



Moribund cormorants during *El Niño* 1983.

El Niño Returns to the Peruvian Upwelling System

The upwelling system off Peru is one of the richest marine areas in the world. Although it has been the subject of intensive research for several decades, its dynamics are only gradually being understood. In normal years the cool surface waters of the Peruvian ("Humboldt") Current, moving with a thickness of up to 200 m toward the equator, are continually replaced by even colder waters from moderate depths, mostly 200-300 m, which ascend at a rate of several meters per month. This upwelling of water is driven by the trade winds. On its north-westward path, the Humboldt Current encounters warm water-masses of equa-

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torial origin moving in a southwesterly direction. Each summer, when the trade winds weaken, the upwelling slows, and the warmer waters are carried to the south, sustaining a subtropical fish and invertebrate fauna off southern Ecuador and northern Peru.

In some years, however, meteorological changes (the causes of which are by no means fully understood) weaken the Humboldt Current and enhance the southward

currents, and equatorial waters penetrate into the upwelling system as far south as Pisco, Peru (14° S) or even into northern Chile. This phenomenon, called *El Niño* ("the Christ-child") because its start usually coincides with Christmas, occurs at irregular intervals; on the average every 5-6 years. Since 1874, nineteen *Niños* have been registered; in this century, e.g., in 1925-26, 1939-41, 1953, 1957-58, 1972-73, 1976, and 1982-83.

A *Niño* is characterized by warm waters of low salinity and poor nutrient content. The effects of a strong *Niño* on the pelagic and nearshore fauna, on guano birds and on sea lions are catastrophic.



Invertebrates killed by *El Niño* 1983 and scattered on a Peruvian beach.

There are decisive changes in the composition and distribution of the pelagic and demersal fish populations and the benthos. In addition, the adverse effects of fishing at high levels can become more severe, as is shown by the history of Peruvian fisheries.

The Peruvian Upwelling System in Recent Decades

Up to the 1950s, fisheries off Peru were largely artisanal. The dominant pelagic fish species, anchoveta (*Engraulis ringens*), was used only by immense populations of birds—cormorants, boobies, and pelicans—the feces of which accumulated in thick layers of guano on the islands and some parts of the shore. The guano supported an important fertilizer industry both in Peru and Chile through the 19th and the first half of the 20th century. By the end of the fifties, however, the anchovies became subject to an ever-growing purse seine fishery to meet the growing demand for fishmeal on the world market. By the end of the sixties, the Peruvian anchovy had become the most important fish species in the world, with catches of over 12 million tonnes in 1970. Until 1971, the exploitation of anchovies appeared to be an example of a well managed fishery, although some experts expressed concern over the vulnerability of such a fishery.

Indeed, the picture changed in 1972 with the occurrence of a strong *Niño* but the fishery continued against the advice of the experts. Recruitment failed in 1972 due at least in part to the unfavorable hydrographical conditions. The adults concentrated in immense shoals in the remaining upwelling patches nearshore, where they were easily caught by the

purse seiners and significantly diminished in numbers. From 1972 to 1976 the stock showed slight signs of recovery, but an *El Niño* in 1976 caused another failure in recruitment from which the stock has not recovered up to 1982. Nevertheless, fishing has continued over the years north of the Chilean border and at certain times also off the Peruvian central coast. The guano birds declined after 1965 to about 20% their original number, as a consequence of the increasing competition with man who deprived them of their principal source of food.

Compensating for the losses in anchovy biomass after the 1972-73 *El Niño*, the populations of other pelagic fish increased. Peruvian landings of sardines (*Sardinops sagax*) reached 1.7 million t in 1979, those of horse mackerel (*Trachurus symmetricus murphyi*) climbed to 0.5 million t in 1977, and the catches of mackerel (*Scomber japonicus peruanus*) reached formerly unknown levels of over 100,000 t. However, the catches of these species except for sardines had dropped considerably by 1982. The Peruvian purse seiner fleet designed for the capture of anchovies had difficulty catching mackerels. Horse mackerel, however, continue to be an important item for foreign factory vessels using midwater trawls.

The development of strong populations of demersal fish off Peru is hampered by the narrowness of the continental shelf and the extension of an oxygen minimum zone from about 50 to 700 m deep. This zone is characterized by low oxygen values, a high content of organic matter in the sediment as a consequence of the enormous primary and secondary production in the surface waters, by low

macrobenthic biomass and by mats of filamentous bacteria (Procariota) that cover wide areas. Only nearshore and in the northern part of the shelf where there is enhanced circulation at the bottom are conditions more favorable and sustain a productive artisanal fishery for invertebrates and demersal fish. In the catches of the latter, the hake (*Merluccius gayi peruanus*) is the dominant species. Total catches of this fish increased up to 1978, reaching levels of over 100,000 t mainly caught by foreign factory vessels. Recent investigations indicate, however, that by 1982 the hake may have been overfished as well.

The 1982-83 *El Niño*

Apparently, the 1982-83 *El Niño* is the strongest event of this kind since 1925-26. Contrary to previous phenomena, it started as early as July 1982 although the scientists did not take the first indications seriously. Its effect on the Peruvian coast, especially in the northern and central part of the country, has been severe; torrential rainfalls in otherwise arid areas and landslides continued until May 1983. Temperatures decreased a little by the end of summer, but oceanographers believe there will be a second peak in spring and summer 1983-84. By the end of January 1983, sea surface temperatures between Callao and the northern border were about 8°C above the mean, the maximum temperature being over 31° in the north. Red tides were common in many parts of the coast by the end of March. Temperatures at the seafloor exceeded 20°C at 100 m depth (in a normal year, they are around 12-14°C). While oxygen values in surface

waters decreased, oxygen at the seafloor increased drastically; off central Peru by a factor of 6 in 30-100 m depths. Upwelling was confined to a few restricted nuclei (e.g., off Huarney and San Juan), but even there the temperatures were much higher than normal.

The effect of these changes on the cold water fauna and flora was largely catastrophic. Most of the upwelling plankton was killed and replaced by tropical forms which cannot make up for the loss in density and biomass. Tropical species, among them large salps, invaded the area, but contrary to 1972-73 there was no invasion of jellyfish. The pelagic fish found themselves without their normal rich food, and tried to escape into cooler waters in the remaining upwelling centers and at greater depth; however, dead anchovies drifting at the surface demonstrated that this strategy often was not successful. By May 1983, only minute concentrations of anchovy had survived at some places nearshore in southern Peru. Sardines seemed to survive better but stayed at greater depths where they could not be caught by the purse seiners, leading to a severe situation for the fishmeal industry. Jack mackerel migrated inshore but also stayed beyond the reach of the purse seiners. Large predatory fish (dorado: *Coryphaena hippurus*, bonito: *Sarda chiliensis chiliensis*, skipjack: *Katsuwonus pelamis*, Spanish mackerel: *Scomberomorus maculatus sierra*) immigrated from offshore and the north and further decimated the traditional species, together with several species of tropical swimming crabs. The predatory fish, some with a high market value, made up only to some extent for the losses both the purse seiner and artisanal fisheries suffered from the absence of their traditional species.

The improved oxygen conditions at the seafloor, connected with an increase of benthic production, caused considerable migrations of many demersal fish species into areas normally void of fish (south of Chimbote to the Chilean border) and towards the fringe of the continental shelf. While this dispersion and utilization of a wider range of niches may turn out to be of benefit for the survival and recovery of the demersal fish populations, it worsened the fishermen's situation. In the

north, on the other hand, an immigration of penaeid shrimps led to unusually high catches of great commercial value.

As to the artisanal fishery on invertebrates ("mariscos"), only a few species have so far survived the 1982-83 *El Niño* well: the scallop (*Argopecten purpuratus*), the snail (*Thais chocolata*), the mussel (*Aulacomya ater*), and the octopus (*Octopus fontaneanus*). Shallow water sand clams (*Mesodesma*, *Semele*, *Gari*) and rock fauna (sea-urchins; limpets: *Fissurella*; false abalone: *Cocholepas*) populations were severely damaged. The rocks are without fauna over wide areas, growing large beards of green algae due to the lack of grazing. Crustaceans (mainly *Cancer* spp., *Platyxanthus*, *Hepatus*) suffered a very high mortality.

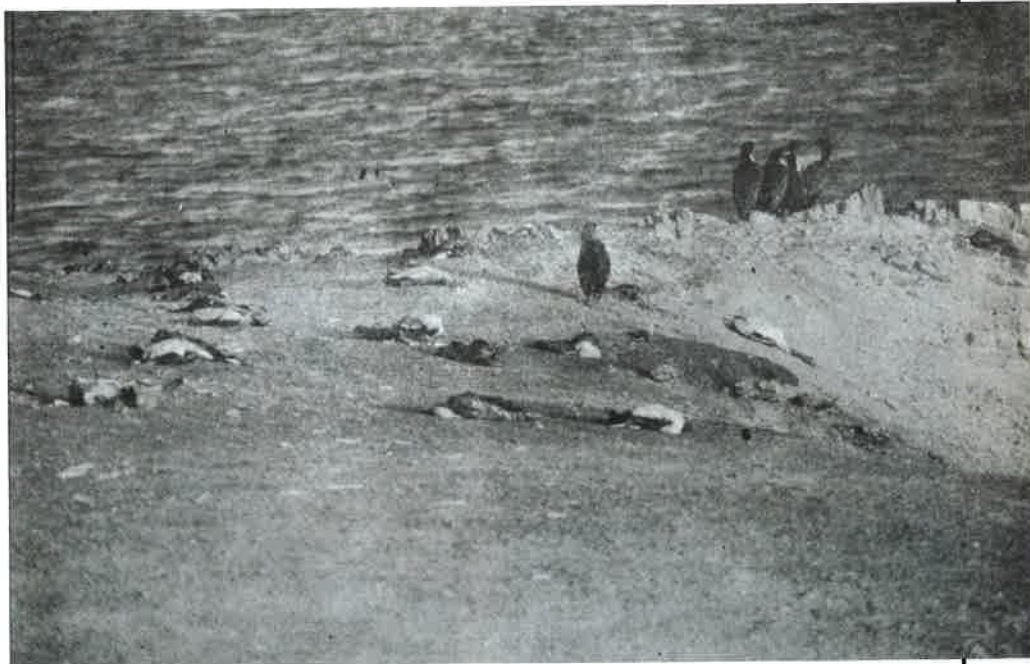
Finally, the guano birds, penguins and sea lions have died in large numbers. Many of them may have emigrated towards the south in time, but thousands of dead animals covered the beaches between March and May. Among the birds, especially cormorants (*Phalacrocorax* spp.) suffered a high mortality whereas pelicans (*Pelecanus thagus*) survived relatively well.

Consequences of *El Niño* 1982-83 for the Future of Peruvian Fisheries

It is yet too early to predict with certainty what the consequences of this exceptionally strong *El Niño* will be.

Probably, the long-term damage will be relatively moderate for the artisanal fishery where some fish species persist quite well (mainly corvina, *Sciaena gilberti* and chita, *Anisotremus scapularis*), and where the invertebrate species killed off will establish themselves again from larvae coming up with the Humboldt Current. There will, however, pass a couple of years before the majority of these species will reach a marketable size. As to the demersal fish, recruitment may be enhanced by the present favorable oxygen and feeding conditions at the bottom. The gloomiest aspect is presented by the pelagic fish: the anchovy, although nearly extinct off Peru, still lacks effective protection; even with an ideal fishery management it seems doubtful whether the species would recover. Almost certainly, all the fishing effort will now concentrate on the sardine which, therefore, is likely to become the next overfished species off Peru. And the next *El Niño* will occur with certainty. ●

(Note: The significance of 1982-83 *El Niño* will be discussed in a special symposium, covering the range of environmental factors to mammals, during the 9th Latin American Congress of Zoology in Arequipa, Peru, 8-15 October 1983.)



Dead cormorants on a Peruvian beach during *El Niño* 1983.