea, Decapoda). Their activities take place during the night and they burrow into the sand, avoiding high exposure to the sun thanks to the depth of their shelters. In the upper part of the muddy or mud/sandy supralittoral zone, plants like Ipomoea pes-caprae (Convulvulaceae), Sesuvium portulacastrum (Aizoaceae), the Gramineas Distichlis and Sporobolus, and Salicornia (Chenopodiaceae) are common.

In the meso- or eulittoral (tidal) zone, where the waves break, the crustaceans named Hippidae (Anomura) are found; in this part of the eulitteral zone the olive shell (Olivella sp.) is also very common. A little more down in the tidal zone, the bivalves Donax sp. and Tellina sp. are found.

2.8.4 Rocky littoral

The supralittoral belt of the rocky substrata is characterized by the presence of incrustations of lichens, cyanophycean algae and some chlorophycean algae. This zone is the home of the sea cockroaches, Ligia sp. (Crustacea, Isopoda) and crabs belonging to the family of the Grapsidae.

In the mesolittoral zone, macroalgae, barnacles of the genus Chtamalus (Crustacea, Cirripedia), some sponges, oysters and sea anemones are common.

3 FISHERY RESOURCES AND FISHING

3.1 General

In Nicaragua, the consumption of fish per head of the population is low (< 1 kg a year). Traditionally, there is a preference for some marine species: red snapper and also shark, umberfish and mackerel are highly appreciated.

Nowadays, in the Nicaraguan Pacific a bit less than 5% of the total available biomass is being exploited.
That means, the majority of fish species is being underexploited or not exploited at all. Shrimp and lobster are fully exploited, although not overexploited. Regarding molluscs, with the exception of the clam (Anadara sp.) and the Pacific oyster (Crassostrea sp.), all the other potentially commercial species are being underexploited. Table 6 shows the estimated biomass concerning the different fishery resources in the Nicaraguan Pacific.

Species	**Biomass** (in T.M. x 1,000)
Pelagic fish	
Machuela de hebra	20,000
Anchovy	22,000
Jacks	19,000
Barracudas and swordfish	11,000
Total	72,000
Demersal fish	
Sea perch	19,000
Red snapper	6,000
Stickle fish	3,000
Sharks	2,000
Total	30,000

Table 6: Estimated biomass of fish in the coastal waters of the Nicaraguan Pacific
Source: INPESCA, MEIC, FNI and SPP, 1990

3.2 Organization of fisheries

3.2.1 Fishing grounds, vessels and fishing methods

3.2.1.1 Traditional methods of fishing

Table 7 shows the number of fishermen and vessels, fishing grounds and the main species that are being exploited through traditional fishing by the communities of Rep. Alemania Federal, Corinto and Aserradores.

Location	Numbers of fishermen	Number of vessels	Species	Fishing grounds
R.A.F.	18	6	red snapper, bass, curvina, ruco, scad, guicho, goldmackerel, perch, halibut, shark, mackerel	tidal creeks and Maderas Negras
Corinto	500	45	lobster, shark (fins), golfmackerel, scad, guicho, perch, ruco, halibut, red snapper, umber, bass, mackerel	the Gulf and Paredones
Aserradores	69	20		sea (from 5 miles to 20 miles)

Table 7: Number of fishermen and vessels, fishing grounds and main species exploited through traditional fishing

The majority of the vessels used for traditional fishing are the so called 'cayucos' (canoes), usually made out of a tree in one piece, with a length of about 5 to 7 metres and a width of about 0.7 to 0.9 metres. They all have outboard motors, generally with a capacity of 25 HP. Due to the fact that the vessels do not carry ice, the fishing job normally does not take more than 12 hours.

With regard to their value, the main species exploited by traditional fishing are the red snapper, perch, umberfish and mackerel. The main way of fishing is using the gill net ('agallera'), which has a height of 2 to 3 metres. For mackerel and red snapper fishing, the net has meshes of 4 to 5 thumbs (92-115 mm).
For the capture of sharks another type of gill net is used, with meshes of 5 to 6 thumbs (115-138 mm), and also the longline or shark line is used for this purpose. Lobster is caught through fykes or by diving. A fixed net is only used for the capture of bait necessary for fishing with hook and line.

3.2.1.2 Industrial fishing

Industrial fishing is mainly based on shrimp and lobster fishing. The vessels used for shrimp fishing are of the Florida type, and their length varies from 19 to 23 metres; they are equipped with diesel engines from 240 to 402 HP. All the trawling vessels use simple nets with a horizontal opening of 25 m. Shrimp fishing is realized at a depth between about 6 and 35 fathoms (approximately 10-60 m). The main grounds for shrimp fishing are located in the Fonseca Gulf, between Corinto and Masachapa and from Puerto Sandino to Ostional and San Juan del Sur.

The trawling vessels used for this type of fishing generally operate with a crew of five fishermen; in the Corinto area, the number of fishermen working in industrial fishing is estimated at 65.

3.2.2 Processing of the catches

The ALINSA processing plant, situated in Corinto, processes mainly Penaeidae shrimps. After being caught, the shrimps are classified in whole shrimps and tail shrimps, and this last category is immediately decapitated. After this selection, the shrimps are washed with sodium bisulphite and stored in the hold, on ice or in an air-cooled space. After returning to the harbour, the load of the ship is deposited in a basin, where a first washing with chlorinated water takes place. Before proceeding to a manual selection, the shrimps are transported to another basin, where they are submitted to a second washing with chlorinated water.

Currently, ALINSA has a processing capacity of 3,500 lbs of shrimps a day. Production varies in accordance with the reproductive cycle of the shrimp, but can be calculated at an average capacity of 80,000 lbs a month. At the moment, 13 trawling vessels of ALINSA are operating.

3.2.3 Marketing of the fishery products

Presently, fishery products intended for the international market are: the penaeid shrimp, lobster and the red snapper from the Pacific. Formerly, North America was the main export market for fishery products. During the commercial embargo of the United States, export to Canada, Europe and other Central American countries was initiated.

Table 8 shows the quantity and the value of the exports of different fishery products from the Pacific Ocean during the period from January till June 1992.

Product	**Quantity** (in pounds)	**Value** (in dollars)
Shrimp	122,100	474,300
Lobster	5,400	59,300
Fish	959,800	1,209,100
Total	1,087,300	1,742,700

Table 8: Quantity and value of the exports of fishery products from the Pacific Ocean, from January till June 1992
Source: INPESCA, 1992

3.3 Shrimp

3.3.1 Fishery development and production

In the coastal zone of the Nicaraguan Pacific, species belonging to the family of the Penaeidae are being commercially exploited, namely: the white shrimp Penaeus vannamei, P. occidentalis and P. stylirostris, the coffee shrimp P. californiensis and the red shrimp Penaeus brevirostris.

Penaeid shrimp frequently are found on the muddy bottoms along the coast. The white shrimp is abundant in waters less than 15 fathoms deep; the red shrimp is more common in deeper waters (> 15 fathoms). The species denominated "white shrimp" is the most exploited resource.

Figure 6 shows the annual shrimp production and the catches expressed in Catch Per Unit of Effort (CPUE), during the period from 1964 to 1992.

During the period from 1964 to 1970, the development of shrimp fishing was started up. Although catches remained on a high level, due to the excessive number of vessels in operation from 1967 to 1978 the CPUE decreased. After the revolt of July 1979, the fishing fleet of the Pacific was plundered and damaged. As a result of the decrease in the fishing effort, the level of the shrimp stocks recovered, which led to a high CPUE over the following years. From 1986, fishing by foreign vessels within the national waters was allowed. In 1989, the percentage of the total catches of shrimp by foreign fleets in the Pacific amounted to 51%.

The major catches of shrimp are realized from October to March. The maximum catches (in November and December) coincide with the abundance of the white shrimp, which comprises 46% of the catches. The red shrimp comprises 27% of the total production and presents its major profits from December to April.

3.3.2 Relation mangrove area/shrimp production

Based on the surface of the mangrove area, an estimate of the potential catches of penaeid shrimp can be made. For the valuation of the importance of the mangrove areas in connection with shrimp fishing, mathematical models have been developed. For example, the equation worked out by Martosubroto and Naamin (1977) is highly significant (e = 0.01) and relates the area of the mangrove forests to the catches by commercial shrimp fleets:

$$Y = 5.473 + 0.1126\,X$$

Y = shrimp production in thousands of metric tons
X = surface of mangrove area in hectares (in unities of ten thousand)

It has been estimated that the mangrove areas of the Nicaraguan Pacific contribute approximately US$ 77 per hectare, only with regard to shrimp fishing. However, to represent shrimp production as a direct function of the mangrove area would be a simplification of reality, because other variables such as the effort of fishing and the reproduction cycle of the species also do determine the production.

3.3.3 **Accompanying fauna**

At the moment, the catches of accompanying fauna ("offal") of shrimp fishing are being sold to the canoes that come along the shrimp vessels, or these catches are brought to the harbour for consumption by the fisherman himself; the accompanying fauna of shrimp fishing consists of approximately 80 different species.

According to the results of the study conducted by IRENA in 1980, the percentage of saleable fish present in the "offal" of shrimp fishing is higher in shallow waters, that is to say, in the area of traditional fishing. At depths of 6 to 35 fathoms, corresponding to the main zone of shrimp fishing, the catches of accompanying fauna can represent up to 88% of the total fish catch.

The species most abundantly present in the "offal" are catfish (Ariidae), sole (Symphurus sp.), eel (Muraenesocidae), 'sable' (Trichiurus), 'ruco'(Pomadasydae), 'frijolillo' (Branchiostegidae), snappers (Lutjanidae), thornfish or 'palometa' (Gerridae: Diapterus peruvianus), umberfish and 'pancha' (Sciaenidae: Cynoscion sp. and Micropogon sp.), sharks (Carcharhinidae) and blue crab (Callinectes spp.).

3.4 Lobster

In the Pacific, lobster (Palinurus sp.) fishing is not as developed as in the Atlantic. From 1979 onwards, catches have decreased, but in 1988 as a result of a major fishing effort, a recovery process was started up. It is estimated that it is possible to exploit up to 3,000 thousand pounds of tails a year from the Nicaraguan Pacific.

3.5 Fish

In the coastal zone, from the shore till approximately a depth of 50 m, the main demersal species are: thornfish or 'palometa' (Diapterus peruvianus), snapper (Lutjanus spp.), 'ruco' (Pomadasydae macracanthus) and 'barbudo' or seacat (Polydactylis approximans).

In the intermediate zone, from 50 to 100 m: parrot fish (Prionutus ruscarius), stockfish (Peprilus spp.), umberfish (Cynoscion sp.) and 'garrobo' (Synodus evermanni) prevail.

At the far end of the continental platform, sharks (hammerhead sharks, black fin sharks and dogfish) as well as the yellow fin tuna fish (Thunnus albacares) prevail.

The maximum reproduction of the majority of the species common in the coastal zone occurs in the period from September to January.

The fish species present in the monthly catches realized by the Mangrove Marsh Project CATIE/UNAN in the Corinto and El Realejo areas, are shown in respectively the Tables 9 and 10.

	MONTHS							
Species	J	F	M	A	M	J	J	A
Elops saurus					x			
Arius seemani (catfish)	x				x		x	x
Polydactylus approximans (barbudo)	x				x		x	
Caranx hippos (scad)								
Chloroscombrus sp.		x	x	x		x		x
Centropomus robalito (bass)					x			
Lutjanus colorado (red mullet)								x
Lutjanus novemfasciatus Lutjanus	x							x
guttatus (mullet)		x						
Pomadasys macracanthus (ruco)			x					
Anisostremus surinamensis	x		x	x	x	x	x	x
Diapterus peruvianus (thornfish)	x							
Mycteroperca interstitialis	x		x	x	x	x	x	
Cynoscion nothus (umber)							x	
Bardiella batabana (ronco)	x						x	
Bardiella ronchus (ronco)								x
Mugil curema (gray mullet)			x			x	x	
Sphoeroides annulatus			x	x		x	x	x

Table 9: Composition of the fish fauna over the period from January to August in the Corinto area

Source: Solís and Delgado, 1990

	MONTHS							
Species	J	F	M	A	M	J	J	A
Elops affinis		x			x			
Elops saurus					x			
Arius seemani (catfish)					x			
Polydactylus approximans (barbudo)					x		x	
Caranx hippos (scad)								
Selene vomer				x			x	x
Centropomus robalito (bass)							x	
Centropomus armatus			x					
Lutjanus colorado (red mullet)	x							
Pomadasys macracanthus (ruco)								
Diapterus peruvianus (thornfish)	x	x	x	x			x	
Bardiella batabana (ronco)		x	x	x				x
Bardiella ronchus (ronco)								x
Mugil curema (gray mullet)			x				x	x

Table 10: Composition of the fish fauna over the period from January to August in the El Realejo area

Source: Solís and Delgado, 1990

4 EXISTING ENVIRONMENTAL PROBLEMS

4.1 Impacts in the hydrographical basin

4.1.1 Deforestation

As early as the colonial period (1502-1821), the forests of the Cordillera de los Maribios and the areas adjacent to El Realejo were seriously being affected by the activities of naval construction on the shipyard of El Realejo.

Nowadays, the cutting of trees for firewood and timber is still continuing. In order to reclaim farmland, frequently a clearing is carried out, which generally does not include the commercial use of the wood for construction or other purposes; the usual practice here is "clear, fell and burn".

The massive removal of the vegetation cover of the upper and lower river-basin has noticeably changed the hydraulic balance. Due to deforestation, the seasonal changes in the river-discharge became more abrupt and the sudden changes in the flow of water did increase the risks of floods.

The increase in surface water runoff, transporting sediments, organic material and other substances, affects life conditions of the populations of aquatic organisms along the stretch river-estuary-sea.

4.1.2 Soil degradation

Thanks to their fertile soils of volcanic origin and the appropriate climatical conditions for a wide range of cultivations, the Departments of León and Chinandega possess the major agricultural potential of the country. An intensive use of the soils, however, has led to its advanced degradation. Because of the generalization of monocultures, like cotton and sugar cane, these are the most degraded soils of the country. Monoculture has deprived the upper layer of the soil of its nutrients and an excessive use of pesticides has degraded the soil even more.

4.1.3 Erosion

Due to the presence of highly erosive soils, the degree of erosion observed in the study area is rather high. Due to the winds that blow from east to west, thousands of metric tons of fertile soils were dragged to the sea by eolic erosion. The use of heavy machinery also contributed to the compression of the soils intended for agricultural use, thus preventing the penetration of rain water.

In the rainy season, this leads to the dragging along of sediments towards the rivers, which results in an accelerated sedimentation of the estuarine zone. This hydraulic erosion drags every year between 60 and 100 metric tons of soil from the zone comprised between the towns of Chinandega and León to the coastal strip.

4.2 Environmental pollution

4.2.1 Introduction

Through the sampling programme presented in Appendix I of this report, additional information was obtained with regard to pollution of water and the sediment of the bottom caused by:
. agricultural activities (agrochemical products);
. discharge of domestic sewage water (bacteriological pollution);
. harbour activities (heavy metals and hydrocarbons).

Sampling and analysis of the water and the sediments were carried out by the Centre for Investigation of Aquatic Resources (CIRA) in Managua. Besides, some samples of the sediment were analyzed by the Institute for Investigation of Materials and the Environment (INTRON) in the Netherlands. For the geographical position of the points of sampling, see Appendix I, Figure I.1.

4.2.2 Agricultural activities

4.2.2.1 Use of pesticides

Cotton with its extensive areas of monoculture has highly influenced the use of pesticides. As a result of the growing of cotton, Nicaragua became the major importer of pesticides in Central America. The centre for cotton production is Region II (the Departments of Chinandega and León). In the cultivation of cotton, use of pesticides is very intensive and they are applied through fumigation from spray planes. One of the important factors through which the use of pesticides diminished over the last few years, was the drastic reduction of the growing of cotton (see Table 1).

Over the last three years, the percentage of organic phosphoric compounds imported in Nicaragua did come down. On the other hand, over the same period the percentage of imported pyretroids has increased (Table 11).

Type of product	1988	1989	1990
biological	1.36%	1.94%	4.01%
carbamates	4.33%	6.81%	9.62%
growth inhibitor	0.78%	1.07%	0.29%
organic phosphoric compounds	81.32%	75.71%	45.12%
organic chlorine compounds	1.98%	3.55%	2.46%
pyretroid	5.98%	10.84%	33.01%
no identified	4.24%	0.08%	--

Table 11: % of pesticides imported in Nicaragua
Source: Matus and Beck, 1991

In Nicaragua, the use of the pesticides toxaphene and endosulfan is restricted; they are only permitted in respectively the growing of cotton and coffee. Toxaphene, produced in Nicaragua, is a chemical mixture of methyl-parathion, malathion and DDT, and is used to suppress a pest species called 'picudo' (Anthonomus grandis). Since the introduction of the 'broca'(Hypothenemus hampe) in 1988, a very serious pest species with regard to the growing of coffee, the use of endosulfan has increased. The list showing the pesticides that are forbidden in Nicaragua is given in Table 12.

Common name	Commercial name	Date of ban
Leptophos	Phosval	1978
D.B.C.P.	Nemagón, Fumazone	1979
D.D.T.	D.D.T.	1980
Aldrin	Aldrin	1977
Dieldrin	Dieldrin	1981
Endrin	Endrin	1981
Lindane	B.H.C.	1977
Ehtyl dibromure	Dowfume	1983
2,4,5-T	2,4,5-T	1983
Clordimeform	Halacrom, Fundal	1987

Table 12: Pesticides forbidden in Nicaragua
Source: DGTA, 1990

4.2.2.2 Environmental impacts

(i) Pesticides

During the period of cotton fumigation, the run-off of water containing traces of pesticides proceeding from the mixture and charge of insecticides and the washing of tanks and planes, formed an important source of the pollution of surface waters and groundwater. The run-off of water polluted by agrochemicals from farmland forms another source of pollution.

In order to evaluate a possible accumulation of pesticides proceeding from the adjacent cotton growing area, concentrations of organochlorine and organophosphorous compounds in pesticides present in the bottom of the Estero El Realejo, close to the landing stage, were determined (Point 4).

Concentrations of organophosphorous compounds in pesticides and in the majority of the organochlorine pesticides, which generally are more persistent, remained below detection limits. Although in Nicaragua the use of DDT is forbidden since 1980, traces of DDE, which is a derivative from DDT, were found in detectable concentrations in the bottom of the tidal creeks.

The pp'-DDE concentration observed, amounting to 4.10 μg.kg (-1), still remains very much below the Dutch standard concerning aquatic sediments, the permissible limit for DDT and its derivatives being 20 μg.kg (-1).

(ii) Eutrophication

Due to the activities related to the growing and processing of sugar cane in the area adjacent to the Amalia-Sucio river, in the beginning of May a physical-chemical analysis was realized in the river, upstream from its discharge into the Estero Limón, in order to detect the possible effect on the quality of the water. For the results of this analysis, see Table I.5 of Appendix 1.

The deficiency of dissolved oxigen and the high rate of biochemical demand of oxygen (DBO) observed in the Amalia-Sucio river, reflect a heavy pollution by organic material.

4.2.3 **Domestic sewage water**

The self-purification capacity is an important characteristic of watercourses and watermasses: upon receiving sewage water, through chemical and biological processes, the oxidable or quick rotting material is being transformed into stable oxidated substances. Biodegradability of organic compounds, however, also implies the consumption of dissolved oxygen and this reduction of oxygen can seriously affect the aquatic ecosystem.

Apart from organic substances, domestic sewage water contains pathogenic bacteria and other organisms that can affect human health. With regard to bacteriological pollution of the analyzed samples, the water proceeding from the Estero El Realejo, close to the landing stage (Point 4), contains the highest number of coli bacteria and fecal streptococcus.

Due to dilution, in the tidal creeks (Points 4, 6 and 7) the concentration of bacteria decreases during high tide. On the other hand, in Corinto opposite Costa Azul, bacteriological pollution is higher during high tide than during low tide. There is a possibility that part of the sewage water, by the sewage outfall pipe discharged into the bay, is being transported towards the coast by the tidal flow.

Due to dilution, in the Estero La Chocolata, that receives sewage waters directly from the village, bacteriological pollution is less during the rainy season. In the rainy season, pollution increases in the Estero Esparta, when the flow of fresh water proceeding from the populated zones located upstream, prevails.

At all the observed points, the coli bacteria concentration exceeds the standards set for swimming water in the United States; moreover, in the Estero El Realejo close to the landing stage (Point 4), the current standard for fishing is largely exceeded.

4.2.4 **Harbour activities**

4.2.4.1 Heavy metals

For the values of heavy metals found in the samples of sediment proceeding from Corinto harbour, close to the pier for general cargo, and in those from the Estero El Realejo (Points 1 and 8 respectively) see Table I.6, Appendix I.

No significant difference can be detected between **copper** concentrations in the sediments proceeding from the harbour area (Point 1) and from the reference point (Point 8). Copper concentrations in the additional samples, taken at a distance less than 20 metres from Corinto pier, however, are much higher and amount to 90.96 and 87.80 mg.kg (-1).

According to Dutch standards, the basic quality requirement for aquatic bottoms is 35 mg.kg (-1). Thus, it can be concluded that in the harbour area as well as in the Estero El Realejo (Point 8), copper concentrations in the sediment exceed the limits permitted.

At the stations 1 and 8, **lead**, **nickel**, **cadmium**, **zinc**, **arsenic** and **chromium** concentrations still remain far below permissible limits regarding the basic quality for aquatic bottoms in the Netherlands, and also the concentrations of **mercury** still remain within the existing standards.

4.2.4.2 Hydrocarbons

In addition to heavy metals, 10 different Polycyclic Aromatic Hydrocarbons were analyzed in sediment samples taken at the Points 1 and 8. The results of this analysis are shown in Appendix I, Table I.7. The values found, in the harbour as well as in the Estero El Realejo, are below the Dutch limits with regard to the basic quality for aquatic bottoms.

4.3 Degradation of the mangrove forest

4.3.1 The mangrove ecosystem under pressure

Each and every factor or situation forcing the mangrove ecosystem to consume energy in order to maintain the homeostasis of the system is defined as being a stress factor. The different stress factors can be classified as follows:
- the ones that change the nature of the main source of energy;
- the ones that divert part of the main source of energy before it has been incorporated in the system (for example, hydrological changes);
- the ones that extract potential energy before it is stored, but after it has been transformed by photosynthesis (for example, plagues of herbivores);
- the ones that have an impact on the respiration rate (for example: water pollution or a high degree of sedimentation);
- the ones that extract stored energy (for example, the cutting of forests).

Figure 7 shows the flow of energy of the ecosystem and the point of attack of the different types of stress factors, accompanied by examples of each category of stress factors. The repercussion on the ecosystem can consist, for example, of a reduction of the size of the leaves, a loss of leaves and the susceptibility of the trees to an attack of insects and an invasion of epiphyte plants.

4.3.2 Cutting of forests

Through the cutting of mangrove trees not only a part of the material produced by the system that normally forms a very important source of energy for the organisms of the estuarine waters is being removed, it also changes the structure of the mangrove forest itself. The different impacts on the coastal zone, that can be generated by the cutting of the forests, are summarized in Figure 8.

Traditionally, the exploitation of mangrove forests took place in a no planned way; mangroves were being exploited without respecting zones with a different forestry potential. The exploitation of the forests still is not being realized according to its ecological potential, but according to the degree of accessibility.

The exploitation of the mangroves that border the Corinto estuary, is facilitated by their accessibility. Due to their easy accessibility -the trees grow on the shores of the tidal creeks- Rhizophora forests suffer most from exploitation; Avicenna germinans and A. bicolor are being exploited to a lesser extent. The wood of Laguncularia racemosa is sometimes used for construction and Conocarpus erecta is mainly exploited for firewood.

The height of the trees serves as a parameter for the degradation of the mangroves. In areas of frequent exploitation, trees are low compared to the trees in less affected areas. In zones of heavy felling, trees not only remain low, but also large barren patches can be observed.

In the study area, the impoverishment of the mangrove areas is mainly due to the extraction of firewood, and to a lesser extent due to the extraction of wood for construction purposes. Extraction techniques remain limited to the use of the straight timber, while branches, twigs or roots remain totally unused. The firewood cutters do not use the whole biomass available for commercial purposes. The extraction of roots with a diameter of more than 5 cm is more time consuming than cutting only the main stem, and the same with the branches. Practically 48% of the material with a commercial value is left behind in the forests. Moreover, the trees used in order to obtain bark for tannins and that will die because of the extraction techniques applied, generally are not used for the production of firewood.

In 1990, the production of firewood material from the mangrove area added up to 19,586 m^3 for the study area, while the total consumption of firewood and wood for construction purposes was estimated to be 26,623 m^3 (Table 13). Thus, in 1990 there was a deficit of 7,037 m^3. Assuming a total exploitation of the forests, this would amount to approximately 397 hectares of lost mangrove area a year.

Town	Number of inhabitants	Firewood consumption in m^3
Corinto	23,695	15,401.75
El Realejo	6,953	8,235.75
R.A.F.	840	982.80
Poneloya	910	1,064.70
Las Penitas	650	760.50
Salinas Grandes	240	280.80
Total	33,288	26,726.30

Table 13: Firewood consumption in 1990
Source: Windevoxhel Lora, 1992

The number of persons that exploit firewood products from the mangrove areas is increasing even more when profits of fishermen are low, or when they are unable to finance repairs on their fishing equipment.

It may be clear that an overexploitation of the mangrove forests is taking place and in order to avoid their total eradication, it is necessary to take appropriate measures.

4.3.3 Other impacts

Apart from the excessive cutting of the forests, water pollution caused by the adjacent agricultural zones also contributes to the impoverishment of the mangrove areas. In the Corinto area, the development of Avicenna forests is seriously being affected by activities on the mainland, like for example agriculture. The water drained from the sugar cane areas is being discharged into the Estero Esparta. In the up-stream part of the creek, a partial defoliation of the red mangroves (Rhizophora) can be noted, as well as an invasion of these forests by epiphyte plants.

The poor recovery rate of the forests suggests unfavourable environmental conditions, like a reduced fresh water supply to the system, due to climatological factors or hydrological changes occurred in the basin. Although mangroves do develop in a saline environment, they have the same needs as other plant species with regard to an adequate fresh water supply. An elevated salinity reduces the growth of mangrove trees, as the elimination of salt forms an energetic effort for the trees, thus reducing the energy available for primary production.

Finally, the interior belt of the mangrove area is being affected by landreclamation for agricultural purposes; for example, the growing of sugar cane reaches till the border of the mangrove area.

4.4 Impacts on the fauna

4.4.1 General

Due to the impoverishment of the mangrove areas, the terrestrial fauna as well as the aquatic fauna are seriously being affected. The density of raccoons, snakes, green iguanas, parrots, blackbirds and migratory birds of different species has fallen back, mainly because of the destruction of their natural habitat. Other causes that contribute to the decrease of the fauna in the mangrove areas are hunting and the catching of living specimens in order to sell them. For a list of species of fauna and flora that are in danger of even threathened with extinction, see the document prepared by the Wildlife Department of IRENA (1992).

4.4.2 Fishery resources

The impoverishment of vital habitats, like mangrove areas and estuarine waters, can also lead to a reduction of the profits of fishery resources. Apart from the impoverishment of their habitats, some fishery resources are being affected by overexploitation or a poor use of the resources. The abundance of the clam Anadara spp. has fallen back, mainly as a consequence of the excessive exploitation of this species. The population of young clams, that still did not reproduce, has been overexploited. Other factors that have led to the decrease of their production are: water pollution and a high degree of sedimentation. The fiddler-crabs (Ucides occidentalis) are caught especially in their pre-reproductive phase, namely when leaving their burrows; this means that many of them are caught even before they could reproduce.

According to the law, the capture of lobsters under 23 cm is forbidden, but nevertheless juvenile lobsters in their pre-reproductive phase are being exploited.

Sharks are also exploited during their pre-reproductive phase, namely when they come closer to the beach. Moreover, in the main areas of exploitation (Salinas Grandes and Reparto Alemania Federal), only the fins of the caught sharks are used and the meat is not commercialized.

Due to the collection of their eggs and the number of turtles killed by the activities of fishermen, their populations also decrease. The Tortuga paslama (Chelonidae) can be found in the "offal" of shrimp fishing.

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BIOPHYSICAL DIAGNOSIS

APPENDIX I

SAMPLING PROGRAMME FOR THE

ASSESSMENT OF THE BIOPHYSICAL ENVIRONMENT

1 OBJECTIVES OF THE SAMPLING

The objective of the sample survey programme presented below, was to obtain information about:

- fluctuations in salinity in the different parts of the Corinto estuary, as a result of the tides and the different seasons; salinity forms the parameter that affects most the composition of the biota of the estuarine system;

- the pollution of the water or of the bottom sediments, caused by:
  . discharges of sewage water (bacteriological pollution);
  . harbour activities (heavy metals and hydrocarbons);
  . agricultural activities (agrochemical products).

The sample survey and the bacteriological and physicochemical analyses were realized by the Centre for Investigation of Aquatic Resources (CIRA) in Managua. Moreover, some samples of the sedimentation were analyzed by the Institute for Investigation of Materials and the Environment (INTRON) in the Netherlands.

2 SAMPLING PROGRAMME

2.1 Geographical position of the points of sampling

Samples were taken at the following sites:

1. Corinto, harbour area, close to the pier for general cargo;
2. Corinto, opposite Costa Azul;
3. The Estero El Realejo;
4. The Estero El Realejo, at the landing stage;
5. The Amalia-Sucio river, before discharging into the Estero Limón;
6. The Estero Esparta, Esparta harbour;
7. The Estero La Chocolata, opposite the village;
8. The Estero El Realejo, mangrove area, shallow waters.

For the geographical position of the sampling points, see Figure I.1.

2.2 Parameters and frequency of the sampling

Station 1
In order to be able to evaluate the negative impacts caused by harbour activities, concentrations of heavy metals in the sedimentary deposits of the harbour were determined. Furthermore, the sediment of the bottom was analyzed with regard to the presence of hydrocarbons (Polycyclical Aromatic Hydrocarbons).

Station 2
In order to be able to evaluate the degree of water pollution caused by the discharge of sewage waters from Corinto, a bacteriological analysis of water samples proceeding from the estuary opposite Costa Azul was realized.

Station 3
In order to be able to evaluate changes in salinity, as a result of the tidal movements and different seasons of the year, salinity was determined during low tide and during high tide, in the dry season as well as during the rainy season.

Station 4
In the same way as was indicated in point 3, the salinity was measured. Moreover, to be able to evaluate the load of sediments transported by the river towards the Estero El Realejo, the concentration of total solids and solids in suspension were determined during low tide, in the dry season and during the rainy season.
In order to estimate the impact of pollution caused by sewage waters proceeding from El Realejo, a bacteriological analysis was realized during low tide, in the dry season and during the rainy season.
In order to be able to evaluate a possible accumulation of pesticides proceeding from the adjacent area where cotton is grown, concentrations of pesticides with organochlorine compounds and organophosphorous compounds present in the sediment of the bottom were determined.

Station 5
To be able to evaluate a possible effect on the quality of the water caused by agricultural activities in the adjacent area, the following parameters in the Amalia-Sucio river were measured:

- the temperature of the water
- pH
- dissolved oxygen
- electric conductivity
- total phosphate
- nitrates and nitrites
- total solids and solids in suspension.

Station 6
Apart from the measurements with regard to the degree of salinity during low tide and high tide in the dry season and in the rainy season, at this point the concentration of total solids and solids in suspension was determined and a bacteriological analysis was carried out in the dry season as well as in the rainy season.

Station 7
Apart from the measurements regarding salinity carried out in the same way as was mentioned in point 6, at this point of sampling a bacteriological analysis was realized in the dry season during low tide and high tide, and in the rainy season during low tide.

Station 8
This point of sampling served as a point of reference; namely, the percentages of heavy metals present at this station were compared to the percentages found at station 1 (Corinto harbour).

The parameters measured and the frequency of sampling are summarized in Table I.1.

Table I.1

Point	Parameter	Frequency
1	Heavy metals	sample survey of the sediment of the bottom; one time only
	Hydrocarbons (PAH)	sample survey of the sediment of the bottom; one time only
2	Bacteriology	dry season · high tide · low tide
3	Salinity	dry season · high tide · low tide
	Temperature	rainy season · high tide · low tide
4	Salinity	dry season · high tide · low tide
	Temperature	rainy season · high tide · low tide
	Bacteriology	dry season · high tide · low tide
	Total solids and solids in suspension	dry season · low tide rainy season · low tide
	Pesticides	sample survey of the sediment of the bottom; one time only

Point	**Parameter**	**Frequency**
5	· pH · temperature of the water · dissolved oxygen · electric conductivity · total phosphate · nitrates + nitrites · total solids · solids in suspension	dry season
6	Salinity Temperature	dry season · high tide · low tide rainy season · high tide · low tide
	Total solids and solids in suspension	dry season · low tide rainy season · low tide
	Bacteriology	dry season · high tide · low tide rainy season · low tide
7	Salinity Temperature	dry season · high tide · low tide rainy season · high tide · low tide
	Bacteriology	dry season · high tide · low tide rainy season · low tide
8	Heavy metals	sample survey of the sediment of the bottom; one time only

The sample survey programme was realized in the period from May to August 1993; the samples representing the dry season were taken on May, 5th, and the samples representing the rainy season were taken on August 31th.

In addition to this, on the basis of the results of the first sample survey, on June 30th 1993 two samples from the marine sediment were taken, at a distance of < 20 metres from the Corinto pier.

3 RESULTS

3.1 Bacteriology

Table I.2 shows the values of turbity, total coli, fecal coli and fecal streptococcus for the points 6 and 7, found during low tide and high tide in the dry season and during low tide in the rainy season.

Table I.2

	Tidal phase	**Turbity** (T.U.)	**Total coli** (cfu/100 ml)	**Fecal coli** (cfu/100 ml)	**Fecal streptoc.** (cfu/100 ml)
2	low	> 5	170	2	0
	high	> 5	580	600	0
4	low	< 10	6700	3900	2850
	high	5	5	2	19
6	low	> 5	150	58	22
	low *		300	70	80
	high	> 5	10	4	15
7	low	> 5	180	160	0
	low *		30	23	240
	high	> 5	50	4	0

* = during the rainy season
T.U. = Unity of Turbity
cfu = colony forming unities

3.2 Physico-chemical parameters

The results of the physico-chemical analysis of the points 3, 4, 6 and 7, during low tide and high tide in the dry season are given in Table I.3.

Table I.3

Parameter	Point 3		Point 4	Point 6	Point 7
Salinity (‰)	LW HW	32 35	11 35	30 35	35 35
Temperature (°C)	LW HW	30 30.2	28.9 30.8	30.6 31.0	30.2 31.1
pH	LW HW	7.31 7.59	7.75 7.61	7.41 7.52	7.40 7.51
Total solids (mg/l)	LW HW	38270 42944	33498 40632	33380 39592	46350 38938
Solids in suspension (mg/l)	LW HW	9342 2682	19280 3898	644 18142	7890 13588

LW = low water
HW = high water

The salinities and temperatures close to the surface and close to the bottom in the points 3, 4, 6 and 7, during low tide and high tide in the rainy season, are given in Table I.4.

Table I.4

Tide/depth	Point 3		Point 4		Point 6		Point 7	
	S.‰	temp. (°C)	S.‰	temp. (°C)	S.‰	temp. (°C)	S.‰	temp. (°C)
high tide								
surface	32	31.1	18	32	30	31	30	32
bottom	32	31.1	30	31.9	30	31	30	32
low tide								
surface	21	29	2	29.2	15	29.6	30	29.8
bottom	30	29	2	29.2	15	29.6	30	29.8

In point 4, in the Estero El Realejo, close to the landing stage, during the rainy season a concentration of total solids of 6441 mg/l, of dissolved solids of 6350 mg/l and of solids in suspension of 91 mg/l was measured.

The results of the physico-chemical analysis of point 5, in the Amalia-Sucio river before discharging into the Estero Limón, during the dry season, are given in Table I.5.

Table I.5

Parameter	**Value**
Temperature (°C)	33.4
Electric Conductivity (μS/cm)	725
pH	8.04
Dissolved oxygen (mg/l)	0.00
Total phosphorus (mg/l)	2.11
Orthophosphate (mg/l as P)	1.33
Nitrates (mg/l)	< 0.050
Nitrites (mg/l)	< 0.050
Total solids (mg/l)	742
Solids in suspension (mg/l)	34
BOD (BOD_5 in mg/l)	118
COD (mg/l)	330

3.3 <u>Heavy metals</u>

The values of heavy metals found in the samples of the sediments taken in Corinto harbour, close to the pier for general cargo, and in the Estero El Realejo (Points 1 and 8) are given in Table I.6. The concentrations of copper found in the additional sediment samples, taken close to the Corinto pier, amount to 90.96 and 87.80 mg.kg. (-1).

Table I.6

Parameter (mg.kg.-1)	Station 1		Station 8	
	CIRA	INTRON	CIRA	INTRON
Mercury (Hg)	0.26	< 0.2	0.24	< 0.2
Chromium (Cr)	26.06	12	38.63	15
Selenium (Se)	0.8		1.3	
Copper (Cu)	41.82	49	48.94	45
Arsenic (As)	8.23	2.5	6.89	16
Zinc (Zn)		93.84		210.57
Nickel (Ni)		< 8		< 8
Lead (Pb)		8.7		39
Cadmium (Cd)		< 0.2		< 0.2

3.4 Hydrocarbons

Ten different Polycyclical Aromatic Hydrocarbons (PAH) present in samples from the harbour sediments close to the pier for general cargo and from the Estero El Realejo, were analyzed; respectively the Points 1 and 8. The concentrations found, expressed in mg.kg. (-1), are given in Table I.7.

Table I.7

Parameter	Point 1	Point 8
Naphthalene	< 0.10	< 0.10
Phenantrene	< 0.10	< 0.10
Antracene	< 0.10	< 0.10
Fluorantene	< 0.10	< 0.10
Benzo (a) antracene	< 0.10	< 0.10
Chrisene	< 0.10	< 0.10
Benzo (k) fluorantene	< 0.10	< 0.10
Benzo (a) pyrene	< 0.10	< 0.10
Benzo (g, h, i) perylene	< 0.10	< 0.10
Indeno (1,2,3-c,d) pyrene	< 0.10	< 0.10
Total PAH	< 0.3	< 0.3

3.5 <u>Pesticides</u>

At Point 4, in the Estero El Realejo, close to the landing stage, the following values regarding pesticides were measured:

Table I.8

Organochlorine compounds	**Concentr.** ((µg.kg-1)	**Organophospho-rous compounds**	**Concentr.** (µg.kg-1)
alpha-BHC	nd	Mocap	nd
beta-BHC	nd	Naled	nd
delta-BHC	nd	Forate	nd
Lindane	< 0.1	Terbuphos	nd
Heptachlorine	nd	Dysistone	nd
Heptachlorine-epoxyde	nd	Dyazinone	nd
alpha-endosulphane	< 0.1	Metyl-parathion	nd
beta-endosulphane	nd	Ehtyl-parathion	nd
Aldrin	nd	Malathion	nd
Dieldrin	nd	Chlorphenvinphos	nd
Endrin	nd	DEF	nd
pp-DDT	< 2.0	thion	nd
pp-DDD	< 2.0	ediphenphos	nd
pp-DDE	4.10	Gution	nd
Toxaphene	nd	Zolone	nd

nd = not detected

FIGURES

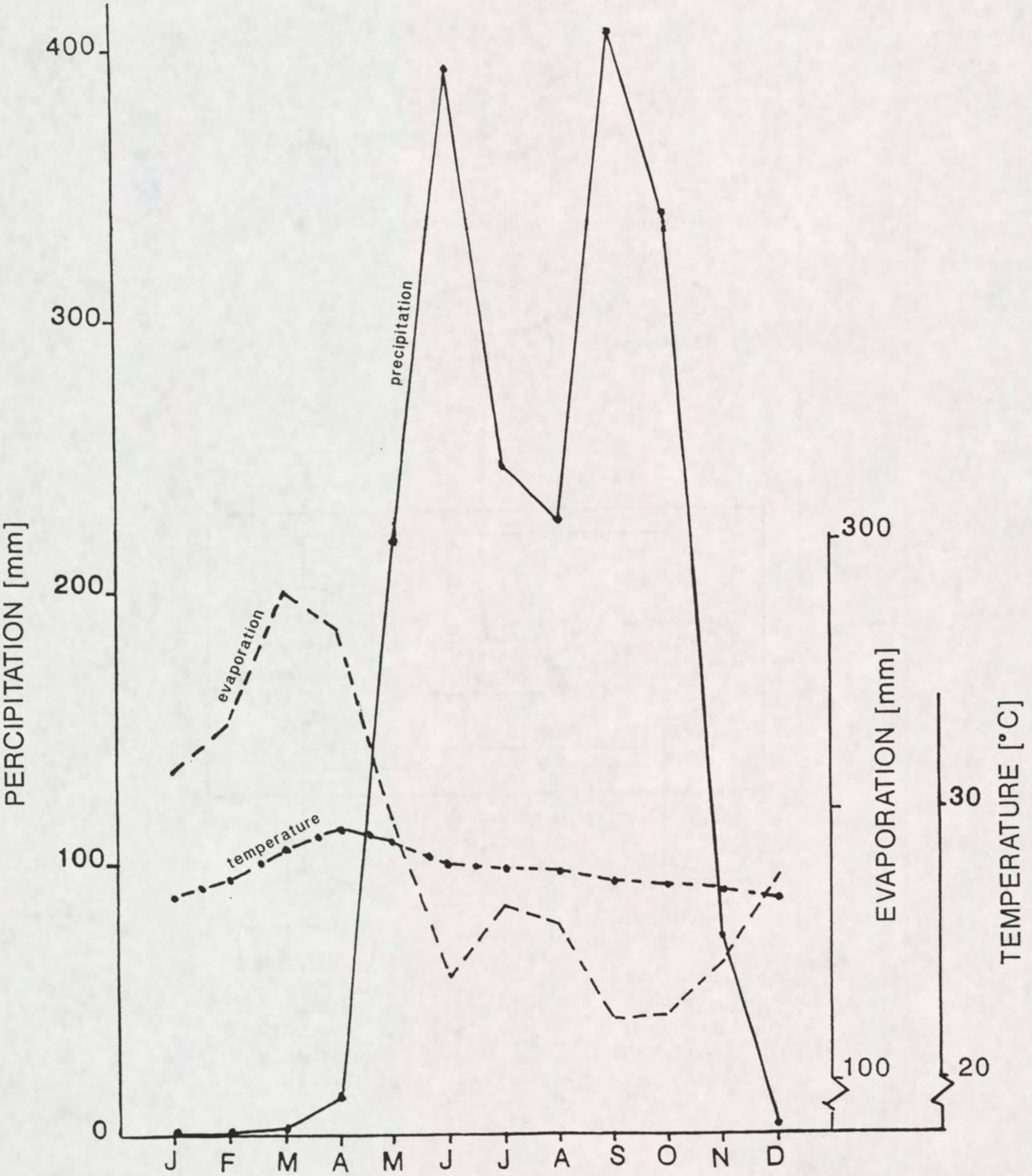


Figure 1: Monthly averages of temperature, precipitation and evaporation in the study area (meteorological station 'Ingenio San Antonio')

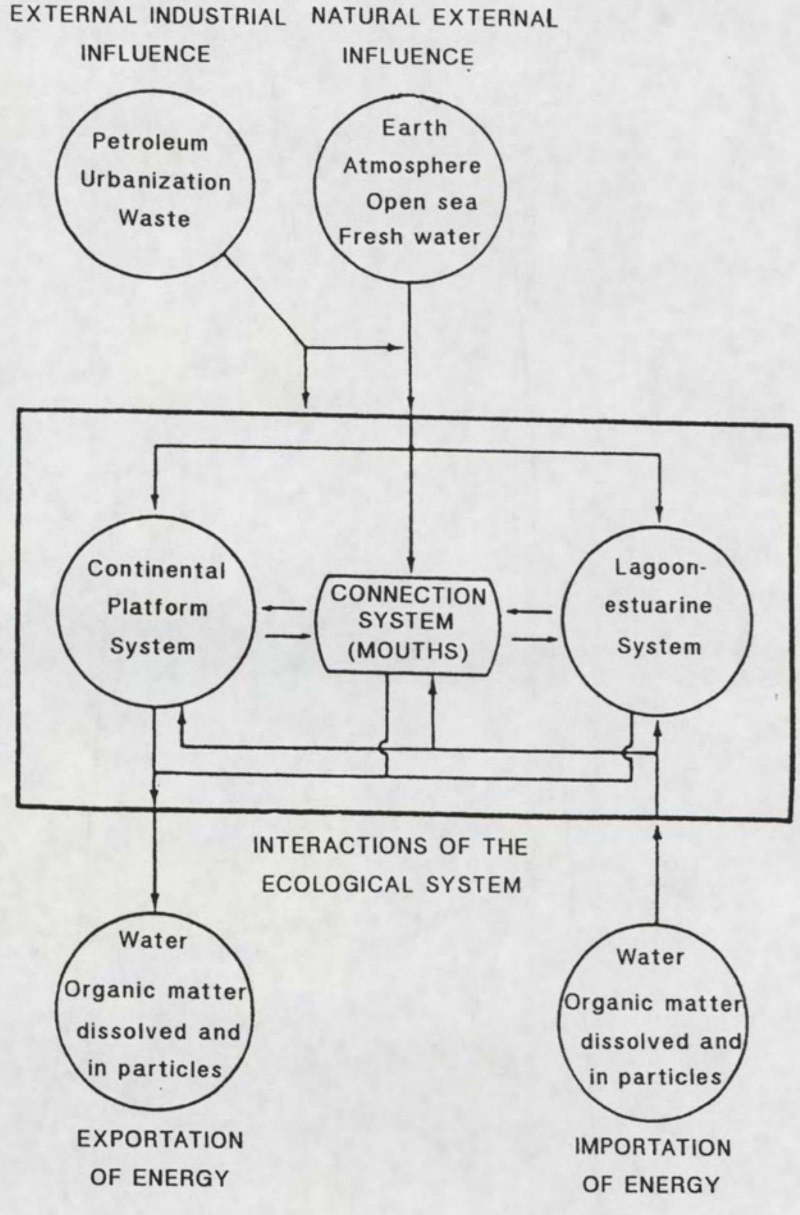


Figure 2: Interactions between the estuarine system and the system of the continental platform

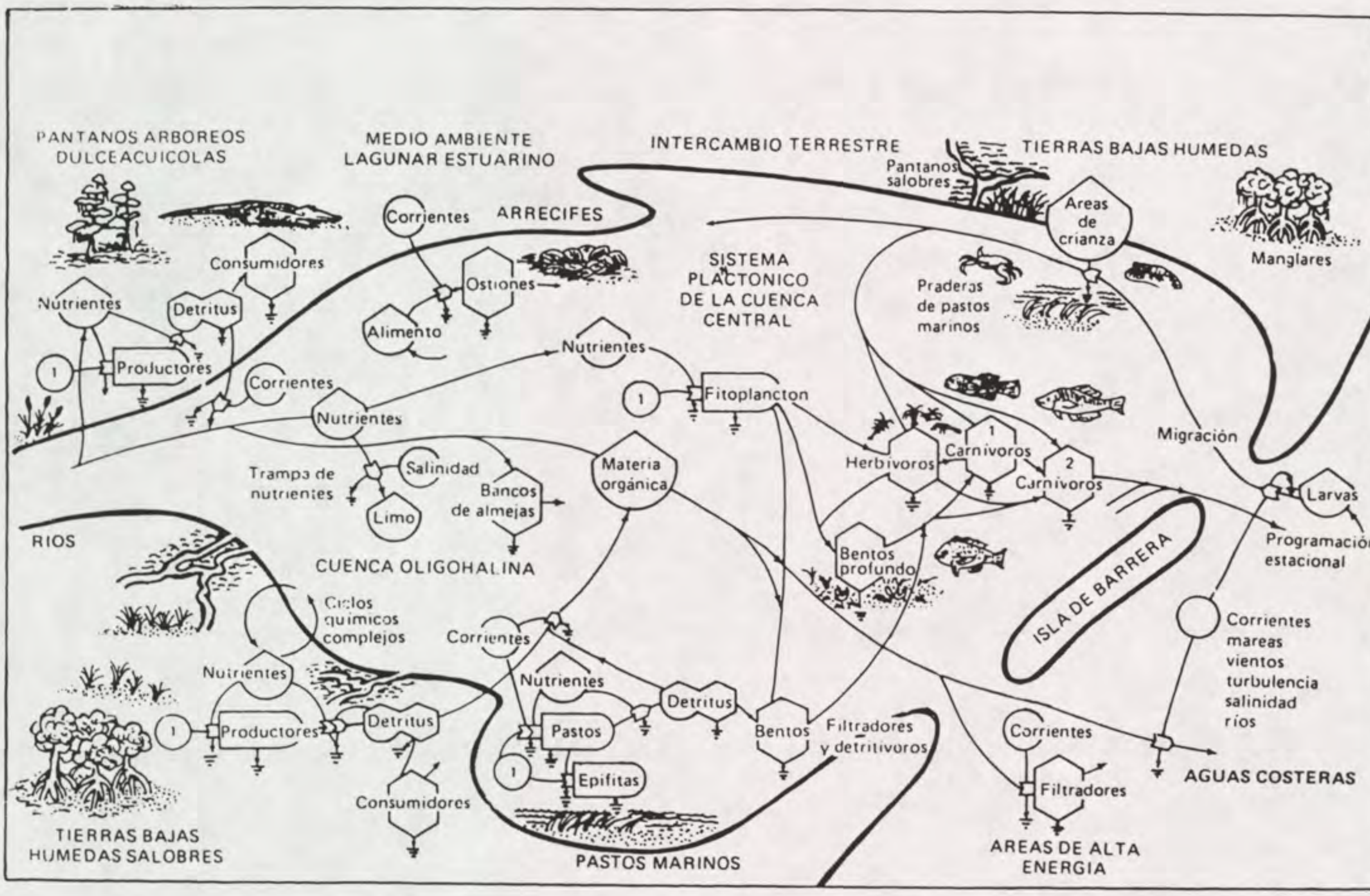


Figure 3

Lagoon-estuarine system: high diversity of habitats, complex food web, complex interactions between flora, fauna and physical environment (Source: Yánez-Arancibia, 1986)

pantanos arbóreos dulce	fresh water marshes with	herbívoros	herbivores
acuícolas	trees	materia orgánica	organic matter
medio ambiente lagunar	lagoon-estuarine environ-	salinidad	salinity
estuarino	ment	trampa de nutrientes	nutrient trap
intercambio terrestre	terrestrial exchange	bancos de almejas	mussel beds
tierras bajas húmedas	wetlands	limo	mud
pantanos salobres	brackish marshes	programación estacional	seasonal programming
manglares	mangroves	rios	rivers
corrientes	currents	bentos profundos	deep benthos
arrecifes	reefs	Isla de Barrera	barrier island
areas de crianza	nursery areas	cuenca oligohalina	oligohaline basin
consumidores	consumers	ciclos químicos complejos	complex chemical cycles
sistema planctónico de la	planktonic system of the	mareas	tides
central	cuenca central basin	vientos	winds
praderas de pastos marinos	meadows of sea-grasses	turbulencia	turbulence
ostiones	oysters	pastos marinos	sea-grass beds
nutrientes	nutrients	filtradores y detritívoros	filter feeding and detritivo-
detritus	detritus		rous
alimento	food	bentos	benthos
productores	producers	epifitas	epiphytes
fitoplancton	phytoplankton	aguas costeras	coastal waters
carnívoros	carnivores	tierras bajas húmedas salo-	brackish wetlands
migración	migration	bres	
larvas	larvas	areas de alta energa	high energy zones

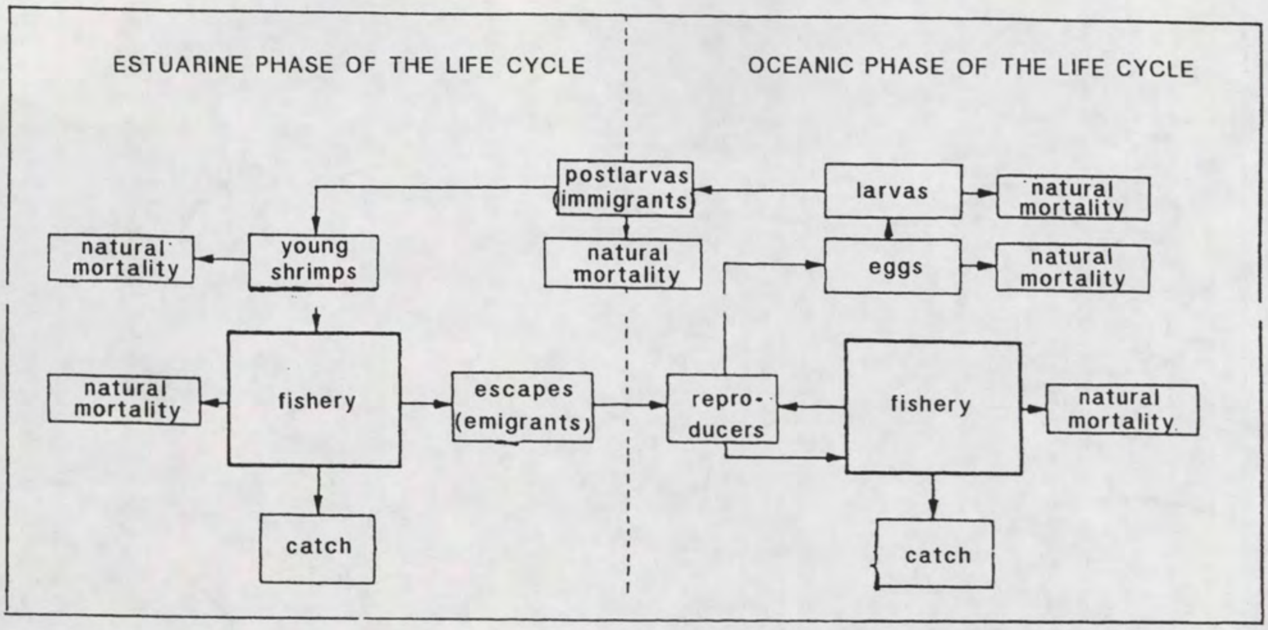


Figure 4: Relations between the components of the life cycle of penaeid shrimp and shrimp fishery

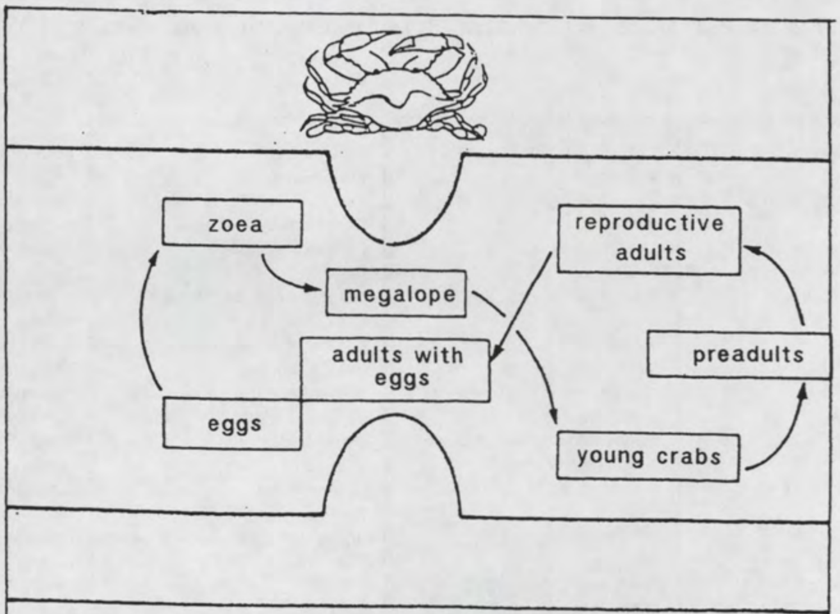


Figure 5: Life cycle of the blue crab, Callinectes sp.
(Source: Yánez-Arancibia and Sánchez-Gil, 1988)

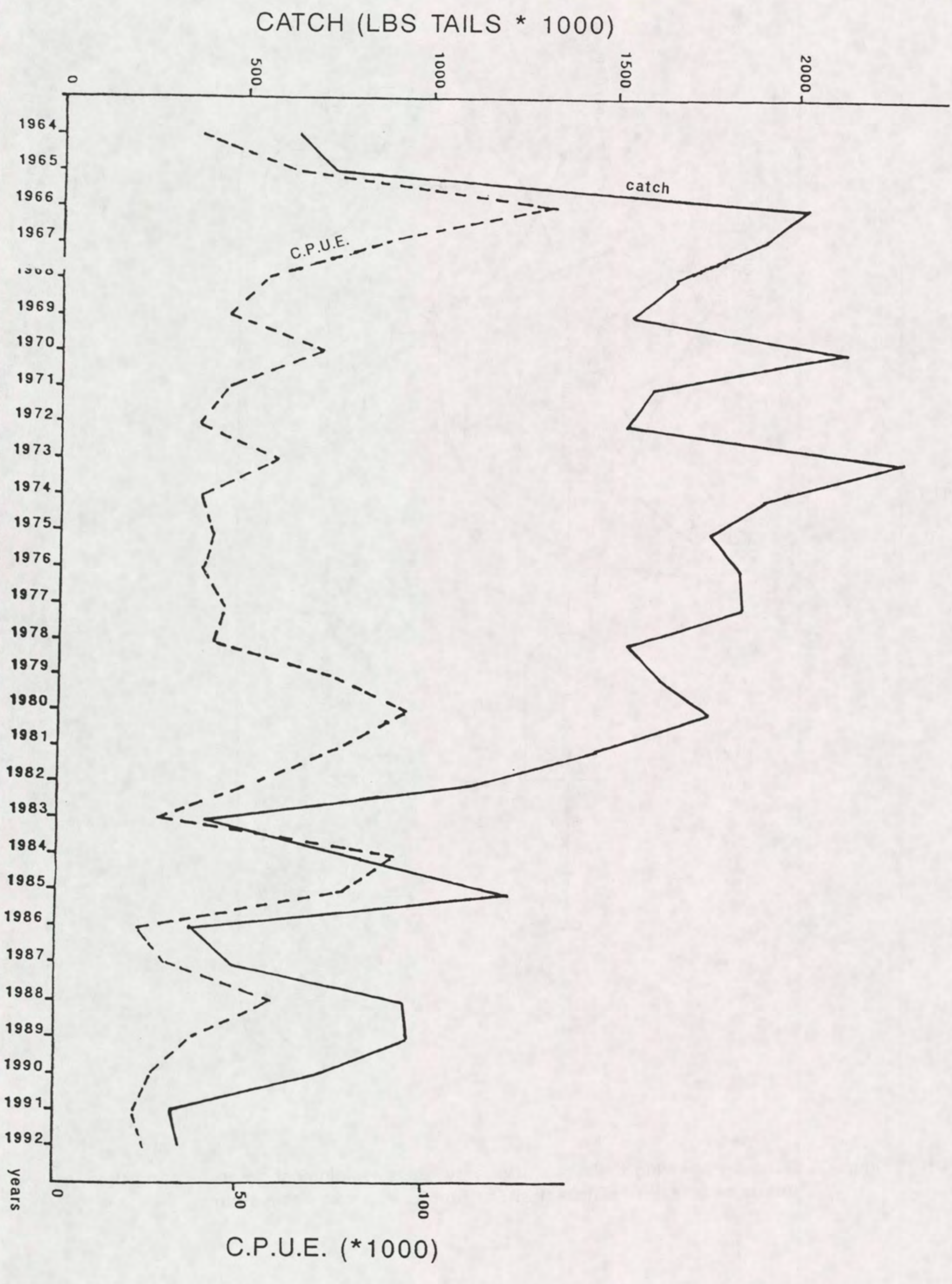


Figure 6: Yearly exploitation of shrimps and catch per unit of effort (CPUE)

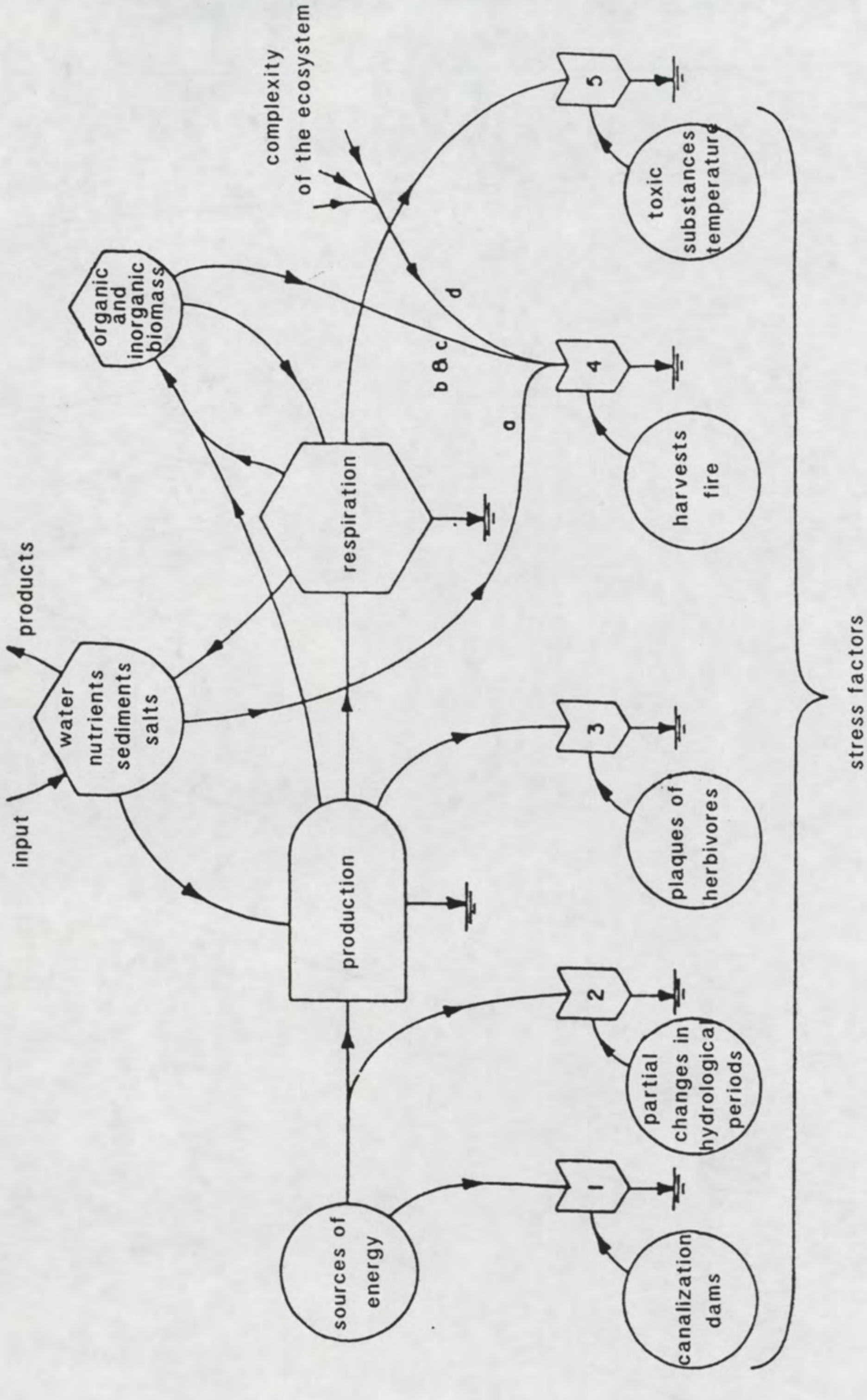
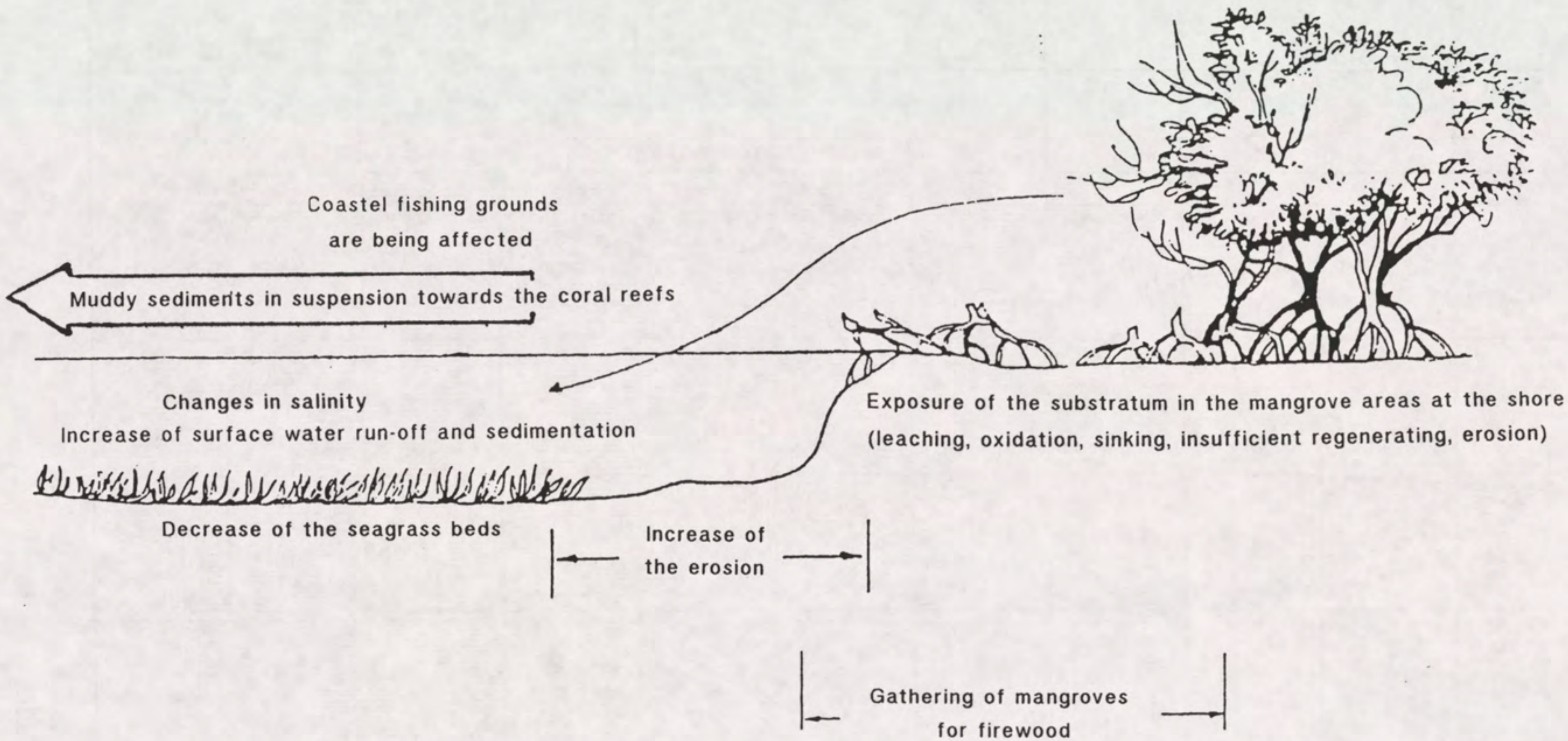


Figure 7: Diagram showing the flows of energy, the physiological processes and the points of attack of different stress factors in a wet ecosystem

Figure 8: Environmental effects of the clear felling of mangroves on the coastal resources close to the littoral



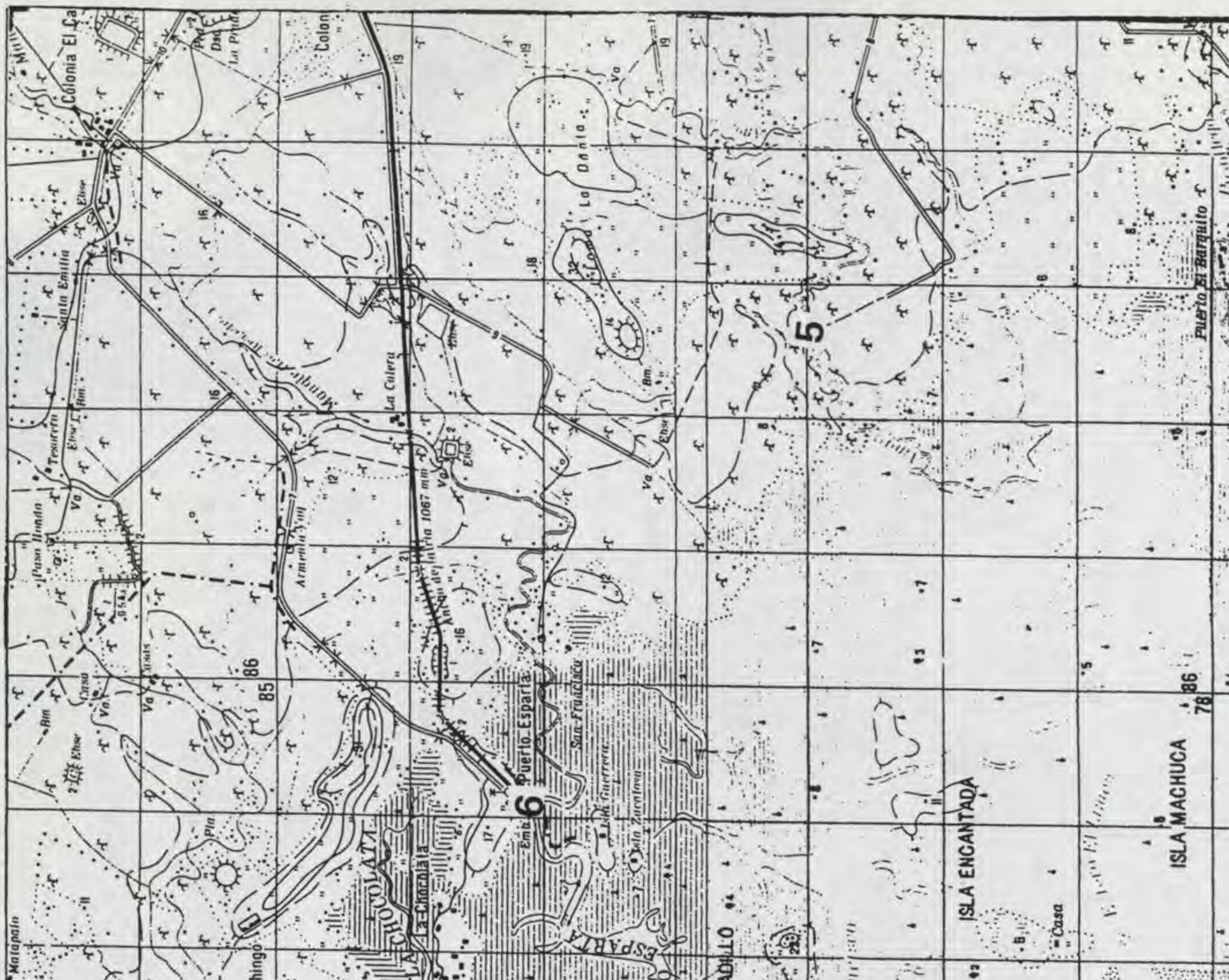


Figura No.I.1 Ubicación de los puntos de muestreo del programa de muestreo efectuado para el diagnóstico biofísico

Figure I.1

Geographical position of the sampling points regarding the sample survey programme realized for the assessment of the biophysical environment