THE 1982-83 EL NINO: SOME OF ITS CONSEQUENCES FOR GALAPAGOS WILDLIFE

by

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Noticias has published several reports on the effects of the phenomenal El Niño event of 1982-83. These have been written by scientists and have mostly been concerned with the particular section of the flora or fauna which the author was studying. Godfrey Merlen has been serving as a Naturalist Guide in the Galapagos National Park for over four years and his occupation, which involves much travelling around the scattered islands of the archipelago, has given him an unequalled opportunity to gain an overall view of the consequences of the most catastrophic El Niño for at least a century. He has assembled his impressions in this article, which has already appeared in ORYX, the very distinguished journal of the Fauna & Flora Preservation Society. Because it provides a more complete picture of the consequences of the extraordinary event, we have thought it of interest to our readers to reproduce it here and Godfrey Merlen has very kindly added a postscript, bringing the story up to January 1985. As mentioned in Noticias 40, page 23, he is also selling prints of his watercolours in aid of the conservation work of the Darwin Research Station. — Ed.

At irregular and unpredictable intervals exceptionally warm surface waters appear in the central and eastern tropical Pacific Ocean, disrupting climate and ocean coditions. The occurrence is referred to as El Niño* and it usually begins in December, around Christmas time (El Niño is Spanish for Christ-child).

In order to place El Niño in context, it is worth outlining the usual seasonal pattern in the eastern equatorial Pacific. In the cool season, when many Galápagos animals breed, the south-east trade winds blow. These winds are a vital climatological facet in the productivity of the eastern Pacific, drawing surface water off the coast of South America and allowing cold nutrient-rich water to the surface to recycle its wealth. On these nutrients depend the organisms which are food for millions of birds, mainly boobies, cormorants and pelicans, and which are also the base for the extraordinarily productive anchovy fishery on the west coast. The winds also drive huge sections of the surface waters of the Pacific Ocean westwards, causing a rise in sea-level in the western Pacific. Part of the return system is via the North Equatorial Countercurrent, which passes well to the north of the Galápagos archipelago. Another section returns as the cold (15.5°C at 100m depth) Cromwell Under-Current. Its core may be 200m thick and 400km wide and somewhere between 20 and 250m below the surface and within 50km of the equator. It is this current that causes unstable water mixing within the Galápagos and is of great importance in preserving the extraordinary diversity of animals, some of which are of subantarctic origin. The sea surface temperatures may fall as low as 16°C. In December there is a change to a warmer climate as the Intertropical Convergence Zone (area of convergence of the north-east and south-east tradewinds and also represented by the Galápagos front which separates warm freshwater from the North from cool saltwater from the South, waters advected by the wind systems) moves southwards and the sea temperature increases.

Since 1940 there have been 10 'warm events' or Niños. The most obvious feature of one of these exceptional years is a rise in sea surface temperatures. The question is, where does this come from? In 1982-83 there were believed to be two sources: (1) warm water in large quantities from the northern Panama area, and (2) an unprecedented supply of warm water travelling from the western to the eastern Pacific. Some believe this first source to be principal cause of most Niño years, with hot water appearing off the west coast of South America and moving westwards until it may affect the whole equatorial region. The second source is apparently more rarely associated with the Niño years, although studies are in their infancy. There is a suggestion that the 1982-83 Niño was in fact two events, the first triggered in the western Pacific, which peaked in the east in December-January and perhaps masked the arrival of the hot conditions from the north, which persisted as high sea surface temperatures (4-8°C higher than normal) until June-July in the Galápagos, and which might have been a Niño in its own right.

* According to the definition of the Scientific Committee on Ocean Research (Working Group 55), El Niño occurs when the monthly mean departures of sea surface temperatures from the 25-year long-term monthly mean value exceed 1 standard deviation for four consecutive months at three of five coastal stations of Peru (Talara, Puerto Chicama, Chimbote, Isla Don Martin and Callao). At the end of 1982 surface temperatures exceeded the long-term means by 5 or more standard deviations at most of these stations (Halpern *et al.*, 1983).

Although little is yet known about the ultimate cause, or causes, of El Niños it seems that the abnormal conditions may be associated with changes in the normal relationships between pressure areas in the Pacific: the pressure gradient is virtually reversed, allowing equatorial westerlies to blow (i.e. from the west, whereas the normal wind flow is towards the west). The gradient in 1982 was greater than had been ever recorded since records began 35 years previously and the resultant winds were strong. Because of the imbalance already set up in sea-level heights across the Pacific, these winds triggered sub-surface wave patterns to surge across this ocean, carrying warm water with them. The Eastern ocean level rose by up to 45cm (about twice the usual annual change), due to decreased density in the upper water column caused by increased temperature; this in turn may be related to local heating or advected water. With the wind behind the sea, extensive flooding occurred on the coast of mainland Ecuador. It also allowed troughs to form in both hemispheres and the formation of tropical cyclonic storms, some reaching hurricane force, which in unprecendented strength and number hammered their way through French Polynesia. The westerlies, which began in July 1982, had by December 1982-January 1983 reversed the current flow of the equatorial surface waters and from mid-January to mid-February the cold Cromwell Under-Current disappeared to at least 250m depth at 109°W. The temperature at 100m was 27.5°C, 1°C cooler than the surface. This is 12-13°C warmer than in inter-Niño years. This huge volume of very warm water inundated the tropics of the eastern Pacific as far as the west coast of the Americas and set the scene for ecological drama.

Warm water invasion

Having summarised the background environmental changes that occurred during the period July 1982 to December 1983, I would like to make specific reference to the main Niño area, the coastal areas of South America within the tropics, and the Galápagos Islands in particular. The unparalleled invasion of warm water into the region had two major outcomes. First, a very high rate of evaporation developed and strong convection currents wafted the wet air to high altitudes, producing magnificent cumulus and cumulo-nimbus cloud formations, which resulted in storms of exceptional intensity. Between October 1982 and July 1983, 3264mm of rain were recorded at the Charles Darwin Research Station; an average figure is 254mm a year and the area is classified as a botanical desert. Secondly, the upper 100m of the sea became very stable. The blue, clear warm water may have been aesthetically pleasing but, nutritionally, it was a frightening, empty place. The productivity of the sea is extremely complicated, but the one most important factor is the recycling of essential elements to the surface, or at least to the zone that is reached by sunlight. I do not believe that anyone envisaged how rapidly this altered environment would be reflected in the web of life.

Tortoise exodus

If we consider two zones in the Galápagos, the arid, low-altitude areas characterised by scrub and cactus forest, and the rich intertidal and submarine environment, we find the effects of the two major features of El Niño are to reduce species diversity and abundance. The super-abundance of rain causes considerable damage to crops, removes topsoil, sends torrents of water surging and cascading down the ravines to the coast. According to Alf Kastdalen, a Norwegian who arrived in the islands in 1935 and was a keen observer of Galápagos nature, these ravines were filled 14 times in 1940-41, when there was another exceptional El Niño which also began out of season. In 1982-83 the ravines flowed more than 30 times. But Kastdalen also pointed out that since the 1940s man has damaged the ground in the farming areas by fires, by removal of the spongy moss-liverwort cover and protective shrubs, and by the development of a hard pan by ever-increasing cattle movement; thus these factors could account for the increased run-off, at least in part.

Flood waters coursed through the Tortoise Reserve on Santa Cruz and so unnerved the giant tortoises that they abandoned their highland homes for the drier coastal lands. Linda Cayot, studying tortoise — plant relationships, give up her study as an initial migration turned into a rout, and no tortoises were seen in the highlands for several months. Although in the past it has been difficult to imagine inter-island colonisation by these enormous beasts, it is not now difficult to visualise them being swept into the ocean by the violence of the floodwaters. Where the waters flowed they left a swath of destruction, with *Opuntia* cacti snapped like twigs in a gale.

The effect of the rain varied with species. Some plant families, especially the Convolvulaceae, responded with extraordinarily luxuriant growth. *Ipomoea* sp. and *Merremia aegyptica* on the coast, and *Stictocardia tiliifolia* in the highlands, climbed up and over rock, bush and small tree, submerging all in undulations of verdure, as if green snow had fallen. The appearance of ponds all over the islands offered great opportunities to insects. Hood Island became untenable by human beings because of the massive

explosion of mosquitoes (*Aedes* sp.) and perhaps by the blue-faced boobies *Sula dactylatra,* whose chicks had bare necks from irritation by these parasites. And on the land, insect larvae, which stripped bushes of their leaves, provided abundant food for terrestrial birds whose populations are usually limited by the lack of protein foods for the young. The amazing comparison between the breeding seasons of the Darwin's finches in the years 1982 and 1983 on the small island of Daphne Major will serve as an example. In 1982 60 nests were started at the beginning of the rainy season; all were abandoned for lack of food. But from December 1982 to the following June 1000 young birds were ringed. Some pairs bred four or five times and some birds hatched early in the season were themselves breeding by June. The genetic variation which must now be available is staggering. Soon selection pressure will bear down more heavily as more stringent times approach, but the future of the species must be optimised by these explosions in numbers.

Diasaster for seabirds

I would like to remark here, albeit unscientifically, that the impression one had in 1983 was of organisms caught in the circumstances of the times and as victims of fate rather than as finely-adapted results of evolution. The solid, water-storing trunks of the tall *Opuntia* cacti may adapt the plants to outcompete other species in normal conditions but that endowment did not stop the engulfing vines, nor did it prevent them being felled by their own weight as the pads became engorged with life-giving or death-bringing moisture.

The coastlands are the main reproductive area for the seabirds and here disaster struck, an outcome not restricted to Galápagos. From Christmas Island (157°W, 2°N), which has huge populations of terns — the colony of sooty terns *Sterna fuscata* alone is estimated at 14 million — shearwaters, frigatebirds, red-footed and blue-faced boobies, Ralph and Anne Schreiber (1983) reported: 'During our visit in November 1982 we discovered virtually a total reproductive failure on the island; the bird populations had essentially disappeared, and many dead and starving nestlings were present.' Although Galápagos cannot boast of such enormous colonies, the effect on its seabirds was similar. Heavy rains swamped the nesting areas of the boobies, ruining many eggs, and pathetically sodden birds were trying to ease the eggs out of puddles with their bills.

The waved albatros *Diomedea irrorata* of Galápagos had a very poor year in 1982, with about 60 per cent egg desertion, most probably from lack of food, and 1983 was even worse. Cathy Rechten abandoned her studies of this species after she ended up watching, within her whole study area, one incubating adult, and that not even incubating its own egg. Not only were eggs destroyed by rain, but many fell through the dense ground cover which had grown up, and were lost. By the end of December 1982 there was a stark contrast between the lush vegetation and the desperately begging young albatrosses finding no succour from their parents, which had spent days scouring the blue, vacant water. Despite the disastrous season, they returned at the end of March 1983 to try again, even though the productivity of the seas had not improved.

The shortage of food became acute and affected all animals that have a relationship with the sea. There was a remarkable correlation between increasing sea surface temperatures, rainfall anomaly and sardine catch (Chavez *et al.*, 1983). By December 1982 the catch was falling; in February-March 1983 it checked itself momentarily as the temperature fell slightly; in April 1983 it plummeted to zero as temperatures soared to 25°C — a 10°C anomaly.

Soon, those animals that could flee did so. Blue-footed boobies *Sula nebouxii* vanished from their colonies and were not seen in any numbers on their breeding grounds until June-July 1983. Although the blue-faced boobies *S. dactylatra* persisted in trying to raise their young well into 1983, by the time the blue-foots were returning the blue-faced boobies had vanished. The beautiful endemic swallow-tailed gulls *Creagrus furcatus* also disappeared early in the year and only started to return in June. Even now, in December 1983, I have only seen one bird with an egg, although much courtship is in evidence. One missed their buoyant flight of white over black basaltic rocks.

The breeding of the Red-footed Booby, *Sula sula,* was less affected by El
that that of the other seabirds.

Frigatebird failure

The great frigatebirds *Fregata minor* had a spectacular display season in April-May 1983 and then apparently completely abandoned all attempts to breed. The salt bush *Cryptocarpus pyriformis* plants on top of which they breed, would be growing lank by now if it were not for the fact that the red-footed boobies *S. sula* have moved in, taking advantage of the absence of the frigatebirds, and are keeping them cut back by removing twigs for nesting material. The red-foots have bred continuously during this difficult time, although at a lower rate, for they are adapted to feeding far from land in impoverished water on prey species such as flying fish and squid.

The failure of the great frigatebird is interesting because they are apparently catholic feeders as far as fish species are concerned. This either means that a large number of shore species disappeared or went deeper in the water, or that frigatebirds are much more dependent on stealing other birds' food than I had realised: with boobies not returning to their colonies, food of this kind was indeed scarce. The traditionally fished grouper, bacalao *Mycteroperca olfax,* was not caught for many months. In its place we had a prodigious influx of yellow-finned tuna *Thunnis albacorus,* dorado *Coryphaena hippurus* and wahoo *Acanthocybium solandri,* all blue-water predatory species. Sharks and turtles fled south, as did many birds, probably following the boundary of water masses where some mixing was still occurring.

Plight of the flightless

Some could not flee. Surveys of Galápagos penguins *Spheniscus mendiculus* and Galápagos flightless cormorants *Nannopterum harrisi* revealed that the numbers of penguins fell from 1720 in 1980 to 398 in 1983, and that numbers of flightless cormorants were reduced to 409 from 802 in the same period (Valle, in press). It will require another survey in 1984 to verify the damage done to the populations as these figures may reflect a very wide scattering of members of the species and could account for the setting up of new colonies of flightless cormorants, normally an extremely sedentary species.

Seaweeds and corals died everywhere. On average about 90-95 per cent of hermatypic corals (reef-forming corals — which are characterised by the presence of symbiotic unicellular algae in their tissues) died. The loss of the endosymbiotic algae *(Dinophyceae),* whose photosynthesis contributes food and aids in skeletal formation, appears to be critical for these animals. Stress from various sources may cause the loss; amongst these may be pollution and shading, also rain run off may cause an imbalance in osmotic pressure causing rejection of the algae. This may have been the reason for the separation within the Archipelago. This was true of genera such as *Pavona, Porites* and *Pocillopora,* and soon the naked white domes were covered with a monotonous filamentous alga. However, I was fascinated to see that the unattached fungus corals, which, when I last saw them in June 1983, were looking extremely vulnerable, alive but transparent, revealing every detail of their fine calcareous skeletons, had in fact survived and by November 1983 were once again clothed in green and brown.

Iguanas starved

The marine iguanas *Amblyrhynchus cristatus* have shown themselves to be very vulnerable and poorly adapted to these changed times. They seem to depend upon certain species of algae and are unable to deal with many others because of the limited ability of their stomach microbes to break down the cellulose of cell walls (Andrew Laurie, pers. comm.). With the death of whole carpets of algae such a *Ulva* spp., the iguanas were doomed. Thousands died. Their skeletons now lie under nesting cormorants.

The population of Galapagos Fur Seals, *Arctocephalus galapagoensis,*
suffered heavy losses during the 1982-83 El Niño but is since making a vigorous recovery
Photo by Fritz Pölking

The fur seals *Arctocephalus galapagoensis* and *A. australis* in Peru both fared very badly. These animals are shallow divers (30m or so) and feed mostly at night, perhaps largely on squid, and the rise in water temperature may have inhibited the vertical migrations of these animals or may have caused them to migrate laterally. In any case, by mid-February all but one pup of 90 originals were dead from starvation at Cape Hammond on Fernandina Island. It was a pathetic sight to see the hard outlines of vertebrae and ribs as food became more and more scarce. Pup mortality, from limited observation, was 40 per cent in 22 days for *A. australis* at Punta San Juan in Peru, where water temperature anomalies were similar to Galápagos (+9°C). In 1979 pup mortality was estimated to be 10 per cent during the first month of life.

The turn of the wheel

The event ended abruptly, in July 1983. Rainfall figures at the Darwin Station for July were 278.2mm and for August 5.2mm. This coincided with a strong increase in the south-east trade winds and a 2-3°C drop in sea temperatures. Up to December 1983 there was no sign of a re-entry of warm water.

Although all life was affected, with some species experiencing a population explosion and others a dramatic decline, none was, as far as we know, eliminated by these changes and perhaps many survive as they are because of these periodic 'tests of strength'. It is difficult now (December 1983) to appreciate the extent of the events that occurred; the islands seem so normal. The swallow-tailed gulls, sharks and turtles are back; boobies are displaying in their old haunts; marine iguanas lie fat beside new green algal beds; the grouper are back and fishing is good; flamingos and flightless cormorants are raising their young; penguins are moulting, a sign of possible breeding. And the old giant tortoises, which may have lived through several such seasons, have ambled back to their highland ranges, using the stream beds cleaned by the thundering waters. The wheel has turned.

POSTSCRIPT: JANUARY 1985

1984 has been a cool dry year, and although the cyclic events of tropical rainstorm and *garua* seem to be establishing themselves again into thier regular seasons, the Niño year of 1982-83 has left in its wake changes that will take many years to eradicate.

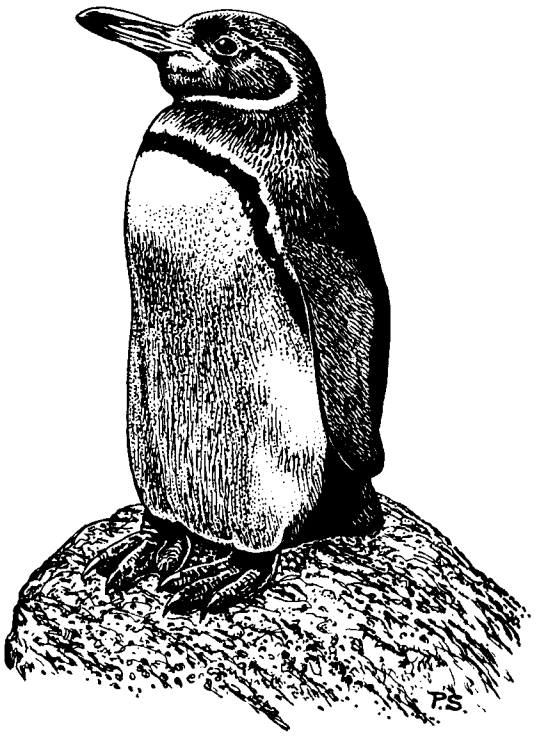
The enormous quantities of rain that fell (3264mm) were followed by a mere 151.2m for the same period a year later (November-July 1983-1984), according to records at the Charles Darwin Research Station. This is a low precipitation even when compared to other dry years and it has tended to reverse the trend of the Niño year with aquatic organisms being more successful while terrestrial species suffered in some cases severe reductions in their swollen numbers.

It has become obvious that the Flightless Cormorant, although needing man's assistance to face the peril of invading dogs, is quite capable of responding unaided to improved natural conditions. The latest (September 1984) census figure of 869 shows that there are possibly more birds now than before the Niño season, with vigorous reproduction being maintained into 1985. Unfortunately that other flightless bird, the Galapagos Penguin, is not showing the response that had been hoped for. The census of these small marine birds is extremely difficult and the fact that one can see recently moulted and post-Niño juveniles gives hope for the future. However, there is still cause for concern, especially since we do not know the factors restricting their recovery. Knowledge of the physiology of these birds and their environment is still very limited.

The response of other organisms has been as varied as that of these two flightless seabirds. The Fur Seals, having lost nearly all the young born in the four years 1980-83 and possibly 30% of the adult population, have responded with a very active breeding season, there now being no less than 250 pups in the study area of Fritz Trillmich; the females are in good condition and the yearlings heavier than in other years. Not only do the oceanic waters seem to have become once again highly productive, from primary producers on up, but also the reduced intraspecific competition gives each individual a greater chance to improve its condition and therefore to breed more successfully. This may also be said of the Marine Iguanas, where Andrew Laurie's study on Santa Fe is showing females to be in excellent condition, heavier than expected. At this time (January 1985) the males are jousting fiercely on the Galapagos shores to establish their territories.

The underwater environment shows masses of near-shore fishes, turtles and sharks, especially the hammerhead, while the *bacalao* fishery is characterized by heavily laden boats low in the water. For the Heliaster Starfish (2 species, one endemic) and that attractive bright green urchin *Lytechinus semiturberculatus* the outlook still seems dubious because they are conspicuous only by their absence, though perhaps they survive in some remote areas.

The corals still show a very slow regrowth. On many coral heads the die-off has been complete and the invading filamentous green alga covers everything; but on other heads, where small patches remained living, regrowth is occurring although it will take decades at the present rate before the pre-Niño condition is restored. It should be noted that, because of weak coral reef development in the Galapagos due to the low average sea temperatures, the highly complex ecosystems of reefs in other seas are not dominant, so the present loss of much of the hermatypic coral may not have such a profound effect on other organisms.



Galapagos Penguin *Spheniscus mediculus*
Drawing by Peter Scott

On the whole I think it fair to say that Galápagos is already showing its old face again. On a recent journey around the archipelago we saw amazing nesting activity of the teeming Blue-footed Boobies at Vicente Roca, where the cold, upwelling waters (15.8°C) were recycling the vital minerals to the upper photic zone. We saw Galapagos Penguins at the Mariela Islands, Punta Espinosa and Tagus Cove. Masked Boobies were busy in courtship at Punta Suarez, Hood Island, and the Great Frigatebirds were just beginning their courtship on Tower. The ubiquitous sealions have given birth to countless pups, even two pairs of twins are recorded. One of the symbols of Galápagos, the beautiful Swallow-tailed Gull, has been breeding successfully and many ethereal black and white fledglings are to be seen. The flamingoes, even after losing the Espumilla lagoon as a feeding area due to sedimentation, do not appear to have been greatly affected; a calculated 11.6% reduction in adult birds after the Niño year is not important. Perhaps the extreme tolerance of salinity changes by the Artemia brine-shrimp may have helped them to survive. A very good breeding year in 1984 was recorded on Floreana for that otherwise endangered seabird, the Hawaiian Petrel.

That most organisms are opportunistic seems to have been borne out by the 1982-83 El Niño experience. Cuckoos, anis, finches and rice rats multiplied enormously in the wet weather only to be violently cut back by the re-establishment of more normal regimes of climate. On the other hand, seabirds and aquatic mammals, reduced by the nutritionally impoverished state of the ocean, became prolific breeders as soon as advantageous conditions returned.

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TWO GALAPAGOS BOOKS

Boletín Científico y Téchnico, Vol. VI, No. 3, published by the National Institute of Fisheries, Guayaquil, 1984, 163 pages, 300 sucres.

This collection of papers (in Spanish with short English summaries) on the marine biology of the Galapagos includes:

A preliminary evaluation of the characteristics of *Mycteroperca olfax* from the biological and fishing points of view, by W. Tito Rodriguez P.

Lobster fishing in the islands, 1974-1979, by Günther K. Reck.

A statistical study of the nesting of the Green Turtle, *Chelonia mydas,* 1976-82, by Mario Hurtado.

Investigations into the exploitation of Black Coral (Antipapthes panamensis) by Priscila Martinez and Gary Robinson.

The population structure of the Sally Lightfoot Crab (Grapsus grapsus) and the human impact on this species, by Edith Herrera V.

Methods of improving the production of salted and dried fish in the islands, by Tim Bostock and René Mosquera.

Report on the stranding of six Beaked Whales on Baltra Island, by Gary Robinson, Friedemann Köster and José Villa.

Galapagos : Studies and Investigations of the Gruppo Ricerche Scientifiche e Tecniche Subacquee of the Zoological Museum of the University of Florence. Edited by Baldassare Conti. 426 pages. (1982).

This beautifully produced volume includes sixteen essays by members and associates of the first Italian scientific expedition to the Galapagos (1971), sponsored by Ludovico Mares. Half the articles are in Italian, half in English. The emphasis is largely but by no means entirely on marine biology. The book is richly illustrated by black & white and colour photographs, drawings and maps.

G.T.C.S.