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SECOND DRAFT

REPORT OF THE TASK TEAM OF EXPERTS ON

EFFECTS OF CLIMATIC CHANGES IN THE SOUTH EAST PACIFIC REGION

United Nations Environment Programme - UNEP

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FOREWORD

As a response to the concern expressed in certain regions about the possible implications of expected climatic changes (mostly man-induced) in the marine and coastal environment, the UNEP has initiated the preparation of studies which would review the situation in the various regions covered by the Regional Seas Programme. This Report is the assessment of the South East Pacific region and includes the impact on the Pacific Coast of Colombia, Chile, Ecuador, Panama and Peru as well as the "El Niño" Phenomenon as a case study.

The study covers the marine environment and adjacent coastal areas influenced by or having an influence upon the marine environment. The proposed objectives of this study are the following :

a) to look into the possible effects of sea level changes on the coastal ecosystems (deltas, estuaries, wetlands, coastal plains, coral reefs, mangroves, etc.).

b) to inquire about the possible effects of temperature elevations on the terrestrial and aquatic ecosystems, including the possible effects of such changes on economically important species;

c) to examine the possible effects of climatic, physiographic and ecological changes on socio-economic structures and activities;

and

d) to determine areas or systems which would appear to be most vulnerable to the above mentioned changes.

A Task Team of Experts was set up to elaborate on the analysis of the objectives stated above. The Permanent South Pacific Commission,as Regional Co-ordinating Unit of the Action Plan for the Protection of the Marine Environment and Coastal Areas of the South East Pacific, in consultations with the IOC and UNEP, invited a selected group of experts from the region's countries to participate in the preparation of this regional study.A meeting of the Task Team was held in Bogotá (Colombia) from 30th November to 2nd December 1987. The meeting adopted a work schedule to review the regional situation as regards the implications of climatic changes considering, as starting point, the effects of such changes which have been linked to the occurrence of the "El Niño" Phenomenon the resulting effects of which are considered in this Regional Report.

INTRODUCTION

The various outlooks borne in mind in this regional review have been addressed by regional experts in different scientific fields such as marine biology, oceanography, ecology, meteorology, hydrology, economics, etc., on the basis of a large number of scientific and technical contributions; most of such contributions refer to the Regional Study of the "El Niño" Phenomenon - ERFEN, to the identification and assessment of the different implications of climatic changes on the regional ecosystems and socio-economic structures.

It has been widely accepted that the question of forecasting climatic changes is closely associated with the determination of physical causes accounting for them. On the long term the emphasis has been made on the variations observed in CO_2 concentrations. The assessment of recent results on the basis of climatic models shows that the increase of the earth's mean surface temperature due to an increase of CO_2 and other "greenhouse" gases equivalent to twice the current atmospheric concentration of carbon dioxide could vary from 1.5°C to 4.5°C, showing higher values at high altitudes (Charney, 1979; Smagorinsky, 1982). By comparison, during the Ice Age the world mean temperature was 5° - 6°C colder than the current temperature (Titus, 1986). It has been estimated that by year 2.030 this heating could represent a 1.5°C increase in the mean surface temperature. This projected world heating would result, on its turn, in the acceleration of the current rate of elevation of the mean sea level due to the expansion of oceanic water, the thawing of glaciers and, eventually, would cause the thawing or sliding of polar ice layers towards the ocean. The thawing and sliding of Greeland and Antarctic ice caps account for more than 50% of the elevation of the mean seal level during the last forty years (12 cm). In like manner, it has been stated that the thawing and sliding of the Antarctic ice cap would result in an increase in the movement of the earth (represented by the deceleration in the rotational speed and a tiny increase in the day's length (SCOR/IOC, 1982).

Complying with the recommendations of the Villach 1985 Meeting, the UNEP has embarked in the writing up of reports on the possible effects of climatic changes on marine and coastal ecosystems. This study is being carried out in the various regions involved in the Regional Seas Programme. Within the framework of the UNEP project, the Permanent South Pacific Commission, as Regional Co-ordinating Unit of the Action Plan of the South East Pacific, counting on the support of UNEP and IOC invited a group of regional experts to gather together in Bogotá, from 30th November to 2nd December 1987 to set up a Task Team whose job would be to prepare the report on the South East Pacific region.

The Group decided to adopt the same recommendations issued by the Villach meeting as guidelines for the preparation of the Regional Report, i.e.,

a) Sea Surface Temperature (SST) = Increases of 1.5°C up to year 2.025, on the basis of latitudinal variations; and

b) Relative Sea Level (RSL) = Increases of 20 cms. up to year 2.025.

The Group was of the opinion that "El Niño" Phenomenon represents one of the most significant regional events occurring in the ocean and in the atmosphere, one having an outstanding impact on the climate and the marine environment; therefore, the Group decided to include the 1982-1983 "El Niño" Phenomenon in the Regional Report as a case study to show the short-term effects of climatic changes in the South East Pacific. There exist sound reasons to carry on a study of the "El Niño" Phenomenon notwithstanding the fact that the phenomenon does not occur on a time scale within a long-term climatic change. To eventually come to understand the causes that give origin to "El Niño" could allow us to have an inkling on how ocean circulation could react to future changes in the world heating balance.

The "El Niño" Phenomenon has been regarded as the occurrence along the coastal areas of Ecuador, Peru and Chile of a large scale anomaly in the oceanic-atmospheric interaction (Wyrtky, 1982), mainly affecting the Pacific Ecuadorian strip and involving most of the world regions (Rasmusson and Wallace, 1983). This coastal phenomenon reaches dramatic proportions in the areas facing the coastal regions of some countries of the South East Pacific System showing positive temperature anomalies in a range of 2°C to 3°C above the surface mean temperature as well as increases in the sea mean level of up to 40 cms and a maximum of 50 cms as recorded during the 1983 Phenomenon (Fonseca, 1985). Therefore, we may assume that the effects sustained by the various regional ecosystems and socio-economic structures during the events may, in the short-term, reflect those to occur in year 2.025.

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CHAPTER I

IMPLICATIONS OF CLIMATIC CHANGES IN THE SOUTH EAST PACIFIC REGION

Physical Aspects

The most strongly felt impact of a sea level rise is the flooding of those areas located right above the original water level. These areas, known as "wetlands" are usually found at altitudes below the yearly highest tide and above sea level. Therefore, "wetlands" account for the largest land areas located at less than 1 metre above sea level.

Flooding depends on the gradient immediately above the original sea level alone. Due to the fact that the shore profiles are usually flatter than the shore land right above sea level, the erosion resulting from a sea level rise covers an area larger than the land being directly affected by the flood (Bruun, 1962). It has been widely recognized that a sea level rise equivalent to 1 cm. would result in a 1 m. landward retreat of the coastline (Bruun, 1962). Nevertheless, this effect has a stronger impact along the coast bathed by larger size waves; in some instances, the coastline may show a landward retreat of 2 - 4 m. by each cm. of sea level rise (Army,1979).

The potential erosion of the coastal zone resulting from a sea level rise could have a meaningful impact on recreational beaches. Considering that only a few of the region's most developed bathing places have access to a beach area of less than 20 m. during the high tide, the 20 cm. sea level rise being forecast for year 2.025 would erode most recreational beaches in developed areas. Northern Peru can be quoted as an example of these effects.

Besides, the sea level rise could increase the damage produced by floodings and tidal waves in coastal areas. Three factors should be considered mainly: The resulting erosion would increase the vulnerability of some communities to withstand the dashing of large waves; high water levels would supply waves with a highest base on which to grow; higher water levels would, therefore, affect natural and man-made drainage systems. Thus, a 20 cm. sea level rise could severely impair certain protective structures during a period of strong wave motion due to the higher sea level and to the larger size of waves resulting from the erosion of sand submerged in front of the structure (Kyper and Sorensen, 1985).

Notwithstanding the fact that the emphasis has been made mainly on the global sea level projections, the impact in certain areas will also depend on the relative sea level. Some of the factors influencing the local sea level and which could change as a result of the global warming up include : Currents, winds and the flow of rivers into the estuaries. Nevertheless, none of these possible impacts has been calculated so far. The ever increasing warming up of the Earth surface as projected within the next few decades implies as well a rise of the sea subsurface temperature and the subsequent expansion of ocean water thus resulting in an additional sea level rise.

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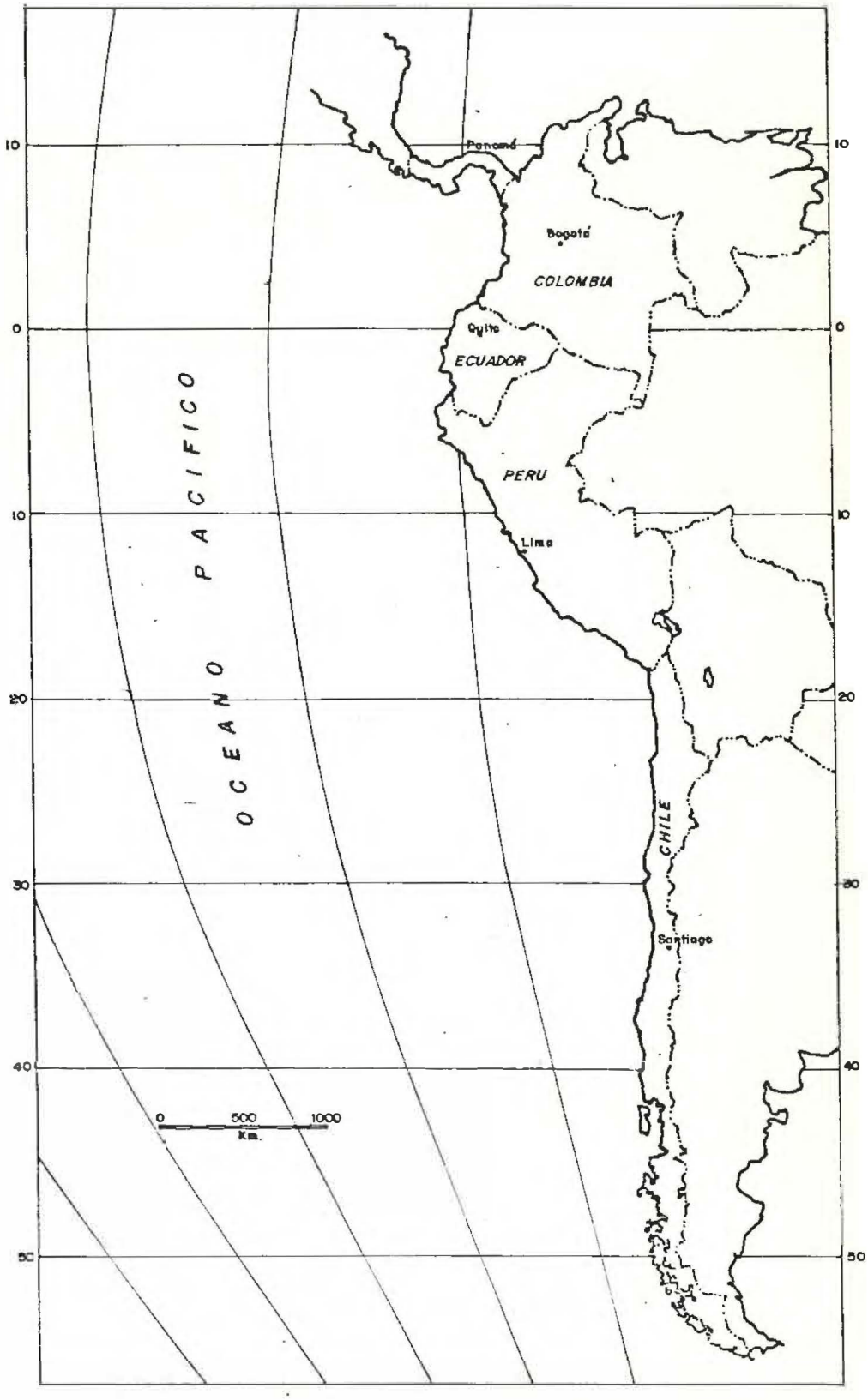

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Simultaneous to the changes sustained by the ocean in terms of heat and water content in the surface layer, there occurs a change in the ocean's density. The resulting thermal circulation will reflect these changes in its contribution to the global redistribution of heat and water.

As far as the Pacific Basin is concerned, storms and hurricanes develop in the central and western regions giving origin to large-sized waves (swells) which on many instances reach the South American western coast affecting its morphology. What is more, a more frequent trend in the occurrence of storms would tend to making the typical shore profile even flatter resulting in a substantial landward retreat of the coastal line. Contrary to the above and on its turn, a decreasing trend in the frequency of winter storms could have an opposed impact at higher latitudes.

Due to the fact that warmer temperatures would intensify the hydrological cycle, it has been estimated that a global warming up would result in a change in the rainfall pattern with rain being heavier in some areas than in others.

Notwithstanding that most researchers have focused their concern upon the increase of floodings and the landward retreat of the coastal line associated with a rise in the sea level, the inland penetration of salty water could have a significant effect in some areas. A rise in the sea level would increase the salinity rates of some estuaries thereby altering the balance between the fresh water and salty water powers of strength. A rise of the sea level has an impact similar to that of a decrease of the fresh water inflow : By enlarging and deepening the estuary, the rise of the sea level increases the ability of the salty water to be conveyed upstream.

The most sophisticated models currently in use are unable to accurately point out local or regional anomalies present in the coastal circulation and resulting from the projected changes in temperature and sea level. This is mainly due to the high levels of natural variability and the consequential large amount of simulation required to reach statistically meaningful results.

To conclude, we must anticipate that our climate and natural environment would be subjected to changes beyond historical experience. Our descendants will have to develop new definitions of what is "normal", they will have to adjust their expectations as regards floodings and droughts, and they will have to modify their food and water sources. Some of the expected changes may be beneficial, some others may be harmful; still some others may be unconsequential. Notwithstanding, unless these changes are timely perceived and understood, most of them will probably be harmful. At least we must try and set up the ground basis of knowledge and understanding upon which our descendants may act.

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CHAPTER II

IMPLICATIONS OF CLIMATIC CHANGES ON KEY MARINE ECOSYSTEMS IN THE SOUTH EAST PACIFIC REGION

1. Coral Reefs

Coral reefs are of frequent occurrence in the East Pacific. Scientific literature abound in descriptions of coral reefs and associated communities in Costa Rica, Panama, Colombia and the oceanic islands of Cocos, Malpelo and Galapagos. Generally speaking, coral reefs present in the region are characterized by the relatively small number of species populating them (from 8 to 10 species by reef). Amongst these species, pociloporide reefs prevail. Coral reefs thrive in protected, shallow waters, at a depth of no more than 10 to 15 m. The presence of cold water arising from the Peruvian current, coastal outcroppings, high turbidity rates of water in the areas close to the coast resulting from the outflowing of a large number of rivers and the wide tidal range seem to be accountable for restricting the distribution of reefs in the region and are also responsible for their small size and discontinuity (Glynn, 1982; Glynn, Von Prahl and Gulh, 1983).

Paleobiological information available suggests that during the Pliocene and the Quaternary periods there occurred changes in the sea level and the temperature of the sea which favoured the growth and distribution of reefs in general (Wells, 1956). Therefore, a 20 cm. increase in the sea level does not seem to be the likely reason for the occurrence of irreversible changes in the South East Pacific coral reefs. Changes sustained by the temperature could entail a significant outcome (Dana, 1975). A 1.5°C increase in the sea surface temperature may favour the growth and distribution of those reefs currently thriving close to the low temperature (20°C) tolerance limit, as is the case with those reefs growing near outcropping areas or cold currents. The reefs found near the Perlas Islands, in the Panama Gulf, fit this description; they are affected by periodical outcroppings. The same applies to reefs present in the Galapagos Islands. For those reefs subjected to usually high temperatures (28 to 29°C), such as the reefs found around the Gorgona Islands in Colombia, and the Secas, Uvas and Contreras Islands in the Chiriquí Gulf (Panama) a 1.5°C increase could produce a negative disturbance. During the occurrence of the 1982-1983 "El Niño" the sea surface temperature rose up to somewhat higher than 30°C in several areas of the East Pacific; as a result of this, in early 1983 there were reports of a whitening of reefs due to the expelling of zooxantelles. Therefore, it has been established that whenever these reefs occur in areas too close to the highest thermal tolerance limit, a 1.5°C rise in the sea surface temperature could have calamitous effects.

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2. Mangroves

The South East Pacific mangrove ecosystem is located in the so called "wetlands" and is generally made up by Rhyzophorae and Avicennia Luguncularia in an association which varies from place to place. In Panama, Colombia, Ecuador and the northernmost area of Peru, the mangrove forest appears in the shape of a strip of land parallel to the coast which breaks into the mainland in sections of differing thickness. The intrusion of this strip of land is more extended in the Northern region of Ecuador, in some areas of Guayas and in the Southern zone of Colombia. The mangrove ecosystem extends itself over 283.775 Ha. in Colombia whilst in Ecuador it covers some 177.755 Ha.

During the 1982-83 "El Niño" event, in some mangrove areas of Northern Peru and Ecuador the sea level reached heights of more than 2 m. above normal. The high temperatures and extremely low salinity rates recorded, which had been caused by a continuous precipitation during the 1982-83 event, together with a high load of sediments and sludge resulted in high mortality rates of filter mollusks (Anadara grandis, Chione subrugosa, Ostrea sp) as well as of mangrove crabs (Ucides sp). On the other hand, catch rates of different penides from the mangrove area (Peneus vannamei, P brevirrostris, P californiensis, P stylirrostris, Xiphopenaeus rivertii) increased from 10-20 kg/Fisherman/day pre-event to 80-100 kg/fisherman/day during the event.

Temperature elevations should not have a direct effect on these species given the usual ranges in which they develop. This would imply qualitative changes in the composition of the ecosystem as well as variations in its high productivity rates.

3. Coastal Pelagic Ecosystem

The outstanding biological productivity of countries located on the South East Pacific coast relies on intensive coastal outbreaks, on the presence of a shallow mixture layer and on the occurrence of a thermocline close to the surface. These conditions determine an extraordinary wealth of fitoplankton which is reflected in the high yearly produce of the ecosystem's whole trophic levels. Drastic reductions of this high productivity occur at intervals between three and ten years as a consequence of changes in the conditions mentioned. These anomalous conditions are due to the effects of the "El Niño" Phenomenon and result in serious biological sequels mainly recorded in low primary productivity and changes in the composition and distribution of species in pelagic communities.

Yielding a primary production higher than 1.000 gr $Cm^{-2}/year^{-1}$, the Peruvian current is regarded as the world's most productive ecosystem. Scientific evidence on the effects of climatic changes on the basis of those recorded during the "El Niño" Phenomenon are soundly supported by appropriate reference material in Arntz (1985). Under "normal" conditions, values of surface nutrients fluctuate from 10 to 20 ugr at l^{-1} for silicates; from 10 to 15 ugr at l^{-1} for nitrates; from 2 to 3 ugr at l^{-1} for phosphates (Zuta y Guillen, 1970). During the 1982-83 "El Niño" event chlorophyll values ranged from 0.1 to 0.2 ug at l^{-1} in Ecuador (ERFEN, 1984). The low chlorophyll values suggest the disappearance of outbreaking areas during the event, particularly in northern Peru. Under normal conditions in the outbreak area located between 5° and 23°S diatoms thriving in cold water prevail. During the event diatoms are reduced and confined to smaller areas of up to 10 Kms. Under normal conditions, such areas extend up to 200 Kms. offshore. During the event, the neritic area is invaded by tropical and subtropical dinoflagelates as well as by a large number of warm water diatoms. Dinoflagelates replace prevailing diatoms. Some typical invaders are : Ceratium trichocerus, C. carriense and C. gibbrum (Rojas de Mediola et al. 1985). Ecuadorian and oceanic zooplankton invade outbreak areas from the early stages of the event introducing drastic changes in species composition, reducing density rates and increasing diversity.

Alterations in environmental conditions and those changes occurring at lower trophic levels have a serious effect on the region's pelagic fisheries bringing about disorganization of fish schools and changes in species distribution patterns.

The most dramatic effects of climatic changes associated to "El Niño" were its influence on anchovetta (Engraulis ringens) fisheries. The Peruvian and Chilean 1970 catch amounted to 13 million M^3 Tons whilst the 1973 catch produce only reached 1.200.000 M^3 Tons. The dramatic reduction of the anchovetta biomass produced an ecological vacuum in the ecosystem. By diminishing the intake of plankton and by relaxing the competition stress over other related planktophagus species, the expansion of the latter was hastened thereby increasing the biomass of sardine (Sardinops sagax), jurel (Trachurus murphy) and mackerel (Scomber japonicus). This was particularly evident as far as the catch of sardine was concerned since it showed a 150% increase during a ten year period.

Serious alterations in the physiological features of the species during the "El Niño" event are also to be taken into account. Such alterations are to be found in the loss of body weight due to the diminishing fat content. This effect rebounds in the fish reducing industry since the oil content per ton of catch is greatly reduced. In like manner, the reproductive cycle of species is affected by alterations in the spawning season and by larvae and juvenile mortality which, on its turn, has an influence on later years' recruitment figures.

The anchoveta, which is the species better adapted to the unusually high biological productivity of the coastal pelagic ecosystem and, therefore, the species most affected by its changes, virtually vanished from the Chilean coast from where it came to show up again in rather restricted areas of the Peruvian coast. The change in the fitoplankton composition, from the prevalence of diatoms to that of dinoflagelates, altered the feeding habits of the anchovetta and the sardine, thereby modifying the physiological conditions of both species which sustained a loss of body weight of up to 30%. The jurel species widened its scope of latitudinal distribution northwards and gathered together around the inner fifty miles lessening the pressure of fishing and that of ocean predators which kept close to them, such as tuna fish and stripped tunny. However, the jurel sp. quickly went back to fishing once the event was over thus stressing the fact that it is endowed with the power to endure the most rigorous phenomena.

The mackerel sp. also widened its distribution patterns and showed a positive relationship between the spawning season and the alteration of environmental conditions. All three species mentioned, i.e., sardine, jurel and mackerel, showed better endurance than the anchovetta sp. to the impact of the "El Niño" event.

Due to the close relationship existing between pelagic fish and guano birds, population figures of the latter have been seriously impaired by the climatic changes associated to the "El Niño" event. In Peru, the populations of 'guanay' (Phalacrororax bougainvilli), 'piquero' (Sula variega) and Pelican (Pelecanus occidentalis) amounted to some 30 million birds in 1950 figure which by 1982 had been reduced to 6 million and only 300.000 birds were left after the 1982-83 event. The disappearance of the traditional pelagic trophic net not only affected the guano birds but was also responsible for the death of seals and the loss of nearly a yearly class.

4. Bentic Environment

Most bentic species thriving in the Region's outbreak areas are adapted to sustaining low temperatures. When warm conditions increase as a result of the "El Niño" effects these species see themselves greatly reduced in numbers due to migration and to the depredation of immigrant species from warm waters assisted by high oxygen and temperature levels (Tarazona, 1985). Polychaetos and nermeteos increase their biomass and density to berils from 50 to 100 m. in the central coast of Peru showing a substantial decrease during the event's acute phase. "El Niño" also has an effect on the behavioural and distributive patterns of demersal fish. Small scianides, pomalasides and other demersal species usually caught in large quantities in the Guayaquil Gulf seem to be absent during the event. At the same time, lutjanides and other tropical fish invade the equatorial waters from the North downwards (Herdson, 1984). In Peru, the area southwards of Chimbote, usually fish scarce, produced large quantities of dog fish and 'lorna' during the 1982-83 "El Niño" event. The latter species showed unusual behaviour following a pattern never before recorded : It migrated from its traditional grounds 20 kms. off the shore up to the border of the continental shelf to distances of up to 150 kms. offshore, simultaneously enlarging its range of distribution southwards. Other recorded migrants are the swiming crabs (Portunidae family). During the event, they migrate southwards in large numbers reproducing themselves outside their usual distribution range thus creating serious problems to fisheries. The rock lobster (Panulirus gracilis) - other tropical species - is rather abundant during the "El Niño" event in northern Peru (Yockteng et al. 1985). It has also been reported that during the occurrence of the event most crustaceans autoctonous of the outbreak area sustain massive mortality. Amongst them mention should be made of the Cancer sp., Platyxanthus orbigny, Hepatus sp. et al.

No sudden alterations in the bentonic ecosystem composition are expected due to the fact that most of its species are eurithermal, so that the 1.5°C heat increase fluctuates between normal distributive ranges.

An increase in the temperature would entail :

- Adaptation of subtidal organisms.
- Migration of stenothermal subtidal organisms (rather scarce or non existent) to higher latitudes.
- Unimportant effects on intertidal organisms given their eurithermic condition.
- Temperature increases could favour metabolic processes, i.e., growth and spawning.

5. Estuarine Ecosystems

They are one of the less studied ecosystems in Latin America. From the ecological viewpoint estuaries are complex, diverse and open systems which, together with a high biological productivity, offer short trophic chains.

Between the southern and central areas (35° to 42°S) the Chilean coast displays estuaries linked to large and medium size coastal rivers, some of them severely affected by urban or industrial pollution. The significance of demersal resources, joined to the estuaries, increases along the waterways and fjiords area supporting important shellfish fisheries. In Colombia and Ecuador most estuaries are associated to the mangrove ecosystem.

An increase in the temperature also translated into an increase of the sea level would produce a deeper penetration of the salty wedge, producing a change in the natural successions of the ecosystems prevailing in the estuary. In the South East Pacific, changes recorded during the "El Niño" Phenomenon have been associated with the high precipitation which results in floodings, alteration of sedimentation patters and massive mortality of the fauna thriving in the estuary. For the most part, the South East Pacific coasts are low, with soft slopes and soft sands, with the exception of the region's southern part. An increase in the sea level would produce a landward retreat of the shoreline.

CHAPTER III

IMPACT ON KEY TERRESTRIAL COASTAL ECOSYSTEMS

OF THE SOUTH EAST PACIFIC REGION

391.500.000 Ha. are dedicated to agricultural and/or forestry related activities through the South American Andean region. More than three-quarters of this territory are covered by woody areas and only 82 million Ha. belong to agriculturally developed lands; 22 million Ha. of this total are dedicated to permanent annual crops, prairies and fallowing whilst 60 million Ha. correspond to native prairies. 10% of land under exploitation corresponds to farming land.

Panama : The country enjoys 112 km² of pastures located alongside the Pacific slopes. For the most part, the country's pastures are made up by the gramineous 'faragua' (Hyparhenia rufa).

Colombia : 30.000 Ha. are covered by native pasture prairies.

Ecuador : 2.081.000 Ha. correspond to farming lands.

Peru : Measuring 128.522.000 Ha. exploits 14.5% of the total figure; 61% of the surface is covered by forests or native pastures. There are 2.547.000 Ha. dedicated to crops which correspond to 2% of the country's surface.

Chile : Agricultural and cattle exploitations account for 30.648.700 Ha. 14.7% of which are dedicated to farming lands; 11.900.000 Ha. are native prairies and 5.805.600 Ha. are forests and woodlands. The surface planted with exotic species was increased from 230.000 Ha. in 1973 to 1.400.000 Ha. in 1987 which, added to the native forest, represent a total figure of 9 million Ha.

1. Forests

In the whole of Andean America there are more than 300 million Ha. endowed with forests most of which are to be found at inaccessible places, located in rough terrain.

Panama :

Forty per cent of the country shows a forested covering; the most important of these forests are those located in the lowlands of the Panamanian Pacific slopes which are covered by 'cuipo' (Cavanilesa platanifolia) in an extension equivalent to 10.000 Km²; 'cativo' (Prioria copaifera) which makes up forests, mostly monospecific, in alluvial lands, or mixed forests, with the Mora oleifera tree in lands subjected to the influence of brackish waters. The size covered by these forests has been estimated at 4.000 Km² whilst the size of the mangrove forests is of 5.000 Km².

Peru :

Forests of up to 40 m in which the following species prevail : Notophagus sp., Laurelia sp., Podocarpus sp., Weinmania sp. entangled with Chusquea cover a wedge in the North Peruvian Andes. Together with these species there appear the species Notophagus of austral origin.

Chile :

There are more than 9 million Ha. dedicated to native forests and 1.4 million Ha. to exotic species : Pine 'insigne', eucalyptus, poplar and Atriplex sp. Starting at 20°L.S. there appears a small woody mass which does not surpass the 1° Latitude. This natural resource vanishes up to 30°L.S. where it reappears in the shape of an unexploited native forestal woody mass and as a resource under exploitation in the coastal area situation which remains up to 35°L.S. From 38°L.S. onwards there are only man-made forests covering huge areas. The rather thick native vegetation is restricted to the Andean Piedmont and extends up to 54°L.S.

Productivity of some species cultivated in Chile show growth rates one-third higher than those obtained by the best farming methods used in Central Europe. These high productivity rates would not be affected by changes in the temperature of the adjacent coastal sea; perhaps it could project southwards the current distribution of some xeromorphic species and, northwards, that of some austral species currently being restricted, as regards their distribution patterns, by rainfall conditions. Productivity of some native forests would not be affected by a sea level rise with the exception of those species which grow in the region advancing from the sea towards the Andean Range ('coigue' Valdivian forest and 'chilote'). The effect on man-made plantations would be less serious because, even though they advance from near the coastline, they are cultivated above sea level.

2. Prairies :

Panama :

Most of the 112 Km^2 of the country's pastures are located on the prairies along the Panamanian Pacific slopes. Nearly 85% of these prairies are made up by the gramineous 'faragua' (Hyparhenia rufa). Temperature alone does not seem to have a direct influence over the coastal prairies ecosystems. A sea level rise could enlarge the area affected by floodings thereby altering the composition and distribution of coastal vegetation. It would be expected that halophytic species prevail over those typically terrestrial. Some salinity resisting weeds, such as Cyperaceae, could sustain larger distribution and growth rates.

Ecuador :

The country shows a cover made up by natural pastures representing 1.722.615 Ha. distributed in the four coastal provinces, as follows : Guayas: 551.000 Ha.; Manabi 814.000 Ha.; Esmeralda 159.500 Ha.; El Oro 198.115 Ha. Given the endurance of these pastures to high temperatures and pluvial indexes, it could be expected that a lower degree of moisture in the continental areas or, at least, changes in the rainfall indexes, would result in different distribution patterns of the pasture covering. The intrusion of marine waters in the coastal or river banks, due to the intrusion of salty wedges, could produce changes in the specific composition of pastures, particularly native ones, allowing for the development of halophite species.

Chile :

There exists a great variety of prairies, both native and man-made, in the country's metropolitan regions. Native prairies exist in five regions (I - II - VIII - XI - XII) and man-made praries are to be found in seven regions (III - IV - V - VI - VII - IX - X). As far as agriculture and forestal activites are concerned in each Region, the VIII is dedicated to forests, whilst the I, II, V, VI and XII are dedicated to sheep breeding accounting for 49% of the country's production. Goats are raised in four Regions (I - II - V and VI); sheep in five Regions (V - VI - VII - IX and X) represent 36.5% of national production. Taking advantage of the wide variety of microclimates, the IV Region offers fruit and vegetable agroindustries. It is quite possible that an increase in rainfall may allow for the development of existing prairies currently restricted to water courses and to the coastal strip under the influence of the 'camanchaca'. A higher rainfall index would produce a change in the pastures specific structure : from xeromorphic species to meso or hydromorphic species. A sea level rise should affect existing species, particularly terrestrial ones, since a salty wedge, particularly in the northern zone, would encourage the further development of halofile species.

3. Hydrographic Basins :

Panama :

In the Panamanian Pacific slopes there exists an extensive drainage network in which thirty-three hydrographic basins may be observed. The yearly average rainfall washing the country amounts to 233.760 million M^3. Some twelve basins are located in the lowlands, very close to the sea and, therefore, they may be subjected to the effects of the environmental changes under study. A sea level rise may be the cause of significant alterations due to an enlargement of the salty wedge intrusion which, in some large rivers, travels upstream to a distance of 20 Km. The likely changes due to a rise in the sea level could be the following :

- Higher salinity
- Changes in the quality of water
- Changes in drainage patterns
- Changes in river bank vegetation with high mortality rates of stenohaline species as well as an increase in the distribution of eurihaline species.

Ecuador :

The country is endowed with a large variety of hydrographic basins. These are distributed in the Esmeraldas Province and are formed by three main systems, i.e. : Santiago Cayapas, with a low riverbed; Esmeralda, receiving a large amount of discharges, and Cojimies, with sediments of sand and mud. There are twenty-six rivers in the Manabi Province. The River Guayas basin is located in the Guayas Province; the basin's extension runs for 34.000 Km. presenting a low riverbed and clayed sediments. The basin shows a deep salty intrusion through the Daule River which reaches a 70 - 80 Km length between July and December. Several rivers of various sizes run through the El Oro Province, all of them originating in the Andean Range. The Jubones River covers with its sediments an area of 4.285 Km^2 whilst the Arenillas River floods some 482 Km^2 and the Santa Rosa River inundates some 985 Km^2 A sustained increase of the sea surface temperature would give origin to heavy rains during low rainfall seasons thus increasing river flows.

Chile :

Along the country's twelve administrative regions there are many hydrographic basins of different size. A rise in the temperature would increase the rainfall index both in the intermediate depression and in the Andean Range. This increase in rainfall would be linked to an increase in thawing which, on its turn, would greatly contribute to the appearance of large floodings and landslides. This is particularly meaningful for Chile's I and II Regions where, during the dry season there occurs the "plateau rainy season" accompanied by large river overflowings due to heavy rains. The rise of the sea level would open the way for salty wedges to penetrate upstream always depending on the size of the river flow, its gradient and the difference of normal level. In some places, where the intrusion travels several km. upstream, this would cause the exchange of typically estuarine species by other species of marine origin.

CHAPTER IV

IMPLICATIONS OF CLIMATIC CHANGES ON FISHERIES OF THE SOUTH EAST PACIFIC REGION

The effects on fisheries of a drastic change in some environmental parametres related with the regional climatic conditions are best elucidated by the effects sustained during the occurrence of the 1982-83 "El Niño". The study carried out on the Region's fishing activities indicated that the impact of the "El Niño" on the South East Pacific fisheries has been different in each one of the events from 1958 afterwards. The 1957-58 event had an effect on the distribution and behaviour of the anchovetta. The 1965 event introduced new changes in the distribution and vulnerability of the anchovetta and catches were seriously impaired with harmful effects on fisheries. The effects of the 1972-73 event were even more serious and lasted much longer : the anchovetta population was greatly reduced.

The unloading of fisheries produce in Peru during year 1983 amounted to 1.537.019 Tons equivalent to the lowest ever record obtained since the time industrial fisheries were established back in 1959. Mention should be make of the fact that average catches in normal climatic conditions were in the region of 6 to 8 million tons/year. In 1983, the loss due to non-receivable income for fish products amounted to approximately US$100 million.

1. Fish :

Pelagic Fish : Most important species are : Anchoveta (Engraulis ringens), sardine (Sardinops sagax), Jurel (Trachurus murphy) and Mackerel (Scomber japonicus). The catch of these species for year 1983 amounted to 1.404.700 Tons (93.5% of the total fish catch. This allows us to state that as far as Peru is concerned, the impact of the 1982-83 "El Niño" Phenomenon adversely affected the availability of fish resources.

Anchoveta : Activities related to the fish reduction industry, which started in 1950, have been supported, up to the present time, on the exploitation of the anchoveta species. Nevertheless, we should point out that at the beginning there were huge stocks of the species which were adversely affected by the "El Niño" events, particularly those of 1972/73 and 1982/83 (1.787.000 Tons in 1972/73 and 118.000 Tons in 1982/83) which account for the near collapse of fisheries, particularly during 1982/83 when sardine took the place of anchoveta in catch figures (1.172.000 Tons out of 1.404.000 Tons of pelagic fish). During the occurrence of the 1982/83 event a rather reduced anchoveta population was reported. What remained of the species sought refuge in areas with little upsurging activity, going down as deep as 100 m. The anchoveta population was erratic and uncertain due to the scarce 1982/83 spawning and the high mortality of larvae situation which, to a certain degree, was evident in 1984 when the unloaded catch amounted to 23.000 Tons only.

Sardine :

Between 1950 and 1972 unloading figures of this species were rather low. During year 1964 the sardine catch unloaded amounted to approximately 10.000 Tons. From 1973 onwards the situation undergoes a radical change : the unloaded figure is now 132.000 Tons and it steadily and rapidly grows to surpass the million ton figure in 1978 remaining on this level up to year 1987. During 1983 the unloaded catch amounted to 1.172.000 Tons largely replacing the anchoveta in the fish reducing industry. During the period of unusual oceanographic anomalies - 1983 - sardine migrated in a north-south fashion until it reached the Peruvian southern coast and the Chilean northern coast where it came to settle. The incidence of such a migration on fishing activities was adverse since land processing factories located along the littoral came to a standstill.

The Jurel and the Mackerel species withstood the "El Niño" event with high biomasses; Jurel concentrated in the south whilst Mackerel went northwards. Adverse results related to them were the outcome of their lack of vulnerability (they went deep down) to traditional fishing boats and gear. It has been estimated that around 40.000 people whose livelihood depends on the development of fishing activities were adversely affected by the situation.

Demersal Fish :

Main species is Hake (Merluccius gayi peruanus); then comes 'Cabrilla' (Paralabrax); 'Coco' (Paralonchurus); Sole (Paralichthys); 'Tollos' (Mustelus) 'Lorna' (Saaena deliciosa) and 'Falso Volador' (Prionotus Stephano phrys). Their catch increased from 1973 onwards surpassing the 100.000 Ton figure. 1978 was an outstanding year since more than 300.000 Tons were unloaded. There is reason to believe that the 1972/73 "El Niño" event substantially contributed to this figure. On the other hand, 1983 unloadings of these species only accounted for 26.300 Tons of which 5.800 tons were represented by Hake.

Coastal Fish :

Artisan fisheries largely depend on these species which are associated to marine littoral areas. The most important species are : 'Cabinsa' (Isacia conceptionis), 'Cojinoba' (Seriolella violacea), 'Lisa' (Mugil cephalus), 'Lorna' (Saaena deliciosa) 'Machete' (Ethmidium maculatum) 'Pejerrey' (Odontes thes regia) and 'Pintadilla' (Cheilodactylus).

Unloaded figures remain stable, showing some improvement from 1970 onwards with approximately 38.000 tons. The 'Lisa' species catch amounted to 16.000 Tons. In 1982 the total unloading amounted to 70.000 Tons. This group is characterized by the fact that traditional species were replaced by those thriving in tropical waters, particularly 'Dorado' (Coryphaena), 'Barrilete' (Auxis) Sawfish (Scomberomorus), 'Manta' (Manta) Skate (Myliobatis) and Crawfish (Penaeus). The 'Pejerrey' species was practically extinguished severely affecting artisan fisheries.

2. Crustacean Fish :

During the last fifteen years the catch of these species has fluctuated between 1.000 and 2.000 Tons. 1983 witnessed an increase to more than 10.000 Tons by virtue of an unusual appearance of the 'titi' crawfish species (Xiphopenaeus riveti) which enlarged its living ground from the north down along the littoral to the Chilean border. The catch of this species amounted to 60%, or 6.000 Tons. As a result of high temperatures there was an unusual appearance of crab such as the species Euphylax robustus which caused damages to artisan fisheries.

3. Mollusks :

This group is made up by species such as 'Machas' (Mesodesma), Clams (Semele, Gari), 'Choros' (Aulacomia), 'Chanques' (Concholepas), etc., which underwent drastic mortality rates during 1983 even though the total catch figure did not show a significant variance as regards previous years. The species 'Concha de Abanico' (Argopecten purpuratus) reached outstanding levels due to successful spawning and recruitment. Whilst yearly unloadings amounted to 1.000 Tons, the 1983 catch increased to 10.000 Tons.

4. Algae :

The massive obliteration of Macrocystis forests was recorded as well as a development favouring other algae such as green, brown and red algae. They show a level of extraction of 100 - 300 Tons/Year as from 1972.

5. Birds :

Guano birds are closely associated to the anchoveta and appear in the shape of three species, particularly 'Guanay' (Phalacrocorax bougainvillei), 'Piquero' (Sula variegata) and Pelican (Pelecanus occidentalis). All three species sustained high mortality rates and, besides, the 1982/83 reproductive cycle was lost. The bird population was reduced to approximately 300.000 birds during 1983, which is the direct response to the unavailability of anchoveta as their food source. The decline in the bird population, on its turn, accounted for a decrease in the production of guano.

6. Mammals :

The species 'Chusco' (Otaria) and 'Fino' (Arctocephalus) sustained high mortality rates of their adult population due to lack of food. On their turn, sucklings also died as a result of their being neglected by their parents. Regarding largest mammals, such as whales, the species Brydae was absent from its usual area of distribution in the north.

Chilean Fisheries :

Positive anomalies of the sea surface temperature occurred during the 1982/83 "El Niño" event (2°-4.5°C) which introduced substantial changes in the supply, distribution and migration patterns of some economically important species such as crustaceans, mollusks and shellfish. The species Anchoveta (Engraulis rigens) was not caught and practically vanished. Specimens studied showed altered physiological conditions translated into low fat content. Catch figures were reduced from 325.145 Ton in 1981 to 7.696 Ton in 1983.

The Mackerel species (Scomber japonicus) widened its distribution range migrating off its usual capture grounds; this migration was reflected in a reduction of the species catch which decreased from 97.457 Tons in 1981 to 9.280 Tons in 1983. Concerning the Jurel sp. (Trachurus murphy) the stock size was apparently unchanged but alterations in its vertical and horizontal distribution contributed to its accessability resulting in a drop in catch figures. These were reduced from 1.060.909 Tons in 1981 to 865.272 Tons in 1983.

'Chascon' plants (Lessonia nigrecens) literally vanished from the littoral coastal zone in the I Region. The species was obliterated in Antofagasta, Mejillones Peninsula (23°15'S) by February, 1983. Unloading figures during 1983 amounting to 50.838 Tons account for nearly half of those recorded during 1982 and were similar to those of 1981. The 'Huiro' species (Macrocystis intergrifolia) sustained an unusual reduction during 1982 totally disappearing in 1983. Its obliteration results in a reduction of other economically important invertebrate such as the 'Cholga' (Aulacomya ater), 'Lapa' (Fisurella sp.), 'Piure' (Pyura chilensis) and 'Loco' (Concholepas concholepas) and Edible Sea Urchin (Loxechinus albus). Yearly unloadings did not differ much in 1982 and 1983 with the exception of the edible sea urchin.

Species which migrations were beneficial to fisheries due to the climatic impact of the 1982/83 "El Niño" were : Spanish Sardine (Sardinox sagax), which migrated from Ecuador to the north of Chile. Other species which substantially increased in the catch unloaded during the event was the 'Bonito' (Sarda chilensis). Yearly unloadings of Spanish Sardine which in 1981 amounted to 1.628.229 Tons, increased to 2.823.424 Tons in 1983 whilst those of 'Bonito' which in 1981 were of 2.727 Tons increased to 6.776 Tons in 1983.

Concerning Colombia and in the Tumaco Cove, catches of White Shrimp (Peanaeus occidentales) went up whilst those of 'titi' shrimp (Xiphopenaeus rivertii) decreased. Catch averages per fishing vessel for the P.occidentalis sp. went down from 2.900 Pound/Tail in 1982 to 1.600 Pound/Tail in 1983 whilst that of 'titi' went down by 52% during the same period. Fisheries of shallow water and ocean fish were reduced due to the southwards displacement of resources. In Ecuador, mackerel (Scomber japonicus) and other pelagic species reduced their catch from 1.800.000 Tons in 1982 to 443.000 Tons in 1983. Spanish sardine (Sardinops sagax) was absent from the catch.

This species was the one most affected by the event. Other species of fish usually thriving in the Guayaquil Gulf migrated towards the South introducing changes in their density and availability. Other tropical species were recorded for the first time, such as Haemulum sexfaciatum. Reproductive cycles of marine birds living in the Galapagos Islands was none during 1982 and highly reduced during 1983, showing populational decreases of up to 50% in some species of penguins and 'cormoranes'. High mortality rates were recorded for 'Piquero Azul' (Sula nebouxi), 'Fragata común' (Fregata minor), 'Fragata Real' (Fregata magnifiens) and Brown Pelican (Pelecanus occidentales). Seals (Zalophus californianus) also sustained high mortality.

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CHAPTER V

SOCIO-ECONOMIC IMPACT OF CLIMATIC CHANGES IN THE SOUTH EAST PACIFIC REGION

Little information is available on the socio-economic impact of changes in the sea level. Provided that the changes in the temperature and the sea level appear gradually, the severity of damages could be alleviated since there would be sufficient time to introduce changes in the current infrastructure in response to those changes. Such structural modifications are embodied in the building up of physical works capable of adjusting to the new situation. On the other hand, if the rise in the temperature and the sea level appear suddenly and aperiodically, then the socio-economic impact would be rather strong and notorious; they would be even more acute due to the lack of an adequate infrastructure designed to endure such sudden alterations. This assumption is valid insofar as short-term socio-economic effects are concerned. Severe droughts and high rainfall indexes which resulted in overflowing of rivers, erosion of sloping zones, accumulation of sediments, etc. produced manifold economic and social damages. During the occurrence of the event widespread floodings destroyed the existing infrastructure therefore significantly reducing production indexes. Changes in the ocean regime had an adverse effect in the availability and catch of many species. Droughts impaired agricultural produce. Damages sustained by the sector included loss of crop, reduction of sediments, delay in sowings and, in some instances, soil salinization.

The cattle raising sector was also affected by death of cattle and drying up of pastures. Physical infrastructure was also affected by damages to roads, bridges, railways, airports, resulting in increases in operation costs and loss of perishable commodities. As far as the social sector is concerned, climatic changes heavily damaged the basic infrastructure impairing health and nutrition levels and increasing morbility. Some diseases, such as malaria, reached epidemic proportions. Large numbers of urban and rural dwellings were destroyed and/or damaged. Total damages, according to ECLA (1983) calculations, amounted to US$3.480 million; US$2.000 million correspond to damages sustained by Peru; US$840 million to Bolivia; US$640 million to Ecuador. 67% of the total figure, i.e., US$2.667 million, correspond to losses of the productive sectors; 18% (US$634 million) to damages to the physical infrastructure and the remaining 5% (US$179 million), to the social sector.

In Bolivia, 380.000 Km^2 were affected by droughts - approximately 35% of the country's area - affecting 1.6 million people and causing the disappearance of some 4.000 head of cattle, 162.000 head of sheep and 68.000 head of camelides. Floodings covered an area of 150.000 Km^2 affecting some 700.000 people. Malaria and other diseases became rampant in these areas. A total of 14.500 dwellings were obliterated or heavily damaged. The total amount of material damages sustained by basic services and which may be

AREAS INUNDADAS Y ZONAS CON SEQUIA DURANTE EL FENOMENO DE "EL NIÑO" 1982 ——— 1983.

MAPA No

attributed to the climatic changes was calculated at US$22.5 million. Cultivated land was reduced by 17% with total loss of crop and a significant fall in yields. According to estimates, the total loss sustained by this sector amounted to US$241 million. Because of floodings, 200.000 Ha. of agricultural land were subjected to erosion and were flooded by alluvial sediments. Losses in this sector have been estimated at US$20 million. The total figure corresponding to damages to the agricultural sector and which can be directly attributed to climatic changes has been calculated at US$447 million.

In Ecuador, the coastal Provinces of Esmeraldas, Manabi, Guayas, El Oro, were severely affected by torrential rainfall, floodings, avalanches and strong dashing of waves. The total surface affected by the climatic change represents 12% - 15% of the total surface of the country and some 950.000 people suffered heavy material losses. Some 5.700 dwellings in the shanty-towns were totally destroyed and 8.000 more were damages. All areas under the influence of floodings witnessed an increase in morbility. Water supply works in twenty-nine towns were damaged. Nineteen hospitals and health centres were also affected. Total damages to the educational infrastructure were calculated at US$6.6 million. Loss of income from agriculture, fisheries and industry amounted to US$22.7 million and the total cost of material damages to the social sector was of US$23.6 million.

In Peru, a protracted and extreme drought season affected one-fifth of the country's surface (460.000 people). The coastal region was subjected to heavy rainfall and swells which resulted in floodings of large proportions. The insignificant capacity of natural and man-made drainage works was useless to prevent the occurrence of severe erosion in the top sector of the basin with the result that heavy floodings and alluvial depositions affected some 830.000 people. Sectors damaged by floodings sustained losses calculated at US$53.3 million as a result of damages to sewage systems. Forty-one water supply works were destroyed; 875 schools, 10.800 urban dwellings were also effected. Damages to social services were calculated at US$133 million. The loss of income by the agricultural sector amounted to US$297 million; US$241 million of which correspond to decreases in sowing and US$56 million to indirect losses. The irrigation infrastructure was affected by sludge intrusion with a loss of US$60 million.

CHAPTER VI

IMPACT OF CLIMATIC CHANGES IN THE CONTINENTAL COASTAL ZONE

PRODUCTIVE SECTORS : AGRICULTURE, CATTLE, SILVICULTURE, FORESTRY

Overall features of the area under discussion are as follows :

Colombia

Area : 73.000 Km^2. Mean Temperature : 26°C. High Rainfall Indexes, showing a top mean of 8.000 mm. Important forest-related activities, comprising 70% of the country's total figure.

Ecuador

Its Pacific Coast comprises a 73.300 Km^2 strip of land. Its climate is tropical, varying from warm to rainy with temperatures of 24°C and rainfall indexes of 3.640 mm in Bucay and Esmeraldas to the dry and warm climate found in the Santa Elena Peninsula, Guayas and El Oro, where rainfall indexes increase in a West-East fashion, from 200 mm to more than 3.000 mm.

Peru

The country's Pacific coast measures 140.000 Km^2, 2.480 Km in length and 50 to 70 Km wide. The region is comprised by ten Provinces : Tumbes, Piura, Lambeyeque, La Libertad, Nacash, Lima, Ica, Arequipa, Moquegua and Tacna. The area is virtually devoid of rain with the exception of a tiny strip in the northern section of the country where the climate is tropical and rainy. Generally speaking, the climate is desertic, showing sectors where rainfall indexes are between 40 mm and 100 mm. Mean yearly temperatures fluctuate between 18 and 22°C.

Chile

The coastal region is comprised by the western sections of the country's twelve regions with the exception of the Metropolitan Region. The Norte Grande region shows a desertic climate, low rainfall and a mean temperature of 16 - 19°C. In the Norte Chico the desert is the prevailing feature, with a dry climate, with a marginal desert between Copiapo (28mm) and Vallenar (64 mm); a barren plain, dry and luminous and a barren plain coastal climate with rainfall above 100 mm/year and mean temperature of 15°C.

Central Chile offers a Mediterranean climate, with a yearly mean temperature of 14°C. Rainfall is heavier during winter months. Bio Bio and La Frontera show a dry Mediterranean season which lasts less than six months. Rainfall surpasses 1.000 mm reaching 1.600 mm at the utmost meridional point. In the Región de los Lagos there prevails a warm and rainy climate. Mean annual temperature of 12°C. Rainfall shows a range of 1.300 mm - 3.000 mm/ Aisean and Magellan offer severe climatic conditions with heavy rainfall fluctuating between 2.800 mm and 8.000 mm. Temperature is rather low producing huge ice fields.

1. Climatic Changes

Increases in rainfall indexes as a result of climatic changes would be responsible for the following situations :

- Mangrove forests in Colombia and Ecuador would not be subjected to significant changes given the climatic conditions in which they usually grow.

- 'Taguales', 'pitales' and fine wood (head of the Atrato River) in Colombia : It is likely that they may be affected since these species require dry weather.

- Jungles containing varied wood species in Colombia (San Juán River) No changes have been foreseen in crops conditions.

- In the northwestern sector of the Basin of the Santiago and Atacames rivers in Ecuador, where there exist reserves of valued hard woods, it is expected that species would adapt to relative changes. No changes are foreseen in the piedmont strip of the Western Range where important forestal resources are to be found.

- Bushes and species such as carob trees (Prosopis limensis),'Huarango' (Acacia huarango) in the coastal sector may benefit from soil fertility.

- Olive Groves (south and central coast) : No changes are foreseen in environmental conditions required by the crop.

- Regarding Chile's Central Region, no changes are foreseen regarding species such as Hawthorn (Acacia cavens), 'Boldo' (Peumus boldus), 'Quillay' (Quillaja saponaria), 'Maiten' (Maytenus boaria) Oak (Notofagus oblicua). the same applies to the Poplar (Populus tremulus) existing in the IV Region. Forests of 'Pino Insigne' (Pinus radiata), 'Coigue' Oak (Notofagus dombeyi), 'Araucaria' (Araucaria araucana) in the Bio Bio and La Frontera Regions, as well as the Valdivian forest in the Los Lagos Region are not supposed to withstand any changes. In the Aisen and Magellan Regions, 'Coigue' (Drymis witeri) forests, 'Guaitecas' Cypress (Pilgerodendrium uviferum), 'Coiron' (Festuca gracilaria), 'Lenga' (Hothofagus pumilius) and 'Nirre' (Notofagus antarctica), and cold barren plains : NO changes are expected because of thermal and rainfall conditions in which the species grow.

As far as agricultural activities are concerned, climatic changes could give origin to the following conditions :

- Colombian Pacific Coasts - Crops of rice and coconut trees (High and Low Chocó) : Changes in crop conditions. Banana crops (Low Chocó) : These would be adversely affected.

- In Ecuador, Tabacco and Banana crops in the Esmeraldas Province would not be affected unless there occur overflowings caused by an increase in rainfall. The crops require dry weather conditions to ripen.

- In case of floodings, the Banana crops growing in the Guayas River Basin would be adversely affected. The African Palm Tree (Elaeis quineensis) Soja, Peanuts, 'Fabaca', Rubber : Bearing in mind that these are irrigated soils, no meaningful changes are foreseen. Regarding the El Oro Province, its Banana crops could adapt to new conditions. Coastal crops of Cacao and Rice would be adapted to climatic changes. Finally, agricultural activities in the Galapagos Islands would not be subjected to meaningful changes.

- Regarding the Peruvian Pacific Coast sugarcane crops (Northern Oasis, Provinces of Lambeyaque, La Libertad, Ancash and Northern sectors of Lima), an increase in rainfall would add to soil fertility thereby introducing beneficial changes. For Cotton (Gossypium peruvianum), or the cotton varieties known as 'tanquis' or 'pima', changes in rainfall indexes would benefit crops. Rice growing areas, subject to irrigation, positive changes are foreseen as regards yields and enlargement of cultivated lands; the opposite could apply to the Vineyards of Pisco provided irrigation is permanent; otherwise, irrigation possibilities would have a beneficial influence on the crop.

- Some changes are foreseen in the various Chilean administrative regions: such is the case of the Norte Grande region where vegetables, corn, potatoes and fruit orchards would be greatly favoured by climatic changes since these crops could enlarge their domains. Crops such as Chili, Lima beans, watermelons and squash, corn, potatoes and alfalfa, growing at an altitude between 1.000 and 2.500 m., would not sustain meaningful changes.

- Fruit trees, Cherimoya, Lucumas, Walnuts and horticultural crops growing in the Norte Chico Region would improve conditions by the direct influence of temperature and the reduction of irrigation practices. Positive changes due to an increase in environmental humidity would affect crops of tomatoes, garlic, lettuce, chilies and onions; also, fruit trees such as peach, almond, nectarines, plums, avocados, olives, apricots, pears, lemon and oranges, cereals and vineyards. The Atriplex sp. (Norte Chico IV Region) would increase its area of cultivation.

- Cereals and Legumes growing in Chile Central (Petroca - La Ligua), would be positively affected by an increase in water supplies. Vegetables fruit and traditional crops (corn, wheat, beans) fruit trees (apple, table grape, pear and peach) cultivated in the VI Region as well as rice, legumes and potatoes would not sustain meaningful changes due to an increase in rainfall. The same applies to industrial Hemp crops (San Felipe and Los Andes), Tobacco (Catemu, Valparaíso), Sugar beetroot (Linares, Curico).

- Small farm crops cultivated in Bio Bio and La Frontera (legumes, cereals, such as wheat, oat and barley) would not be affected. Higher humidity rates would benefit grapevines (Colemu, Yumbel, Quillón and Nuble), and beetroot (Los Angeles and Chillan). No changes are foreseen in Los Lagos where crops of potatoes, 'raps', oat, beetroot, lupine and linen are to be found.

- In the Aisen and Magellan Region changes in wheat crops could be expected (XI Region). Also, crops of alfalfa, vegetables, fruit (nectarines, figs, walnuts, almonds) would be affected. The situation would remain stable concerning crops of potatoes and oat in the island and coastal territories.

As far as cattle raisining activities are concerned, the following could be expected :

- Colombia : Existing numbers of head of cattle would be drastically reduced since the excess of water would worsen soil conditions restricting the availability of pastures and raising grounds.

- As far as Ecuador is concerned, no changes are foreseen along its coastal region provided floodings are nonpresent.

- In Peru, an increase of rainfall over the country's desertic areas would imply a beneficial effect since new grazing lands could be developed allowing for cattle raising.

- In Chile, the Regions of Norte Chico (goats), Central Chile (Sheep and goats), Bio Bio and La Frontera (dairy cattle), Los Lagos (Cattle fattening and sheep) and Aisen - Magellan, where the country's largest sheep flocks are raised, would be greatly favoured by an increase of water supplies.

2. Sea Level Rise :

- The Colombian Pacific Coast would witness a development of halofite species an a reduction of the area inhabited by typically terrestrial species found near the coast or along riverbanks where the salty wedge would have a protracted effect. No changes are foreseen regarding 'Taguales' and 'Pitales'.

- In Ecuador, hard woods (Basin of the Santiago River and sector of Atacames); forestal resources (Piedmont strip); tabacco, banana and cattle (Northerly sector, Santiago and Esmeraldas Basins); banana (Guayas); coffee, cotton, peanut and castor oil plant (Manabita Savanna); bananas, cacao, sugarcane, rice and cattle (valleys washed by the Daule, Vinces and Babahoyos Rivers) and, generally speaking, all resources located far away from the influence of the coastal area would not be affected by the eventual intrusion of a salty wedge.

- Bearing in mind that in Peru most crop areas are far away from the coast - in the oasis - it is unlikely that these soils may be affected.

- In Chile, changes would affect crops of what, man-made prairies near the coast; fruit trees and small farm crops in Norte Chico, as well as the Atriplex sp. which, affected by the increase in salinity, would have an adverse impact in the development of sheep and goat flocks in the Central Coast because of the reduction in grazing grounds. Annual crops and prairies located in the VIII and IX Regions would be affected, thus, having an adverse incidence on cattle. Forests existing in the VIII Region would be damaged.

CHAPTER VII

INSTITUTIONAL ASPECTS

The occurrence of climatic changes modify distribution patterns of temperature, rainfall and other meteorological parametres which translate into effects which could either be beneficial to some areas or harmful to others producing socio-economic impacts which bring us to think about the need to introduce social and institutional changes to strengthen their ability to adjust to them.

The recurring and aperiodical alterations of the ocean climate have prompted the South East Pacific Region to initiate their co-ordinated study on the basis of a regional programme, as brought forward during the XII Ordinary Meeting of the CPPS (1974). This programme has come to be known as ERFEN (Regional Study of the "El Niño" Phenomenon - Estudio Regional del Fenómeno "El Niño").

According to Jordán (1988) ERFEN is a co-operative and multidisciplinary programme in which eighteen scientific institutions take part. The Programme counts on the support of the Intergovernmental Oceanographic Commission - IOC -, the World Meteorological Organizacion - WMO -, through the efforts of the Permanent South Pacific Commission - CPPS. Within the Commission's framework, an analysis is made of the progress of oceanographic, biological, fish related and meteorological regional research activities. A Joint IOC/WMO/CPPS Group reports on those activities at the international level. The ERFEN Programme is linked to many other global programmes on the ocean-atmosphere interaction, amongst which we would like to mention the Tropical Ocean and Global Atmosphere Programme, being implemented through TOGA-Pacific which is the organization concerned with "El Niño"; also, the "El Niño" and the Southern Oscillation - ENSO - Programme which, besides IOC and WMO counts on the participation of other organizations such as the United States National Academy of Sciences. As far as the biological component is concerned, ERFEN is linked with the Ocean Sciences in Relation to Living Resources - OSLR - through the International Recruitment Programme - IREP. Other international programmes related to ERFEN are : EPOCS, EBUC, ICOSS, et. al.

As an outcome of the Chapman Conference (International Symposium on the "El Niño" Phenomenon, Guayaquil (Ecuador) 27th - 31st October 1986), the need was apparent in the sense that all information regarding ERFEN should be related to socio-economic aspects and that institutional arrangements should be included. To this effect, a project on the socio-economic impact of "El Niño" is being developed by the Permanent South Pacific Commission. The project involves the Planning offices of the Region's countries besides all marine research organizations existing in the Region. An UNDP-ERFEN project, recently negotiated by the CPPS - with the participation of IOC - incorporates a socio-economic component.

A N N E X

THE 1982/83 "EL NIÑO" PHENOMENON IN THE SOUTH EAST PACIFIC :

A CASE STUDY

The term "El Niño" Phenomenon is a description of an oceanic-atmospheric large scale anomaly (Pacific Ocean) basically characterized by the aperiodical inflow of extremely warm waters (28°-30°C) into the South East Pacific Ocean, particularly off the Ecuadorian and Peruvian Coasts.

The appearance of unusually warm water produces dramatic alterations in the local meteorological, oceanic and biological regimes. Insofar as this Century is concerned, medium and high intensity "El Niño" Phenomena have occurred in : 1902, 1905, 1911, 1914, 1918, 1925, 1929, 1939, 1941, 1953, 1957/58, 1965, 1972/73, 1976, 1982/83 and 1987. The 1982/83 event has been the most intensively felt so far.

In wider oceanographic terms, the "El Niño" Phenomenon could be defined as the expression, in oceanic scale, of the ocean-atmosphere interaction : It is the answer of the Equatorial Pacific Ocean to fluctuations of the atmospheric pressure systems and, therefore, of the winds regime. The collapse of Equatorial trade winds and the sudden appearance of western winds in the Pacific central region produce Kelvin inner waves which travel along the Equator reaching the South American coast within a two-to-three month period. The Kelvin waves have a dual effect : They intensify circulation trends eastwards and they deepen the thermocline (maximum vertical temperature gradient). Both effects show a tendency to warm up the surface of the sea : The first, by conveying warm water from the west and, the second, by preventing the surface upwelling of deeper and colder waters (from below the thermocline) thereby producing coastal upwellings.

In 1983, the anomalous warming up recorded off the South American coast was related to two different water sources : North of 15°S the warm surface and low salinity water was associated with the tropical water of the Panama Bight and South of 15°S the warm surface and relatively higher salinity water was associated with an advection of subtropical water towards the coast (ERFEN, 1984). As a result of this invasion of abnormally warm water, the sea surface temperature recorded great anomalies throughout the region. Thus, off the Peruvian coast warm anomalies of up to 10°C were recorded whilst off the Ecuadorian and Chilean coasts such anomalies reached up to 5°C (Lagos, 1984; Cucalon, 1987).

The arrival of Kelvin waves at the Easternmost Equatorial Pacific Ocean and the subsequent dissemination of these waves towards the pole along the American coast was evidenced by a strong deepening of the subsurface thermal structure throughout the region. Thus, and as a result of this motion, off the Ecuadorian coasts and the northern Peruvian coasts, the thermocline was found at depths up to four times deeper than normal. Besides, all isotherms, from the surface up to 12°C, were significantly depressed (more than 100 m. in some cases). As a result of this, large subsurface thermal anomalies were recorded, up to 9°C at 50 m. depth (Lagos, 1984; Silva y Rojas, 1984; Cucalon, 1986).

Variations in the sea level also reflected the vertical movements of the thermocline. An increase of the sea level must be hydrostatically offset by a surface layer of warmer and thicker water. Thus, a rise of the sea level was offset by a deepening of the thermocline. In 1983, off the Ecuadorian and Peruvian coasts, the sea level reached values of up to 30 and 40 cms. above normal, respectively (Lagos, 1984; Cucalon, 1987). See Figure No. 1.

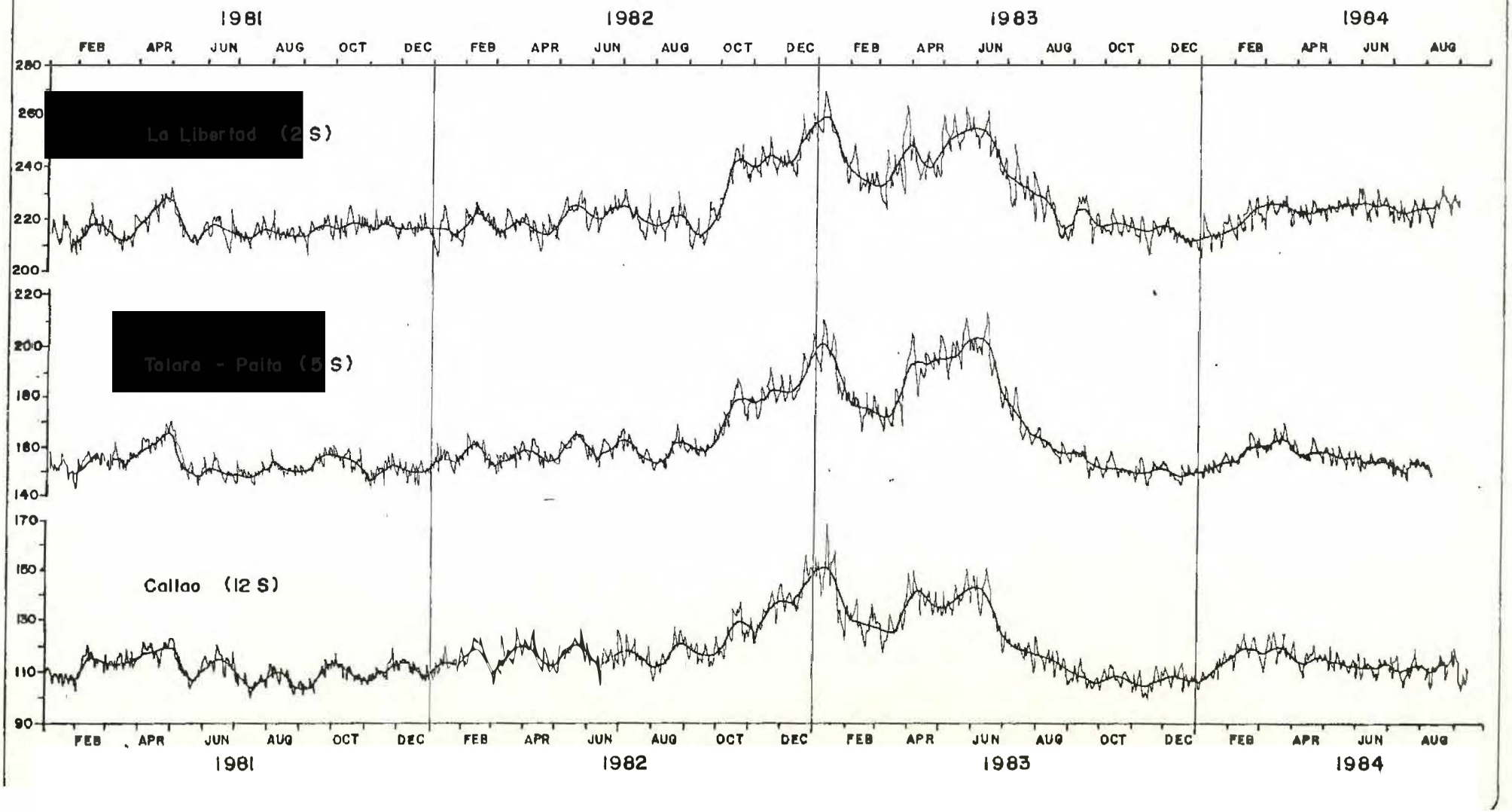
Due to the increase in the sea superficial temperature, to the deepening of the thermocline and, to a lesser extent, to the rise of the sea level, the heat content of the ocean surface layer in the East Equatorial Pacific was substantially increased. In this way, the flow of heat from the ocean to the atmosphere was also increased producing an intensification of convective processes in the atmosphere which accounted for unusual rainfall in the South East Pacific region.

The whole South American littoral was seriously impaired by heavy rains associated with an abnormal displacement soutwards, beyond the Equator, of the Intertropical Winds Convergency Zone. This Zone represents a feature common to all "El Niño" events. Along the Colombian Pacific coast rainfall during 1983 was twice the average figure; in Ecuador, rainfall was forty times higher than the normally high average (Guayaquil, June 1983); and in Peru, it was up to 340 times the average figure, Paita, May 1983. (Jordan, 1985; Cucalon, 1987).

On their part, rivers considerably increased their water volume resulting in frequent overflowing which, together with landslides occurring in the Andean western slopes widely contributed to the enlargement of the ocean floor in the lower sectors and to the alteration of the soil and the ecological substratum. Torrential rains and the subsequent overflowing of rivers, floodings and washings had a harmful impact on other sectors, including : agriculture, housing, public health, education, transport, industry, archeological remains and, above all, the loss of human life.

The increase of the sea surface temperature and, therefore, the increase of the heat content of the ocean surface layer in the central and eastern Pacific also accounted for the unusual building up of hurricanes in places like Tahiti and Hawaii. In like manner, big storms were produced northeast from the western North American coast (Lagos, 1984).

LLP AND VLP SEA LEVEL IN 1981 - 1984.



As a result of this, large swells repeatedly stroke the South American coast drastically impairing its morphology. The joint action of the seal level rise and the dashing of large waves produced a landward retreat of the coastline, the flooding of large sections of the lowlands, the erosion of immense coastal areas, the wiping out of shrimp cultivation ponds, the destruction of molluskan communities and coastal infrastructure as well as the disappearance of some fishing communities.

Current circulation, both coastal and oceanic, evidenced substantial changes as well. Associated with the abrupt variations in the sea level and with frequent swells which repeatedly stroke the South American coast, coastal currents showed a rather erratic behaviour basically overborne by a marked strengthening of the very same currents. The flow of cold waters from the Humboldt Current was substantially weakened and forced to fall back southwards, beyond usual distances for the period of the year whilst the meridional flow of warm tropical water from the Panama Bight was significantly intensified reaching latitudes as southwards as 15°S (Lagos, 1984). Inside the Equatorial currents system, the Northern Equatorial Countercurrent showed a marked intensification whilst the Southern Equatorial Current experienced notorious reversions (Hanser, 1984).

To a great extent, the above contributed to the accumulation of warm water off the South American coast and to the appearance of certain fish species in areas normally devoid of them. Thus, off the Peruvian coast and north of Chile the massive appearance of tropical species was reported; in like manner, many oceanic species were forced to fall back towards the coast. The changes sustained by the marine environment, particularly the depression of the subsurface thermal structure, gave rise also to deep alterations in the behavioural and distributive patterns of the region's most important pelagic fisheries. In this regard, notorious horizontal and vertical migrations of these species were reported (Jimenez and Herdson, 1984). As a result, catch figures of these species by fishing fleets, particularly from Ecuador to Peru, were drastically reduced to the point of forcing them to stop operations. In short, the losses sustained by the fishing sector in Ecuador and Peru surpassed US$200 million (Jordan, 1985).

The economy of the region's countries is heavily influenced by the region's fisheries and agriculture so that a deeper knowledge about the climatic, ecological and economic implications of the "El Niño" Phenomenon would provide meaningful guidelines for sound medium- and long-term economic planning.

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