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DISTRIBUTION OF NESTS OF THE BROWN BOOBY (*SULA LEUCOGASTER*) IN RELATION TO THE INCLINATION OF TERRAIN

Johel Chaves-Campos & Juber Torres

Escuela de Biología, Universidad de Costa Rica, San José, Costa Rica.
E-mail: jchavesc@costarricense.com

Distribución de los nidos del Piquero Moreno (*Sula leucogaster*) en relación con la inclinación del terreno.

Key words: Brown Booby, Cabo Blanco, Costa Rica, nest, nest density, nest-site selection, *Sula leucogaster*.

INTRODUCTION

Brown Booby (*Sula leucogaster*) is the smallest species of the Sulidae family, which comprises gannets and boobies (Carboneras 1992). Brown Boobies are pan-tropical birds that nest on a wide variety of habitats (Dorward 1962a, 1962b; Skutch 1976, Nelson 1978). Brown Boobies nest on much steeper terrain than most boobies and gannets (Nelson 1978, Carboneras 1992); for this reason, it seems that this booby species prefers to nest on steep terrain (Nelson 1978).

As the range of Brown Booby overlaps with most booby species (Harrison 1983), some researchers have suggested that this species nests more frequently on steep slopes than other boobies to avoid competition with those larger species (e.g., Dorward 1962b, Nelson 1978). Notwithstanding, this hypothesis remains untested.

In Costa Rica, the Brown Booby is a locally common breeding resident on islands along the Pacific and Caribbean coasts (Stiles & Skutch 1989). On some Costa Rican islands, Brown Booby is the only species that nests and roosts (J. Chaves-Campos & J. Torres pers. observ.). We selected one of these islands to inspect nest distribution in relation to angle of slope of the land. Our prime objective was to examine and quantify the distribution of the nest of the Brown Booby to determine if this species nest more frequently on steep slopes even in the absence of competition with stronger species.

STUDY AREA AND METHODS

We conducted this study on Cabo Blanco Island (9°32'16"N, 85°06'42"W), located on the Pacific coast of Costa Rica and included in the Cabo Blanco Absolute Natural Reserve. The island receives rain from May to November with the dry period extending from December to April (Coen 1983). Most of the island is covered with grasses (Cyper-

TABLE 1. Mean densities and population estimates of breeding Brown Boobies nesting on Cabo Blanco Island, Costa Rica, 1996-1997. Mean densities are expressed as number of active nests per 120 m^2 areas with one SD.

Month	Mean density	Pairs
December	7.2 ± 5.5	1194
February	3.7 ± 2.9	625
March	1.8 ± 1.7	292
April	1.2 ± 1.7	194
July	2.4 ± 3.0	402

aceae, Poaceae) in the rainy season, but vegetation practically disappears during the dry season. We selected this island because only Brown Boobies nest and roost there, and because it contains the largest colony of this species in Costa Rica (Stiles & Skutch 1989).

Cabo Blanco Island has an area of approximately 100,000 m^2 with sea-cliffs 70 m in height around 70% of its perimeter. The top of the island has a small flat area (c. 4000 m^2) which is surrounded by slightly inclined ground (25–40°), which in turn is limited by abrupt cliffs (70°–90°). The boobies nest on the flat and slightly inclined areas, and in small flat spots on the cliffs (c. 20% of the cliff area has this kind of rock-ledges). Substrates are very similar in the three areas: rock covered with guano.

To evaluate nest distribution, we divided the land study area into sub areas based upon the angle of slope: flat, slightly inclined and cliffs with flat ledges. Four randomly-selected transect lines of 30 m in length were placed in the three types of terrain, giving a total of 12 transects. We counted nests located within 2 m of each side of each transect line, and recorded the presence or absence of eggs and chicks. We surveyed each transect line on December 1996, February, March, April and July 1997.

A two-way ANOVA was used to detect spatial variation (according to slope categories) and temporal variation (reproductive peaks) during the study. The dependent variable was the density of active nests (nests under construction, nests with an egg or chick) per sample survey. To calculate density, we divided the number of active nests in each transect by the transect area (120 m^2). Nest density is expressed as the number of nests in 120 m^2 for calculated values to be above zero.

We also used a *G*-test of homogeneity to examine whether the distribution of the nests on the three types of slope changed over time, and to compare any change with concurrent nest density and population size. To calculate population size, we multiplied the mean nest density (nests per m^2) by the total area of the island to be used by boobies for constructing nests (flattish areas, and cliffs with flat ledges: c. 20,000 m^2).

RESULTS

We found nests under construction, eggs and chicks in different stages throughout the study period. Nest density was higher in December and February than other months (F = 10.09, df = 4,53, P < 0.001; Table 1), which suggests a reproductive peak during this period. Moreover, mean nest density (nests/120 m^2) on flat ground was 5.5 ± 4.7 (mean ± one SD), 4.0 ± 3.1 on slightly inclined ground, and 1.1 ± 1.9 on cliffs. Differences were statistically significant (F = 16.9, df = 2,53, P < 0.001), which indicates that nest density was higher on flat and slightly inclined areas.

The proportional distribution of nest on the three types of terrain (flat, slightly inclined, cliffs) did not change over time (G = 7.4, df = 8, P = 0.49; Fig. 1). Noteworthy, the total number of pairs on the island on March, April or July 1997 could have fit in the flat area, according to the number of pairs that nested on that area in December 1996 (56%

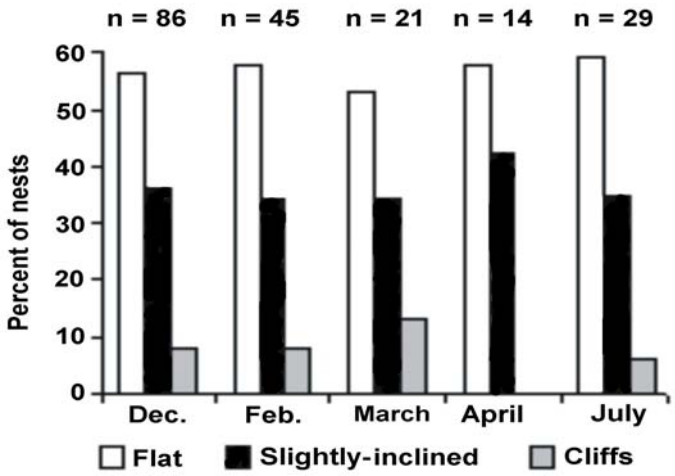

FIG. 1. Proportional distribution per visit of Brown Booby nests according to slope, Cabo Blanco Island, Costa Rica, 1996–1997.

of 1194 pairs; Table 1 and Fig. 1).

DISCUSSION

The number and density of nests were clearly higher on flat and slightly inclined areas on Cabo Blanco Island through the eight months of study. At other locations (e.g., Boatswain Bird Island), Brown Boobies nested on steep slopes where they were not displaced by the larger Masked Boobies (*Sula dactylatra*) that nest on flatter areas (Dorward (1962b). On Mazorca, Macabi, and Ballestas islands, Duffy (1983) suggests that Peruvian Booby (*Sula variegata*) is forced by larger species to nest on cliffs. This information on Brown and Peruvian boobies suggests the possibility that, on Cabo Blanco Island, Brown Boobies might be expected to show a preference for nesting in the flat area instead of cliffs in absence of interspecific competition. At other islands, Brown Boobies seem to prefer nesting on isolated ledges on cliffs (Nelson 1978). It is possible that on Cabo Blanco Island there are not enough of such ledges for all reproductive pairs, so boobies must nest on the large flat area. Nevertheless, Brown Boobies could really prefer to nest on large flat areas instead of flat "spots" on cliffs. We saw at least two chicks that fell down from nests located on cliffs. Eventually, all these chicks died. This observation suggests that nesting on large flat areas could be safer than nesting on cliff ledges. Another possibility is that Brown Boobies choose the flat area on the top of the island because wind levels facilitate take off (Dorward 1962a).

In spite of the fact that there was a reproductive peak during the study, the proportional nest distribution on the three habitats (flat area, slightly inclined area, and cliffs) was similar over time. Therefore, nest distribution seemed to be independent of nest density and size of the breeding population. Brown Boobies showed fidelity to nest site (Nelson 1978). If boobies defend their territories yearround and the proportion of pairs that nest outside the breeding peak is similar in the three areas, a similar distribution of nest would be expected over time on such areas. Notwithstanding, at Ascension Island, Brown

Boobies are usually absent outside the breeding season, so they do not defend nest-site year-round as White Boobies do (Dorward 1962a). On Cabo Blanco Island, Brown Boobies are present year-round, so the similar distribution of nests on the three habitats could be an indication that pairs defend nest site year-round. Further studies are necessaries to evaluate this possibility.

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