Breeding ecology and conservation of Brown booby in Gorgona Island, eastern tropical Pacific Ocean☆

Andrés Ospina-Alvarez[c,d]

[a] *Asociación para el estudio y conservación de las aves acuáticas en Colombia CALIDRIS, Cra 24 # 4-20 Cali, Colombia.*
[b] *Current address: Institut de Ciències del Mar (CSIC), Passeig marítim de la Barceloneta 37-49, CP 08003, Barcelona, Spain.*

Abstract

Breeding ecology and reproductive traits of Brown Booby *Sula leucogaster etesiaca* in Gorgona Natural National Park, Colombia, were studied. Adults morphometrics, eggs dimensions, chicks growth and nesting site characteristics, were examined at three different locations in the park. As with other subspecies, Brown Booby in Gorgona presents inverted sexual dimorphism, with adult females being lengthier, wider and heavier than adult males. Breeding of S. l. etesiaca results in eggs from the first deposition bigger in weight and dimensions than eggs from the second or third deposition. Growth of brown boobies chicks fit to a natural log equation: $bodymass(g) = 0.8773 \ln(days) + 3.3895$. A variety of spawning aggregations was found, and their relationship with the other marine birds nesting in the area is discussed.

Keywords: Sula leucogaster, behavior, sexual dimorphism, egg size, colonial breeding, conservation

---

☆Running title: Brown booby on a neotropical island.
Email address: aospina.co@gmail.com (Andrés Ospina-Alvarez)
URL: http://andresospina.tumblr.com/ (Andrés Ospina-Alvarez)

Breeding ecology and conservation of Brown booby in Gorgona Island, eastern tropical Pacific Ocean☆

Andrés Ospina-Alvarez[c,d]

[c] *Asociación para el estudio y conservación de las aves acuáticas en Colombia CALIDRIS, Cra 24 # 4-20 Cali, Colombia.*
[d] *Current address: Institut de Ciències del Mar (CSIC), Passeig marítim de la Barceloneta 37-49, CP 08003, Barcelona, Spain.*

1. Introduction

Sula leucogaster (Boddaert, 1783) is a Sulid with pantropical distribution that breeds colonially in the Atlantic, Pacific and Indian Oceans. Its typical subspecies S. l. leucogaster is located in the Atlantic Ocean. Two subspecies can be found in the Pacific: S. l. brewsteri Goss 1888, in the north hemisphere, and S. l. etesiaca Thayer & Bangs 1905, whose distribution spans from western Panama to the northern part of Ecuador. The two Pacific subspecies are morphologically distinct from the typical Atlantic subspecies, in that the former presents white head and collar while in the latter these parts are brown (Murphy and Jaques 1936).

The etesiaca subspecies is an endemic inhabitant of the American tropical Pacific and was originally described using individuals captured in Gorgona Natural National Park, Colombia (Ortiz-von Halle 1990). In the eastern tropical Pacific S. *leucogaster* is known to breed in the rocks of Octavia, Los Vidales and Centelinas de Jurubidá, in Chocó, with a low number of individuals (Naranjo et al. 2001). Another confirmed reproduction site is Gorgona NNP proper, with its cays of Gorgonilla, Juanchincho and El Horno (Ortiz-von Halle 1990; Ospina-Alvarez 2008).

Gorgona Island (Colombia), with its 150 confirmed pairs of Brown Boobies (S. *leucogaster*), is the most important known reproduction site for the etesiaca subspecies in the world (Naranjo et al. 2001). Nesting sites are located in the sectors of Gorgonilla islet, which hosts nine nesting sites, Juanchincho which hosts two, and El Horno with another two nesting sites. The two cays of Juanchincho are in the NW coast; in this zone Pelicans, Frigate birds and Blue-footed Boobies are less frequent and no nests of these species have been found (Cadena-Lopez 2004; Ospina-Alvarez 2008).

In Gorgona Island, Brown Boobies breed asynchronously; in censuses carried out every fifteen days, at the same moment nesting pairs, nests with eggs, nests with chicks and nests with fledged chicks were recorded (Cadena-Lopez 2004; Ospina-Alvarez 2008). Two reproductive peaks can be observed, with the period of higher activity between October and January. From March until July the reproduction rate was lower, reaching less than 27% of the preceding reproductive peak (Ospina-Alvarez 2008).

☆Running title: Brown booby on a neotropical island.
Email address: `aospina.co@gmail.com` (Andrés Ospina-Alvarez)
URL: `http://andresospina.tumblr.com/` (Andrés Ospina-Alvarez)

Preprint submitted to Nature Precedings *February 1, 2011*

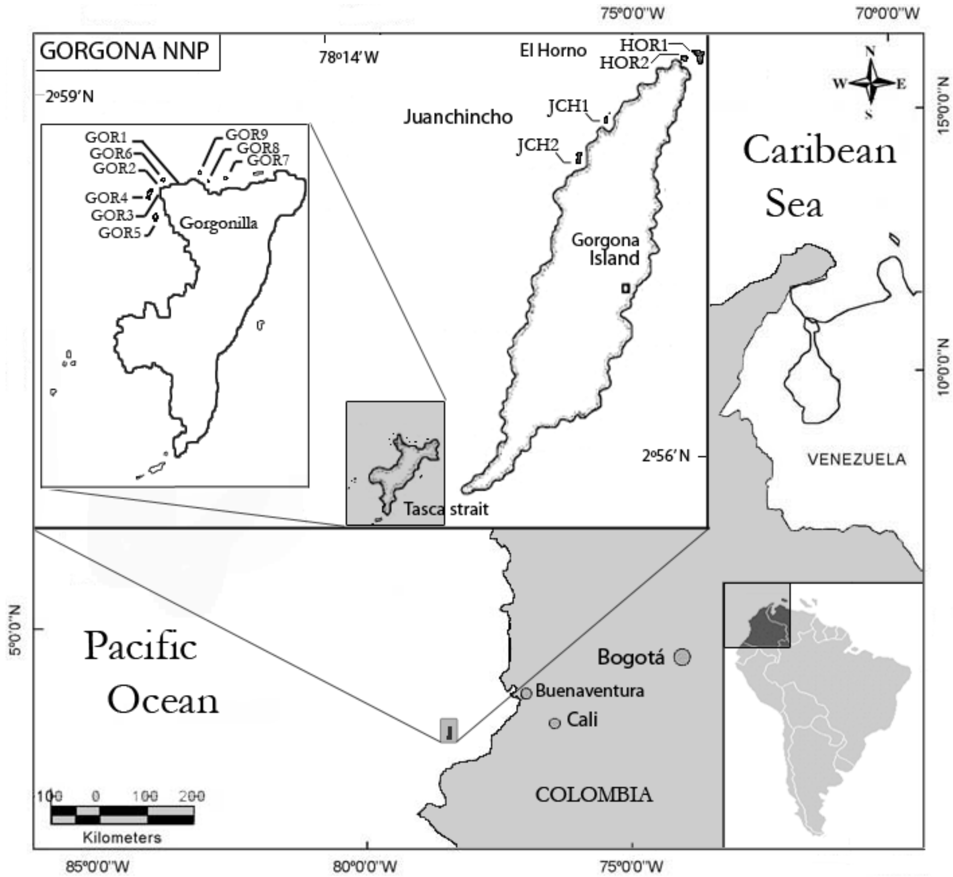

Figure 1: Map of Gorgona National Park, with location of sampling sites.

S. l. etesiaca in Gorgona NNP presents all the conditions supporting the center-satellite model (Ospina-Alvarez 2008). In this species occurrence, a central male with an higher Physical Quality Index (PQI) lives surrounded by satellite males with lower PQIs, following the commodity selection hypothesis (Danchin and Wagner 1997).

This study described poorly known aspects of the reproductive biology of Brown Booby in Gorgona Island, with the objective of improving management of protected areas for this species by relating it with the occurrence of other cohabiting marine bird species.

2. Methods

Data was collected during surveys conducted between October 2002 and October 2003 in Gorgona Island, in the Gorgona Natural National Park, Colombia (Figure 1). Gorgona is the principal island, 27 km from the Colombian Pacific coast (2°56' N, 78°12' W). The mean annual temperature is 27°C, the relative humidity is 88%-95%, and the mean annual precipitation is 6694 mm. Surface temperature of sea water ranges between 27.0 and 28.5°C. Distributed around the main island, Gorgona, are a number of small cays and emerging rocks, of which the northern Horno (HOR) and Juanchincho (JCH), along with the south-western Gorgonilla Island (GOR), were considered in this study. Aboard a 6 m boat, visual surveys were conducted around the NNP to assess the presence of nesting sites. Occurrences of more than ten pairs were counted as colonies. Nine colonies were found in Gorgonilla (GOR1 to GOR9), two in Horno (HOR1 and HOR2), and another two in Juanchincho (JCH1 and JCH2).

In the JCH2 colony, adults were captured at each nest site and weighted with a field scale (d = 1 g). Their morphometric parameters (wing and body length) were acquired with a flexible meter (d = 1 mm). At the same colony chicks were captured in the same way, weighted and gently massaged on the abdomen to facilitate regurgitation. Stomach contents were collected and preserved in formalin. In the laboratory, stomach contents were identified using Fishbase website (Froese and Pauly 2000) and Fishes of the tropical eastern Pacific (Allen and Robertson 1994) as references. Eggs were also carefully weighted and measured for length and width (d = 1 mm), discriminating between first and second egg deposed.

At the same sites, completely-built nests were measured for height, internal and external diameters (d = 1 cm). For each nest site we considered quantitative physical parameters: height (m), mean inclination (degrees), percentage of herbaceous cover, number of bordering walls (0 - 3) and width of platform (m). We also considered qualitative physical parameters: type of land (top, cliff or platform), direction of inclination (null, towards the rock, towards the sea), roof presence/absence, cracks presence/absence, drainage type (good or dry, bad or floodable terrain). Each of the variables considered was tested for pair choice using Pearson's χ^2 test for contingency tables and Fisher's exact test where applicable. Statistical analyses were conducted using SPSS v.13 software and R 2.8 package.

3. RESULTS

Even if Brown Booby is a species that breeds colonially, in Gorgona Island it was equally possible to find pairs nesting individually, in trios or aggregations of up to 10 individuals. Of 132 pairs studied between October 2002 and December 2003, 77 (58.3%) nested in six different colonies, 46 (34.8%) nested in 7 aggregations of up to ten pairs, three (2.3%) in one single trio, four (3.0%) in groups of two pairs, and two (1.5%) nested alone. The majority of nesting pairs was found in the GOR sector, but the bigger colonies were recorded in the JCH and HOR sectors. In the 50 casually selected nesting sites, it was found that Brown Booby builds nests in 86% of the cases. Specifically, 31 (62%) of these were well-built nests and 12 (24%) were only stubs. In the remaining 14% of the cases, Brown Boobies did not build nests, and deposed eggs on the rock or in a small hole.

In the GOR and HOR sectors, and in the JCH1 colony, Brown Booby shares its breeding territories with Blue-footed Booby, *Sula nebouxii* Milne-Edwards, 1882, which utilizes the same rocky cays and islets as resting sites while reproducing in areas other than Gorgona island. JCH2 was the only site where massive occurrence of S. *nebouxii* was not recorded during this study. A total of twenty-five (25) females and twenty-seven (27) males of S. l. etesiaca were captured, weighted and measured (Figure 2). Mean body length of females was 80 ± 2.0 cm, their wing length was 150 ± 2.0 cm and their weight was recorded to be 1300 ± 4.2 g. Males were smaller, with 75 ± 2 cm length; their wing length was 140 ± 2.3 cm and their body weight was 1000 ± 4.1 g. In addition, male's tails were longer in relation with body length, and their bill was more thin and short. Male/female body mass ratio was 0.77, indicating the presence of inverted sexual dimorphism.

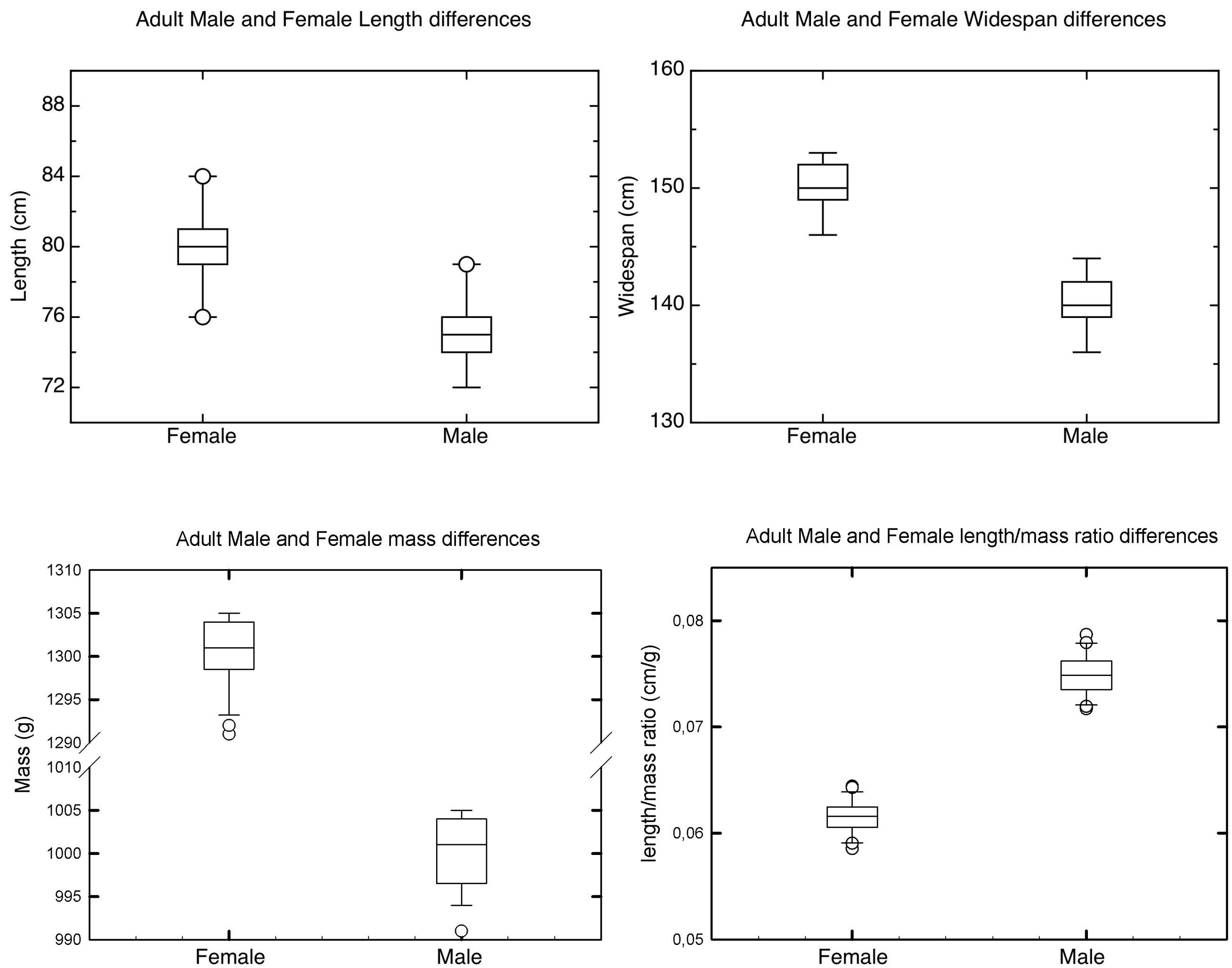

Figure 2: Morphometric parameters of adult males and females of S. l. etesiaca.

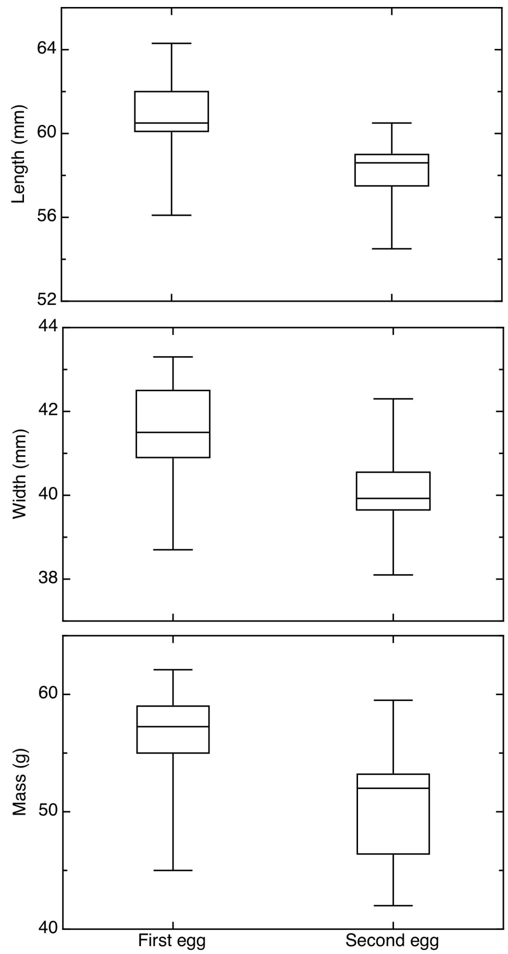

Figure 3: Comparison between eggs from first and second depositions.

Strong statistical differences between sexes were found for all variables: body length (U-test, $p < 0.0001$), wing length (U-test, $p < 0.0001$) and body mass (U-test, $p < 0.0001$) were all higher in females than in male individuals. The length/mass ratio were higher in males (U-test, $p < 0.0001$), suggesting that the males are less heavy than females in relation to their length.

A total of 26 eggs were measured and weighted. Strong statistical differences were found (U-test, $p < 0{,}0001$ in all cases): first deposed eggs were heavier, lengthier and wider than eggs deposed in second instance (Figure 3). S. l. etesiaca chicks come to life naked, with translucid skin that presents purple coloration. The first plumage is white and dense, which morphs into a brown one with fledging, at an age of about 90 days, when individuals are normally able to begin flying autonomously. Brown Booby chick showed a natural log increment in body mass, from birth to an age of 90 days fitting to a natural log equation where: $bodymass(g) = 0.8773 \ln(days) + 3.3895$ (Figure 4).

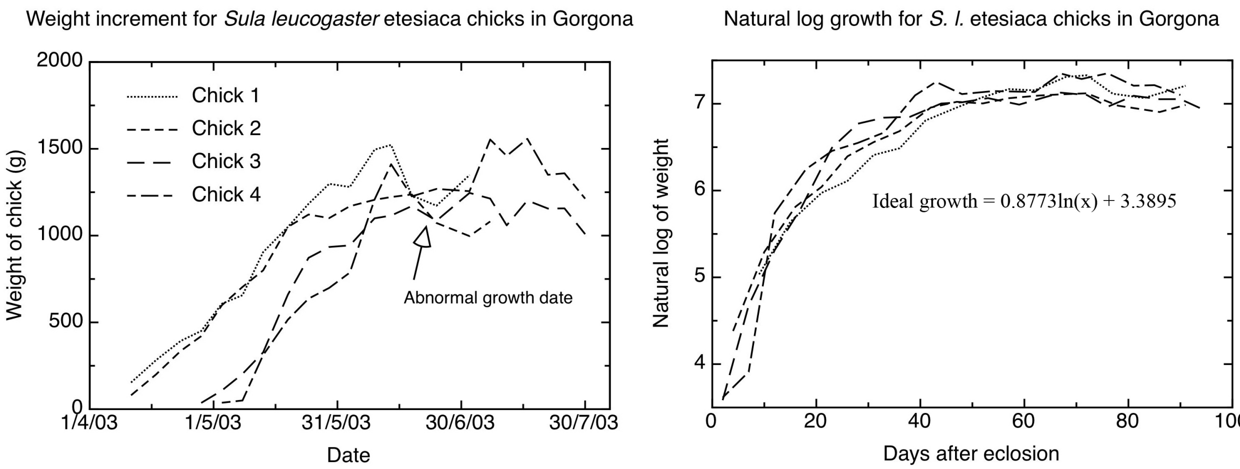

Figure 4: Growth parameters of S. l. etesiaca chicks.

Regurgitations of chicks were available for analysis in 27 occasions, involving individuals with ages between 45 and 90 days. Habitual diet was composed of Longfin halfbeak *Hemiramphus saltator* Gilbert and Starks, 1904 (66.67%) and Beautyfin flyingfish *Cypselurus callopterus* (Günther, 1866) (25.93%), while the remaining part (7.4%) could not be identified due to its advanced stage of digestion.

The sites where aggregations and colonies were found have a mean maximum altitude of 11.3 (± 3.2 cm S.D.) and a mean available surface of 196.1 (± 172.28 m^2 S.D.). The only difference between sites supporting colonies and sites supporting aggregations was the available area (U-test, $p = 0.01$): the surface of colonies sites (326.1 ± 170.9 m^2) was significantly greater than the surface of aggregations sites (84.7 ± 60.3 m^2).

A total of 31 well-built nests were measured for dimensions, recording an external diameter of 31.5 cm (range: 22.5 – 51.0 cm), an internal diameter of 17.4 cm (range: 14.0 – 22.5 cm) and a height of 5.1 cm (range: 2.4 – 6.8 cm). All of the considered qualitative variables resulted statistically significant for S. l. etesiaca choice in at least one of the two sites, in that pairs exhibited a preference for all the characteristics examined (Table 1).

4. DISCUSSION

According to data collected in this study, in Gorgona NNP *Sula leucogaster* etesiaca presents inverted sexual dimorphism. Male/female body mass ratio was comparable with that calculated for other areas or subspecies, namely S. l. etesiaca in Johnston Atoll, Sula leucogaster plotus (J. R. Forster, 1844) in Christmas Island and S. l. leucogaster in Ascension. This suggests that inverted sexual dimorphism in this species is diffuse and no particular alterating conditions occur in Gorgona NNP.

Even if a greater number of colonies was found in Gorgonilla (GOR), the number of individuals per colony was lower than in our other studied sites (JCH and HOR). In the Gorgona Park, the

Characteristic	Description	JCH1 choice	JCH2 choice
Altitude from sea level		Yes ($F = 9.31$; $p = 0.006$)	Yes ($F = 38.37$; $p < 0.001$)
Terrain inclination		Yes ($\chi^2 = 5.28$; $p = 0.022$)	Yes ($\chi^2 = 11.33$; $p = 0.001$)
Width of platform		Yes ($\chi^2 = 11.35$; $p = 0.001$)	Yes ($\chi^2 = 14.85$; $p < 0.001$)
Terrain type	Top, cliff, platform	Yes ($\chi^2 = 7.41$; $p = 0.025$)	Yes ($\chi^2 = 8.89$; $p = 0.012$)
Orientation	Seaward, landward, none	Yes ($\chi^2 = 7.47$; $p = 0.024$)	Yes ($\chi^2 = 7.72$; $p = 0.021$)
Landing facility	Presence / absence	Yes ($\chi^2 = 14.01$; $p < 0.001$)	Yes ($\chi^2 = 10.43$; $p = 0.001$)
Drainage conditions	Dry / humid	Yes ($\chi^2 = 4.17$; $p = 0.041$)	Yes ($\chi^2 = 5.03$; $p = 0.025$)
Protection / shielding from waves	Protected / exposed	Yes ($\chi^2 = 4.17$; $p = 0.041$)	Yes ($\chi^2 = 13.49$; $p < 0.001$)
Plant cover around nest		No	Yes ($\chi^2 = 11.33$; $p < 0.001$)
Natural walls around nest	Presence / absence	No	Yes ($\chi^2 = 13.03$; $p = 0.005$)
Protection / shielding from wind	Protected / exposed	Yes ($\chi^2 = 4.89$; $p = 0.027$)	No

Table 1: Qualitative characteristics of nesting sites, with results of the site-choice tests.

breeding season of Brown Pelican *Pelecanus occidentalis* Linnaeus, 1766 is known to occur between January and April and mainly in the Gorgonilla area. The reason for this is the presence on the main island of the White-headed Capuchin *Cebus capucinus* (Linnaeus, 1758), a Cebidae monkey whose dietary habits include bird eggs and who is not present in Gorgonilla (Alberico 1986). However, the occurrence of Brown Pelican may not be a competing factor for Brown Boobies, because the Brown Pelican is a tree nester while S. *leucogaster* is a rocky nester. On the other hand, Le Corre and Jouventin (1997) determined in a Red-footed Booby *Sula sula* (Linnaeus, 1766) colony that less than 1% of population was losing food due to Great Frigatebird *Fregata minor* (J. F. Gmelin, 1789) and Lesser Frigatebird *Fregata ariel* (Gray, 1845). Diverse adopted strategies were identified to evade aggressors, such as flying in big groups (>50 individuals) or returning to colonies during periods of low light. In Gorgona, Brown Boobies form flocks with Blue-footed Booby (*S. nebouxii*), which can confer them hypothetical advantage (Ospina-Alvarez 2008). We discarded kleptoparasitism by Magnificent Frigatebird *Fregata magnificens* Mathews, 1914 but there may be a behavioural aversion encouraging Brown boobies to identify as less attractive a site with a high density of Frigatebirds.

Sula nebouxii has been reported to use Gorgona Island and its surroundings as a roosting zone, and this was observed also during this study. No occurrences of this kind took place in Juanchincho (JCH) while in the other two sites there was a massive presence of this species. Competition with *S. nebouxii*, if present, may therefore be less intense in JCH leaving S. l. etesiaca pairs with more energy resources to invest in reproduction.

In the Juanchincho sites, spawning took place during the whole year in contrast with other sites, indicating that it may be the nesting site of preference in Gorgona NNP for Brown Booby. Pairs who find an optimal site are less incline to abandon it and will likely remain there to reproduce a second time. This explains the extended spawning period in Juanchincho and from this point of view, it is likely that this difference in sites quality is maintained in subsequent years.

An important characteristic of a protected area for the 21st century is that it helps maintaining the diversity of ecosystems, species, genetic varieties and ecological processes (McNeely 1994). Originally, Natural Parks were often viewed as compact environments where species could live with advantages with respect as the non-protected areas, i.e. Yellowstone Park (IUCN 1969), and fine-scale analyses of reproductive success between zones were rarely conducted (Schneider 2001). The structure, sizes and spacing of patches of habitat are each very important in determining abundances of local populations and their rates of change (Underwood et al. 2000). Recent studies have emphasised the large variability in abundances of individual species at very small scales (Bell et al. 1993; Underwood et al. 2000). In some cases, the physical features of the habitat are sufficient to explain the patterns (Fairweather 1988; Archambault and Bourget 1996; Thompson et al. 1996) while in others, complex behavioural interactions among individuals are important in determining patterns of abundance at different spatial scales (e.g. Chapman 1994; Underwood et al. 2000). Even protected areas host zones with highly variable quality, and this translates into differences in reserve effect between sites of the same NNP. We think that these fine-grained characteristics should be taken into account when deciding the size of protected areas so as to improve results in conservation of marine birds, especially when considering a colonial bird species with marked site-choice capabilities like S. l. etesiaca.

Finally, we encourage research efforts to develop pattern models, aimed at explaining the interspecific competition, nest site and pair choice in S. l. etesiaca. Our observations, even if just mensurative experiments (sensu Hurlbert 1984) provide a starting position to propose explanations or theories. Another deeper approach is necessary to clarify the processes involved in the possible competition between S. l. etesiaca and the other species in Gorgona NNP. If this competition really exists, then some sort of negative association between relevant variables in the species would have to be found.

ACKNOWLEDGEMENTS

The author wishes to acknowledge funding from Fondo para la Acción Ambiental de Colombia, Unidad Administrativa Especial del Sistema de Parques Nacionales Naturales de Colombia, Gorgona Natural National Park, IDEA WILD, Samuele Tecchio and Jose Trancito Grueso.

LITERATURE CITED

Alberico, M. 1986. Los mamíferos. Pages 193 - 207 in Isla de Gorgona (v. Prahl, and M. Alberico, Eds.). Textos Universitarios, Banco Popular, Universidad del Valle, Cali.

Allen, G., and D. Robertson. 1994. Fishes of the tropical eastern Pacific. University of Hawaii Press.

Archambault, P., and E. Bourget. 1996. Scales of coastal heterogeneity and benthic intertidal species richness, diversity and abundance. Marine Ecology Progress Series 136:111-121.

Bell, G., M. J. Lechowicz, A. Appenzeller, M. Chandler, E. DeBlois, L. Jackson, B. Mackenzie, R. Preziosi, M. Schallenberg, and N. Tinker. 1993. The spatial structure of the physical environment. Oecologia 96:114-121.

Cadena-Lopez, G. 2004. Distribución, abundancia y reproducción de las aves marinas (Pelecaniformes) en el Parque Nacional Natural Gorgona durante el año 2003. B. Sc. B. Sc., Universidad del Valle, Cali.

Chapman, M. G. 1994. Small- and broad-scale patterns of distribution of the upper-shore littorinid Nodilittorina pyramidalis in New South Wales. Australian Journal of Ecology 19:83-95.

Danchin, E., and R. H. Wagner. 1997. The evolution of coloniality: the emergence of new perspectives. Trends in Ecology & Evolution 12:342-347.

Fairweather, P. G. 1988. Predation creates haloes of bare space among prey on rocky seashores in New South Wales. Australian Journal of Ecology 13:401-409.

Froese, R., and D. Pauly. 2000. FishBase. Top| Responsibles| Parameters| Instances| Project| URL Describing this dataset: Froese, R.; Pauly, D.(Ed.)(21.

Hurlbert, S. H. 1984. Pseudoreplication and the Design of Ecological Field Experiments. Ecological Monographs 54:187-211.

IUCN. 1969. Standards and nomenclature for protected areas. 10th General Assembly, New Delhi, India.

Le Corre, M., and P. Jouventin. 1997. Kleptoparasitism in tropical seabirds: vulnerability and avoidance responses of a host species, the Red-footed Booby. Condor:162-168.

McNeely, J. 1994. Protected areas for the 21st century: working to provide benefits to society. Biodiversity and Conservation 3:390-405.

Murphy, R. C., and F. L. Jaques. 1936. Oceanic Birds of South America: A Study of Species of the Related Coasts and Seas, Including the American Quadrant of Antarctica, Based Upon the Brewster-Sanford Collection in the American Museum of Natural History. American Museum of Natural History.

Naranjo, L. G., A. Aparicio, and P. E. Falk. 2001. Evaluación de áreas importantes para aves marinas y playeras en el Litoral Pacífico Colombiano. Colombia. Fondo FEN.

Ortiz-von Halle, B. 1990. Aspectos generales de la comunidad de aves. Pages 215-235 in Biota y ecosistemas de Gorgona (J. Aguirre, and O. Rangel, Eds.). Fondo para la protección del Medio Ambiente (FEN), Bogota.

Ospina-Alvarez, A. 2008. Coloniality of Brown Booby (Sula leucogaster) in Gorgona National Natural Park, Eastern Tropical Pacific. Ornitología Neotropical 19:517 - 529.

Schneider, D. 2001. The rise of the concept of scale in ecology. BioScience 51:545-553.

Thompson, R. C., B. J. Wilson, M. L. Tobin, A. S. Hill, and S. J. Hawkins. 1996. Biologically generated habitat provision and diversity of rocky shore organisms at a hierarchy of spatial scales. Journal of Experimental Marine Biology and Ecology 202:73-84.

Underwood, A., M. Chapman, and S. Connell. 2000. Observations in ecology: you can't make progress on processes without understanding the patterns. Journal of Experimental Marine Biology and Ecology 250:97-115.