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CHANGES IN THE DISTRIBUTION AND ABUNDANCE OF WAVED ALBATROSSES AT ISLA ESPAÑOLA, GALÁPAGOS ISLANDS, ECUADOR[1]

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Abstract. In 1994 a complete census of the Waved Albatross (*Phoebastria irrorata*) at Isla Española, Galápagos Islands, Ecuador estimated the world population as at least 18,200 breeding pairs, a 52% increase over the 1970–1971 estimate of 12,000 breeding pairs. Two small inland colonies disappeared between 1971 and 1994, estimates for two coastal colonies increased by at least 138 and 335%, and one other large colony remained stable over this same time period.

Key words: census, Galápagos Islands, nest site limitation, Phoebastria irrorata, *population ecology, Waved Albatross.*

The Waved Albatross (*Phoebastria irrorata*), formerly *Diomedea irrorata* (Robertson and Nunn 1997), is the only species of albatross that breeds in the equatorial zone, and it has one of the most restricted breeding and pelagic distributions of any albatross species (Harrison 1983, Tickell 1996). Nearly the entire world population of Waved Albatrosses nests at Isla Española, Galápagos Island, Ecuador (1°22'S, 89°40'W), formerly known as Hood Island. Up to 10 pairs have been recorded at the only other colony on Isla de la Plata (1°17'S, 81°3'W) off mainland Ecuador (Murphy 1936, Owre 1976, Ortiz-Crespo and Agnew 1992). At sea its range extends from the Galápagos Islands to the South American mainland, concentrating from the Equator south to northern Peru (Harris 1973, Tickell 1996). Waved Albatrosses are unusual in that they regularly transport their eggs in the colonies, a behavior responsible for up to 80% of egg loss (Harris 1973).

Waved Albatrosses are annual breeders, commencing egg-laying between mid-April and late June (Harris 1973). Incubation takes 2 months and they do not relay if eggs are lost. Chick rearing requires 5.5 months. Subadults recruit to the breeding population in their fifth (50%) or sixth years (50%). Harris (1973) reported on mean annual reproductive success (25%), interannual adult survivorship (95%), interannual subadult survivorship (93%), and mean dates of laying, hatching, and fledging (4 May, 3 July, 17 December, respectively).

Lévêque (1963) carried out the first census of Waved Albatross at two colonies on Española in 1961; Brosset (1963) discovered a third colony in the island's center. Harris (1973) made the first complete census of Española in 1970–1971. It was presumed that the population remained stable into the 1990s, however the census methods used by the Galápagos National Park Service (Servicio Parque Nacíonal Galápagos; SPNG) were not systematic and covered only part of the island (Gales 1993). Concern about albatross populations worldwide motivated the need for an updated census. I compared several census methods and attempted to develop a monitoring system consistent with the needs of SPNG; one which could be used on an annual basis at different levels of intensity according to funding. This paper reports census results, interprets changes in abundance and distribution of Waved Albatrosses at Isla Española, and provides a baseline population estimate for future comparisons.

METHODS

Isla Española (14 × 8 km) is an uplifted submarine lava flow divided by a central ridge, sloping off from central hills to eastern and western points, Punta Cevallos and Punta Suárez, respectively (Harris 1973). The south side is relatively steep and is exposed to the prevailing southeasterly breezes. Wind, slope aspect, and vegetation delineate the albatross colonies. Most Waved Albatrosses nest along the southern coastline, which is bounded by cliffs of up to 100 m. Lower nesting densities occur on hillsides farther inland. No albatrosses nest on the north side of the island where winds are not as strong. Dense thickets (*Acacia, Prosopis, Cordia, Parkinsonia*) cover the island and are impassable to humans in some places without the use of a machete. Harris (1973) speculated that the introduction of feral goats may have benefited Waved Albatrosses by creating additional nesting areas. The herbivory of goats also altered the vegetation structure of Española by removing giant tree cactus (*Opuntia* sp.), allowing shrub thickets to dominate (Douglas 1998).

Four methods for population estimation were compared in the whole island census (18 May–6 July 1994), conducted between the peak and the end of egg laying: (1) all eggs (active and abandoned) in the colonies were counted, (2) egg counts from Method 1 were adjusted for rates of egg laying and egg loss to arrive at a figure of total eggs laid (Harris 1973), (3) only actively incubated eggs (active eggs) were counted and an adjustment was made for rates of egg laying and egg abandonment to arrive at a figure of total eggs laid, and (4) an estimate of attendance rates was ap-

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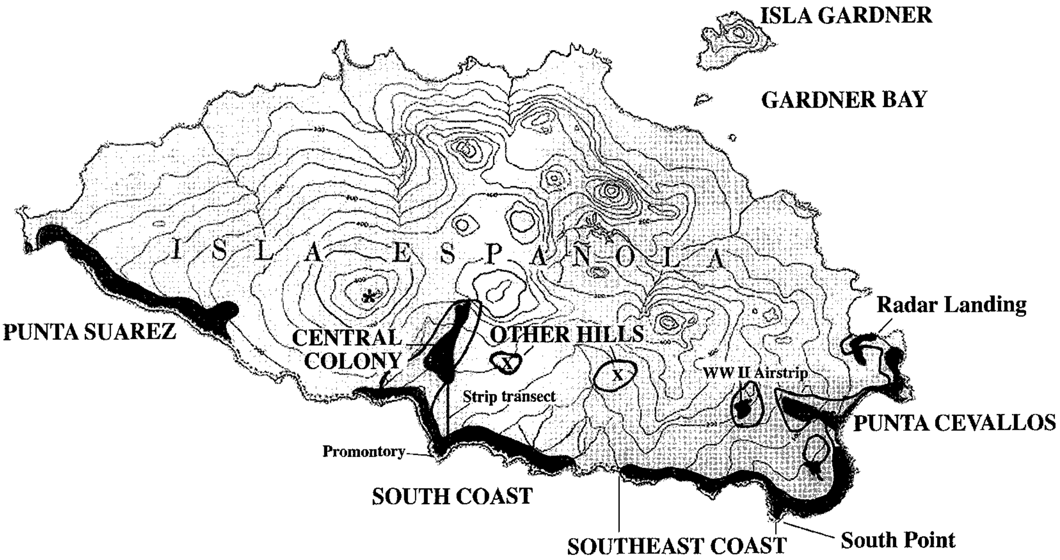

Figure 1. Map of Isla Española, Galápagos Islands, Ecuador, showing the boundaries of the albatross colonies as delineated by Harris (in outline) and as delineated in 1993–1994 (filled in solid). These boundaries are not necessarily directly comparable because different levels of technology were used. The X's mark colonies which have disappeared since 1971.

plied to counts of adult albatrosses to derive an estimate of breeding pairs. Method 4 would provide SPNG with a less labor intensive approach to population monitoring. Method 2 was the only method directly comparable to the 1970–1971 census. Disadvantages of this method are that the fate of census units (lost eggs) is difficult to confirm, and abandoned eggs are probably not equally detectable across habitats (e.g., bare ground vs. lush vegetation). The advantage of Method 3 is that incubating albatrosses are readily visible, and the fate of census units (incubated eggs) is easily confirmed.

Intensive census work on two study areas at Punta Cevallos provided detailed data to supplement the island wide census. Like Harris (1973), we documented rates of egg laying (Fig. 2) and egg loss through the incubation period (14 April–7 July), and these data were used to correct colony counts for eggs not yet laid or laid and lost by the census date. Eggs were numbered and identified with a numbered piece of flagging tape, tied to a nearby rock (1 m) that was moved as the eggs moved. The sample sizes for the two study areas were 177 eggs and 236 eggs. Nest sites were monitored every 1–2 days. Both members of a pair were marked at the base of the neck with dilute picric acid as they incubated. The total number of albatrosses present in each study area also was tabulated with the egg counts to estimate attendance rates. For Method 2, I calculated what percentage of total eggs were intact on each census date, and for Method 3, I calculated what percentage of total eggs were active (incubated) on each census date. For method 4, I calculated colony attendance (numbers of albatross per total eggs) averaged over 5-day intervals. Method 3 was compared at a coastal colony and at an interior colony on 4 July. The number of active eggs was divided by total eggs (active nests, chicks, abandoned eggs, broken eggs), and this percentage was compared to a predicted value.

Each colony (n = 6) in the whole island census was visited once. Teams of two to three people counted the numbers of albatrosses and eggs, forcing all sitting albatrosses to stand up, and marked albatrosses with dye where there was a potential for confusion. The few abandoned eggs which persisted from 1993 were readily distinguished by their dull surface, often dirty appearance, and mostly evaporated contents. The coastal colonies (Fig. 1: Punta Cevallos, Punta Suárez, South Coast, Southeast Coast) were subdivided into separate census areas with boundaries established perpendicular to the coast and photographed for future reference. Inland colonies (n = 2) were subdivided using flagging tape to avoid counting areas twice.

I cut a 20-m strip transect across a band of dense vegetation (approx. 2 × 0.4 km) between the Central and South Coast colonies (Fig. 1) and assigned half of the habitat to each colony (Table 1) at a natural transition from semi-open to very dense thickets. This habitat was inaccessible to us given our limited resources, yet it was apparent when viewing the colonies from the highest hill on the island that albatrosses were diffusely spread throughout this habitat. All eggs were counted within 10 m, either side of the trail. This figure was divided by four to obtain a conservative population estimate for the strip transect (because nesting density was probably not con-

TABLE 1. Comparison of Waved Albatross census cata 1970–1971[a] vs. 1994, Isla Española, Galápagos Islands, Ecuador.

Colony	Method 1 egg count 1970–1971	Method 1 egg count 1994	Method 2 corrected count 1970–1971	Method 2 corrected count 1994	Method 3 egg count 1994	Method 3 corrected count 1994	Method 4[b] Attend. [*Adults*] 1994
Punta Suárez	1,903	3,200	3,330	4,000	2,392	3,330	
Punta Cevallos							
Coast	1,916	4,335	2,316	5,555	4,000	5,515	6,270 [*5,038*]
Interior	602	395	743	585	224	337	966 [1,036]
Southeast Coast	514	1,074	642	1,511	803	1,200	1,399 [*1,358*]
South Coast[c]	1,026	3,918 (5,293)	1,140	5,492 (7,392)	3,277 (4,027)	4,963 (6,090)	5,253 [*6,146*]
Central Colony[c] (w. extrapolation)		800 (1,250)	2,000	1,111 (1,711)	699 (1,149)	1,050 (1,727)	1,324 [*1,549*]
Other hills (estimate)		None	500	None	None	None	
Total count		13,722	12,000	18,254	11,445	16,394	
Total with extrapolation		(15,547)		(20,754)	(12,645)	(18,199)	

[a] Census data from 1970–1971 taken from Harris (1973).
[b] Method 4 shows colony population estimates based on attendance, and colony counts of adults in brackets below.
[c] Data in parentheses after South Coast and Central Colony include an extrapolation from a strip transect.

sistent), and I extrapolated this density estimate across the habitat (Table 1). Minimum population estimates also were made for a sheer cliff face at the South Coast colony and a dense thicket at the eastern terminus of the Punta Suárez colony.

RESULTS

In 1994, Isla Española's breeding population of Waved Albatross was at least 18,200 adult pairs (Method 3, Table 1), based upon a single count of active nests adjusted for rates of egg laying (Fig. 2) and egg abandonment. This population estimate is 52% greater than that reported by Harris for the 1970–1971 census. An estimate based upon Harris' methods yielded an increase of 73%: 20,750 adult pairs (Table 1, Method 2). I had greater confidence in Method 3 because it could be more uniformly applied by less experienced observers. However, Method 3 underestimated population size at inland colonies (Table 1, Punta Cevallos interior) by underestimating the number of abandoned eggs. This method predicted that 64.5% of nests would be active on 4 July. The predicted value closely matched the obtained value for the coastal colony (Southeast Coast, 66% of eggs active) but not that of the inland colony (Punta Cevallos interior, 46% of eggs active), suggesting that more albatrosses had abandoned nest sites at the inland colony. The results of attendance-based estimates for five colonies are shown in Table 1 (Method 4; colony counts of adults shown in brackets).

Three primary population centers persist at Isla Española: Punta Suárez, the South Coast, and Punta Cevallos, but two small interior colonies recorded in 1971 (Fig. 1, marked with Xs) have disappeared. The extent

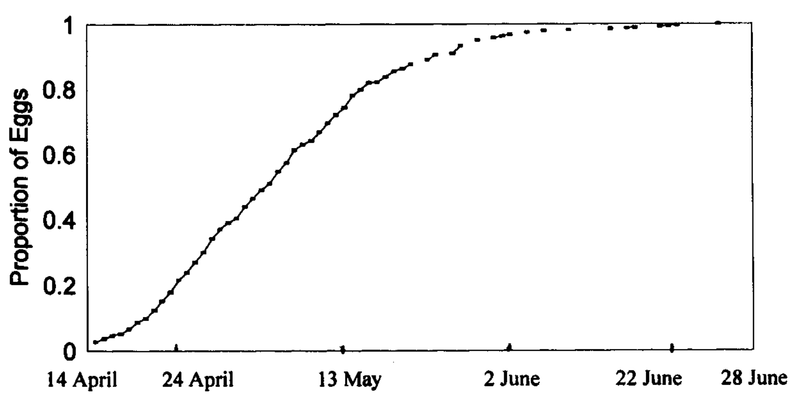

Figure 2. The average rate of egg laying in 1994 as determined from two census plots near Punta Cevallos.

of some other colonies may have diminished since 1971 (Fig. 1), however different levels of technology were used to draw these boundaries (GPS in 1994 vs. rough orienteering in 1971). The open coastal colonies (Punta Cevallos, South Coast) were more than double in size in 1994 as compared to 1970–1971, whereas brushy inland colonies (Punta Cevallos interior, Central Colony) were smaller or about the same (Table 1). Punta Suárez, a brushy coastal colony, did not increase by as much as the other coastal colonies.

DISCUSSION

In 1994 the world population of Waved Albatrosses was estimated as at least 18,200 breeding pairs (Table 1). This was 52% larger than the 1970–1971 estimate (Harris 1973), yet the spatial extent of some colonies was reduced (Fig. 1). This reduction resulted from revegetation, and this in turn was caused by the eradication of feral goats, which released the island's vegetation from herbivory (Douglas 1998). Some counts in 1970–1971 were incomplete (Central Colony, Southeast Coast; Harris 1973), so the population may have been larger at that time. Of the three main population centers, Punta Suárez has remained similar in size to 1971 estimates, while the Punta Cevallos coastal colony and South Coast colony have had large increases (Table 1). This is consistent with a pattern of large increases in open coastal habitats and stasis or decline at brushy sites, suggesting nest site limitation at inland colonies.

A primary challenge in censusing the Waved Albatross is that eggs may be laid and lost without being detected, precluding the usefulness of Method 1 for direct comparisons. I considered Methods 2 and 3 to be the most accurate, and the exact population size probably lies between these two estimates. Each method has inherent biases, which I was able to assess for Method 3 but not for Method 2. Method 3 could be improved by using separate intensive census plots for inland and coastal habitats to generate separate correction factors for each habitat. The higher rate of egg abandonment at the inland colony was probably due to thermoregulatory disadvantages of that habitat, e.g., less wind and hence less ventilation (Douglas 1998). In some cases, Method 4 yielded results similar to Methods 2 and 3. However, attendance patterns were variable and at times appeared to be synchronized with wind. Variable wind patterns may interject randomness in attendance patterns, thus further study will be needed to make Method 4 accurate and reliable.

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