El Niño en las Islas Galápagos: El Evento de 1982-1983. pp. 125-130
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SATELLITES, SEABIRDS, AND SEALS*

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The conditions for, and the unique character of, life on the Galápagos Islands is directly related to the oceanographic setting and the biological productivity of the surrounding waters. Variations in ocean conditions have been shown to have profound effects on the biota of these islands, particularly during times of El Niño (Boersma, 1978). A recent investigation, utilizing satellite ocean color observations and complemented with coincident oceanographic measurements has demonstrated the tight coupling that exists between the distribution of phytoplankton populations around the Galápagos Islands and the oceanographic conditions observed during the 1982-83 El Niño (Feldman, Clark, & Halpern 1984). The reversal of winds and ocean currents during February-March, 1983 is associated with a major redistribution of food resources around the archipelago. This redistribution, combined with a decrease in primary productivity of the region (Barber & Chavez, 1983), might explain the observed reproductive failure of seabirds and marine mammals on the Galápagos Islands during this El Niño.

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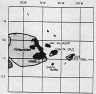
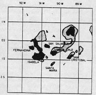
Barber and Chavez (1983) have noted that ocean waters around islands have inherently higher productivity than waters far removed from land. This increased productivity depends mainly on the supply of nutrients to the euphotic zone. Vertical mixing in the island wakes, often in the form of eddies, provides one mechanism that can explain the regions of high primary production associated with oceanic islands. Maxwell (1974) concluded that for the marine life in the Galápagos, the patterns of upwellings are instrumental in maintaining the lower trophic levels which in turn supply the higher carnivores (ie. seabirds and marine mammals) with food. It is the variability in these patterns that satellite ocean color observations with their broad spatial and high temporal resolution allows us to monitor.

The phytoplankton pigment distributions around the Galápagos Islands for 1 February and 28 March 1983, which were derived from Nimbus-7 Coastal Zone Color Scanner (CZCS) imagery are presented in Figure 1. A detailed discussion of the imagery and of the oceanographic conditions that were observed during that period can be found in Feldman, Clark, and Halpern (1984). On 1 February 1983, a plume with pigment concentrations greater than 1.5 mg/m^3 extends approximately 150 km to the west of Isabela (Figure 1A). The appearance of cold subsurface water and strong westward flows throughout the euphotic zone indicated that conditions were apparently returning to normal during this period. In fact, the patterns observed on 1 February correspond closely with those found in past CZCS images and shipboard observations made during non-Niño conditions (note Figure 14 in Maxwell, 1974).

By the end of March, at the peak of the 1982-83 El Niño, there was a resurgence of strong eastward flow along the equator. In addition, there was a collapse of the trade winds in the eastern Pacific



1A



1B

Figure 1. Graphic representation of the phytoplankton pigment concentrations around the Galapagos Islands derived from Nimbus-7 Coastal Zone Color Scanner imagery on (A) 1 February 1983 and (B) 28 March 1983. The lightly shaded areas represent pigment concentrations greater than 1.0 mg/m³. The darkly shaded area seen in (B) represents pigment concentrations between 3.0-10.0 mg/m³. In general, concentrations of less than 0.2 mg/m³ were found throughout the region.

with anomalous westerly winds taking their place. These changing conditions drastically altered the patterns of phytoplankton distribution around the islands. Plumes of phytoplankton-rich waters extend toward the northeast (Figure 1B). A large patch, approximately 60 km in diameter with pigment concentrations between 3.0-10.0 mg/m^3 can be seen to the northeast of Santa Cruz. These patterns, representing peak El Niño conditions are highly unusual based upon past observations. Perhaps as important as the appearance of plumes of phytoplankton-rich water to the east during this phase of El Niño, was the decrease in pigment concentration to the west of Isabela, normally characterized as the most productive region in the Galápagos.

This evidence of the dramatic effect that El Niño can have on the distribution of phytoplankton, which ultimately affects the productive capabilities of the higher trophic levels, raises some interesting ecological questions. The plumes of pigment-rich water evident in the satellite images suggest a possible causal relationship between changes in phytoplankton distributions and the conditions necessary for life on the Galápagos Islands. Satellite-derived pigment concentrations, an indicator of phytoplankton biomass, is not in itself an indicator of the abundance of organisms at higher trophic levels. However, frontal regions and eddies have been shown to be areas where zooplankton, squid, and fish are often found to congregate (Owen, 1981). Many seabirds can feed effectively only when their prey has been concentrated, as is the case along frontal zones (Ashmole, 1971).

Perhaps it is the persistance of regions of high primary production, rather than the absolute magnitude that is important to the higher trophic levels. The short-term (days-weeks) spatial variability evident in the satellite-derived pigment distributions are probably responses to changes in such short-term physical processes as winds, tides, and small fluctuations in the strength and direction of current flows. A region of high production may move about some central position in response to these events, while the mean location remains relatively stable throughout the longer time scales (weeks-months). It is changes over the time frame of weeks to months, as seen in Figure 1, which may produce the most significant effects on organisms at higher trophic levels.

The catastrophic reproductive failure of seabirds and marine mammals during El Niño has been well documented (Schreiber & Schreiber, 1983; Limberger et al., 1983). Researchers point toward a disruption in the normal food web and the disappearance of the small fish and squid which are the usual prey for these species as the prime cause. Short-term growth fluctuations for several species of seabirds on the Galápagos Islands have been related to the availability of food resources (R. Rickleffs, unpublished manuscript). During the breeding season the foraging range of many species of seabirds is very limited leaving the birds susceptible to any major redistribution of food. Breeding strategies, particularly the location of nesting colonies and the season in which breeding occurs, have been optimized over many generations through natural selection (Boersma, 1978); therefore, the long-term environmental conditions at a particular location will determine the suitability of that site. When environmental conditions change dramatically, as is the case during El Niño, populations that are tied to specific locations and therefore unable to exploit a geographic redistribution of food resources may suffer reproductive failures.

Satellite ocean color observations with their synoptic, broad areal coverage places the often limited surface measurements into a broader perspective. This new perspective allows us to refine our interpretation of the ecological consequences of the physical changes that take place in the ocean.

An investigation of the spatial and temporal variability of CZCS-derived phytoplankton distributions in the eastern equatorial Pacific, including the coastal upwelling regions, beginning in 1978 and continuing through the 1982-83 El Niño is now underway.

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