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OBSERVATIONS ON THE BREEDING BIOLOGY OF THE BOOBIES (*SULIDAE*) AT CLIPPERTON ISLAND, EASTERN PACIFIC

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Résumé

Des observations portant sur les sites des nids, leur densité et l'état de développement des Fous de l'île de Clipperton en mars 1980, ont révélé la présence du Fou à pattes rouges *(Sula sula websteri)*, du Fou à ventre blanc *(S. leucogaster nesiotes)* et du Fou masqué *(S. dactylatra granti)* à diverses étapes de leur cycle reproducteur. L'espèce la plus abondante, le Fou à ventre blanc, semblait être au maximum de son activité reproducteur. Les Fous à pattes rouges ont été vus avec des jeunes mais l'observation de leurs nids était impossible à cause des habitudes arboricoles de l'espèce. Le Fou masqué semblait avoir terminé son principal effort de reproduction. La densité des nids, les sites et la reproduction asynchrone sont discutés en fonction de la qualité de l'habitat et de la disponibilité de la nourriture. Nos résultats sont comparés aux observations faites sur des Fous d'autres régions. Les interactions entre le Fou à ventre blanc et le crabe *(Gecarcinus planatus)* sont aussi discutées.

Abstract

Observations of the nest sites, nesting densities and developmental states of the boobies at Clipperton Island, March, 1980 revealed brown *(Sula leucogaster nesiotes)*, white *(S. dactylatra granti)* and red-footed *(S. sula websteri)* boobies at various stages in the reproductive cycle. The dominant brown booby appeared to be at the peak of its reproductive effort, red-footed boobies were seen with nestlings but were inaccessible to observation due to their arboreal nesting habit and the white booby appeared to have passed their major reproductive effort. Brown booby nesting sites, nesting densities and asynchronous breeding are discussed relative to habitat type and available food supply and compared with observations of boobies in other regions. Interactions between nesting brown boobies and the abundant red land crab *(Gecarcinus planatus)* of Clipperton are reported.

Introduction

Clipperton Island, situated at latitude 10°18'N and longitude 109°31'W is the most easterly coral atoll in the Pacific ocean. The nearest land, about 960 km to the northeast, is the coast of the Mexican state of Guerrero.

Clipperton has long been recognized as a haven for large numbers of seabirds (Stager, 1964; Ehrhardt, 1971). The first census of the avifauna of Clipperton Island, conducted in July, 1968 (Ehrhardt, 1971) revealed that boobies comprised 77.3% of the 26,000 birds counted, followed by terns (19.3%) and frigates (2.5%). Seventy-seven per cent of the boobies were brown boobies *(Sula leucogaster nesiotes)*, 21 per cent were white boobies *(Sula dactylatra granti)* and 2 per cent were red-footed boobies *(Sula sula websteri)*. No published information exists concerning the ecology or the breeding biology of the booby populations of this unique ecosystem.

In March, 1980, an expedition to Clipperton Island was undertaken by the Cousteau Society in collaboration with the government of Québec. From March 7 to 17, 1980, we described nest sites, nesting densities and developmental states of the young of the brown booby. Limited observations are presented on the white and red-footed boobies as these species appeared to have either completed their reproduction or were relatively inaccessible.

Clipperton island

Despite its isolation and desert climate, Clipperton Island has been the subject of numerous explorations and expeditions, scientific and otherwise. Between 1951 and 1958, Clipperton received at least a dozen known visits from French researchers as well as American scientists from the Scripps Institute of Oceanography. Between 1966 and 1969, the *Marine Nationale de France* undertook the 5 "Bougainville" expeditions to study principally the hydrology and hydrography of the lagoon. In 1976 and, most recently, in 1980, expeditions organized by the Cousteau Society visited the island. The results of these and other expeditions are contained in numerous manuscript reports and articles reviewed most recently by Niaussat (1978). The following brief description of the island's physiography and biology are taken from Niaussat (1978), Sachet (1962a, 1962b) and Stager (1964), and the reader is referred to these articles for more extensive descriptions.

Clipperton is a narrow, low, uninterrupted landstrip of limestone debris supported by an oval-shaped coral reef (Fig. 1). The ribbon of land varies in width from 45 m to 400 m and completely encloses a lagoon of brackish water. The circumference of the island is about 12 km and the long, NW-SE, axis of the island measures 4 km. The island varies in elevation from 0.65 to 4.0 meters above estimated high tide level, while a small volcanic rock (Clipperton Rock) rises 29 m high near the south point.

The intertidal reef flats that surround the island are lined by sand beaches or cobble

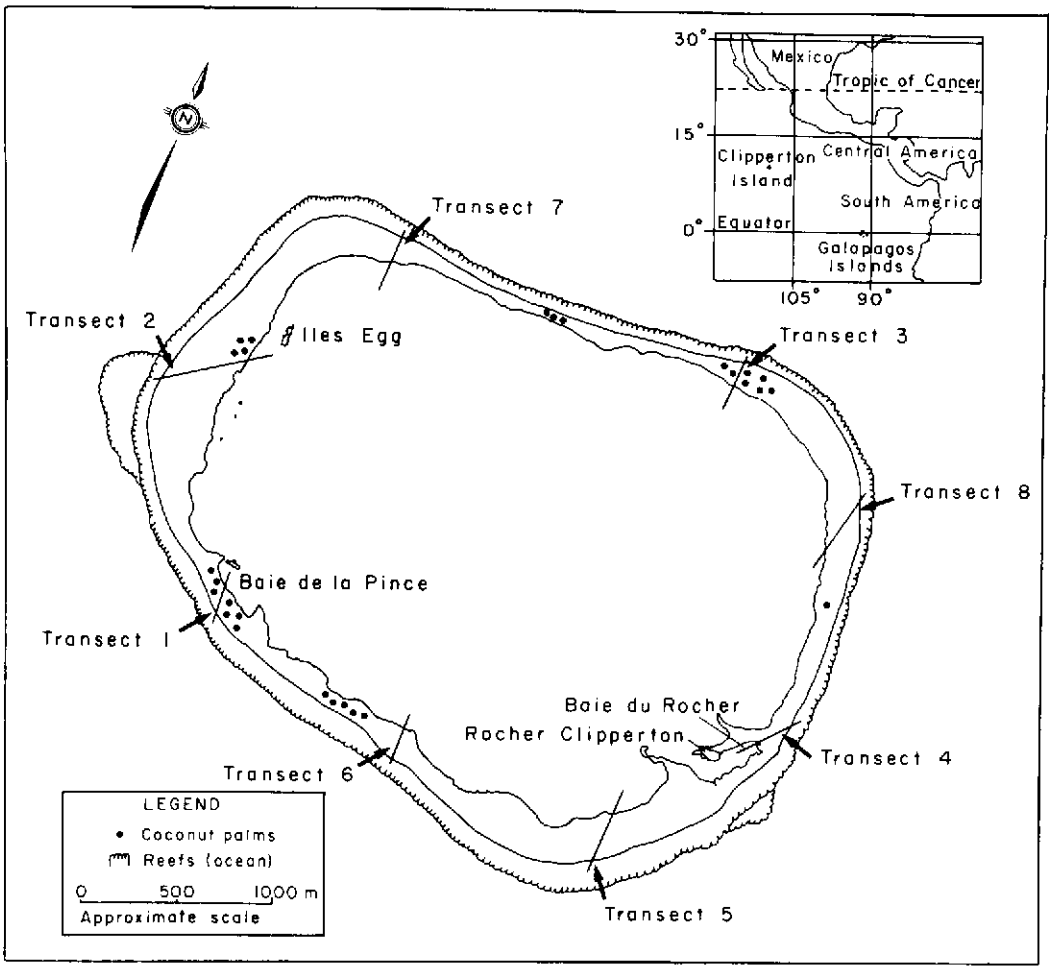

Figure 1. Clipperton Island. Lines crossing landstrip indicate locations of transects where observations of the booby populations were made in March 1980.

strands which rise to ridges of unconsolidated limestone and coral fragments. The land slopes down to the lagoon from the tops of these ridges and consists of loose or consolidated sediments that end in small cliffs or low muddy shores at the lagoon edge. In the consolidated sediments, the limestone pieces are bound by a phosphatic cement derived from the guano of seabirds. In some cases, the coral fragments are themselves partly phosphatized. These phosphatic conglomerates form flat pavements that are often interrupted by concentric step-like ledges that parallel the shores. Sand and coral fragments ranging in size from pebbles to boulders are scattered over the surface. Only in the coconut groves and amongst the mats of goatsfoot morning glory *(Ipomoea pes-caprae)* can one observe any accumulation of decomposed litter and humus.

The major terrestrial animal is the red land crab, *Gecarcinus planatus* Stimpson, 1860, whose extraordinary abundance was evaluated from 1966 to 1969 to be eleven million individuals, a density of approximately 6 crabs per square meter of island (Niaussat, 1978).

Pigs were introduced on Clipperton around 1897 and their numbers in 1958 were estimated at more than 50 (Stager, 1964). A pig extirpation plan was pursued during Stager's stay on the island as it was felt that the feral pigs were responsible for a depletion in the numbers of ground-nesting birds.

The vegetative cover of the island represents the most variable aspect of Clipperton's ecology. At the turn of the 20th century, a British company maintained a bird-guano mining operation on Clipperton. At this time is was reported that except for a lone coconut palm *(Cocos nucifera)* the island was almost completely devoid of vegetation, supposedly due to the presence of large concentrations of birds and crabs and the mining operations (Stager, 1964). During the 1958 expeditions, several hundred coconut palms were present and a portion of the island was covered with luxuriant mats of goatsfoot morning glory. Sachet (1962b) observed that the greater part of the island was covered with an ill-defined, variable assemblage of weedy species forming a low grassy or brushy cover. Sedge marshes were present along the lagoon shore.

Based on observations from the 1967 and 1968 Bougainville expeditions, Niaussat (1978) concluded that there had been a general increase in the biomass of the island's vegetation since Sachet's times. Comparison of Sachet's (1962b) vegetation map for August, 1958 with that presented by Niaussat (1978, p. 121) for June, 1967 indicates a doubling of the area covered by coconut palms particularly in the south-west corner of the island, and a slight increase in the area covered by goatsfoot morning glory, most notable in the north and north-east sector of the island. In 1976, Niaussat (1978) observed areas of the atoll completely denuded of vegetation, particularly next to Clipperton Rock, to the east and to the north, but continued to observe an important cover of "pioneering" species elsewhere on the island. A certain number of *Casuarina* trees were introduced to the island in 1967 and 4 such trees were observed in March, 1980 to persist in the southwest corner of the island.

Our observations in March, 1980 indicate that whereas the density and surface area of the coconut palms continued to increase, the area of goatsfoot morning glory had been reduced since the 1976 observations and that the brushy cover of weedy species referred to by Sachet (1962b) and Niaussat (1978) had been destroyed. By far the greater part of the atoll was denuded of significant vegetative cover in March, 1980.

Methods

Eight 3m-wide transects located around Clipperton island (Fig. 1) were each surveyed once between March 7 and 17, 1980. The length of the transect, the number of nests by species and their contents were noted for each transect. For each nest we recorded the number of eggs, nestlings and juveniles. We define nestling as all developmental states between naked and down beginning to cover the whole body, the chick thus becoming white. Juvenile includes all developmental states from fully downed and about half the size of the parent to partially plumaged and still loyal to the nest site.

The habitat of each transect was noted according to the following code: (a) loose or consolidated sediments with coral fragments ranging in size from pebbles to stones; (b) loose or consolidated sediments with coral fragments ranging in size up to boulders; (c) mixed, vegetation with open spaces of loose or consolidated sediments covered with coconuts, palm fronds and

Figure 2. *Sula dactylatra granti,* variously known as the white, blue-faced and masked booby, standing on the consolidated sediments typical of the Clipperton landstrip. *Left foreground*: adult, mainly white with dark brown flight feathers, greater wing-coverts and tail; color of bill yellowish or pinkish, feet and legs bluish-green; bare skin of face and throat blue. *Middle foreground*: chick, partially plumaged with down remaining only on the head, neck and back; approximate age, 85 days (after Dorward 1962). *Right foreground*: fully-feathered chick; head, neck, back and wings mainly brown and flecked with white; approximate age, 100 days, not yet fledged.

coral fragments of variable size; (d) vegetation with accumulation of decomposed litter.

Results and discussion

Of the 326 nests observed, 90% (291) were of brown boobies, 8% (27) were of red-footed boobies and 2% (8) were of white boobies. Concerning white boobies (Fig. 2), clusters or "clubs" (Dorward, 1962) of near adults, juveniles and immatures were observed everywhere on the island, generally oriented into the wind along the lagoon shore. Adults were frequently observed feeding fully-feathered chicks that were still unable to fly to sea. Nests were observed only intermittently about the island (transect 2,3 and 5, Figure 1). Of the 8 nests observed, 4 contained one juvenile each, 1 contained one nestling, 2 contained 2 eggs each and one contained 1 egg. White boobies were not observed to construct nests, the eggs being laid directly on the coral-limestone ribbon.

It was evident that the major reproductive effort of the white booby had passed. Dorward (1962), studying the white and brown boobies at Ascension, established that chicks of both species were fully-feathered but not yet fledged after approximately 105 days of development. Incubation lasts 42-46 days in the white booby. Due to the preponderance of fully feathered but not yet fledged chicks, we assume that the breeding season of the white booby was initiated approximately 150 days before our visit to Clipperton, that is, during the month of October, 1979. In the Galapagos, breeding of the white booby has only been reported in the late and early months of the year whereas at Ascension, breeding occurs mainly around July (Dorward, 1962).

Figure 3. The red-footed booby *(Sula sula websteri),* brown phase; adult, mainly pale brown with sooty black primaries; bill pale blue with a pinkish base; feet bright red; bare skin of face blue and of throat black. White-phase adults are mainly white with pale brown tail feathers.

Red-footed boobies are the only *Sulidae* of the island to build their nests in trees (Fig. 3). The twenty-seven nests were all observed in and around the large coconut palm grove in the southwest corner of the island. Of 16 nests observed perched on the crown or nestled amongst the fronds of coconut palms, 10 were cared for by brown-phase adults, 2 were cared for by white-phase adults and 4 were unattended at the time of observation. Ten other nests were observed clustered close together in four *Casuarina* trees. Eight of the nests were attended by white-phase adults and 2 by brown-phase adults. One white-phase adult was observed nesting at ground level amongst the roots of a coconut palm. Although it was not possible to observe the contents of all of the nests because of their height, each of 5 nests observed contained one fully-downed chick.

Brown boobies and their nests were present everywhere on the island (Fig. 4). Generally speaking, this species builds nests on the ground out of material available in the immediate vicinity. We observed nests constructed of coconut palm fronds, feathers, aquatic vegetation from the lagoon, bits and pieces of flotsam from the high tide line and small coral fragments.

The density of brown booby nests varied greatly over the island (Table I). Such variability may have been due to an interaction between habitat type, exposure and competition with the white booby. The west and northwest areas of the island are barren stretches of loose and consolidated sediments littered with coral and limestone fragments presenting little potential nesting material for brown boobies. The area is buffeted during the summer months by westerly winds bringing squalls and storms (Sachet, 1962b). This area is primarily associated with the white booby (Ehrhardt, 1971; present study) whose earlier nesting period and non-existent nesting-material requirements seem better suited to the area than those of the brown booby.

Figure 4. The brown or white-bellied booby *(Sula leucogaster nesiotes). Left*: adult, female, predominantly brown with a white belly and white underwing; bill and legs yellowish-green, bare skin of throat and face bluish. *Right*: adult, male, much lighter in coloration on the head, neck and chest, the characteristic straight line of demarcation across the breast remaining distinct.

Elsewhere on the island, the brown booby is much more abundant in all habitat types. Although the variability in nesting density between transects is not clearly associated with habitat type (Table I), nesting densities along any one transect were influenced by the presence of large objects lying on the ground. Coral and limestone boulders, aggregations of coconuts and fallen fronds appeared to act as blinds permitting greater densities of nests. Inter-nest distances were generally less than 2 meters in the vicinity of blinds but greater than 3 meters on open flat areas. Brown booby nests were absent from heavily vegetated areas.

The nesting sites of brown boobies on Clipperton do not conform to those described for other areas. Simmons (1967) reported that Ascension Island brown boobies tend to space their nest-sites such that nests are "some yards apart" with no encirclement by other nests. The brown booby also characteristically chooses steep sites such as slopes and clifftops and faces on the periphery of islands overlooking the sea. Simmons (1967) suggests that spaced nests and steep sites influence the brown boobies antagonistic behavior. They are unrestrained by close neighbours and can readily take wing from a vantage point. Dorward (1962) observed brown and white boobies at Ascension and noted that white boobies preferred level places for nesting and always exhibited greater nest densities than brown boobies. Although interspecific fighting over territories was rarely observed, Dorward (1962) reported the general impression that brown boobies nested where they were not pushed off by the white. In a situation resembling more so that of Clipperton, Hernandez and Jiménez (1972) observed that brown boobies nesting on islands in the Bay of Chamela, Jalisco, Mexico generally chose sites totally free of vegetation or partially-shaded sites adjacent to vegetated areas. Internest distances in areas of high nest density were in the order of 1.20 to 1.30 meters becoming generally greater and more variable in areas of low nest density.

TABLE I

The distribution, density and basic clutch composition of brown booby nests at Clipperton Island, March, 1980.

Transect	*Sector*	*Date*	*Habitat type*	*Density (nests per paced m)*	*% Nests eggs only*	*% Nests with chicks**	*% Nests empty*
7	NW	14/03	a,b	.003	0	100(1)	0
2	W	12/03	a	.01	57(4)	0	43(3)
1	SW	11/03	c	.22	73(33)	26(12)	0
6	S	13/03	c	.16	95(22)	5(1)	0
5	SE	13/03	a,b	.38	52(39)	45(34)	3(2)
4	E	13/03	b	.14	57(23)	43(17)	0
8	NE	14/03	a	.16	93(38)	5(2)	2(1)
3	NE	12/03	b,c	.34	94(56)	2(1)	4(2)

Numbers in brackets represent number of nests in sample.
* 'chicks' includes both nestlings and juveniles.

Apart from Clipperton rock and the minor lagoon-shore terraces, steep habitat is not available to brown boobies nesting on Clipperton. This lack of appropriate nesting habitat may be compensated for by the observed tendency of brown boobies to cluster closer together in areas providing blinds. Blinds serve the dual purpose of hiding nests from close neighbours and providing vantage points for non-brooding adults. The observations of Stager (1964) include a mention of brown boobies nesting about objects acting as blinds but he concluded they acted as barriers against marauding feral pigs, all of which were destroyed subsequent to Stager's visit in 1958. Due to the brevity of our visit to Clipperton, we are unable to evaluate the importance of interspecific competition between brown and white boobies in determining the observed distributions of nests.

Reproductive synchrony of the brown booby at Clipperton was not apparent as some birds were observed copulating and nest building while others cared for clutches of eggs, nestlings and juveniles (Table II). The greatest degree of development was observed at transect 5 with 30% of the clutches containing nestlings and 13% containing juveniles, followed by transects 4 and 1. Transects 6, 8 and 3 formed a second younger grouping with over 90% of the clutches containing eggs only. Dorward (1962) observed that brown booby chicks were entirely covered by down and about half the size of the parent at 27 to 36 days of age. Thus breeding was probably initiated at

TABLE II

Clutch size and composition of brown boobies at Clipperton Island, March 1980. Numbers in brackets represent number of nests observed.

Transect	*% Composition*						
	1 egg	*2 eggs*	*1 egg + 1 nestling*	*1 nestling*	*2 nestlings*	*juveniles*	*empty*
7	0	0	100(1)	0	0	0	0
2	43(3)	14(1)	0	0	0	0	43(3)
1	22(10)	51(23)	2(1)	20(10)	0	2(1)	0
6	17(4)	78(18)	0	5(1)	0	0	0
5	21(16)	31(23)	1(1)	29(22)	1(1)	13(10)	3(2)
4	25(10)	32(13)	20(8)	18(7)	5(2)	0	0
8	17(7)	76(31)	2(1)	2(1)	0	0	2(1)
3	37(22)	57(34)	2(1)	0	0	0	4(2)
Totals	25(72)	49(143)	4(13)	14(41)	1(3)	4(11)	3(8)

transect 5, followed by transects 4 and 1, approximately one month prior to breeding at transects 6, 8 and 3.

Differences in developmental state between transects were not clearly related to density or habitat type (Table I). Simmons (1967) suggests that while an intrinsic, physiological rhythm brings the birds to the peak of breeding condition about every eight months, the current food situation actually determines the start of breeding. At Clipperton, it is unlikely that fish available to birds from transects 1, 4 and 5 were not available to birds from transects 6, 8 and 3. Therefore, availability of food cannot alone account for the asynchrony observed. Longer term studies are needed to investigate the causes of asynchronous breeding on such a small land mass and to establish if brown boobies at Clipperton exhibit a less than annual reproductive cycle as reported by Dorward (1962) and Simmons (1967) for brown boobies at Ascension.

Several authors have discussed the fact that brown and white boobies have an anomalous clutch of 2 eggs even though only a single chick is reared, the second chick hatched being almost invariably evicted from the nest by its sibling (Simmons, 1967). The second egg and resultant chick are considered as insurance against the loss of the first egg or chick such that the reproductive process can proceed with no need to restart breeding (Dorward, 1962; Simmons, 1967). Our observations revealed the same phenomenon for the brown booby population at Clipperton. Of the 215 clutches observed containing eggs only, 66.5% (143 clutches) contained 2 eggs whereas of the 65 clutches containing chicks only, less than 5% (3 clutches) contained 2 chicks (Table II). Furthermore, expulsion from the nest of chicks by siblings was observed on several occasions.

Predation on the booby populations at Clipperton appeared to be minimal. The millions of red land crabs represented the most likely source of predation. They searched incessantly for food and were often observed harassing brooding boobies (Fig. 5) although we never observed land crabs preying on eggs or young. It appeared that the crabs were more interested in eating the fish regurgitated by boobies in the vicinity of their

Figure 5. A brooding male brown booby and its attendant land crabs *(Gecarcinus planatus)*. Crabs in the foreground are devouring the remains of a regurgitated fish while others graze on nesting material and profit from the shade. Note crab in the nest to the right of the bird.

nests and in grazing on the green succulent vegetation used by boobies to construct their nests. On one occasion, a crab was observed to displace an egg from a nest so as to graze on the green vegetation lining the bottom of the nest. However, there is no doubt that unattended defenseless chicks would quickly succumb to the persistant and omnipresent crabs, although this was never observed as small nestlings were never observed to be left unattended by their parents.

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