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Seabird densities and aggregations during the 1983 El Niño in the Galapagos Islands.—The El Niño-Southern Oscillation (ENSO) phenomenon of 1982–1983 was one of the most severe ever recorded in the Pacific Ocean, with major changes in fisheries, climate, and bird populations (Barber and Chavez 1983). In the Galapagos Islands, approximately 1000 km off the west coast of South America, Valle (1985) documented major breeding population decreases of Flightless Cormorants (*Nannopterum harrisi*) and Galapagos Penguins (*Spheniscus mendiculus*) and observed mortality of Blue-footed Boobies (*Sula nebouxii*), Magnificent (*Fregata magnificens*) and Great (*F. minor*) frigatebirds, and Brown Pelicans (*Pelecanus occidentalis*). Effects appeared to be more severe than during previous occurrences of El Niño, when adult mortality was not reported (Boersma 1978, Harris 1979). The widespread adult mortality and reproductive failure reported for breeding seabirds (Valle 1985) most probably were caused by reductions in food resources in the marine environment (e.g., Boersma 1978) during the 1983 El Niño. Unfortunately, there has been little information on seabird distribution and numbers at sea during El Niño events in the Galapagos. We report seabird densities and flock sizes recorded on 6 transects made within the archipelago during and after the 1983 El Niño.

Methods.—Birds were counted on continuous transects between islands, using the vessel Beagle III, cruising at 8 knots (Fig. 1). Sea-surface temperatures (SST) were taken with bucket

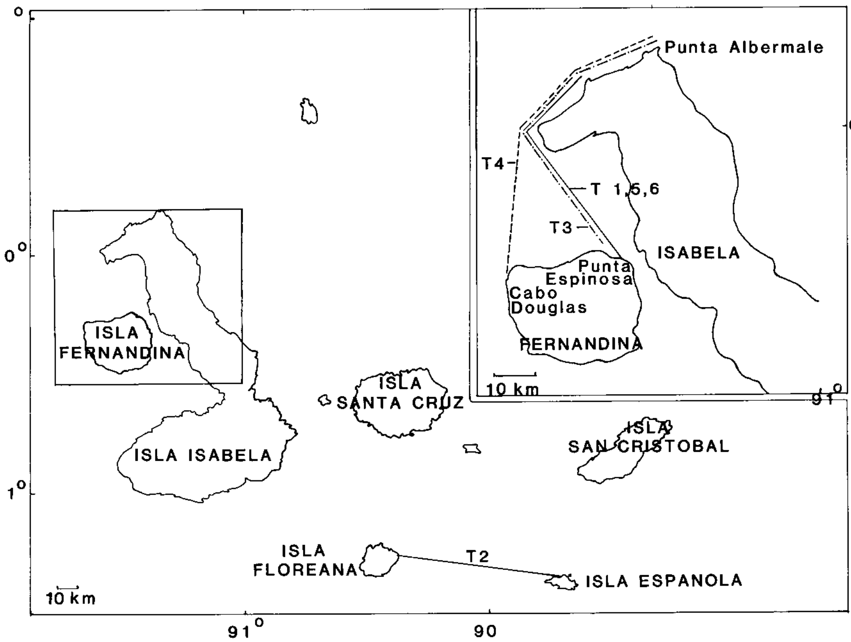

FIG. 1. Map of the Galapagos Islands showing locations of transects.

samples. An observer (GM) stood 4 m above the surface and counted all birds crossing a line perpendicular to the ship and extending out 300 m. All individuals and groups were recorded separately. We combined all records of frigatebirds because of the difficulties in distinguishing Magnificent and Great frigatebirds (cf. Harrison 1983).

Densities were calculated by dividing the total numbers of birds of each species seen by

TABLE 1

DURATIONS, DISTANCES, AREAS SURVEYED, AND SEA SURFACE TEMPERATURES FOR SIX TRANSECTS IN THE GALAPAGOS ISLANDS

	Transect					
	El Niño			Post-Niño		
	1	2	3	4	5	6
Duration (min)	171	182	68	133	93	29
Distance (km)	42.18	44.89	16.77	32.81	22.94	7.15
Area (km²)	12.65	13.47	5.03	9.84	6.88	2.15
Sea surface temperature (°C):						
at start	29.4	27.5	28.0	23.4	20.2	15.8
midpoint	29.4	—	—	24.0	20.3	—
at end	29.4	—	28.8	25.8	17.8	—

TABLE 2
DENSITIES OF BIRDS PER KM^2 DURING SIX TRANSECTS IN THE GALAPAGOS ISLANDS

	Transect					
	El Niño			Post-Niño		
Species	1	2	3	4	5	6
Waved Albatross (*Diomedea irrorata*)	0	0.5	0	0	0	0
Galapagos Penguin (*Spheniscus mendiculus*)	0	0	0	0	0.2	0
Dark-rumped Petrel (*Pterodroma phaeopygia*)	0.1	0.8	0.6	0	0	0
Audubon's Shearwater (*Puffinus lherminieri*)	1.3	0.2	5.0	15.8	0.3	37.2
White-vented Storm-petrel (*Oceanites gracilis*)	0.5	0.7	3.6	0.1	0	4.2
Band-rumped Storm-petrel (*Oceanodroma castro*)	0.1	0.2	0	0.1	0	0
Wedge-rumped Storm-petrel (*O. tethys*)	0.5	1.0	3.0	1.5	5.4	8.8
Storm-petrel spp. (*Oceanites, Oceanodroma*)	0.1	0.2	0.2	0.3	0	0
Red-billed Tropicbird (*Phaethon aethereus*)	0	0	0	0	0	0.5
Brown Pelican (*Pelecanus occidentalis*)	0.2	0	0.6	0	0.2	0.5
Blue-footed Booby (*Sula nebouxii*)	0.8	0.5	5.4	16.9	55.1	29.8
Masked Booby (*S. dactylatra*)	0.2	0	0.4	0.5	0.7	0.9
Frigatebird spp. (*Fregata*)	0.1	0.4	1.6	19.3	7.0	0
Northern Phalarope (*Lobipes lobatus*)	0	0	0	0	0	9.3
Gull spp. (*Larus*)	0.1	0	0	0	0.2	0
Swallow-tailed Gull (*Creagrus furcatus*)	0	0.1	0	0.1	0	3.3
Brown Noddy (*Anous stolidus*)	0.2	0	5.4	2.0	0	18.6

the area covered during a transect. Errors resulting from the small number of transects were minimized by using the entire transect length, rather than its subdivisions.

Transects (Fig. 1) were run on (1) 10 April 1983 (12:50–15:41 h) from Punta Espinoza, Isla Fernandina, to Punta "Atun," Isla Isabela; (2) 25 June 1983 (13:40–16:42 h) from Punta Suarez, Isla Española, to Punta Cormorant, Isla Floreana; (3) 1 July 1983 (12:15–13:23 h) from Punta Espinoza to Punta Albemarle, Isla Isabela; (4) 7 April 1984 (14:49–17:02 h) from Cabo Douglas, Isla Fernandina, to Punta Albemarle; (5) 4 January 1985 (12:23–13:56 h) from Punta Espinoza to Vincente Roca, Isla Isabela; and (6) 4 January 1985 (14:20–14:49 h) from Vincente Roca to Cabo Berkeley, Isla Isabela.

Transect 1 (Table 1) was run close to the time that El Niño was most severe (Feldman 1984); transects 2 and 3 were made later in the event. Subsequent transects were made approximately 10 and 18 months after the return of non-ENSO conditions to the area (Merlen 1985).

Results and discussion.—Audubon's Shearwaters (*Puffinus lherminieri*), Wedge-rumped Storm-petrels (*Oceanodroma tethys*), and Blue-footed and Masked boobies (*S. dactylatra*) were more abundant after, rather than during, El Niño; Brown Pelicans and White-vented Storm-petrels (*Oceanites gracilis*) appeared equally abundant in both periods; and Band-rumped Storm-petrels (*Oceanodroma castro*) and Dark-rumped Petrels (*Pterodroma phaeopygia*) were more abundant during El Niño than subsequently (Table 2). The higher numbers of the last 2 species during El Niño may reflect the fact that they fed closer to the islands at that time, or that they experienced considerable mortality, depressing their numbers in later counts.

Group sizes of Audubon's Shearwaters (El Niño: $\bar{x}$ = 2.5 ± 4.9 [SD], N = 26; post-Niño: $\bar{x}$ = 19.75 ± 44.4, N = 12), and Blue-footed Boobies (El Niño: $\bar{x}$ = 2.9 ± 2.1, N = 18; post-Niño: $\bar{x}$ = 31.0 ± 26.3, N = 106) were consistently but not statistically larger after El Niaño (median and *t*-tests, corrected for unequal variances, $P > 0.10$). Patchiness or local abundance of prey resources must have been reduced greatly, because even such typical flock-feeders as Audubon's Shearwater and Brown Noddy (*Anous stolidus*) fed in smaller flocks or alone during El Niño.

Our results indicate that for some species such as Audubon's Shearwaters and Masked and Blue-footed boobies, adult emigration from Galapagos waters or mortality must have occurred during El Niño. If nesting failure alone had occurred, adults would have been present at sea. Although we do not have pre-Niño counts, the rapid increase in bird densities on transects since the end of El Niño suggests that most adult birds emigrated and returned, rather than died. Extensive adult mortality of seabirds during ENSO is known to occur in Peru, where thousands of birds wash onto beaches (Jordan and Fuentes 1966), but distinguishing between mortality and emigration may be more difficult in other systems. Regular transects and long-term studies of marked individuals are probably essential in such cases (e.g., Harris 1979). Additionally, we need more information on the diets and distributions of Galapagos seabirds under normal conditions so we can make inferences about changes in distribution caused by changes in resources during El Niño.

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