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A SUSTAINABLE SHRIMP MARICULTURE INDUSTRY FOR ECUADOR

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Oceanographic Characteristics Off the Coast of Ecuador

Características Oceanográficas frente a la Costa del Ecuador

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Resumen

En el presente trabajo se resaltan las principales características oceanográficas prevalecientes frente a la costa de Ecuador, su variabilidad estacional e interanual. Se presentan algunas evidencias de como variaciones ineranueales de baja frecuncia en las concdiones ocieanográficas de la región, El fenómeno de el Niño, inducen cambios significativos en la compsocipo y distribución de aguans de lasmás importantes pesquerías, provocando el descalabro de unas y foreciendo el desarrollo de otras. Asío por ejemplo, durante el desarrollo del último fenómeno de El Niño en 1982-83, la pesquría de peces pelpagicos de gran importancia comercial como macarela (Scomber japonicus), sardinas (Sardinops sagax, Estremeres teres) y pincahagua (Opisthonema spp.) fue drásticamente reducida, mientras que la pesquería del camarón alcanzó nivles nunca antes registrados.

Se destacan, además, otros tipos de variabilidad interanual de característica y frecuencias diferentes a las de El NIño, las cuales podrían también estar relacinadas ocn fluctuaciones en algunas pesquierías. Tal es el caso del "Frente Ecuatorial" que durante el invierno de 1985 estuvo más al norte de su límite usual, originando que las aguas costeras sean 2°C más frías que lo esperado. En este año las capturas totales de los pequeños peces pelágicos (macarela, sardinas) superó el millón de toneladas, constituyen así un record en estas pesquerías.

Summary

The main seasonal and interannual variations in oceanographic characteristics off the Ecuadorian coast are presented in this paper. In addition, some evidence is presented as to how low frequency interannual variations in the oceanographic conditions of the region (El Niño) induce significant changes in the composition and distribution of important fisheries, causing the collapse of some, and favoring the development of others. For example, during the development of the last El Niño phenomenon in 1982-83, the pelagic fisheries of great commercial importance, such as mackerel (*Scomber japonicus*), sardines (*Sardinops sagax, Etrumeus teres*) and pinchagua (*Opisthonema spp.*), were drastically reduced, while the shrimp fishery reached record levels. Other kinds of interannual variability besides those of El Niño, which could likewise be related to fluctuations in some fisheries, are also presented.

Introduction

All the seacoast countries around the world recognize the vital necessity of increasing their knowledge about how the variations of oceanographic conditions influence the composition, distribution and abundance of the living resources of the sea, so they can be administered reasonably as a sustainable food resource. The oceanic region along the coast of Ecuador presents great variability, both in physical environment and living resources, a factor that has an important impact on the economy of the country.

Since any phenomenon that affects water temperature, currents and other ocean characteristics, will likewise affect annual abundance or distribution of many species of fish and crustaceans, it is crucial that resource managers have as complete an understanding as possible of the relationships between living resources and environmental conditions.

Study Area

The study zone is an area of the eastern equatorial Pacific Ocean situated immediately off the coast of Ecuador. This area, which extends latitudinally from 1°N to 3°20'S, is a transition zone between the tropical and subtropical regimes. To the north, the Panama Bight is defined as the area of the eastern tropical Pacific Ocean that lies between the Isthmus of Panama (about 9°N) and Punta Santa Elena (about 2°S), and extends from the coasts of Panama, Colombia and Ecuador to about 81°W longitude (Figure 1). This area is characterized by warm (>25°C), low salinity (<34.0 ppt) tropical water. To the south, off Peru, the subtropical water is cold (<22°C) with high salinity (>35.0 ppt) because of the Humboldt Current (or Peru Current), which is strongly influenced by coastal upwelling. Between these two water masses lies a transition zone called the equatorial front, which displays marked seasonal variations and is identified by intense surface thermo-haline gradients.

Seasonal Variability: Circulation and Associated Hydrography

The area is characterized by two clearly differentiated seasonal periods: summer (January-April) and winter (July-October). The remaining months are considered transition periods between these two seasons. More than 95 percent of the annual precipitation falls during summer (Stevenson, 1981).

In summer, a narrow, southward coastal flow of warm (25°-27°C), low salinity (33.0-33.8 ppt) water from the Panama Bight is evident along the coast of Ecuador to approximately 2°-3°S (Figures 2 and 3). This tropical surface water is also characterized by low-nutrient concentrations, and its flow may be defined as a response of the local circulation to seasonal variations of the wind field in the region. The summer meridional winds that blow parallel to the coast weaken, whereas the northeast trade winds blowing across Central America strengthen, increasing the meridional transport of water across the equator.

This flow is indicated on several maps as the El Niño Current (the Holy Child Current), not to be confused with the El Niño phenomenon. This current develops each year during the summer months, and is responsible for the presence of warm waters along the coast of Ecuador during this period. On the other hand, the El Niño phenomenon describes a large scale ocean atmospheric anomaly (Pacific Ocean), characterized by the aperiodic influx of unusually warm surface water (29°-30°C) in the southeast Pacific Ocean, particularly off Ecuador and Peru.

Ordinarily, during the summer, the position of the equatorial front is quite unpredictable, since it may be formed weakly and moved to the south off Peru, or may be completely absent. To the south, in the Gulf of Guayaquil, the surface temperature varies between 26° and 28°C. The isohalines tend to be orientated longitudinally, varying from 26.0 ppt in the inner part of the Gulf to 34.0 ppt in the outer, due to the river discharges into the estuary during this season.

The vertical distribution of temperature presents a sharp, shallow thermocline (maximum vertical temperature gradient) between approximately 10m and 20m depth, associated with the seasonal increase of solar heating and the weakening of the meridional winds during this time. The thermal gradient reaches values of up to 10°C/5m depth in some areas. In general, the water column is well stratified.

In winter, the presence of the intense equatorial front is the most important oceanographic feature. The front is identified by surface thermo-haline gradients between approximately 1°S (25°C-33.6 ppt) and 2°S (19°C-35.0 ppt) (Figures 4 and 5) and extends down to 30-40m depth. The seasonal position of the front is determined by a balance between the force of the Humboldt Current (induced by the meridional winds) and the horizontal hydrostatic pressure gradient generated across the front. Thus, any change in the strength of the wind in the region will produce a latitudinal displacement of the front.

During winter the subtropical surface water is displaced to the north relative to its summer position, in response to strengthening meridional winds and the Humboldt Current. To the south, in the Gulf of Guayaquil, the presence of relatively cold (21°-23°C) and saline (34.0-34.8 ppt) surface water indicates that river discharges into the estuary are lowest because it is the dry season.

Also at this time, the distribution of temperature and salinity throughout the water column presents strong thermo-haline gradients from 30m to 50m depth below a surface mixed layer. This mixed layer displays seasonal variations associated with the force of the meridional winds, being normally evident during winter.

The cold and saline water on the southern side of the equatorial front is also characterized by high nutrient concentrations. This water corresponds to the mixture between the subtropical surface water from the Humboldt Current and the underlying equatorial subsurface water which upwells to the surface south of 2°S. This upwelling process brings cold and nutrient-rich subsurface water up to the surface, giving rise to a higher productivity of the phytoplankton, which through successive links in the ocean food chain ultimately reaches the major fish populations.

Interannual Variability: The El Niño Phenomenon

Occasionally and quite unpredictably, extensive areas of the southeast Pacific Ocean, particularly off Ecuador and Peru, are subjected to an aperiodic influx of unusually warm surface water, commonly referred to as the El Niño phenomenon. These invasions of anomalously warm water, coming mainly from the north and/or from the west, produce dramatic changes in the local meteorological, oceanic and biological regimes. In this century, major El Niño events were recorded in 1925, 1929, 1939, 1941, 1953, 1957-58, 1965, 1972-73, 1976, and 1982-83.

During El Niño, warm water accumulates along the coasts of Ecuador and Peru and the upwelling of colder water seems to weaken. Fish stocks practically disappear, drastically reducing the catches of the fishing fleet and causing many marine birds, dependent on fish for food, to die of starvation. For example, during the 1972-73 El Niño event, the Peruvian anchovy (*Engraulis ringens*) catch dropped from over 10 million metric tons (m.t.) in 1970 and 1971, to approximately 4.5 million m.t. in 1973 (Caviedes, 1975). Also, the population of guano birds fell from 6.5 million in 1971, to 1.8 million in 1972 (Vildoso, 1976).

Moreover, the coastal areas suffer torrential rainfalls due mainly to an abnormal southward displacement of the intertropical convergence zone of the winds (ITCZ) during El Niño years. Disastrous floods cause severe damage to the crops of the region. The financial consequences of these events are catastrophic for the local fisheries, and the economic repercussions are adversely felt throughout the affected countries.

During the development of the last El Niño phenomenon (October 1982-July 1983), the entire coast off Ecuador was covered by very warm waters, up to 28°-30°C (Figure 6), and there was a remarkable increase in the stability of the water column that isolated the surface layer from the nutrient-rich water below the thermocline. In fact, the thermocline was depressed to depths four times greater than normal, 80-100m. Since the major supply of inorganic nutrients to the euphotic zone is in water below the thermocline, it is clear that any process depressing the thermocline away from the surface layer, where there is enough light for photosynthesis, will necessarily reduce productivity (Barber and Chavez, 1983).

Another important feature observed during the development of the 1982-83 event, was the existence of a surface mixed layer. In normal conditions, there is no surface mixed layer in summer, however, during 1983, this layer was evident up to 30m depth. Because light decreases exponentially as a function of depth, the depth of the surface mixed layer determines the quantity of light that can be captured by the phytoplankton for the synthesis of organic material; less amount of light will be available to the phytoplankton as the surface mixed layèr deepens. In this way, the supply of both nutrients and light was significantly reduced as El Niño progressed.

The subsequent decrease in phytoplankton productivity caused considerable disturbance to organisms of higher trophic levels, such as zooplankton, ichthyoplankton and fish. Small pelagic fish including mackerel, sardines and pinchagua did not spawn at normal rates, greatly reducing usual abundance (Garcia, 1983). The total catch for these fisheries dropped from over 180,000 m.t. during the first quarter of 1982 (prior to El Niño), to approximately 43,000 m.t. during the same period in 1983, and consisted almost exclusively of mackerel (Jimenez and Herdson, 1984).

The 1982-83 El Niño phenomenon had a great socio-economical impact on the coastal region of Ecuador, caused by a tremendous increase in rainfall, flooding and landslides, damage to transportation facilities, huge agricultural losses, in addition to disturbance of many coastal fisheries. The only commercially important sea resource that benefitted from the anomalous oceanographic conditions prevailing during this event was the shrimp fishery. The total catch reported by the shrimp fleet in 1983 increased by more than 200 percent relative to the previous years (Figure 7, McPadden, 1985).

Other Interannual Variations

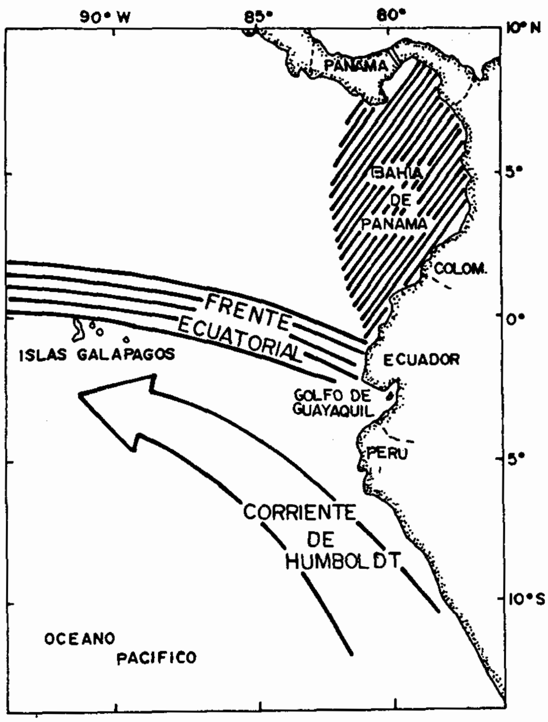
Other kinds of interannual variability in ocean characteristics can also be related to fluctuations in some fisheries. For example, during winter 1985, the equatorial front was located further north than its normal limits, to about latitude 0^{o} (Figure 8). This shift in the front was associated with a strengthening of the Humboldt Current, which pushed its cold and saline waters further north than its usual limits, causing Ecuadorian coastal waters to be $2^{o}C$ colder than expected for this time of the year. The total catch of small pelagic fish (mackerel, sardines) was over 1 million m.t. in 1985, the highest annual catch ever registered (Figure 9). Sardines (*Sardinops sagax*) constituted 70 percent of the catches, surpassing mackerel for the first time (Maridueña, 1986).

In another instance, the advance of cold and saline subtropical water of the Humboldt Current towards the coast of Ecuador was observed in March 1986 and not at its usual time in May or June. This created important changes in the oceanographic conditions of the region, giving rise to the presence of waters $2^{o}C$ colder than expected for the season (Figure 10). This anomaly in the physical environment coincided with the presence of quantities of valuable Peruvian anchovies in Ecuadorian waters for the first time (Maridueña, personal communication). Considering the close relation between the distribution of these small pelagic fish and the circulation of the water masses in the region, long-term monitoring of such oceanographic changes could be invaluable.

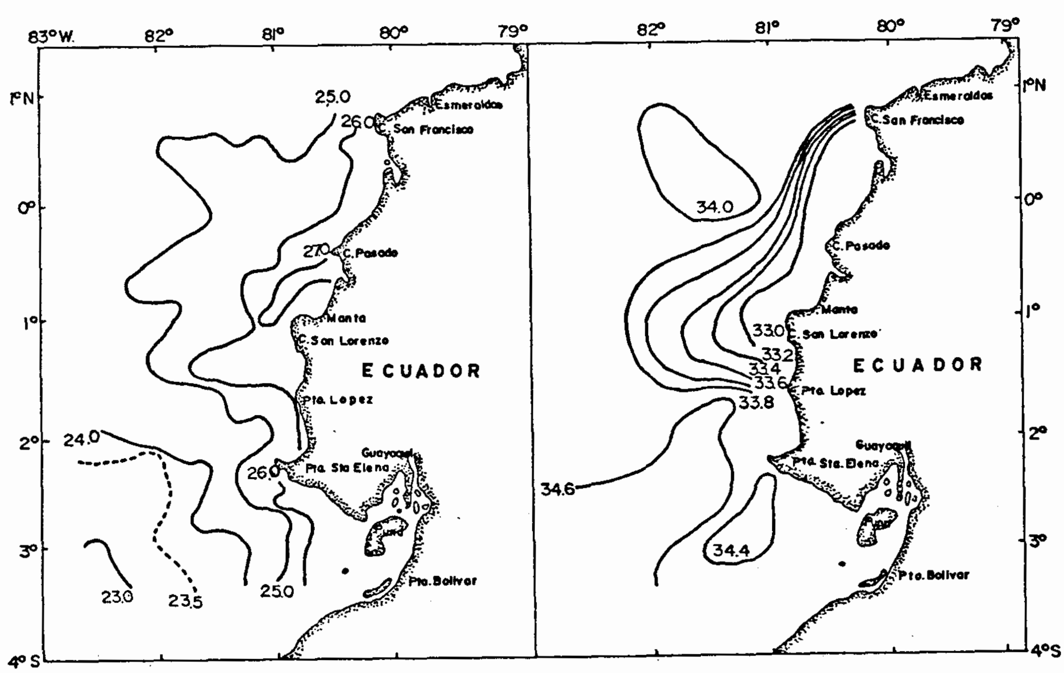
Conclusion

The economy of Ecuador is strongly influenced by its fisheries, so that a better understanding of the climatic, ecological and economic implications of the variability in the oceanographic conditions of the region would provide a very important guide for long-range economic planning. Undoubtedly, the living resources of the sea respond directly and indirectly to these variations in their physical environment, as evidenced by past fluctuations in the composition and distribution of some of the most important fisheries. How and to what extent do these changes in the oceanographic conditions determine fluctuations that can cause the collapse of some fisheries and/or favor the development of others? Are these interannual variations of local or regional character? Do they occur more or less often than the El Niño phenomenon? These are some of the questions that have to be answered in the future to make management of Ecuador's living marine resources more successful and economically dependable.

Figure 1.- Area of the eastern tropical Pacific Ocean showing the different water masses involved in the study zone.



Figures 2 and 3.- Surface distribution of temperature (°C) and salinity (ppt) in February-March 1981, respectively.



Figures 4 and 5.- Surface distribution of temperature (°C) and salinity (ppt) in August 1981, respectively

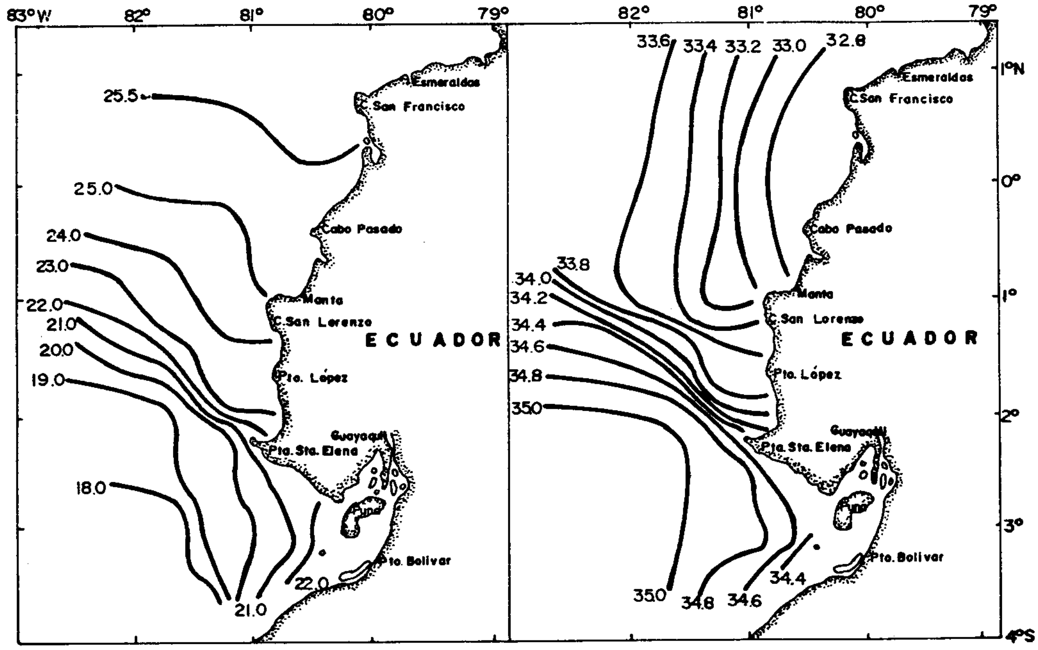


Figure 6.- Surface distribution of temperature (°C) in February 1983, during the development of the El Niño phenomenon.

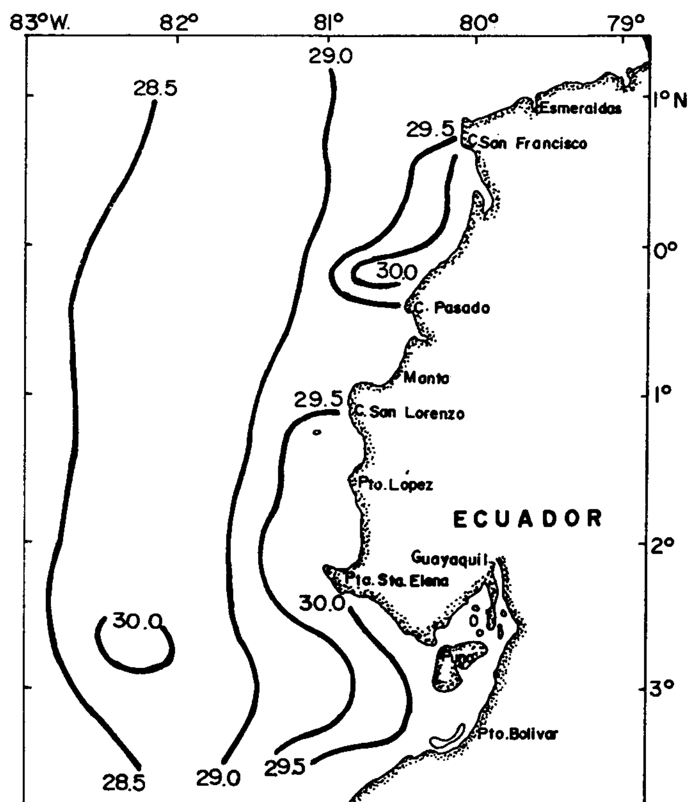


Figure 7.- Estimated total annual shrimp catch for the 1974-1985 period

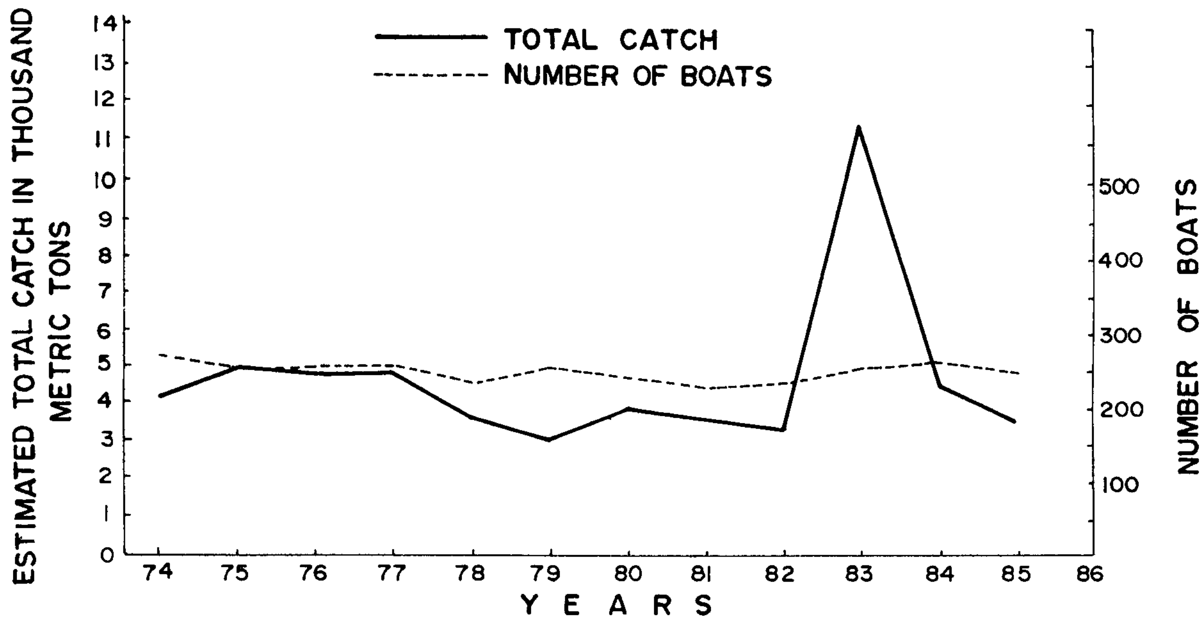


Figure 8.- Surface distribution of temperature (°C) in July 1985.

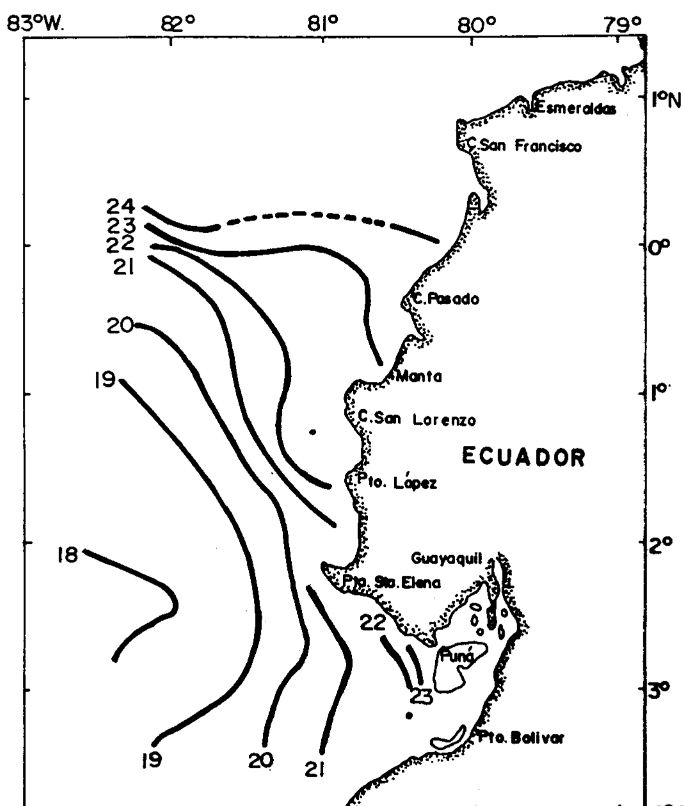


Figure 9.- Total annual catch of the small pelagic fish (mackerel, sardines, pinchagua) during the 1964-1985 period (source: Maridueña, 1986).

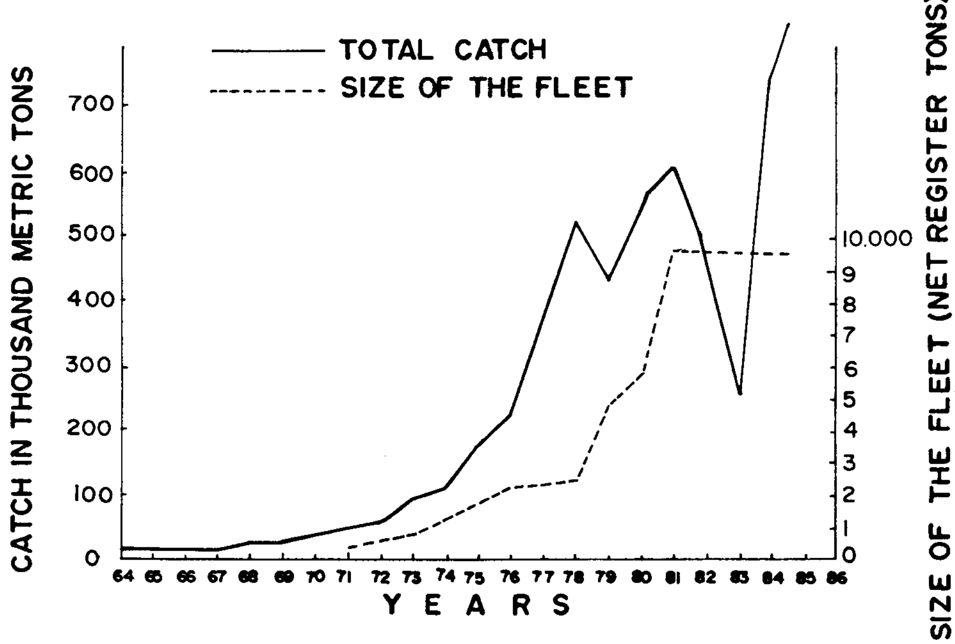
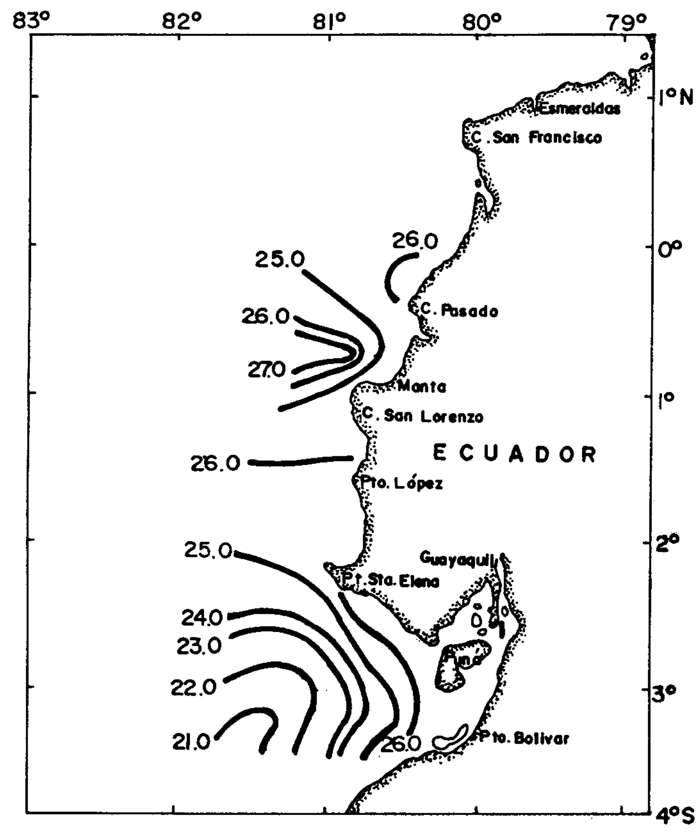


Figure 10.- Surface distribution of temperature (°C) in March 1986.



References

Barber, R. and F. Chavez. 1983. "Biological consequences of El Niño." Science, 222:1203-1210.

Caviedes, C. 1975. "El Niño 1972: its climatic, ecological, human and economic implications." Geogr. Rev., Vol. 65.

Garcia, M.L. 1983. "Variability in the distribution and abundance of eggs and larvae of *Scomber japonicus* (mackerel) and of some clupeids in Ecuadorian waters." Paper presented in the Consultation of Experts to Examine the Changes in the Abundance and Composition by Species of the Neritic Fish Resources. San Jose, Costa Rica. April, 1983.

Jimenez, R. and D. Herdson. 1984. "Effects of the 1982-1983 El Niño on the fishery resources in Ecuador." Paper presented at the Workshop on the 1982-1983 El Niño Phenomenon. Guayaquil, Ecuador. December, 1984.

McPadden, C. 1985. "A brief review of the Ecuadorian shrimp industry." Bol. Cient., Vol. 8, No. 1. Instituto Nacional de Pesca.

Maridueña, L. 1986. "Actual state of the Ecuadorian pelagic fishery." In press. Notes on the third fishery meeting "The Pelagic Fishery in the South Pacific." Univ. Arturo Pratt, Iquique, Chile.

Stevenson, M. 1981. "Seasonal variations in the Gulf of Guayaquil, a tropical estuary." Bol. Cient., Vol. 4, No. 1. Instituto Nacional de Pesca.

Vildoso, A. 1976. "Biological aspects of the 1972-1973 El Niño: fauna distribution." Workshop on El Niño. Guayaquil, Ecuador. December 1974. Fishery Report No. 185. FAO.