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The Reproductive Ecology and Population Biology of the Puerto Rican Nightjar *Caprimulgus Noctitherus*.

Francisco Jose Vilella
Louisiana State University and Agricultural & Mechanical College

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The reproductive ecology and population biology of the Puerto Rican Nightjar *Caprimulgus noctitherus*

Vilella, Francisco Jose, Ph.D.

The Louisiana State University and Agricultural and Mechanical Col., 1989

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Ann Arbor, MI 48106

THE REPRODUCTIVE ECOLOGY AND POPULATION BIOLOGY OF THE PUERTO RICAN
NIGHTJAR CAPRIMULGUS NOCTITHERUS

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Forestry, Wildlife, and Fisheries

by
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B.S., Universidad de Puerto Rico-CAAM, 1978
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May 1989

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ABSTRACT

The reproductive ecology and population biology of the Puerto Rican Nightjar (Caprimulgus noctitherus), and population biology of the small Indian mongoose (Herpestes auropunctatus) were studied in Puerto Rico from 1985-1987.

Six areas in Puerto Rico were selected to determine geographic distribution and estimate density. Nightjar presence was initially detected by using playback recordings; density was estimated using fixed-width transect call counts.

Three areas, located in northern moist limestone forest had no relict nightjars. Nightjars were found in three areas located in southwestern Puerto Rico. A total of 676 nightjars were recorded in 9,838.7 ha surveyed. These were distributed among three separate areas, Susua-Maricao (141), Guanica (347), and Guayanilla (188).

The reproductive ecology of the nightjar was studied at Guanica Forest from 1985-1987. A total of 23 nightjar pairs were located. Nests were initiated between 24 February and 2 July. Courtship and laying activities were most common during the new moon and last quarter phases. Hatching dates were centered 3-5 days around the full moon and first quarter.

Nightjar nests were located in the forested uplands at Guanica Forest. Multivariate analysis of structural habitat data collected at nest and random sites, revealed nightjar nesting habitat had larger amounts of leaf litter biomass, overhanging nest cover, and more open understory and midstory than randomly selected sites.

Density estimates and habitat utilization of the small Indian mongoose at Guanica Forest were investigated during 1987. Mongooses were found to be significantly more abundant below 75 m than above. A strong negative correlation was obtained between numbers of mongooses and nightjars at Guanica Forest.

Separate management strategies should be pursued for the nightjar on private and public lands. Within private lands, acquisition of mature dry limestone forest would preserve habitat presently being threatened. Agroforestry practices that promote plantations of mahogany and native deciduous tree species should be encouraged. Habitat protection of nightjars within public lands will help to insure the continued existence of the species.

Chapter 1. Introduction

Historical Perspective

On October 29, 1888, C.P. Streater shot and collected a small caprimulgid near the town of Bayamon, Puerto Rico. The skin was forwarded to C.B. Cory who recorded the specimen as a female Whip-poor-will (Anetrostomus vociferus). This was for many years the only actual evidence for the occurrence of the "whip-poor-will" in the West Indies (Cory 1889, Ridgway 1914). A collection of sub-fossil bones obtained from caves in the moist limestone region of Morovis in north central Puerto Rico contained five humeri and one metacarpal from an undescribed caprimulgid species. Wetmore (1919, 1922) reexamined the previously collected specimen and found it to belong to an unknown insular species that he called Setochalcis noctithera, the Puerto Rican Whip-poor-will. Wetmore (1916) also published a record of a bird seen in a small tract of forest near Rio Piedras in 1911. The species was later united with the mainland species as Caprimulgus vociferus noctitherus (Peters 1940).

Subsequently, the species went unrecorded and was presumed extinct due to predation by the small Indian mongoose (Herpestes auropunctatus) that had been introduced around 1877 (Danforth 1936).

In 1961 however, G.B. Reynard, while conducting sound recordings of local birds in southwestern Puerto Rico, heard an unknown nocturnal call that resembled in quality the sounds of a caprimulgid.

Attempts to capture the night caller were unsuccessful, but later that year a male Puerto Rican whip-poor-will was shot and collected by R. Cotte and W. Blasini in the Guanica Forest, a reserve of coastal dry limestone forest, 62 Km to the southwest of the last sight record 50 years earlier (Fig. 1).

Following the rediscovery, opinions on the species taxonomic status were varied. Some authors familiar with the West Indian avifauna continued to consider it an insular race of the continental species of Whip-poor-will (Bond 1961, Biaggi 1974).

In nocturnal birds such as caprimulgids, vocalization is used to distinguish between closely related species because song is a prime element in maintaining reproductive isolation. Sonograms of the puerto rican and mainland forms of whip-poor-will were compared and the Puerto Rican form was recognized as a distinct species and known as the Puerto Rican Nightjar Caprimulgus noctitherus Wetmore (Reynard 1962, AOU 1983). This classification has been maintained by leading ornithologists (Vincent 1966, Mayr and Short 1970).

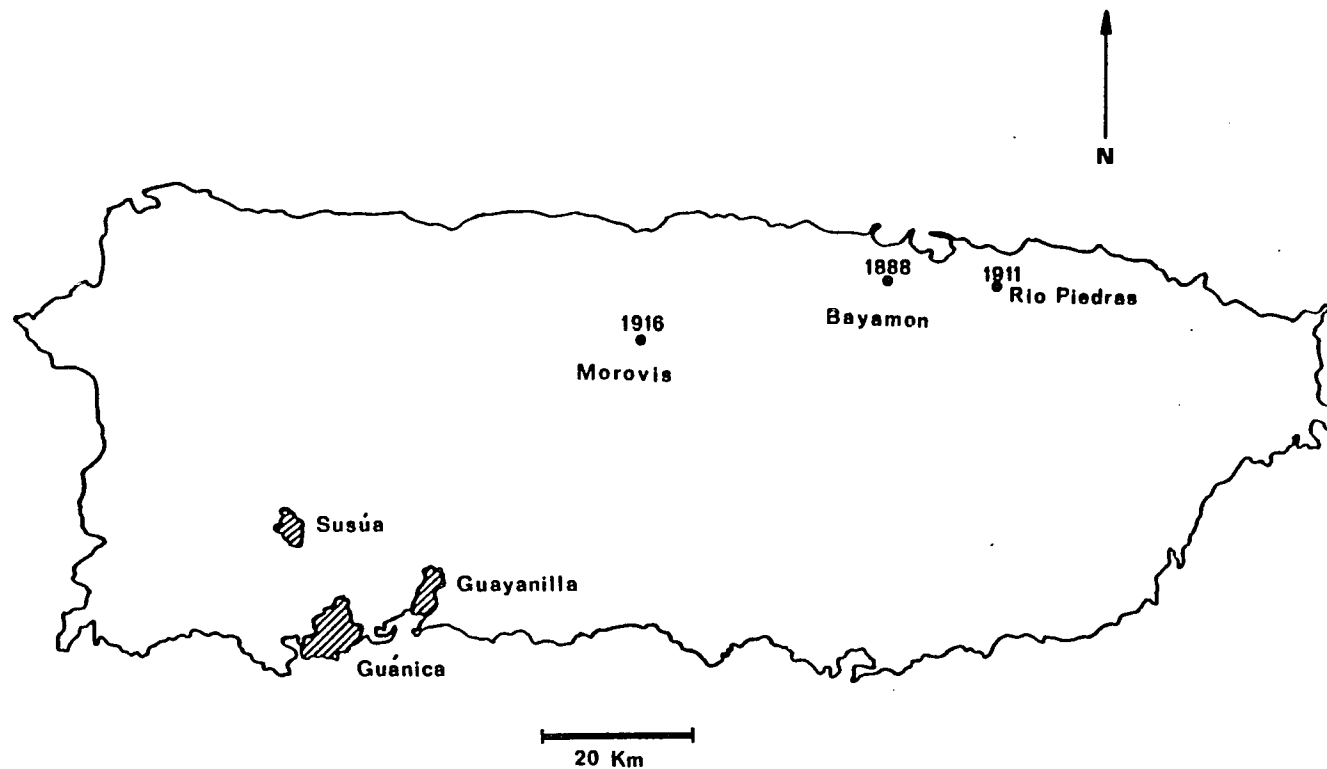


Figure 1. Map of the island of Puerto Rico indicating the date and locations of historical nightjar records. The known distribution of the species by 1985 is shown by the cross-hatched areas.

Previous Studies

After Reynard's work, research was limited to censuses conducted in the Guanica Forest. These initial surveys only covered a limited area of the forest, were not conducted on a regular basis and standardized methods were not utilized (Leopold 1963). Puerto Rican Nightjar, hereafter termed nightjar, numbers were estimated to be 25 to 100 breeding pairs confined to the Guanica Forest (Bond 1962). Due to the small estimated number and long period of presumed extinction on an island whose avifauna was considered thoroughly surveyed, the nightjar at Guanica was considered very rare and limited in distribution. This led to the species being listed as endangered by the U.S. Fish and Wildlife Service (USFWS) and by the International Union for the Conservation of Nature and Natural Resources (IUCN) in 1966 (Vincent 1966).

The first detailed study on the species was conducted by C.B. and A.K. Kepler from 1969 to 1971 (Kepler and Kepler 1973). They utilized fixed-width transects to sample the Guanica Forest and recorded call counts. In addition, they searched throughout southwestern Puerto Rico and other parts of the island. They found nightjars in the Susua Forest, located in the lower cordillera forest 10 km north of the town of Guanica, and in the coastal dry limestone forest of the Guayanilla

hills located 8 km northeast of the town of Guanica (Kepler and Kepler 1973). Based on their survey data, a total of 450 to 500 breeding pairs were thought to be distributed over 3,200 ha in three separate areas of southwestern Puerto Rico: Guanica Forest (400 pairs), Susua Forest (29 pairs), and the Guayanilla hills (50 pairs).

Following the Kepler's surveys, yearly nightjar counts along a few selected routes were conducted in the Guanica Forest from 1976-1984 (Wiley 1985). Nightjar numbers at Guanica Forest appeared to be stable during this period as the number of birds/km varied little from those obtained by the Kepler's along the same routes. During June and July 1984 and January 1985, a preliminary survey was conducted on Guanica and Susua forests to assess the current status of the species within its presently known range; nightjar numbers at Guanica and Susua forests appeared to be stable (Noble 1984, Noble et al. 1986a).

Research Needs and Justification

Endemic island birds appear to be more prone to extinction than any other group of avian species. Between 1600 and 1980, 93 % of the species of birds that became extinct were island endemics (King 1980). Of today's 240 endangered bird species, 130 (54 %) are island species

(King 1980, Temple 1986). The biological rationale behind this can be divided into two major categories: 1) island birds have characteristics of small, closed populations 2) endemic island birds have usually undergone a series of evolutionary changes and these changes make them more vulnerable than typical continental bird species (Shaffer 1981).

Puerto Rico, formerly a Spanish colony, passed to the United States at the conclusion of the Spanish-American War in 1898. The island's inhabitants have enjoyed commonwealth status since 1952 and, as a result, have shifted from an agricultural to a fully industrialized society. This development has had both positive and negative results, as the move towards industrialization has allowed the regeneration of forestlands in Puerto Rico. However, with the increased standard of living, a tremendous demand for agricultural, urban, recreational and industrial development has been placed on the island resources, particularly in the coastal areas.

Caprimulgids are usually the least known group of a region's avifauna, and few avian species have remained as obscure as the nightjar (Kepler and Kepler 1973). The nightjar is probably the least known of the species listed as endangered in the Caribbean region, certainly the least known of those found in the United States Caribbean (Wiley 1985).

In accordance with the endangered status of the species, a recovery plan was prepared in 1982 by the Puerto Rico Department of Natural Resources for the U.S. Fish and Wildlife Service. In this plan, emphasis was placed in obtaining data on the natural history of the species and on habitat protection and acquisition (Diaz 1983). In addition, possible factors responsible for the limited distribution of the species at present should be determined and addressed.

In this study, I attempt to provide the information needed for the implementation of the recovery plan by addressing the following objectives:

- 1) Estimate the density and distribution of nightjars within their current known range and investigate adjacent areas for possible new locations,
- 2) Provide baseline information on the reproductive ecology of the nightjar,
- 3) Determine the habitat use and movements of nesting birds,
- 4) Characterize the nesting habitat and determine nest site selection, and
- 5) Estimate density, distribution and habitat use of the small Indian mongoose in current nightjar habitat.

Since 1971 little or no new information concerning density of this species has surfaced. This information is needed to determine the present status of the species as well as to determine future goals for recovery. The present range of the species should be delineated to provide information that could be used to protect against habitat modification and disturbance.

The investigation on the reproductive biology of the nightjar will help to identify factors limiting potential productivity. The information on the habitat use and movements of nesting nightjars will help to illustrate the spatial requirements of the species during the breeding period. Information about favored areas is needed so that the availability of nesting habitat can be determined and the essential and critical forest or vegetation types can be preserved.

Information on the status of the small Indian mongoose in current nightjar habitat is necessary to evaluate the potential of mongoose predation as a limiting factor.

Here I report on the reproductive ecology and population biology of the nightjar and population biology of the small Indian mongoose, a putative nightjar predator, in current nightjar habitat.

Chapter 2. Geographic Distribution and Density Estimates of the Puerto Rican Nightjar

Introduction

In the West Indies, the genus *Caprimulgus* (Aves: Caprimulgidae) is represented by 6 species. Of these, only 2 are endemic and limited in distribution to the West Indian archipelago (Table 1). The Greater Antillean Nightjar (*Caprimulgus cubanensis*) is widely distributed in Cuba and Hispaniola. The nightjar is thus the only West Indian endemic of this genus restricted to a single island (AOU 1983, Johnson 1987). The nightjar is believed to have been historically distributed in the moist and dry limestone and coastal forests of Puerto Rico (Fig. 1), but now limited to three localities in southwestern Puerto Rico (Kepler and Kepler 1973).

Study Sites

Following ground and aerial surveys to identify large forested areas, I selected 6 areas of Puerto Rico to sample in order to determine current distribution and estimate density (Fig. 2). Forested areas were selected for survey from aerial photographs and

Table 1. Members of the genus Caprimulgus in the West Indies.

Species	Distribution	Status
<u>Caprimulgus carolinensis</u> Chuck-will's-widow	Greater Antilles to Virgin Islands	Winter resident
<u>Caprimulgus vociferus</u> Whip-poor-will	Cuba	Winter resident
<u>Caprimulgus cubanensis</u> Greater Antilles Nightjar	Cuba, Isle of Pines and Hispaniola	Breeding resident
<u>Caprimulgus noctitherus</u> Puerto Rican Nightjar	Puerto Rico	Breeding resident
<u>Caprimulgus otiosus</u> St. Lucia Nightjar	Lesser Antilles	Breeding resident
<u>Caprimulgus cayennensis</u> White-tailed Nightjar	Lesser Antilles	Breeding resident

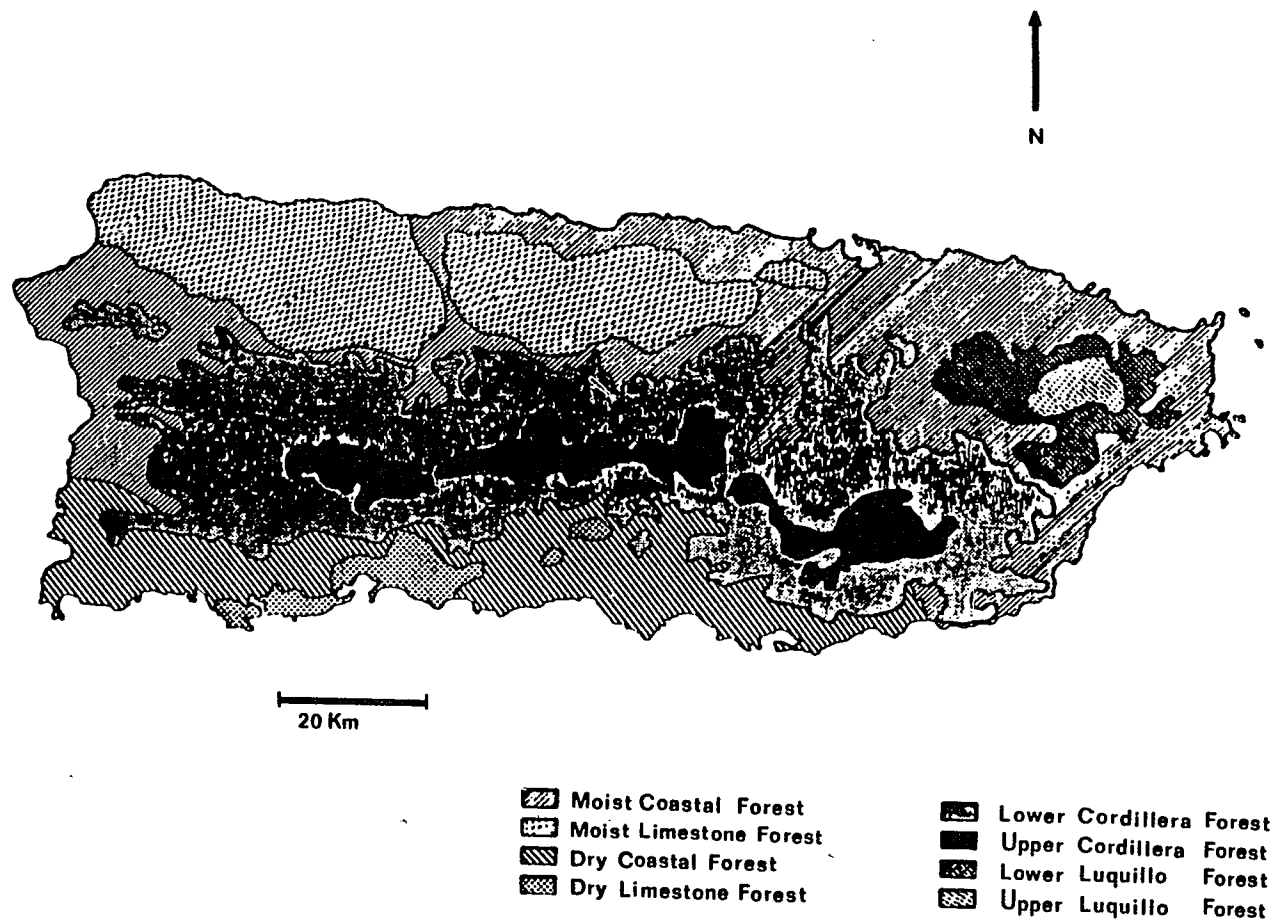


Figure 1. Climax life zones and forest types of Puerto Rico (after Little and Wadsworth 1964).

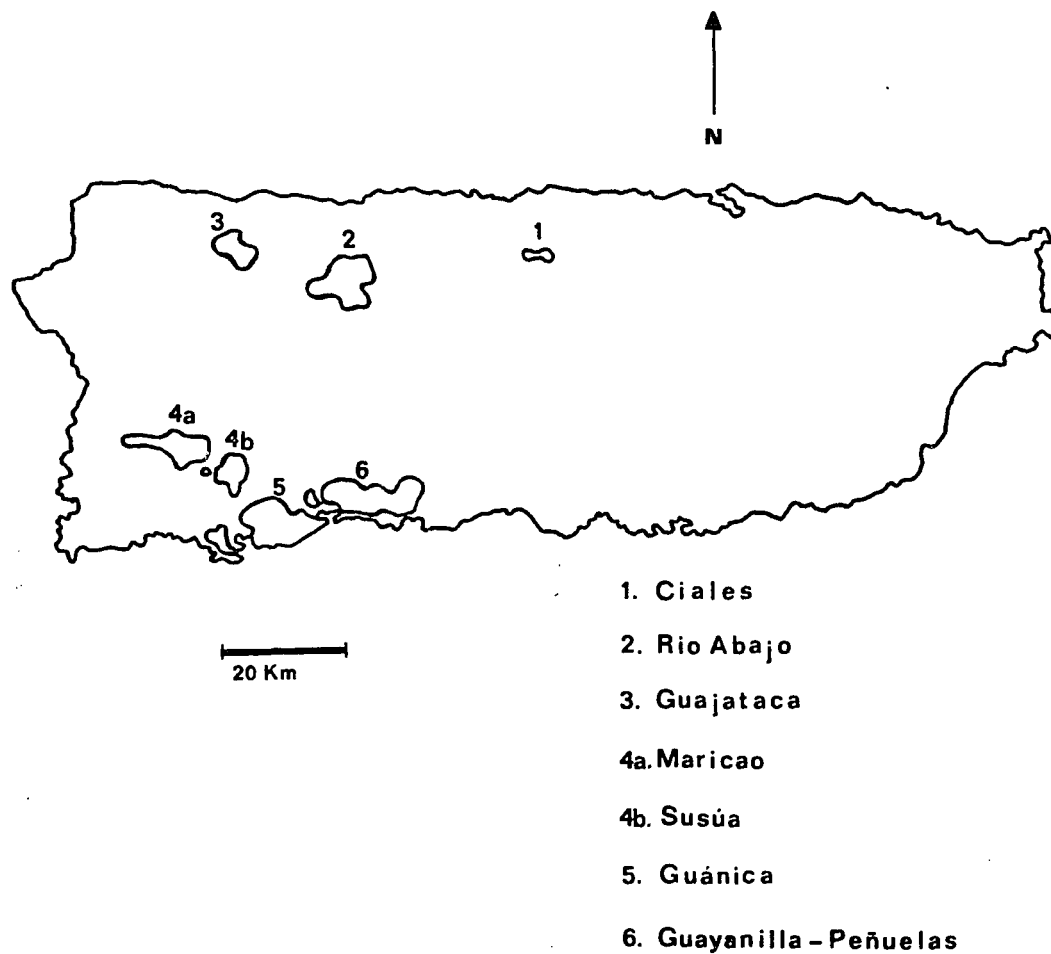


Figure 2. Map of the regions of Puerto Rico surveyed for the presence of Puerto Rican Nightjars. Numbers indicate region surveyed and correspond to locations listed in Table 2.

recent U.S. Geological Survey (USGS) topographic maps. Three of these, located in the northern moist limestone region of the island, were chosen based on proximity to historical nightjar records and the present existence of large, relatively undisturbed tracts of moist limestone forest. The other 3 areas, located in southwestern Puerto Rico, were chosen based on proximity to known nightjar concentrations and presence of apparently suitable habitat (Kepler and Kepler 1973, Noble 1984).

Site descriptions

1) Ciales Cordillera region. This privately owned area of approximately 326 ha was located 10 km west of the cave in Morovis where the nightjar sub-fossil material was collected (Wetmore 1919). Though somewhat disturbed in some parts due to agricultural and residential activities, most of the area surveyed was heavily forested. Climate and vegetation were similar to the Rio Abajo Forest which is described next.

2) Rio Abajo Forest. This commonwealth reserve located in north central Puerto Rico, included 2,275 ha of forest growing on Tertiary limestone of Miocene origin. Most of the forest consisted of mature

secondary moist limestone forest ranging in elevation from 200 m to 424 m. Precipitation exceeds 2,100 mm per year. Vegetation assemblages present include moist limestone forest associated with the karst dome formations and moist evergreen forest found in sinkhole areas and riparian valleys (Cardona et al. 1986).

3) Guajataca Forest. This forest was located 15 km northwest of Rio Abajo Forest and is of similar geological origin. The Guajataca Forest consisted of 927 ha of moist limestone forest with elevations ranging from 150 m to 300 m and a mean annual precipitation of 1,926 mm. Although somewhat drier than Rio Abajo Forest due to the oceanic effect (Silander 1986), the plant associations were very similar to the latter. Climate and vegetation of Guajataca, Maricao, Susua and Guanica forests have been described by Silander (1986).

4) Maricao and Susua forests region. The Maricao and Susua forests are in close proximity and were thus treated as a single study area. The Maricao Forest (4a) is the largest of the reserves in the commonwealth forest system. Its 4,149 ha range from 15 m to 875 m in elevation and include lower cordillera, upper cordillera, wet montane, and elfin forest, all growing on Cretaceous serpentine (Silander 1986). This forest receives an average of 2,466 mm of rain/year. The

forest contains a high number of species of both flora and fauna. The areas surveyed on the Maricao Forest and adjacent lands were located on the southeastern end of the reserve within the lower cordillera forest region, where the topography is generally very steep and rugged.

Susua Forest (4b) is a 1,314 ha commonwealth reserve lying on the lower southwestern flanks of the Cordillera Central, about 10 km east of the Maricao Forest. Four of the island's southwestern rivers originate in the steep rounded hills of Susua Forest. Of these, two bisect the reserve and support a lush riparian community about 100 m in width. Lower cordillera forest occurred some 50 m from the streams and extended to the hilltops. The area receives approximately 1,500 mm of rain per year, with more falling on the upper northern slopes. Elevations range from 100 m to 473 m.

5) Guanica Forest region. The Guanica Forest, a commonwealth forest protected since 1919, consists of 4,006 ha of coral reefs, mangrove cays, and two large tracts of coastal dry forest. One of these two forest units (700 ha) is located west of Guanica Bay and the other (2,798 ha) is located east of Guanica Bay. The eastern section of Guanica Forest contains a small area of 39.2 ha on its northern end which was isolated from the main tract of the reserve by

agricultural and residential areas. The forest, while not totally virgin, is probably the largest and most pristine example of coastal dry forest in the Caribbean region. In 1984, Guanica Forest was recognized as a World Biosphere Reserve by the UNESCO Man and the Biosphere program (Silander 1986).

Precipitation averages 750 mm of rain/year, with most falling between August and November. The entire forest grows upon porous Tertiary limestone. As a result, surface water was limited to intermittent streams during the rainy season and no riparian habitat exists in the forest. Although dry, Guanica Forest supports a greater number of species of trees and land birds than any other part of the Puerto Rican Bank, which includes Puerto Rico, its adjacent islands, and the Virgin Islands (Kepler and Kepler 1973).

The private lands surveyed adjacent to the Guanica Forest were similar in topography and vegetation types. However, these are presently being used for agriculture, cattle grazing, and residential purposes. Private lands had been disturbed and contained dry limestone forest of varying seral stages.

6) Guayanilla-Peñuelas region. The Guayanilla-Peñuelas region, also known as the Guayanilla hills, located 8 km east of the town of Guanica and 2 km from the coast includes approximately 3,600 ha of

privately owned forestland. The dominant plant community was coastal dry limestone forest similar in structure and composition to the Guanica Forest uplands. Climate and precipitation are similar to that found in the Guanica Forest region. The vegetation of the area has been described by Cintron and Beck (1977). Within the past century the lowland valleys have been cleared and converted to agriculture. Most of the limestone forest of the uplands did not appear to have been recently disturbed, although some parts had been selectively lumbered and cut for charcoal production during the latter part of the last century. Some open areas were being grazed by goats and cattle.

Methods

Each selected area was visited to determine current vegetative status and access. Whenever possible, I attempted to contact landowners and caretakers to obtain trespass permission before surveying any area. Linear routes were established along existing trails. The number of routes established on each area was dictated by the availability of footpaths and cattle trails found there.

All potential routes were initially searched on at least 3 occasions during crepuscular hours to determine presence or absence of nightjars by using recordings, a technique that has been used

successfully to detect the presence of many secretive bird species (Marion et al. 1981). Observers stopped every 200 m to play a recording of singing nightjars for 2 minutes. Afterwards, observers would listen for a response for 3 minutes. After a response was obtained on a preliminary search, signifying the presence of nightjars within a region, the route was sampled regularly using the methods developed by Kepler and Kepler (1973) to estimate density.

From 2-14 observers, divided into parties of 2, took part in the surveys. We surveyed the permanent routes by walking slowly along transects and counting all nightjars heard singing within 300 m (see Kepler and Kepler 1973). Survey routes longer than 1.5 km were surveyed by parties starting at each end. Because surveyed routes were often less than 600 m apart, I attempted to avoid duplicate counts whenever possible by alternating the routes being simultaneously surveyed. We also counted nightjars heard at the route ends when possible. For every route end surveyed, area was increased by 14.1 ha (Noble 1984). To obtain a minimum density estimate, I used the highest number of nightjars heard on each route as the minimum number of birds present. Route distances were paced in the field and later corroborated on USGS topographic maps with an electronic digitizer and planimeter.

Surveys were conducted during full moon on clear to partly cloudy nights when wind velocity did not exceed 16 km/hr to reduce the variability that these factors appear to have on calling rates (Kepler and Kepler 1973, Cooper 1981, Mills 1986). All routes were surveyed at least twice in both winter and summer. Winter and summer counts were compared by analysis of variance (ANOVA) (Steel and Torrie 1980). Statistical analysis ($\alpha = 0.05$) throughout was conducted using the Statistical Analysis System (SAS) (Joyner 1985).

I observed 82 birds responding to a taped song. All were males. Thus, I believe that only male nightjars sing. A record exists of a female Eastern Whip-poor-will (Caprimulgus vociferus) singing, but the individual was not collected and sex was determined only by plumage (Bent 1940). In previous surveys of nightjars, it was assumed each singing nightjar represented a breeding pair (Reynard 1962, Kepler and Kepler 1973, Noble et al. 1986). Many researchers who have used call count methods to record numbers of singing males have interpreted results in terms of breeding pairs (Jarvinen and Vaisanen 1976). Because all singing birds may not be mated, interpretation of a singing birds as breeding pairs may overestimate reproductive potential for a particular species. Additionally, based on my observations, unmated male nightjars also sing. Therefore, I herein report the number of singing male nightjars heard per route surveyed, and do not treat each singing nightjar as a breeding pair.

Results

Approximately 985 ha of moist limestone forest were intensively searched in northern Puerto Rico. No nightjars were heard within this region of the species historical range (Table 2). In southwestern Puerto Rico, however, I heard nightjars on the Susua-Maricao, Guanica and Guayanilla-Peñuelas regions.

I estimated density and determined distribution of nightjars from 349 surveys conducted along 71 routes in coastal dry limestone and lower cordillera regions of southwestern Puerto Rico between 15 August 1985 and 15 August 1987. Surveys were conducted at dawn (0545-0635 January-February; 0530-0610 July-August) and dusk (1825-1910 January-February; 1910-2000 July-August). With forest caprimulgids, such surveys can be used to estimate densities due to the strong site tenacity and inclination of males to sing repeatedly during dusk and early night hours (Bent 1940, Lack 1957, Baker and Peake 1966).

The number of nightjars heard along these routes was significantly higher during winter (Jan.-Feb.) than during summer surveys (July-Aug.) (ANOVA, $F = 8.14$; $df = 1,278$, $P < 0.01$). However, some routes in both limestone and lower cordillera forest were consistently higher during the summer surveys. Thus, the maximum number of nightjars heard per route regardless of the survey month, was used to estimate density.

Table 2. Regions of Puerto Rico surveyed for the presence of Puerto Rican nightjars.

Location	Area surveyed (ha)	Habitat type	Nightjars present
1. Ciales	326.4	Moist Limestone Forest	No
2. Rio Abajo	348.2	Moist Limestone Forest	No
3. Guajataca	310.2	Moist Limestone Forest	No
4. Susua-Maricao	2744.6	Lower Cordillera Forest	Yes
5. Guanica	4393.8	Dry Limestone Forest	Yes
6. Guayanilla	2700.5	Dry Limestone Forest	Yes

Surveys in the Maricao-Susua region.

A total of 2,744.4 ha of lower cordillera forest were surveyed in the Maricao-Susua region from 1985 to 1987 (Fig. 3). Survey routes ranged from 0.82 to 5.45 km long. Within this region, 141 nightjars were detected (Table 3). Transect densities ranged from 5.0 to 64.1 ha/nightjar.

Within this region, nightjars were most abundant in and around the Susua Forest (routes 1-14); highest densities were recorded in the southern section of Susua Forest and adjacent lands (routes 2-6). Here, densities ranged from 5.0 to 10.9 ha/nightjar ($\bar{x} = 8.5 \pm 2.5$ ha/nightjar). The vegetation in this area of approximately 535 ha represents a transition zone between the dry coastal and dry limestone forests found to the south, and the more humid lower cordillera forests located on the northern region of Susua and Maricao forests (Silander et al. 1986). This area also had some of the lowest elevations surveyed in this region.

Densities of nightjars on the northern part of the Susua Forest and adjacent lands (routes 1, 7-14) were generally lower, ranging from 19.1 to 36.3 ha/nightjar ($\bar{x} = 24.4 \pm 5.9$ ha/nightjar). This area is steeper, at a higher elevation and receives most of the precipitation recorded at Susua Forest.

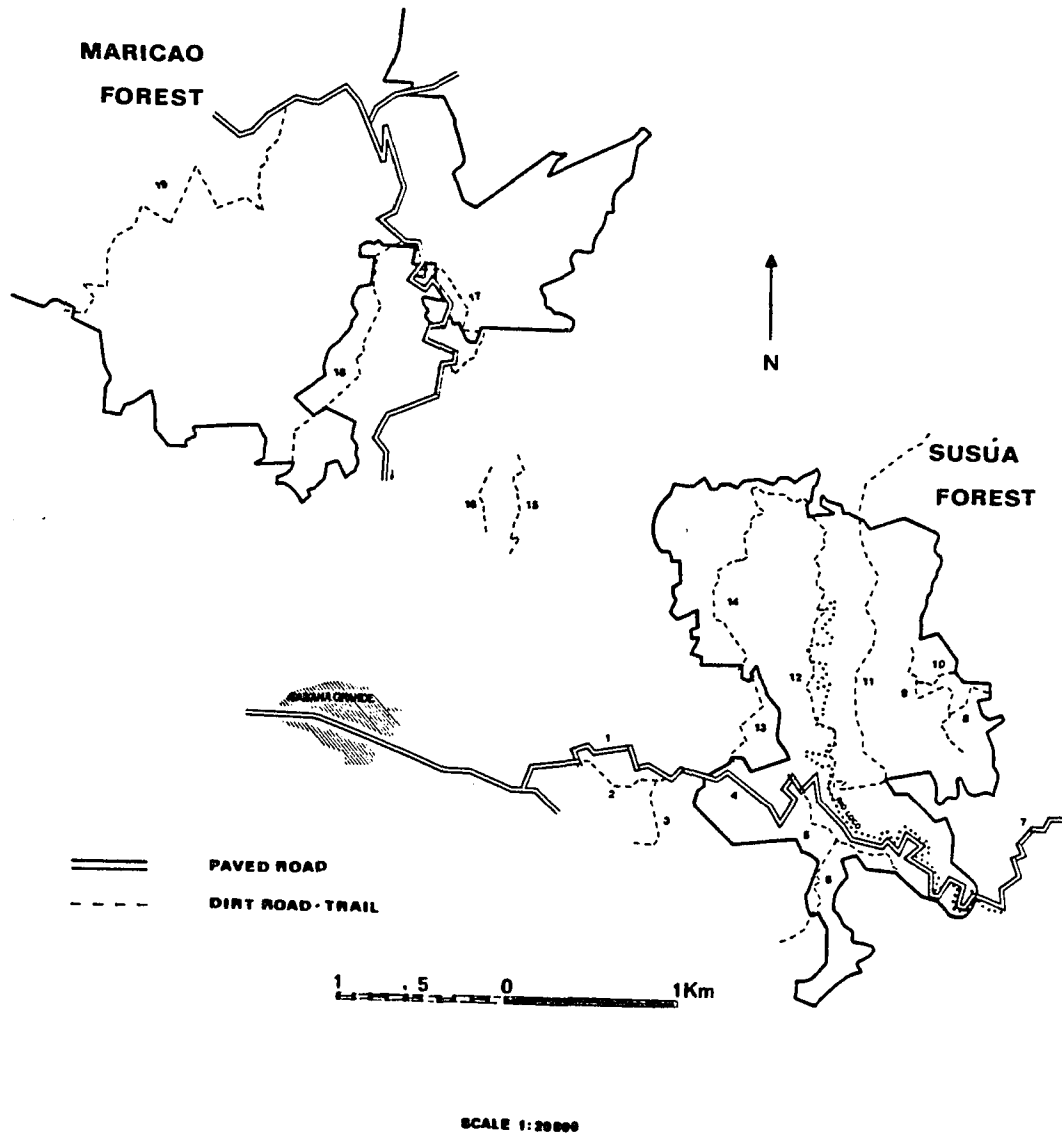


Figure 3. Map of the Susua-Maricao area surveyed. Numbers indicate census routes and correspond to routes listed in Table 3. Boundaries of Susua (right) and part of Maricao (left) forests are outlined.

Table 3. Results of nightjar surveys for the Susua-Maricao region, 1985-1987.

Survey route	Route length (km)	Area surveyed (ha)	Number of surveys	Range of nightjars detected	Density (ha/nightjar)
1 ¹	1.90	128.2	4	3 - 5	25.6
2 ¹	1.04	76.6	4	5 - 7	10.9
3 ¹	1.13	82.0	4	8 - 10	8.2
4 ¹	2.39	157.6	6	12 - 21	7.5
5	1.60	110.2	4	14 - 22	5.0
6 ¹	1.57	108.4	4	6 - 10	10.8
7 ¹	2.01	134.8	4	4 - 7	19.3
8 ¹	1.26	89.8	4	0 - 4	22.5
9 ¹	0.86	65.8	4	1 - 3	21.9
10 ¹	0.96	71.8	4	0 - 3	23.9
11	5.26	329.8	6	12 - 17	19.4
12 ¹	4.00	254.2	4	4 - 7	36.3
13 ¹	1.32	93.4	4	1 - 3	31.1
14 ¹	3.26	209.8	4	8 - 11	19.1
15 ¹	1.40	98.2	3	2 - 5	19.6
16 ¹	0.82	63.4	3	1 - 4	15.9
17 ¹	1.90	128.2	4	2	64.1
18 ¹	3.12	201.2	4	0	0
19 ¹	5.45	341.2	5	0	0
Total	41.25	2744.4	79	141	

¹ Routes never surveyed before 1985

A total of 832.2 ha of lower cordillera forest were surveyed in the Maricao Forest and adjacent lands (routes 15-19). Only 11 nightjars were heard at this locality and of these, 9 were found on forested private land 2 km southeast of Maricao Forest (routes 15-16). Within the Maricao Forest, only 2 nightjars were heard. These were located on the northern end of route 17 in an eucalyptus (Eucalyptus robusta) plantation.

Surveys in the Guanica region.

A total of 4,393.8 ha of coastal dry limestone forest were surveyed in the Guanica region (Fig. 4). Survey routes (N=31) were located in and around the Guanica Forest (routes 1-27), the Barina hills (routes 28-30), and at Punta Verraco (route 31). Routes were from 0.88 to 4.13 km in length. Within this region, 347 nightjars were recorded (Table 4). Density estimates ranged from 5.0 to 110.2 ha/nightjar (\bar{x} = 21.5 ha/nightjar).

Of the 31 routes surveyed, 10 had relatively high nightjar densities of 10 ha/nightjar or less. These routes were mostly found on the forested uplands of the Guanica Forest east of Guanica Bay (routes 2-4, 6, 8-11, 26). Route 27, located on adjacent private land also had a high nightjar density. Of the remaining 21 routes, 10 had

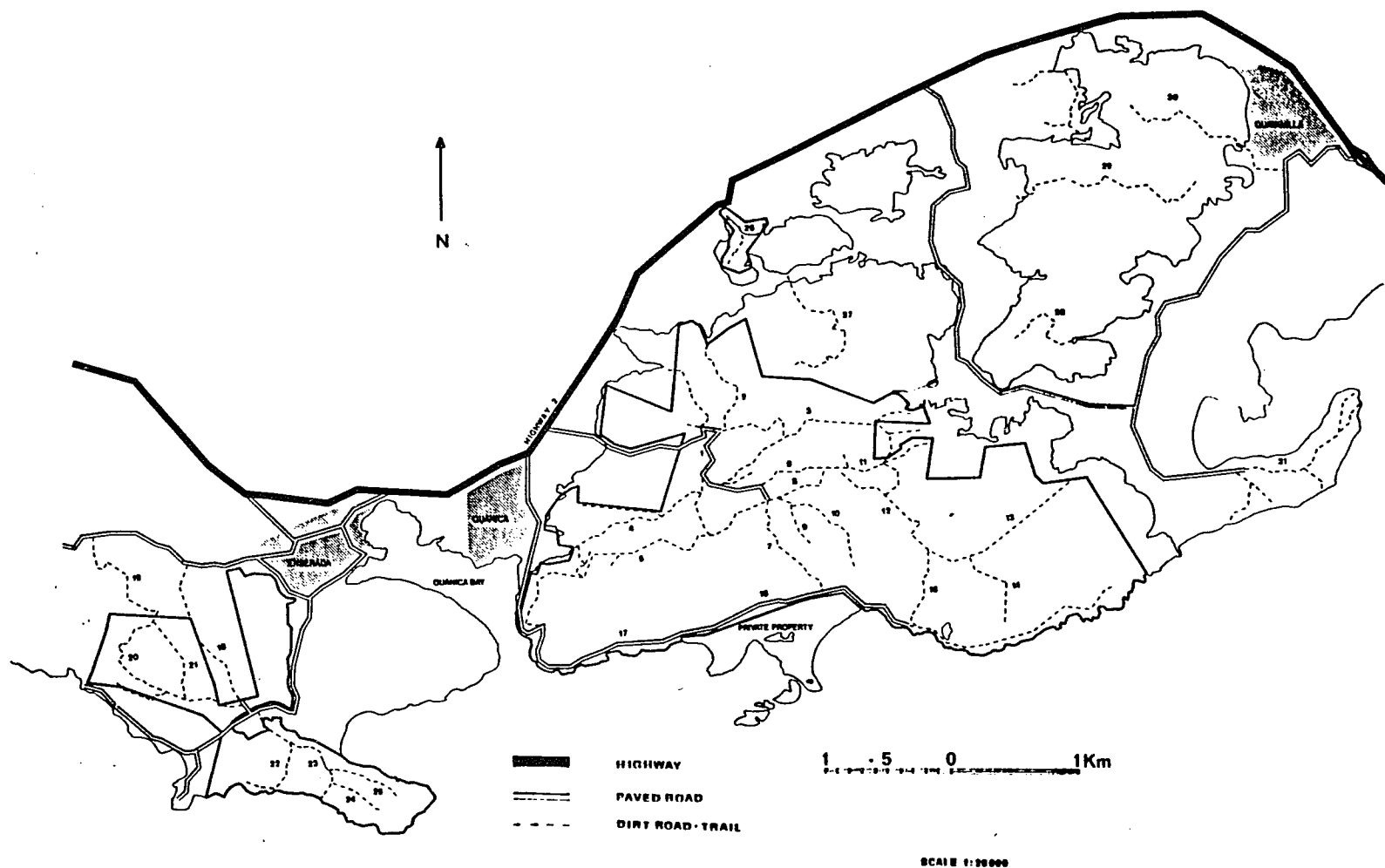


Figure 4. Map of the Guanica Forest region surveyed. Numbers indicate census routes and correspond to routes listed in Table 4.

Table 4. Results of nightjar surveys from the Guanica Forest region, 1985-1987.

Survey route	Route length (km)	Area surveyed (ha)	Number of surveys	Range of nightjars detected	Density (ha/nightjar)
1	2.04	165.0	12	23 - 30	13.8
2	1.68	129.2	6	15 - 26	5.0
3 ¹	2.73	206.4	6	14 - 21	9.8
4 ¹	1.91	128.8	6	16 - 24	5.4
5	5.35	349.6	9	12 - 21	16.7
6	1.07	106.8	4	9 - 15	7.1
7	1.88	141.2	5	8 - 14	10.1
8	1.13	82.0	10	7 - 11	7.4
9 ¹	0.90	96.6	15	9 - 14	6.9
10 ¹	1.26	89.8	5	8 - 11	8.2
11	1.31	92.8	8	6 - 10	9.3
12	2.17	172.8	3	12 - 16	10.8
13	2.65	201.6	3	10 - 14	14.4
14	1.33	122.4	3	3 - 8	15.3
15 ¹	1.21	101.0	4	2 - 5	20.2
16 ¹	4.13	262.0	3	5 - 8	32.8
17 ¹	2.98	193.0	3	3 - 5	38.6
18 ¹	2.36	155.8	4	0 - 2	77.9
19 ¹	2.00	134.2	4	1 - 5	26.8
20 ¹	2.25	149.2	4	2 - 4	37.3
21 ¹	1.35	95.2	4	0 - 3	31.7

Continued.

Table 4. Continued.

Survey route	Route length (km)	Area surveyed (ha)	Number of surveys	Range of nightjars detected	Density (ha/nightjar)
22 ¹	1.60	110.2	4	0 - 1	110.2
23 ¹	1.30	92.2	4	2	46.1
24	0.88	67.0	4	0	0
25 ¹	1.17	84.4	4	0	0
26 ¹	0.91	68.8	6	7	9.8
27 ¹	2.80	182.2	6	10 - 24	7.6
28 ¹	1.47	102.4	4	6 - 8	12.8
29 ¹	3.26	209.8	4	4 - 15	14.0
30 ¹	2.12	141.4	4	8 - 11	13.0
31 ¹	2.43	160.0	5	9 - 12	13.3
Total	61.63	4393.8	166	347	

¹Routes never surveyed before 1985

moderate nightjar densities of between 10 and 17 ha/nightjar. Six of these (routes 1, 5, 7, 12-14) were found within the eastern section of Guanica Forest. The other 4 routes (routes 28-31) were located on the privately owned Barina hills and at Punta Verraco. Nightjar densities at the remaining 11 routes surveyed (routes 15-25) were low (20+ ha/nightjar). Three of these (routes 15-17) were located on the southern slopes of the eastern section of Guanica Forest. Nightjars occur in low numbers at these low elevations, but densities are greater than previously reported (Kepler and Kepler 1973, Noble 1984). In addition, nightjars can be heard singing along these routes throughout the year.

I discovered a small concentration of nightjars on the section of Guanica Forest west of Guanica Bay (routes 18-25). Nightjar densities in this area were low, ranging from 26.8 to 110.2 ha/nightjar. Most of the birds occurred on the northern portion of this area (routes 18-21). Nightjars were heard singing on both private and public land in and around the hills of Cerro Montalva, where elevations exceed 100 m. A total of 3 nightjars were heard in the hills located on the southern section of this area (routes 22-23). These birds were located in the limestone forest found at the top of the hills at approximately 60 m elevation.

Surveys in the Guayanilla-Peñuelas region.

In the surveys of approximately 2,700.5 ha of private land in the Guayanilla hills region (Fig. 5) there were 188 nightjars along 21 survey routes (Table 5). Nightjar densities ranged from 7.5 to 26.1 ha/nightjar within survey routes that ranged from 0.70 to 4.35 km in length.

Within the Guayanilla hills region, highest densities were noted on six survey routes (routes 4, 6, 8, 11-13) that included 636.9 ha. Densities ranged from 7.6 to 9.4 ha/nightjar ($\bar{x} = 8.4 \pm 0.6$ ha/nightjar). Nightjar density estimates along 6 of the remaining 15 routes (routes 2, 9, 14, 16-17, 20) that included 841.6 ha were moderately high ($\bar{x} = 15.3 \pm 2.5$ ha/nightjar, range = 12.4 to 17.6 ha/nightjar). The remaining 9 routes (routes 1, 3, 5, 7, 10, 15, 18-19, 21), totaling 1,265.9 ha, had low nightjar densities ($\bar{x} = 22.4 \pm 2.7$ ha/nightjar, range = 18.2 to 26.1 ha/nightjar).

Discussion

No nightjars were heard during intensive playback searches of the Ciales (326.4 ha), Rio Abajo (348.2 ha), and Guajataca (310.2 ha) regions of northern Puerto Rico, between 1985 and 1987. Rio Abajo and

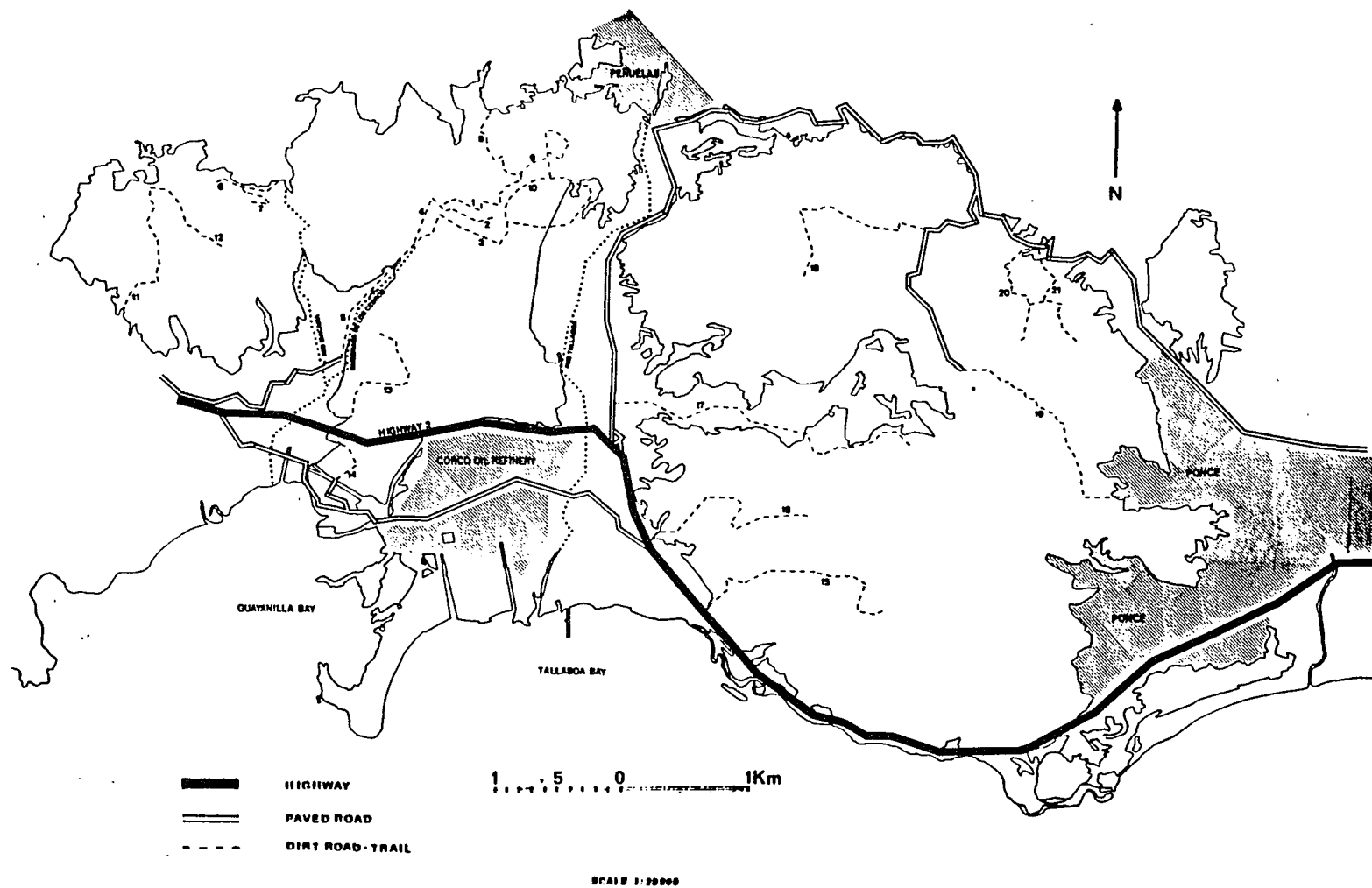


Figure 5. Map of the Guayanilla region surveyed. Numbers indicate census routes and correspond to routes listed on Table 5.

Table 5. Results of nightjar surveys from the Guayanilla-Peñuelas region, 1985-1987.

Survey ¹ route	Route length (km)	Area surveyed (ha)	Number of surveys	Range of nightjars detected	Density (ha/nightjar)
1	1.6	124.4	6	3 - 5	24.9
2	0.8	62.2	6	5	12.4
3	2.3 ₂	60.0	5	2 - 3	20.0
4	0.8 ₂	24.6	5	3	8.2
5	2.6 ₂	91.0	9	2 - 5	18.2
6	0.7	57.7	9	5 - 7	8.2
7	1.1	78.4	9	1 - 4	26.1
8	1.3	92.2	6	8 - 11	8.4
9	1.52	105.4	6	4 - 6	17.6
10	2.95	177.0	6	5 - 8	22.1
11	2.12	155.6	4	11 - 18	8.7
12	1.87	140.6	4	9 - 15	9.4
13	2.30	166.2	4	12 - 22	7.6
14	1.23	102.2	2	5	17.6
15	3.10	200.2	4	6 - 10	20.0
16	2.68	175.0	4	11 - 14	12.5
17	4.35	275.2	4	10 - 19	14.5
18	2.68	175.0	4	5 - 7	25.0
19	3.28	196.8	3	6 - 9	21.9
20	1.79	121.6	2	7	17.4
21	1.75	119.2	2	5	23.8
Total	42.82	2700.5	104	188	

¹Routes never surveyed before 1985

²One-sided 300 m strip along entire route

Guajataca forests have a combined area of over 3,200 ha, are heavily forested, and have very low human densities. As such, they provided the best potential for relict nightjar presence in the moist limestone forest region. My findings agree with those of Kepler and Kepler (1973) who concluded that nightjars had been extirpated from northern Puerto Rico. This may have occurred as a result of the simultaneous effect caused by the large scale deforestation and the introduction of the small Indian mongoose that occurred during the last century (Wadsworth 1950, Wiley 1985).

In southwestern Puerto Rico however, I discovered nightjars at a number of new locations. I believe my success was due to both the intensity of my searches and the use of playback recordings to detect nightjar presence at new sites.

In many avian species, the frequency and duration of singing activity is directly related to density (Krebs 1971, Kroodsma 1976). Within all regions surveyed where nightjars occurred at low densities, birds did not sing for prolonged periods of time and sometimes were only detected following a playback of the recorded song. Furthermore, nightjars exhibit chorusing behavior; when a period of silence is broken by one bird, others nearby readily join in (Reynard 1962). They responded similarly to taped songs.

I heard more nightjars singing along survey routes during winter surveys (Jan.- Feb.) than summer surveys (July- Aug.). My results support those of Kepler and Kepler (1973) who reported the peak calling period for nightjars extends from February to May. However, Noble (1984) found more during the summer.

I found 2,744 ha to presently support nightjars in the lower cordillera forest region of Susua and Maricao. This is approximately twice the area estimated by Noble et al. (1986) and more than four times that estimated by Kepler and Kepler (1973). While most nightjars occur on the southern slopes of Susua Forest, they can be found in the mature lower cordillera forest that occurs at higher elevations. Areas on the southeastern slopes of the Maricao Forest presently do not seem to have nightjars. These areas are similar to the higher elevation sites found in and around Susua Forest and, as such, appear to be marginal nightjar habitat. Extremely steep topography and high precipitation could be the factors limiting use of these areas by nightjars.

In the Guanica region, Noble (1984) estimated a total of 324 nightjars that occupied 2,659 ha of coastal dry limestone forest. Noble (1984) thought nightjars were limited to the section of Guanica Forest east of Guanica bay and adjacent private land. I found nightjars west of Guanica Bay, albeit in small numbers. Densities

were greater there on the forested uplands and least in the limestone forest and coastal scrub areas closer to the coast.

East of Guanica Bay nightjars were much more abundant, with the birds concentrated in and around the eastern section of Guanica Forest. In this area nightjars were consistently heard singing below 25 m elevations on the southern slopes near the coast and at the forest's edge near homes and agricultural fields on the northern boundary of the forest.

Of all areas surveyed, nightjar densities were highest (5.0 ha/nightjar) on the deciduous forest, evergreen forest, and plantation uplands of Guanica Forest. This density is comparable to the highest estimates reported for congeners (Table 6) and thus the spatial needs in this genus may be rather similar. In addition, reported densities have been similar since the Kepler's surveys (Table 7). Thus, nightjars on the eastern section of Guanica Forest may be at near maximum density.

Approximately 66% (2,700 ha) of the available habitat in the Guayanilla-Peñuelas region was surveyed. Nightjars were found throughout this region, although the birds appeared to be more numerous on the western section, where the most pristine tracts of mature dry limestone forest were found. Nightjars were heard singing on grazed lands where the canopy was retained although at lower

Table 6. Population density estimates for species in the genus Caprimulgus.

Species	Location	Habitat type	Highest density (ha/singing male)	Source
<u>C. carolinensis</u> Chuck-will's-widow	Clarke County Georgia, USA	Pasture	4.9	Cooper (1981)
<u>C. vociferus</u> Whip-poor-will	Mason County Illinois, USA	Pine-hardwood forest	4.3	Bjorklund & Bjorklund (1983)
<u>C. europaeus</u> European Nightjar	Hampshire, England	Pine-hardwood forest	4.0	Gribble (1983)
<u>C. pectoralis</u> Fierynecked Nightjar	Mutare, Zimbabwe	Farm woodland	2.5	Jackson (1984)
<u>C. noctitherus</u> Puerto Rican Nightjar	Guanica, Puerto Rico	Dry limestone forest	5.0	Vilella

Table 7. Comparison of 1969-1987 nightjar surveys in the Guanica Forest, Puerto Rico.

Years	Distance surveyed (km)	Number of nightjars	Density Nightjars/km	Source ¹
1969-1971	31.3	275	8.8	Kepler & Kepler (1973)
1976-1984 ²	8.1	57	7.0	Wiley (1985)
1984	14.3	98	6.8	Noble (1984)
1985-1987	13.4	99	7.4	Vilella

¹Survey data obtained from routes numbered 1, 2, 3 & 5 by Kepler and Kepler (1973)

²Figures are mean values obtained between 1976 & 1984

densities, suggesting that nightjars can exist on lands with some degree of disturbance.

At present, privately owned forestlands occupied by nightjars are being rapidly converted to other uses. Forest is being cleared outside protected areas for agriculture, housing and industry. Due to this rapid habitat turnover on private lands, the nightjar density estimates presented reflect only the areas surveyed. I found a total of 676 nightjars in 9,838.7 ha surveyed (Table 8). These are distributed among three separate areas, the Susua-Maricao region (141), Guanica region (347), and the Guayanilla-Peñuelas region (188) (Fig. 6). Noble (1984) estimated the number of nightjars based on the total amount of available private land. His estimates could be high because of continuing habitat changes. On the other hand, there are undoubtedly some nightjars on suitable private land that I have not reported.

Table 8. Nightjar population estimates on public and private land in the Maricao-Susua, Guanica, and Guayanilla regions of southwestern Puerto Rico, 1987.

Region	<u>Area surveyed (ha)</u>		<u>Number of nightjars</u>		Total number of nightjars
	Public	Private	Public	Private	
1. Maricao-Susua	1947.8	796.6	91	50	141
2. Guanica	3308.0	1085.8	270	77	347
3. Guayanilla	-	2700.5	-	188	188
Total	5255.8	4582.9	361	315	676

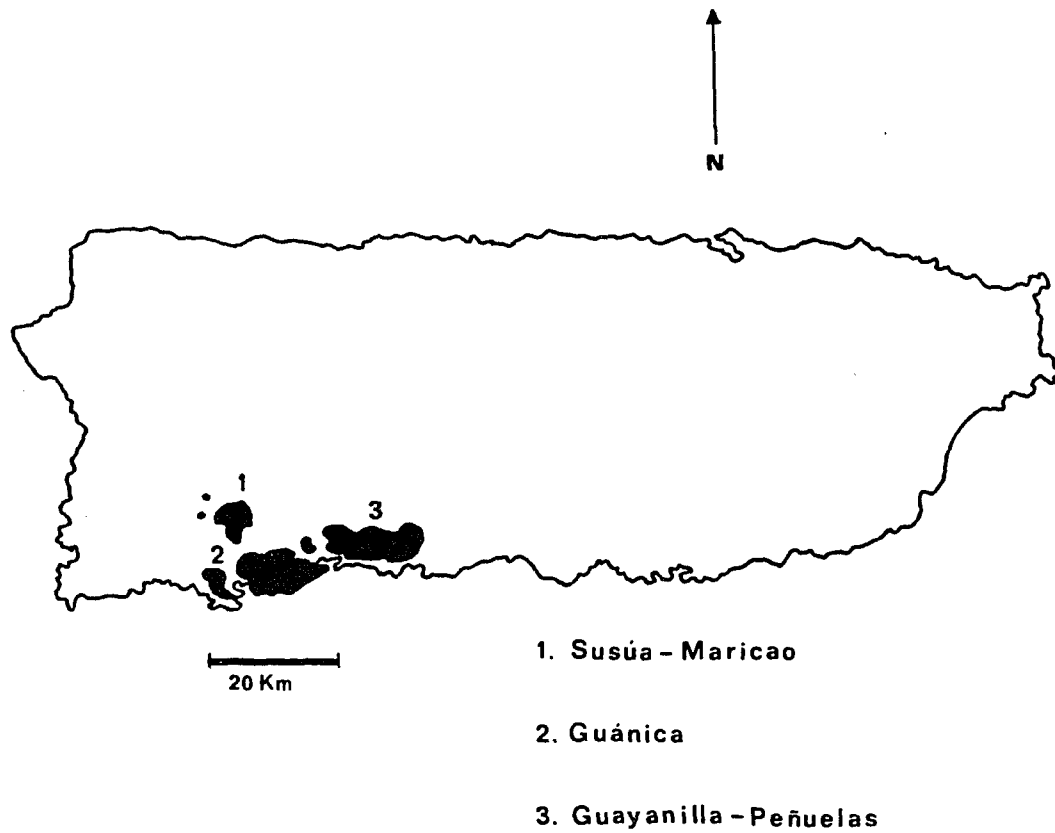


Figure 6. Map of Puerto Rico with presently known locations of Puerto Rican Nightjar populations. Numbers correspond to regions listed in Table 8.

Chapter 3. Reproductive Ecology of the Puerto Rican Nightjar

Introduction

The order Caprimulgiformes contains 5 families of crepuscular and nocturnal birds with quite diverse nesting behaviors. The monophyletic Oilbird (Steatornithidae) of South America nests in colonies deep inside caves. Frogmouths (Podargidae) from the Australasian region, always nest in trees where they build a frail platform in the fork of a horizontal branch. The tiny Owlet Frogmouths (Aegothelidae) of Australia and New Guinea, smallest of the Caprimulgiformes, nest in hollow trees. The neotropical Potoos (Nyctibidae), lay their single egg atop a broken stub or branch where they incubate while sitting bolt upright. Finally, the cosmopolitan goatsuckers (Caprimulgidae) always nest on the ground and lay their eggs on the bare earth or in the leaf litter (Clements 1981).

Most nocturnal insectivorous birds (78 species) are in the Caprimulgidae family (Van Tyne and Burger 1976). About 90 % of the species are in the cosmopolitan subfamily Caprimulginae (Nightjars), and the remainder are in the New World subfamily Chordeilinae (Nighthawks). The members of the genus Caprimulgus (46 species), hereafter termed caprimulgids, are ground nesters usually associated

with forested habitats. All caprimulgids lay their eggs directly on the forest floor without building a nest. Incubation in most species is performed by the female. Semi-precocial chicks hatch asynchronously and are moved from the hatching site by the parents shortly thereafter (Van Tyne and Burger 1976).

The nocturnal habits and cryptic plumages of caprimulgids make them difficult to study. Previous reports on the nesting habits of caprimulgids have consisted of descriptive accounts of nests, the majority of which were accidentally discovered. Furthermore, most studies of caprimulgid breeding biology have relied on casual daytime observations of one or a few breeding pairs (Lack 1930, Raynor 1941, Fowle and Fowle 1954, Babcock 1975).

The available information on the reproductive ecology of the nightjar is limited to 8 accidentally discovered nests from the Guanica Forest. These have provided the only published information on breeding chronology and natural history (Kepler and Kepler 1973, Noble et al. 1986b). Based on these reports, the breeding season was believed to last from May to July, and to reach a peak during May and mid-June. The possibility of two broods a year, typical of other caprimulgids, has been suggested (Kepler and Kepler 1973). The nest has been described as a plain scrape on the ground, usually in leaf litter under brush.

Preferred places seemed to be where the canopy ranged from 4-6 m in height. Eggs have never been found in open areas or clearings. The incubation period is presumed to be 19-21 days. Semi-precocial young are hatched asynchronously and can fly by the fourteenth day. Adults leave the vicinity of the nest site after this date. Here I report on the reproductive ecology of the nightjar.

Study Site

Data on the reproductive ecology of the nightjar were collected on the section of Guanica Forest east of Guanica Bay. There, the coastal dry forest has been protected from human disturbance for over 40 years; however, during the past century the area was selectively lumbered for charcoal production and cleared for grazing and subsistence farming (B. Hernandez pers. comm.).

The topographic relief of Guanica Forest is mostly undulatory. The forest is underlaid by limestones of Miocene and Oligocene origin that surface in some areas, and are virtually the only substrate for plant growth at elevations below 80 m (Monroe 1976). There are approximately 16 soil types contained in 2 principal associations (Canals 1984). The dominant soil type is of calcareous origin; drainage areas are dominated by clay soils. Furthermore, soils are rocky and have low moisture retention.

The climate of Guanica Forest is dry, with short periods of water recharge. Mean annual precipitation for the years of record was 791 mm at the closest climatological station, Ensenada, 2 km to the west of Guanica Bay (Silander 1986). A record of temperature and precipitation has been kept at the forest headquarters since 1984 (Canals pers. comm.). More than half of the precipitation (55%) falls between August and November, with a small secondary peak occurring in May. The dry season extends from January to May, precipitation does not exceed 30 mm during this period.

The Guanica Forest is classified in the Subtropical Dry Forest Life Zone (Ewel and Whitmore 1973). The vegetation of this region has been described by a number of authors (Gleason and Cooke 1927, Wadsworth 1950, Williams 1967, Little and Wadsworth 1964, Kepler and Kepler 1973, Little et al. 1974, Gonzalez-Liboy et al. 1976). For this study, I utilized the habitat description of Gonzalez-Liboy et al. (1976) and the taxonomical classification of Little and Wadsworth (1964). Over 700 plant species, of which 246 are trees, have been recorded at the Guanica Forest. Approximately 35% of the trees are deciduous during the dry season. The dominant families are Fabaceae, Euphorbiaceae and Myrtaceae (Canals 1984).

A total of 8 plant associations are recognized in the Guanica Forest (Fig. 1). These include lowland associations (mangrove swamp, salt flat savanna and beach association) dominated by plants common to the West Indian coastal environments, and upland associations whose vegetation is more typical of coastal dry limestone forests. The upland associations intergrade to a certain extent, but in general there is a gradient in soil thickness, species richness, number of thorny species, and degree of deciduousness as one leaves the coast and progresses upslope.

The most severe habitats and lowest species richness of the upland associations are found near the coast and on ridgetop outcrops. The limestone scrub association represented the extreme conditions along the gradient. The dominant species included Conocarpus erectus, Corchorus hirsuta, Portulaca sp. and Strumpfia maritima. The cactii Cephalocereus rovenii, Opuntia rubescens and Melocactus intortus also dominated this area. The thorn scrub association was found where pockets of soil accumulated and was dominated by Pictetia aculeata, Randia aculeata, Comocladia dodonea, Acacia farnesiana, and Prosopis juliflora. The boundary of the deciduous forest was characterized by shallower slopes where the tree species Bursera simaruba and Bucida buceras constituted the emergent overstory. This association was also characterized by the layering of the forest, with a shorter layer of

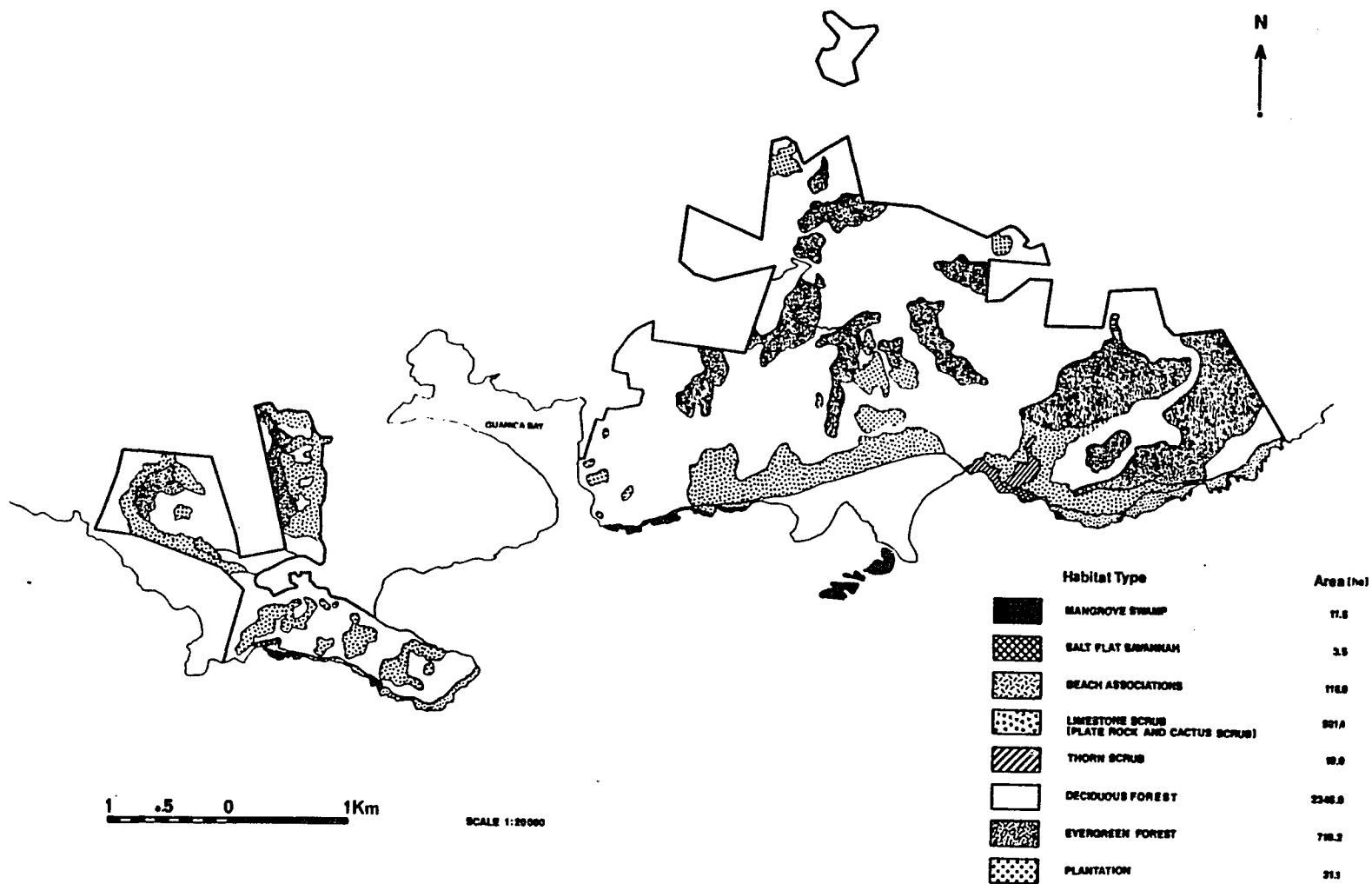


Figure 1. Vegetation map of the Guanica Forest indicating habitat types and area (from Gozalez-Liboy 1976).

shrubs and trees found under the emergents. The most common plant species of the midstory included Coccoloba microstachya, Coccoloba krugii, Colubrina elliptica, Plumeria alba, Capparis sp., and Pisonia albida (Silander 1986).

The evergreen forest association occurred in areas of Guanica Forest with higher soil moisture. This habitat type was dominated by some of the same species found in the deciduous forest plus evergreen species such as Krugiodendron ferreum, Amyris elemifera, Guaiacum officinale, Guaiacum sanctum, Coccoloba diversifolia, and several species of Eugenia. Some areas of evergreen forest were planted with mahogany (Sweetenia mahogany) by the Civilian Conservation Corps (CCC) during the 1930's. While measured growth of the mahogany trees has been very slow, large areas have developed into evergreen forest with a mahogany overstory. Most of the Guanica Forest was composed of evergreen and deciduous forest that accounted for 80.3 % of the total area of the reserve (Gonzalez-Liboy et al. 1976). In some areas of the forest, the abundance of the grasses Panicum maximum, Uniola virgata, and Aristida adensionis can be accounted for by fire disturbance at some previous time. Similarly, the abundance of the shrubs Lantana involucrata, Croton sp., and the trees Leucaena leucocephala and Prosopis juliflora are interpreted as signs of previous disturbance by grazing (Canals 1984).

Methods and Materials

I collected data on the reproductive ecology of the nightjar within Guanica Forest along all existing footpaths, hiking trails and vehicle trails from late May to mid-July during 1985-86 and from late February to July, 1987 (Fig. 2). Trails ranged from small footpaths less than 1 m across to paved roads about 3 m wide. All locations where males were heard singing within 75 m of the trail during crepuscular hours were marked. I tied a strip of flagging tape, hereafter termed flag, to the nearest tree perpendicular to the singing male on the side of the trail where the bird was singing. At locations where several adjacent males were simultaneously singing, playback recordings were utilized to estimate the actual number of singing males. Singing locations were marked throughout the breeding season; flags of different color were utilized each time the trail was traversed. Flags were removed the following year at the beginning of the field season.

Intensive searches were conducted by groups of workers to locate nests in the vicinity of flags. In 1985, 4-7 workers participated; during 1986 and 1987, 3-5 took part in nest searching. Areas were initially searched between 0700-1200 hours the day after the flags had been placed. Before starting, all members of the crew would cover

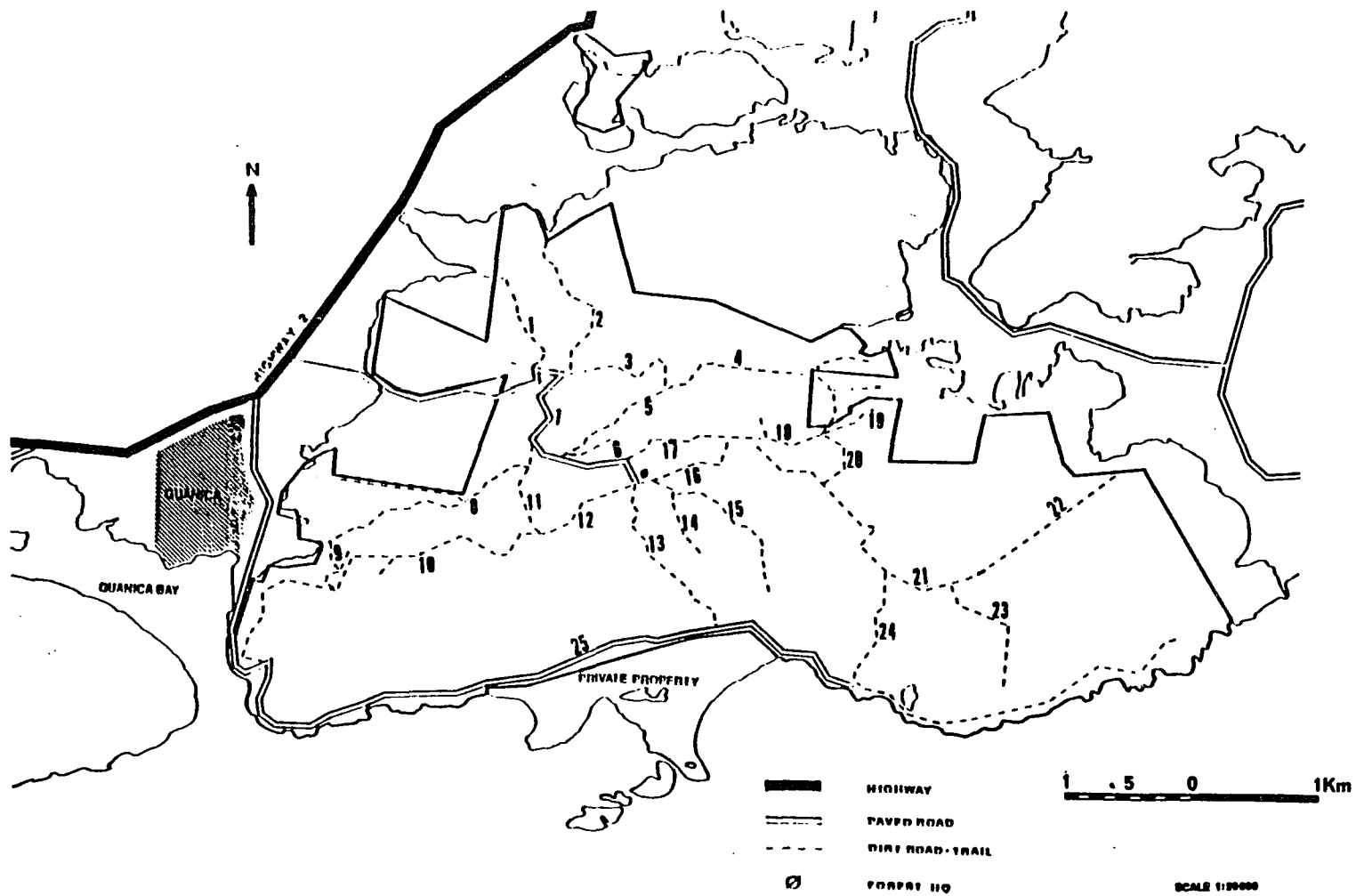


Figure 2. Map of the Guanica Forest east of Guanica Bay. Numbers indicate trails and roads searched for nesting nightjars and correspond to those listed on Table 1.

their shoes and hands with extract from the Aloe vera plant to mask human odor. This escaped exotic was chosen to mask odor because it has long established over much of the forest and has a strong smell. Locations were searched by having the workers line up at 50 m intervals, using the flag as the midpoint of the area to be searched. The group would then slowly search to 100 m into the forest or as far as the terrain would allow, and look for nightjar sign. If no nightjar sign were found after 30-40 minutes of searching, the crew would return to the trail and search the side opposite the flag in the same manner. Once the area had been searched, the outcome was recorded (nothing, roosting bird, roosting pair, incubating bird, brooding bird) and the location of the area searched was recorded on a topographic quadrangle map.

When a nightjar was located with eggs and/or chicks, flagging was placed in the vicinity of the nest. A standard color type was utilized to mark all the nest sites as well as their locations on the trails throughout the study. All nests were monitored by visiting every third day. Eggs and chicks were weighed with a Pessola spring scale and measured with calipers. Laying and hatching dates were obtained by backcalculating eggs at hatching and age of young when discovered, respectively. A Chi-square test was utilized to test the data for synchrony between the lunar month and the reproductive cycle.

Chi-square was also used to test habitat type preference of nesting nightjars (Steele and Torrie 1980).

A sample of 10 nests was monitored from observation blinds during the study: 5 in 1985, 1 in 1986 and 4 in 1987. The blinds were built from camouflage material and vegetation, and placed approximately 7 m from the nest. A light amplifying Noctron V Nightscope (VARO Inc.), equipped with a 135 mm lens was used to monitor the nest during hours of darkness. A Star-Tron IR Pulser (Star-Tron Corp.) infrared light source was placed in the immediate vicinity of the nest to improve light conditions during the observation periods. The blinds were visited every other day and observations recorded during 1 of 3 periods at night (1830-2100, 2300-0100, 0430-0630). I would frequently visit more than one blind on the same night. A headlamp with a red filter was worn when entering and leaving the blind to minimize disturbance.

Radio telemetry was utilized to investigate the habitat use and movements of nesting nightjars. Nesting males were captured using two techniques. In the first, I used a modified fish landing net (50x30 cm) with a 1 m deep pocket. The procedure was to approach to within 1 m of a nesting bird, and then place the net over the bird to capture it.

Three modified mist nets 1-2 m high and 10 m long arranged in a U-shape around the nesting adult, were used for the second capture technique. Two persons would walk towards the nest from the open side and attempt to flush the bird into the nets.

Each captured bird was slipped headfirst into a small cloth bag before being measured and weighed with a Pessola spring scale accurate to 0.01 g. Length of the right wing, the first primary and center rectrix were measured to the nearest millimeter. Tarsus length was recorded. A high frequency (222.00-223.00 MHz) miniature radiotransmitter with a 10 cm whip antenna was glued dorsally to the rachis of the central rectrix. After allowing the glue to dry for 3-5 minutes, the bird was released within 10 m of the nest site.

Locations were obtained during crepuscular and night hours using a high frequency Falcon Five receiver and a hand held 3-element Yaggi antenna (Wildlife Materials Inc.). A model APS-164 Scat-Scanner was utilized to separate signals by pulse rate (Wildlife Materials Inc.). Locations of transmitted birds were taken from dusk to dawn every hour for the first 2 days. Thereafter, locations were taken daily between 1900-2100, 2330-2430, and 0500-0700 for the duration of transmission. One male (N6) was tracked for 13 days, while the other (N18) was tracked for 24 days. A total of 225 locations (N6 = 92, N18 = 133) were recorded. Harmonic means were obtained for distance

covered by movement and number of movements for each instrumented nightjar (Dixon and Chapman 1980). A Chi-square test on the pooled telemetry data was utilized to test for differences in number of movements and distances covered between the time periods sampled. A Student's t-test was used to test movement and distance data between dawn and dusk periods (Steel and Torrie 1980).

The movements of chicks and juvenile nightjars were documented by relocating marked individuals during searches similar to the ones conducted to locate nests. A sample of 10 broods were monitored from the day of hatching during the study. Chicks were marked on the crown with colored pens for identification. Weight and condition of the chicks were recorded on every visit. Movements and location of the chicks and/or juveniles were recorded on a topographic map.

Vegetation data were collected at each nest site and a number of randomly selected sites in order to characterize the nesting habitat. I used a stratified random sampling scheme to select random sites (Petersen 1985). Plots were chosen from the the three upland habitat types (deciduous forest, evergreen forest, mahogany plantation) by overlaying a vegetation map with a numbered grid, and selecting sites using a random numbers table. Nest sites were selected by designating the location of the nest as the center of the plot.

Vegetation data were collected for overstory, midstory and understory at each site by use of a modified nested circular plot (Barbour et al. 1980). Overstory vegetation (vegetation over 2 m tall with a 2 cm or greater diameter at breast height (dbh)) was sampled on a 25 m radius plot (0.05 ha); taxonomic composition, density, dbh, and height of the tallest tree were recorded. Additionally, canopy closure was estimated from the plot center.

Midstory vegetation (vegetation between 1 m and 2 m tall) was sampled on a 2.5 m radius plot (0.005 ha). Taxonomic composition and density were recorded for the midstory.

Understory vegetation (plants less than 1 m tall) was sampled on a 0.25 m radius plot (0.0005 ha). Taxonomic composition, coverage and soil condition were recorded in the understory.

Several measurements were taken in an attempt to quantify microhabitat: cover found within the first 50 cm above ground on the plot center was estimated, the amount of limestone cover was estimated, and a leaf litter sample collected from a 30 cm diameter circle at the plot center. Dry weight and composition were obtained for each leaf litter sample. Elevation, slope aspect and orientation of the plot were also recorded.

The means of seven quantitative habitat variables (leaf litter weight; midstory stem density and species composition; overstory stem

density and species composition; height of the tallest tree; and canopy closure) measured from nest plots were tested between the habitat types where nightjar nests were found by using a Student's t-test (Steel and Torrie 1980).

I used canonical discriminant analysis (CDA) preceded by principal component analysis (PCA) (Joyner 1985) to examine the habitat features associated with nightjar nest site selection. A total of 13 quantitative habitat variables were included in the analysis. These comprised: elevation (ELV), % vegetation cover (CVR), % limestone cover (LIM), dry weight of the leaf litter sample (LFLTR), height of the nearest tree (HTNTR), distance of the nearest tree to the plot center (DIST), stem density of the understory (UNDER), species composition of the midstory (MIDSP), stem density of the midstory (MIDNO), species composition of the overstory (OVERSP), stem density of the overstory (OVERNO), height of the tallest tree (HT), and canopy closure (CC).

PCA was performed on the correlation matrix because the variables were of different units of measure (Pielou 1984). This analysis was followed by a CDA on the habitat data to summarize between-class variation (Rao 1973). The nature of the vegetation plot (nest, random) was utilized as the discriminating variable (Kshirsagar 1972).

Results

Some 2,717 person hours were expended searching approximately 30.8 km of trails, approximately 17 % of the forest (473.6 ha), for breeding nightjars during 1985-1987 on Guanica Forest (Table 1). Between 85-89 locations of singing males were flagged per year. On average, a nightjar (nesting or not) was flushed in the vicinity of 1 of every 10 flagged locations searched.

A total of 23 nesting nightjar pairs were located during the study (Fig. 3). Nests were numbered and their locations mapped as they were located during 1985 (N1-N9), 1986 (N10-N13), and 1987 (N14-N23) (Table 2). At nest sites, breeding pairs were observed during all stages of the nesting cycle, from recently initiated nests to adults brooding immature fledglings.

Breeding Biology and Behavior

The song of the nightjar has been described as a regularly repeated "whip" note, and has a broader frequency range than the first note of the Whip-poor-will (Reynard 1962). The nightjar also exhibits chorusing behavior with respect to singing: one bird's vocalization elicits responses from nearby individuals (Reynard 1962, Kepler and Kepler 1973). I discovered chorusing behavior could be elicited by

Table 1. Trails searched for nightjars heard singing within 75 m of the trails (number of flags) during 1985-1987 on Guanica Forest, Puerto Rico.

Trail	Length (km)	Number of flags			Total area searched (ha)
		1985	1986	1987	
1	1.1	2	3	4	13.5
2	1.6	2	4	4	15.2
3	1.2	6	3	6	27.6
4	1.5	3	3	3	13.5
5	1.2	2	2	3	10.5
6	0.5	-	-	2	3.5
7	1.8	6	5	9	33.7
8	2.4	4	6	2	22.5
9	0.6	-	3	-	4.8
10	2.3	7	8	6	33.5
11	0.7	3	0	2	7.5
12	1.1	5	12	7	45.8
13	1.1	-	-	4	5.7
14	0.9	4	7	2	23.5
15	1.6	5	5	4	43.5
16	0.7	5	2	2	13.5
17	0.8	6	7	4	29.5
18	0.7	5	2	2	14.5
19	0.8	6	2	6	23.8
20	0.7	2	2	2	7.5
21	0.7	3	2	2	26.5
22	1.9	4	2	2	14.5
23	1.4	3	3	5	20.5
24	1.2	2	1	1	5.5
25	2.3	-	4	5	13.5
Total	30.8	85	88	89	473.6

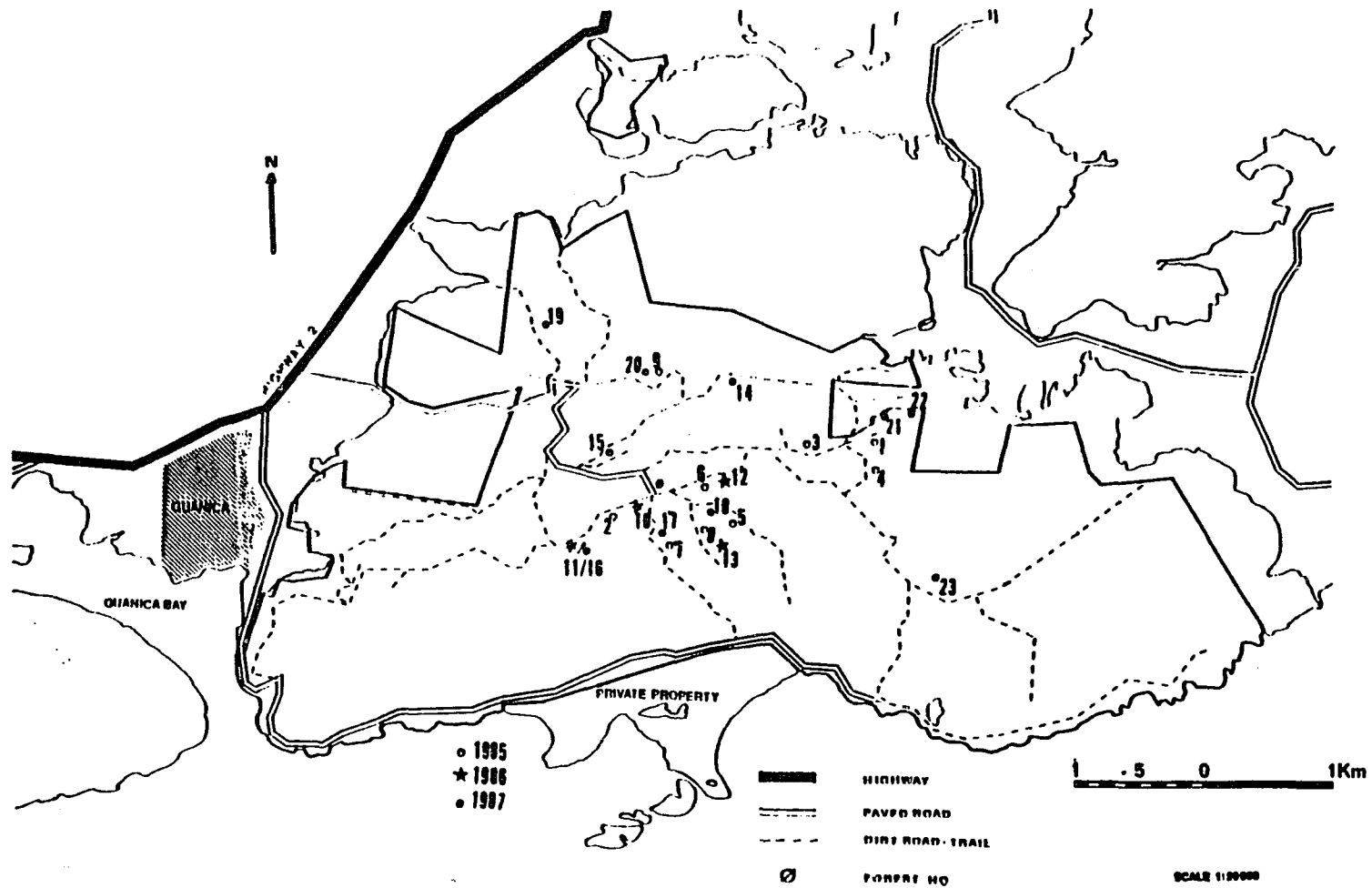


Figure 3. Nightjar nests located at the Guanica Forest between 1985-1987. Number and symbol indicate nest and year and correspond to those listed on Table 2.

Table 2. Nightjar nests located during 1985-1987 on Guanica Forest, Puerto Rico.

Nest	Trail ³	Distance to trail (m)	Habitat type ⁴	(Day/Month/Year) Nest started	Clutch size	Incubation period (days)
1	19	17	Deciduous	7/5/85	2	18
2	12	36	Deciduous	11/5/85	2	19
3	18	15	Deciduous	23/5/85	2	20
4	20	21	Deciduous	28/5/85	2	19
5	15	17	Deciduous	17/6/85	1	19
6	14	60	Plantation	19/6/85	2	19
7	17	30	Plantation	5/6/85	2	19
8	16	40	Plantation	7/6/85	2	20
9 ¹	3	41	Deciduous	28/6/85	2	20
10 ¹	17	75	Evergreen	-	2	-
11 ¹	12	13	Deciduous	27/5/86	2	19
12 ¹	14	11	Evergreen	-	2	-
13	15	125	Plantation	12/6/86	2	19
14	4	31	Deciduous	24/2/87	1	19
15	6	15	Evergreen	25/3/87	1	18
16	12	13	Deciduous	5/4/87	2	19
17 ²	17	20	Plantation	4/4/87	2	19
18 ²	15	20	Plantation	-	2	-
19	1	75	Deciduous	26/4/87	2	19
20	3	20	Deciduous	17/4/87	1	19
21	19	2	Deciduous	7/5/87	2	20
22	19	15	Deciduous	22/4/87	2	19
23	21	37	Evergreen	9/5/87	2	19

¹Nest predation

²Nest abandoned

³As illustrated in Figure 2

⁴As illustrated in Figure 1

taped songs. Playbacks from trails elicited responses from nightjars inside the forest if the recordings were clear and at a volume resembling a singing nightjar or louder. In areas where neighboring males were simultaneously singing, playbacks would elicit a group response that allowed me to estimate the number of birds involved.

I observed that nightjars may deliver long call sequences, like Whip-poor-wills that have been reported to deliver over 1,000 notes in periods of about 15 minutes (Cleaves 1945). On 15 March 1987 at 1917 hours, a nightjar was heard singing approximately 20 m from the western end of trail 10. The bird sang at a rate of 160 notes/min. for periods of 3 min. with short (< 10 sec.), quiet intervals between bouts. Occasionally, the bird would fly to a nearby perch before starting another singing bout.

I heard singing during all months of the year, although the number of singing males and the intensity of singing varied seasonally. In addition, I noted an annual pattern in the number of individuals singing during crepuscular, peak singing hours (Fig. 4). Generally, singing activity was at a minimum in September and October. Thereafter, it increased until it reached a peak during April and May. Then it began to slowly decrease by early July. From bimonthly dawn and dusk counts ($N = 50$) between 1986-87 under ideal conditions along

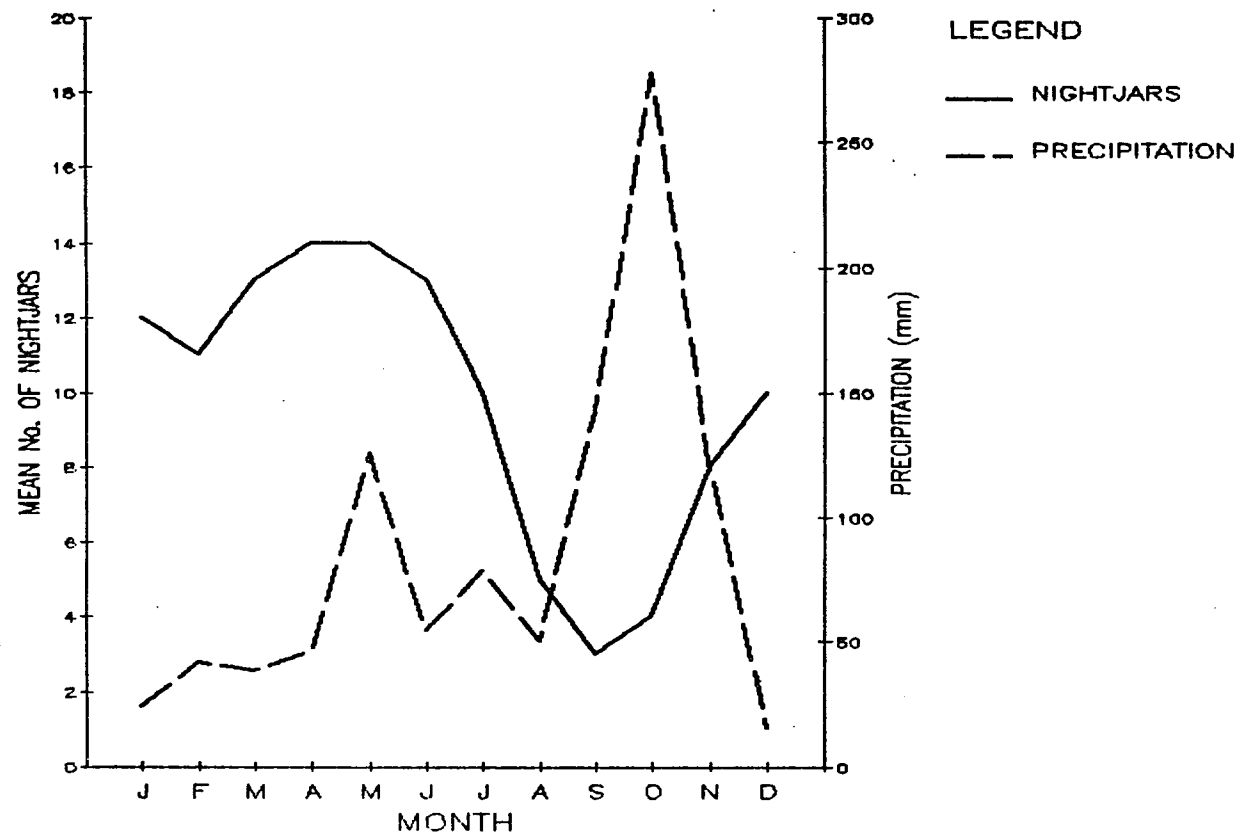


Figure 4. Mean number of nightjars singing during peak hours and precipitation by month at Guanica Forest, Puerto Rico during 1986-1987.

trails 7 and 14, I found a decrease in the number of singing nightjars during late July to early August. This reduction of vocalization coincided with the end of the nightjar's breeding season and the beginning of the rainy season at Guanica Forest.

Weather and moon phase also influenced the calling rate. Calling rate was higher on nights with clear to partly cloudy sky compared to nights of heavy cloud cover and high winds ($X^2 = 12.3$, $df = 2$, $P < 0.001$). Nightjar activity, both singing and foraging, was less during periods of new moon or moonless nights compared to the quarter and full moon phases ($X^2 = 10.1$, $df = 3$, $P < 0.01$).

As calling rate increased during the latter half of December, territorial encounters between neighboring males become more frequent. I observed three basic encounters. The least intense encounters involved bouts during which 2 or more males sang near each other. They engaged in these singing matches for 10-15 minutes with short, quiet intervals.

The other 2 more intensive types always involved a single pair of males. In one type, 2 males would sing from branches less than 10 m apart. Suddenly, both birds would fly up above the canopy utter a hoarse call and clasp bills in midair. These encounters lasted approximately 5-10 seconds, after which the birds released their grip and flew back to favored singing perches. The most intense encounters

involved males who, after clasping bills in midair, fluttered down to the forest floor and rolled in the leaf litter, all the time emitting a loud growling sound. Intense encounters become less frequent as the breeding season progressed.

I only observed courtship behavior twice during the study. The nightjar pair of nest 6 (N6) was observed courting 2-3 days before the first egg was laid, while the N10 pair was observed courting approximately 5-7 days before the nest was discovered (Table 2). On both occasions courtship behavior occurred during early night hours (1900-2100), and within 30 m of where the nest was subsequently located. During courtship, both members of the pair sat approximately 1 m apart parallel on a branch. The male sang repeatedly for about 30 seconds. After terminating the song, he spread his tail, drooped his wings, and vibrated his body as the female watched. While holding his tail spread and wings drooped, he slowly walked towards the female. During the male's approach, both birds emitted soft, clucking sounds. After approaching to within 50 cm of the female, the male flew approximately 2 m away and resumed singing. Mating was never witnessed during the study. Approximately 3 days before laying, females roosted during the day on the forest floor within 10 m of where the eggs were subsequently deposited.

Nightjar breeding pairs initiated nests (first egg laid) between 24 February and 1 July (Fig. 5), with the peak of activity from April through June. This 3 month period includes 91 % (25 of 31) of the nightjar's known nesting dates. Most eggs were deposited during the last quarter and new moon phases ($X^2 = 13.7$, $df = 3$, $P < 0.001$).

The nightjar does not construct a nest as such; the female merely lays the eggs directly on supporting leaf litter. I will use the word "nest" when referring to an adult nightjar that is either incubating eggs or brooding young. Nests were never found in exposed areas or clearings. Clutches consisted of 1-2 eggs, 83 % (19 of 23) of the nests located were two egg clutches (Table 2). The eggs have been described by Kepler and Kepler (1973) as buffy-brown with numerous brownish purple spots over the entire surface, however, I found some degree of variability in the amount of spotting; some eggs were paler and less speckled than others. Eggs appeared only moderately cryptic on the substrate; however, the incubating adult provided excellent concealment through its cryptic plumage and distraction displays.

Incubation in caprimulgids has been previously reported to be almost exclusively performed by females, with males rarely incubating during the day (Lack 1932, Raynor 1941, Steyn 1975, Berry 1979). Male nightjars incubated more (60 %) than females (32 %) (Fig. 6). Only in N9 did the female incubate more (54 %). With the exception of N9, no

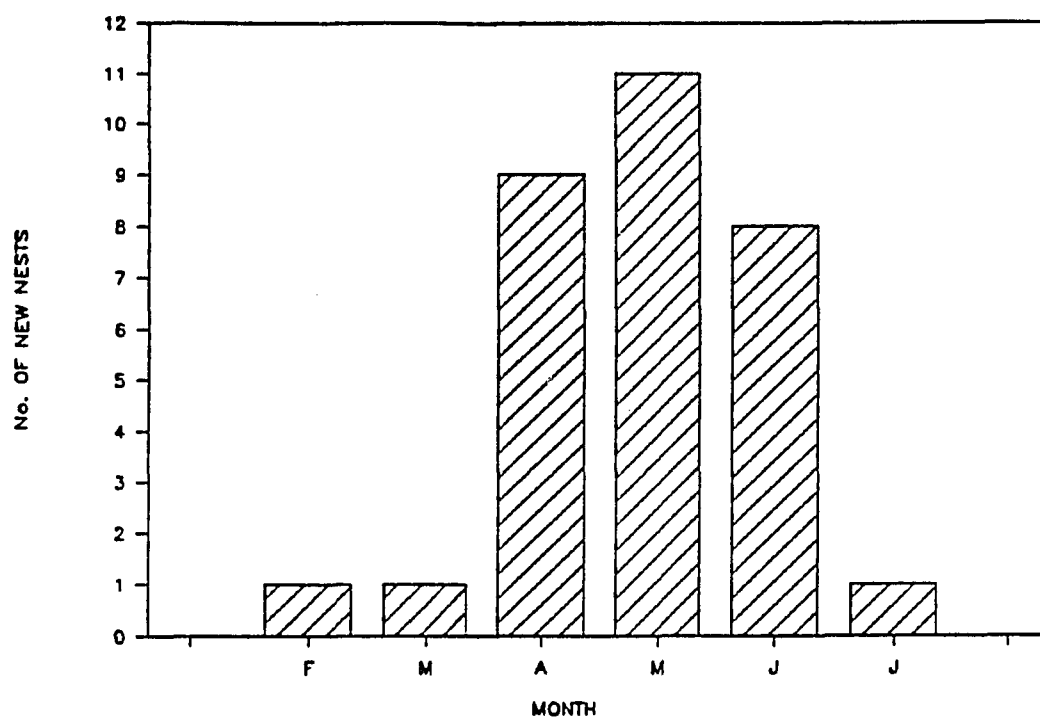


Figure 5. Distribution of nightjar laying activity (N=31) at Guanica Forest, Puerto Rico.

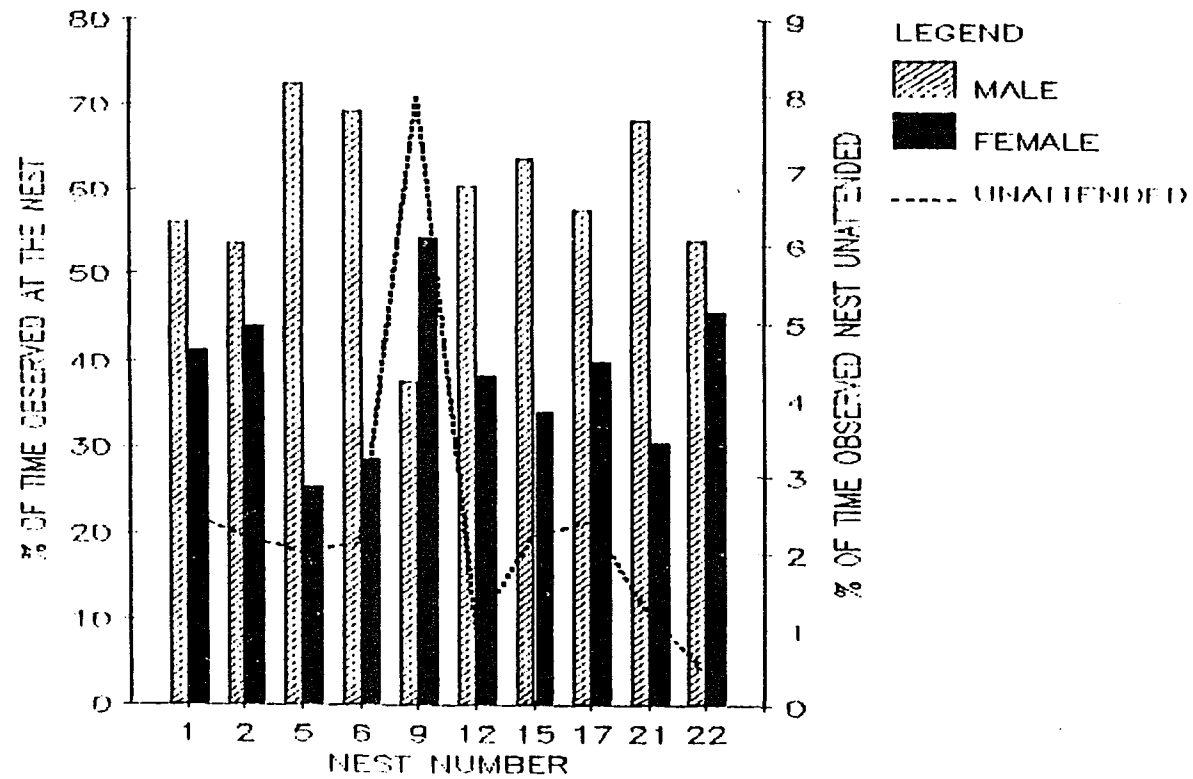


Figure 6. Nest attendance of nightjar pairs (N=10) monitored from observation blinds at Guanica Forest, Puerto Rico 1985-1987.

female nightjar was found incubating during the day. Males sit tightly on the eggs during the day and hold their body pressed to the ground, and thus enhance their inconspicuousness. Incubating birds remain on the eggs even when closely approached. However, if approached within a meter, the adult will usually flush from the nest.

When flushed, the incubating nightjar flew up abruptly and landed a few meters from the nest. Once on the ground, the bird spread its tail and wings widely. The white tail patches of the male were very conspicuous at this time. The bird vibrated its body and hopped, and thus drew the attention of the observer completely away from the nest. This display varies in intensity depending on the phase of the incubation period and the frequency of visits by the observers, as it does in other caprimulgid species (Lack 1957, Gramza 1967).

After incubating throughout the day, nightjar males were relieved at the nest. Nest relief was accompanied by an elaborate nest relief ceremony. This previously unreported behavior has not been noted from any other caprimulgid species; relief at the nest in other caprimulgids simply consists of one member flying off as the relieving bird walks to the eggs and resumes incubation (Raynor 1941). However, I observed nesting nightjar pairs spend approximately 90 seconds displaying before the relieving bird settled on the eggs. The behavioral sequence was as follows. As neighboring males started to

sing during early dusk hours, the incubating male became restless and would frequently shift position on the eggs. The female, who has been roosting nearby during the day, silently flew in and perched on a low branch. Both nightjars emitted soft, guttural sounds during this time. Suddenly, the male stood and displayed in front of the nest (Fig. 7). After the female landed both birds faced each other for 10-15 seconds. The male vibrated its body and ruffled its feathers as the female spread her tail and drooped her wings. The male then flew off, as the female slowly walked to the nest and began incubation.

Every time a member of the pair approached the nest to begin incubation, it moved around in the nest preening and turning the eggs before settling down. Upon being relieved, nesting males flew around their territory singing intensely on favored perches. Areas of the territory adjacent to neighboring males were visited first.

I never observed nesting males to sing while incubating. However, if the female failed to relieve the male during crepuscular periods of peak singing, the male would often fly off to sing and leave the nest unattended. During the study, I noted that nests often remained unattended for more than 1 hour before a member of the pair returned to incubate. Nests of those pairs monitored were left unattended an average of 2.4 ± 0.9 % (30 min/24 hrs) of the time. Frequently, recently relieved males would return and display to the incubating female once the peak singing period was over.

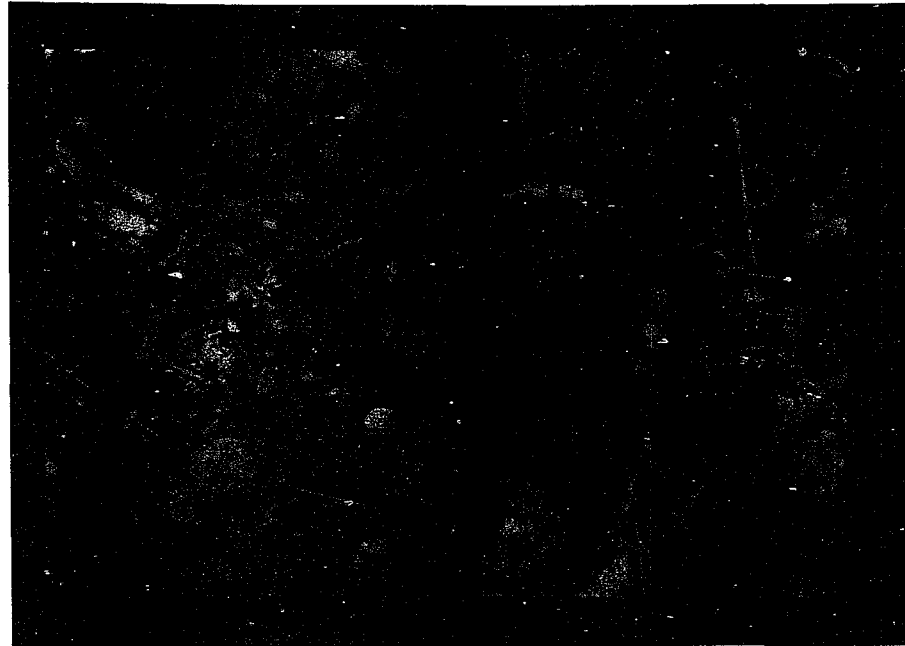


Figure 7. Male Puerto Rican Nightjar assuming the nest relief ceremony position. The female who is perched in a low branch nearby, lands in front of the displaying male before relieving.

Nevertheless, the female remained sitting until the male flew off. Following the period of singing activity at dawn, males resumed incubation by alighting and displaying to the female, who silently flew off.

Eggs hatched after an 18-20 day incubation period; the incubation period for 70% of the nests located was 19 days (Table 2). Hatching occurred from March to July. Hatching was centered around the latter part of the first quarter and during the full moon ($X^2 = 23.1$, $df = 3$, $P < 0.0001$). Brooding was most common during May and June (Fig. 8). Chicks hatched on successive days, and during their first 2-3 days appeared very similar to the young of the Whip-poor-will (Tyler 1940).

A total of 10 broods were intermittently monitored from the day of hatching to fledging between 1985-87 (Table 3). As with incubation, the male was primarily responsible for care of the young. Chicks were fed by regurgitation throughout the night. During twilight hours, both members of the pair alternatively fed the young. Brooding males did not sing for prolonged periods of time during twilight hours, and I never heard them singing within 30 m of the chicks. When a brooding nightjar was disturbed it engaged in prominent displays, similar to those observed during the incubation phase, except they were more intense and lasted for longer periods of time.

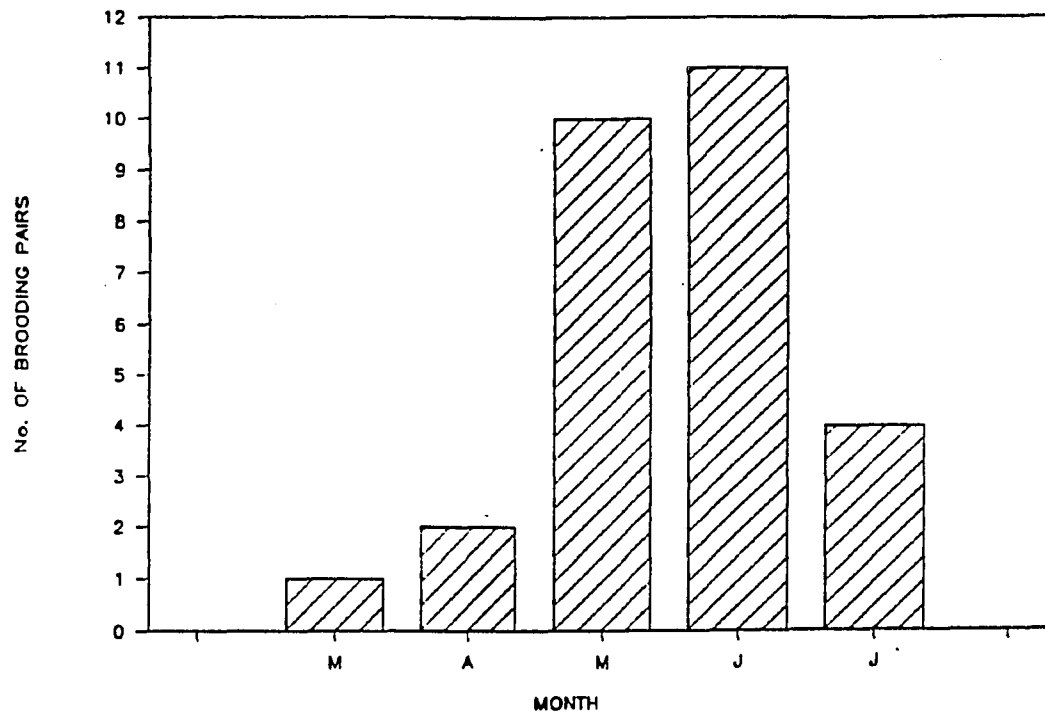


Figure 8. Distribution of nightjar brooding activity (N= 28) at Guanica Forest, Puerto Rico.

Table 3. Weights at weekly intervals and movements of nightjar chicks monitored from the day of hatching on Guanica Forest, Puerto Rico.

Nest	Number chicks hatched	Weight ¹ (g)			Number of movements ²	Mean Distance/movement ³ (m)
		Hatch	7 days	14 days		
5	1	4.18	23.75	41.6	5	4.0
6	2	4.16/4.11	21.85/-	37.80/-	6	5.5
7	2	4.16/4.15	22.50/21.75	36.50/33.10	6	5.3
11	2	4.16/4.13	22.30/21.75	37.50/33.10	7	6.4
13	1	4.16	23.50	39.75	4	6.9
15	1	4.16	23.15	38.10	6	5.8
16	2	4.18/4.15	22.85/21.50	36.50/34.25	7	4.7
17	2	4.15/4.13	22.75/21.45	36.50/-	7	5.2
19	2	4.17/4.15	22.75/-	37.30/-	6	5.3
21	2	4.15/4.13	23.25/22.10	36.75/33.50	6	5.5

¹First chick hatched/Second chick hatched

²Between 1-14 days old

³Harmonic mean

Nightjar chicks averaged 4.13 ± 0.02 g when hatched. Chicks were capable of short distance movements within 24 hours after hatching. Adult nightjars would land a short distance from the chicks and utter soft clucking sounds to which the chicks responded by pushing themselves forward, and then used their short wings as "crutches". These initial movements were never greater than 50 cm from the original nest site.

The sheaths of the flight feathers started to appear during the first week and replace the cinnamon colored down that covers the chicks when they were hatched. Developing rectal bristles also appeared at this time. Chicks averaged 21.1 ± 5.1 g after the first week, and during this period frequently moved. Chicks foraged on the ground when left alone by the parents during night hours. Between 7 and 14 days of age, nightjar chicks assumed an awkward appearance as their feather sheaths continue to develop. If the brooding adult was flushed at this time, the chicks quickly moved to dense cover and remain motionless while the adult performed the distraction displays. Additionally, during this period, chicks were left unattended for prolonged periods of time (>1.5 hrs) during the night.

By the time the chicks were 14 days old, they averaged 36.6 ± 2.5 g, and had the adult plumage pattern, and were capable of considerable movement and short sustained flight. Adult birds roosted

on the ground during the day next to the chicks. However, if disturbed, the adult flew off without displaying and the chicks flew up to the higher branches of the nearest tree. During the latter part of the breeding season, fledged young and immature nightjars sat on the ground at night by the edge of the trails. From the ground, they made short sallies to capture flying insects and foraged for terrestrial insects. Immature nightjars remained on a male's territory for up to a month after fledging.

Three of the 23 nightjar nests located during the study failed. The incubating male was killed and the eggs destroyed at N10 on 5 June 1986, 10 days after being discovered. The eggs had been crushed and consumed; the predator responsible was probably a mongoose, because a feral cat (Felis domesticus) would not have consumed the eggs (J. Keith pers. comm.). Further, even if a feral cat had killed the adult and left the eggs exposed for an avian predator, the remains of the eggs would have then been pecked and not crushed.

During that same year on 3 July, the clutch of N12 was discovered apparently destroyed by an avian predator. A male was heard singing from the N12 territory later that day; no remains of an adult were found and apparently only the brood was lost. Remains of both eggs were still on the N12 nest site when discovered; however these had been pecked open and their contents consumed.

At Guanica Forest, the Pearly-Eyed Thrasher (Margarops fuscatus) is an active ground forager and nest predator that is commonly seen taking eggs and young of smaller Passerines such as the Bananaquit (Coereba flaveola) (pers. obs.). The Red-Legged Thrush (Mimocichla plumbea) also commonly forages on the forest floor; however, its diet consists mainly of insects and fruit (Biaggi 1974). The latter species has not been reported to prey on the eggs and/or young of other avian species.

The third nest failure occurred during the 1987 breeding season after the incubating male (N18) was captured, fitted with a radiotransmitter and released. Although released apparently unharmed, the bird failed to return to the nest. The female was never seen approaching the unattended nest. Although the nest was abandoned, I was able to track the N18 male for 2 weeks until the transmitter failed.

Predation on nightjar eggs and young was observed on two occasions during the course of the study. On 15 August 1985 at 2045 hours as I walked along route 19, a juvenile nightjar flew across the trail about 15 m ahead. Just before the bird reached the other side of the trail and cover of the forest, a Short-Eared Owl (Asio flammeus) flew quietly out of the forest and captured it in midair.

On 3 July 1986 when checking N13, I discovered the male nightjar brooding a 2 day old chick approximately 80 cm from the nest site. At the nest site, a partly pipped egg was found completely covered with fire ants (Solenopsis sp.). The chick apparently had been killed by the ants as it was attempting to emerge from the egg. The male seemingly moved the surviving chick from the ant's path and avoided the loss of his entire brood.

Habitat Use and Movements

Nightjars were mostly seen within the forest, often near its edge. The only time I noticed a nightjar in an open area or clearing was on 4 July 1985, at 2030 as I was walking along a gravel pit located in private property northwest of trail 8. There, I came upon a juvenile nightjar sitting on the ground about 200 m from the forest's edge. It made short sallies, captured insects in flight, and returned to the same location. My presence did not appear to disturb it, as it continued to feed, even as I sat within 5 m of where he landed.

Two males (N6, N18) were captured and fitted with radiotransmitters during the study. The N6 male was captured after both young had fledged, and the N18 male was captured when it was incubating. The maximum move recorded for the N6 male was 270 m. The

average distance covered was 57.2 ± 7.3 m/movement, and the mean area utilized was 0.3 ± 0.1 ha/tracking period ($N = 53$). Additionally, the N6 male moved an average of 4.2 ± 1.7 times/period. The longest distance covered by the N18 male was 360 m. On average, N18 moved 65.8 ± 37.5 m/movement and covered 0.57 ± 0.3 ha/tracking period. The mean number of movements was 6.7 ± 3.5 movements/period ($N = 106$). The areas of primary utilization (home range) encompassed by each nightjar during the period of transmission (23 days), were 4.8 ha (N6) and 5.6 ha (N18). The number of movements and the distance covered between movements (pooled data) were significantly higher during twilight than midnight periods ($X^2 = 23.1$, $df=2$, $P < 0.001$). Additionally, the number of movements and distance/movement were significantly higher during dusk than dawn hours ($t = 7.4$, $df = 157$, $P < 0.0001$).

Distribution of singing males along each trail flagged appeared to vary little during the course of the year and among years, suggesting nightjar males exhibited strong site fidelity. On several occasions as I flagged a trail, previous year flags were adjacent to, sometimes in, the same tree the flags of the current year. In addition nests N11 and N16 were apparently of the same pair but from different years. N11 was discovered on 27 May 1986, at the southwest end of trail 12 approximately 13 m inside the forest (Fig. 3). The

following year on 5 April, N16 was located on the exact location where N11 had been a year earlier. A male was heard singing from this territory throughout 1986-1987, and I assumed both nests involved at least the same breeding male.

I was able to observe nightjars foraging during twilight and night periods at Guanica Forest many times during the study. The nightscope was utilized during periods of darkness when sufficient moonlight was available. Like other caprimulgids (Tyler 1940), nightjars were seen to visit favorite perches at night. Nightjars perched on branches approximately 2.5 m above the forest floor. From there, they sallied after insects and returned to the same branch. On several occasions, a nightjar was seen returning to the branch with a captured insect in its bill. These were usually large insects, probably moths or beetles. After landing, the bird would hold its head upright, shake and swallow the prey.

Nightjars also fed on insects attracted to artificial light sources. At least 3 different male nightjars visited the trees surrounding the management official's house at Guanica Forest every night. A bright lamppost in front of the house attracted insects from a large area. Nightjars sallied out and kept their mouths open as they flew through clouds of small insects. Scarabaeid beetles often

hit the lamp and fluttered to the ground. Nightjars landed and with outstretched wings, picked the beetles from the ground. Other bird species such as Red-Legged Thrush and Gray Kingbird (Tyrannus dominicensis), as well as bats, were also attracted to this source of foods.

Nest Habitat Selection

Nightjar nests were located in all three habitat types found in the forested uplands of Guanica Forest (deciduous forest, evergreen forest, and mahogany plantation) at elevations ranging from 55 m at the edge of the evergreen and limestone scrub associations (N23), to 220 m in deciduous forest on the higher elevations of Guanica Forest (N21). Nests were located from 2 m to 125 m into the forest from the nearest road or trail. Mean distance was 32.6 ± 28 m from the nest to the nearest road or trail. Nests were in areas with gentle slopes and good drainage. Nightjar nests were not evenly distributed throughout, but were concentrated in certain areas of Guanica Forest (Fig. 3). Of three habitat types on which nests were located, mahogany plantation (6 nests, 0.8 % of the area) was significantly favored over evergreen (4 nests, 18.8 % of the area) and deciduous forest (13 nests, 61 % of the area) ($X^2 = 18.3$, $df = 2$, $P < 0.0001$). Evergreen forest and

mahogany plantation, hereafter termed evergreen-plantation, were combined for the pairwise comparisons (t-tests). These two habitat types were treated jointly because the mahogany plantations are presently composed of evergreen forest with an emergent mahogany overstory.

The 13 nests (56.5 %) in deciduous forest ranged in elevation from 80 m (N9) to 220 m (N21) ($\bar{x} = 153.3 \pm 40.6$ m) (Table 4). Nests in deciduous forest averaged 61.3 ± 15.1 % vegetation cover within the first 50 cm above the nest. Only 2 of the nests (N2, N19) in deciduous forest had exposed limestone in their vicinity. All nests were located less than 1 m from the base of a tree. Nearest trees were midstory species with a dbh ≤ 20 cm and from 1.5 m to 4 m in height. They included Exostema caribaeum (N1, N11/N16), Thouinia portoricensis (N2, N3), Capparis cynophallophora (N5), Leptocereus quadricostatus (N9), Leucaena glabra (N14), Reynosa uncinata (N19), Eugenia rhombea (N20), and Pisonia albida (N21, N22). Leaf litter (30 cm diameter) collected from nests in deciduous forest ranged in biomass (dry weight) from 19.7 g to 51 g ($\bar{x} = 31.4 \pm 9.2$ g/sample).

Nest sites in deciduous forest averaged 14 ± 3.4 species of trees in the midstory within the 0.05 ha plots sampled. In total, 43 species of trees were identified within the vegetation plots measured

Table 4. Habitat characteristics of nightjar nesting areas in the deciduous forest association on Guanica Forest, Puerto Rico. Data are based on 0.05 ha circular plots.

Nest	Elevation (m)			Understory		Leaf litter (g)	Midstory		Overstory			Height (m)
		% Cover	% Limestone	Nearest tree (Genus)	Distance (m)		Number species	Number stems	Number species	Number stems	Tallest tree (Genus)	
1	200	70	0	<u>Exostema</u>	0.3	31.5	11	68	3	10	<u>Exostema</u>	6
2	150	70	30	<u>Thouinia</u>	0.2	20.7	14	49	1	5	<u>Bucida</u>	7
3	160	80	0	<u>Thouinia</u>	0.4	51	15	43	1	4	<u>Bucida</u>	8
4	160	60	0	Unknown	0.4	19.7	17	50	4	9	<u>Bucida</u>	8
5	140	50	0	<u>Capparis</u>	0.3	43.9	17	79	2	6	<u>Sweetenia</u>	9
9	80	60	0	<u>Leptocereus</u>	0.7	28	13	40	4	2	<u>Bursera</u>	10
11 ¹	145	50	0	<u>Exostema</u>	0.5	33.1	20	60	2	6	<u>Bucida</u>	7
14	115	60	0	<u>Leucaena</u>	0.3	30.5	13	45	3	4	<u>Bucida</u>	8
19	125	25	80	<u>Reynosa</u>	0.5	25.6	18	42	3	13	<u>Bucida</u>	11
20	135	60	0	<u>Eugenia</u>	0.6	22.9	8	28	4	17	<u>Bucida</u>	8
21	220	70	0	<u>Pisonia</u>	0.3	35.2	11	42	1	5	<u>Bucida</u>	7

¹ Nest 11 and nest 16 on same exact site

around nightjar nests located in deciduous forest (see Appendix A for list of species). The dominant tree species of the midstory included Exostema caribaeum, Pisonia albida, Amyris elemifera, Pictetia aculeata, Thouinia portoricensis, Pithecellobium unguis-cati, Antirhea acutata, Eugenia foetida, Eugenia rhombea, Crescentia linearifolia, and the cactus Cephalocereus rovenii.

The overstory of the nightjar nests in deciduous forest was dominated by the trees Bucida buceras and Bursera simaruba. In the forested uplands of Guanica Forest, this layer of the forest was not always well defined, and consisted in some places of some emergent trees protruding over the midstory. The emergent trees ranged in height from 6 m to 11 m ($\bar{x} = 7.9 \pm 1.4$ m); dbh ranged from 20 cm to 140 cm ($\bar{x} = 34.8 \pm 23$ cm). Canopy closure averaged 52.5 ± 15.6 % and ranged from 25 % to 75 %.

The remaining 10 nightjar nests (43.5 %) were in evergreen-plantation (Table 5). Nests in evergreen-plantation forest were located at elevations from 55 m (N23) to 200 m (N15), with a mean elevation of 134 ± 37.4 m. Cover in the first 50 cm above the nest averaged 64.5 ± 29.3 %, and was similar in quantity to cover found on nests in deciduous forest. In addition, as in deciduous forest, only 2 of the nests found in evergreen-plantation forest (N10, N15) had exposed limestone in the vicinity.

Table 5. Habitat characteristics of nightjar nesting areas in the evergreen and plantation associations on Guanica Forest, Puerto Rico. Data are based on 0.05 ha circular plots.

Nest	Elevation (m)	% Cover		Understory		Leaf litter (g)	Midstory		Overstory			Height (m)
			Limestone	Nearest tree (Genus)	Distance (m)		Number species	Number stems	Number species	Number stems	Tallest tree (Genus)	
6	150	70	0	<u>Sweetenia</u>	0.4	38	15	71	3	11	<u>Sweetenia</u>	8
7	110	20	0	<u>Sweetenia</u>	0.6	72.6	13	54	2	66	<u>Sweetenia</u>	12
8	140	80	0	<u>Albizia</u>	0.3	64	10	69	1	14	<u>Sweetenia</u>	7
10	150	80	15	<u>Bursera</u>	0.1	48	18	51	2	5	<u>Bucida</u>	7
12	150	80	0	<u>Eugenia</u>	0.7	41	13	96	1	9	<u>Sweetenia</u>	9
13	135	75	0	<u>Antirhea</u>	0.2	55.5	10	62	2	13	<u>Bucida</u>	10
15	200	80	10	<u>Amirys</u>	0.1	32.7	16	65	3	7	<u>Bourreria</u>	8
17	110	85	0	<u>Sweetenia</u>	0.5	46	9	33	1	42	<u>Sweetenia</u>	12
18	140	75	0	<u>Hematoxylum</u>	0.3	54.3	10	57	1	25	<u>Sweetenia</u>	6
23	55	0	0	<u>Euphorbia</u>	0.9	29.2	9	54	3	12	<u>Bucida</u>	8

All nightjar nests located in evergreen-plantation forest were also located within a meter of the base of a small tree. Height and dbh of the nearest tree to the nest were not significantly different from nests in deciduous forest ($t = 0.20$, $df = 20$, $P < 0.84$). However, the species composition of the nearest tree in evergreen-plantation nesting areas was different from nests in deciduous forest. Nearest tree species included Sweetenia mahogany (N6, N7, N17), Albizia lebeck (N8), Bursera simaruba (N10), Eugenia rhombea (N12), Haematoxylum campechianum (N18), and Euphorbia petiolaris (N23). Leaf litter samples of evergreen-plantation nests ranged in biomass from 29.2 g to 72.6 g ($\bar{x} = 50.7 \pm 13.8$ g). The biomass of the leaf litter collected from nests in evergreen-plantation forest was significantly higher than that of nests in deciduous forest ($t = 3.91$, $df = 20$, $P < 0.0009$).

A total of 38 species of trees and shrubs were identified from the midstory of vegetation plots located in nesting areas in evergreen-plantation (see Appendix B for list of species). Sites averaged 12.3 ± 3.1 species/plot and stem density averaged 61.2 ± 16.3 stems/plot. Both the number of species ($t = -1.26$, $df = 20$, $P < 0.22$) and stem density ($t = 1.92$, $df = 20$, $P < 0.07$) of midstory trees were not significantly different between habitat types. The dominant midstory species of the evergreen-plantation nest sites included

Bourreria suculenta, Coccoloba microstachya, Sweetenia mahogany,
Guaiacum officinale, Exostema caribaeum, and Amvris elemifera.

The number of overstory species in evergreen-plantation nest sites ranged from 1 to 3 species/plot ($\bar{x} = 1.7 \pm 0.8$ species/plot). There was no difference in the species composition of the overstory between habitat types ($t = -1.71$, $df = 20$, $P < 0.10$). Nevertheless, the number of stems in the overstory was significantly greater in evergreen-plantation nest sites than in deciduous forest nest sites ($t = 2.58$, $df = 20$, $P < 0.01$). Nightjar nests located in evergreen-plantation forest averaged 22.1 ± 19 stems/plot, and ranged from 5 to 67 stems/plot.

The canopy of the evergreen-plantation nesting areas was dominated by Sweetenia mahogany. The canopy of nest sites located in evergreen forest where mahogany was not present was dominated by Guaiacum officinale and Bourreria suculenta. Overstory trees ranged in dbh from 20 cm to 120 cm ($\bar{x} = 44.2 \pm 21.7$ cm). Canopy height ranged from 6 m to 12 m ($\bar{x} = 8.1 \pm 1.8$ m). Canopy height did not differ between habitat types ($t = 0.20$, $df = 20$, $P < 0.84$). The canopy closure of nesting areas in evergreen-plantation forest ranged from 40 % to 90 % ($\bar{x} = 68.5 \pm 8.2$ %). Canopy closure was significantly greater for nest sites on evergreen-plantation forest than on sites located in deciduous forest ($t = 2.47$, $df = 20$, $P < 0.02$).

Structural habitat data were collected at all 22 nightjar nest sites (N11 and N16 on same location) (Table 6) and at 81 randomly selected sites (Table 7) in Guanica Forest. From the PCA on the correlation matrix of the sample ($N = 103$), I identified 5 PC's that accounted for 70.5 % of the total variation in the matrix of original habitat variables (Table 8).

Factor loadings on the first principal component (PC1) were highest for canopy closure, leaf litter biomass, canopy height, and overstory stem density, respectively (Table 9). Negative factor loadings on the first 2 principal components (PC1, PC2) were highest for percentage of vegetation at 50 cm, stem density of the understory, and exposed limestone around the plot center, respectively.

CDA of the structural habitat variables had a canonical correlation coefficient of 0.77. This canonical coefficient was highly significant (Likelihood Ratio test, $F = 10.22$; $df = 13, 89$; $P < 0.0001$) and indicated the effectiveness of utilizing plot type (nest vs. random) as the discriminating variable. The CDA loadings resulted in a linear combination for the discriminating variable that was most highly weighed by leaf litter biomass, amount of cover 50 cm above the plot center, density of the understory, and density and species richness of the midstory, respectively (Table 10).

Table 6. Simple statistics obtained for the structural habitat variables measured at nightjar nest sites (N=22) on Guanica Forest, Puerto Rico.

Variable	Minimum	Maximum	Mean	SE
Elevation (ELV)	55.00	220.00	144.55	39.52
% Cover (CVR)	0	85.00	62.73	22.20
% Limestone (LIM)	0	80.00	6.14	18.00
Leaf Litter (LFLTR)	19.70	72.60	40.20	14.92
Height Nearest Tree (HTNTR)	1.20	5.00	2.90	1.20
Distance Plot Center (DIST)	0.10	0.90	0.41	0.22
Understory Density (UNDER)	0	93.00	15.32	18.50
Number Species Midstory (MIDSP)	8.00	20.00	13.30	3.34
Midstory Density (MIDNO)	28.00	96.00	54.32	16.10
Number Species Overstory (OVERSP)	1.00	4.00	2.10	1.02
Overstory Density (OVERNO)	4.00	67.00	14.20	14.80
Height Tallest Tree (HT)	6.00	12.00	8.02	1.61
Canopy Closure (CC)	25.00	90.00	59.80	16.90

Table 7. Simple statistics obtained for the structural habitat variables measured at randomly selected sites (N=81) on Guanica Forest, Puerto Rico.

Variable	Minimum	Maximum	Mean	SE
Elevation (ELV)	15.00	200.00	108.21	45.94
% Cover (CVR)	0	100.00	34.60	30.80
% Limestone (LIM)	0	100.00	28.60	34.44
Leaf Litter (LFLTR)	0	70.70	18.12	11.13
Height Nearest Tree (HTNTR)	0.50	6.50	2.30	1.50
Distance Plot Center (DIST)	0.01	2.00	0.63	0.40
Understory Density (UNDER)	0	110.00	18.00	19.50
Number Species Midstory (MIDSP)	2.00	19.00	11.73	3.02
Midstory Density (MIDNO)	8.00	157.00	62.20	34.11
Number Species Overstory (OVERSP)	0	6.00	2.01	1.24
Overstory Density (OVERNO)	0	27.00	6.90	5.70
Height Tallest Tree (HT)	0	13.00	6.70	3.00
Canopy Closure (CC)	0	80.00	33.52	26.30

Table 8. Performance of the principle component analysis (PCA) on the structural habitat variables measured from nightjar nests and randomly selected areas at Guanica Forest, Puerto Rico. PCA was performed on the correlation matrix and the first 5 principal components (PC's) retained by the MINEIGEN criterion (eigenvalues ≥ 1).

Performance	PC 1	PC 2	PC 3	PC 4	PC 5
Eigenvalue	3.4267	1.8819	1.7157	1.1083	1.0292
Proportion of variance	0.264	0.145	0.132	0.085	0.079
Cumulative proportion of variance	0.264	0.408	0.540	0.626	0.705

Table 9. Factor loadings of original variables generated from principal component analysis of structural habitat data collected at random sites and nightjar nest sites at Guanica Forest, Puerto Rico.

Variable	PC 1	PC 2	PC 3	PC 4	PC 5
Elevation (ELV)	0.5812	- 0.3779	- 0.1184	0.4908	0.0139
% Cover (CVR)	0.0778	- 0.7779	0.2812	0.0654	0.0789
% Limestone (LIM)	- 0.5991	0.3797	- 0.0614	0.1793	- 0.2740
Leaf Litter (LFLTR)	0.6977	- 0.1744	- 0.0988	- 0.3615	- 0.2008
Height Nearest Tree (HTNTR)	0.3633	0.3033	- 0.0890	0.3884	0.5796
Distance Plot Center (DIST)	- 0.4334	0.3466	- 0.3284	- 0.3058	0.5148
Understory Density (UNDER)	0.1832	- 0.5988	- 0.3456	- 0.1503	0.3431
Number Species Midstory (MIDSP)	0.0508	0.1062	0.8210	0.2624	- 0.0270
Midstory Density (MIDNO)	- 0.0885	0.0128	0.7802	- 0.2086	0.4144
Number Species Overstory (OVERSP)	0.5190	0.3615	- 0.1802	0.3784	- 0.0029
Overstory Density (OVERNO)	0.6091	0.2460	0.2067	- 0.3938	- 0.1193
Height Tallest Tree (HT)	0.6950	0.3829	0.1105	- 0.1074	0.0421
Canopy Closure (CC)	0.8657	0.1977	- 0.0569	- 0.1044	- 0.0064

Table 10. Standardized correlation coefficients obtained from canonical discriminant analysis (CDA) of the structural habitat variables measured from nest and random sites at Guanica Forest, Puerto Rico.

Habitat Variable	CANONICAL 1
Elevation (ELV)	- 0.00035
% Cover (CVR)	0.82845
% Limestone (LIM)	- 0.11360
Leaf Litter (LFLTR)	0.95537
Height Nearest Tree (HTNTR)	0.23689
Distance Plot Center (DIST)	0.09978
Understory Density (UNDER)	- 0.48807
Number Species Midstory (MIDSP)	0.43783
Midstory Density (MIDNO)	- 0.41051
Number Species Overstory (OVERSP)	- 0.09330
Overstory Density (OVERNO)	0.09713
Height Tallest Tree (HT)	- 0.03569
Canopy Closure (CC)	0.25110

Discussion

Nightjar males sing throughout the year at Guanica Forest, but a distinct seasonal pattern in the total number of singing birds and in the duration of the calling period was observed. Both biological and environmental factors contribute to the observed pattern. Cessation of nesting is known to accompany a decrease in singing (O'Connor 1980). Additionally, rainy nights with heavy cloud cover are frequent during this time of the year as tropical depressions move across the Caribbean. Caprimulgids sing little under these atmospheric conditions (Cooper 1981).

The limited number of movements and distance covered by the two male nightjars fitted with radiotransmitters (N6, N18) suggested there is strong site fidelity by males of this species during the nesting season. The maximum distances recorded for two males 270 m and 360 m respectively, compare with the maximum distances reported (Jackson 1985) for marked Fierynecked Nightjars (Caprimulus pectoralis) in Zimbabwe (376 m). The areas I calculated as being used by both N6 (4.8 ha) and N18 (5.6 ha) were similar to the density estimates obtained from call counts for that section of Guanica Forest (7.8 ha). Capturing additional nesting nightjars at Guanica Forest was impractical due to the dense vegetation. Furthermore, the male at

N18 did not return to the nest after being captured and I could not risk further nest abandonment by an endangered species.

The sedentary nature that I observed for nightjars has been documented for other caprimulgids (Berry and Bibby 1981, Cooper 1981). In Zimbabwe, most male Fierynecked Nightjar recaptures occurred within 100 m of where the birds were banded (Jackson 1984, 1985).

At Guanica Forest, the nightjar's breeding season extended from late February to late July, but most nesting and fledging activity occurred from April to June. The breeding season starts 2 months earlier than previously reported (Kepler and Kepler 1973). Lack (1930) demonstrated that the European Nightjar has two broods a season in England; Jackson (1985) documented double-brooding in the Fierynecked Nightjar and Mozambique Nightjar (Caprimulgus fosii) in Zimbabwe. In Guanica Forest, there is sufficient time for 2 broods because of the extent of the breeding season (> 4 mos.). In addition, double-brooding may occur, because new nests (N9) were found late in the season.

Incubating and brooding, were mostly performed by the male though female nightjars would occasionally incubate and brood during night hours. Occasional incubation by male Whip-poor-wills, a close relative of the nightjar, has been previously reported (Babcock 1975). In the Blackish Nightjar (Caprimulgus nigrescens), both members of the pair share parental duties (Roth 1985). Jackson (1985) reported that

in the Fierynecked Nightjar, the male incubates and broods at night and the female does by day.

In only 1 of the 23 nightjar nests located (N9) did the female incubated and brooded more than the male. Two factors may have been responsible for this. N9 was started late in the season when the incubation zeal of males may have been reduced, or the N9 male may have been a young, inexperienced breeder. An inverse relationship between age and reproductive effort has been documented in many avian species (Curio 1983).

Most breeding females laid their eggs during low moonlight conditions and hatching occurred during the periods of greatest available moonlight. Thus, it appeared that in a nocturnal, visually oriented species like the nightjar, breeding pairs were able to synchronize the first 2 weeks of the nestlings's lives with the greatest potential amount of moonlight available for foraging.

Mills (1986) investigated the movements and behavior of radioinstrumented Whip-poor-wills in Canada and found strong lunarphilia, with significantly higher levels of locomotory, vocal, and nest activity during twilight and bright moonlight than under moonless conditions. For caprimulgids, the first 2 weeks after egg hatching are the most sensitive for nestling survival (Lack 1930). The semi-precocial young of the nightjar are fledged by the 14th day;

thus, as the lunar month entered the following dark period, the independence of the young alleviated the burden on the parents.

I used multivariate analysis on structural habitat data collected at nest and random sites to investigate the habitat preferences of nesting nightjars at Guanica Forest. Five PC's explained 70.5 % of the variance in the original data matrix. The PCA generates ordination scores based on the total variation in the data matrix and did not summarize between-class (i.e. nest vs. random) variation (Rao 1973).

Canopy closure, leaf litter biomass, canopy height, and density of the overstory respectively, were the variables associated with the first principal component (PC1). Therefore, factor loadings generated from the PCA reflected the differences in the structure of the vegetation at Guanica Forest due to variation in soil depth, slope angle, compass orientation, and the effects of these factors on soil moisture. At low elevations in Guanica Forest (below 50 m), the substrate was exposed limestone with occasional solution holes and shallow soil pockets. As a result, these areas of the forest had few, widely spaced, large deciduous trees (e.g. Bursera simaruba) interspersed among which were many shrubs, some grasses, cacti, and open areas with exposed limestone. Progressing upslope, one encountered more soil pockets interspersed with exposed limestone. As

the soil became deeper, additional deciduous tree species were found. Evergreen species joined the deciduous species in areas located in deeper red soils. Deeper soils were found in saddles between ridges, in valleys or on gentle slopes.

However, when the data matrix was projected along the first 2 PC's obtained from the analysis (Fig. 9), most of the vegetation plots measured at nightjar nest sites occurred in a cluster that included some random sites. Thus nightjar nesting areas possessed an overall structural similarity; common vegetation structure was also present at several random sites. From the nature of the data collected, it could not be ascertained whether nesting nightjars utilized these randomly located sites, because the random sites measured were dispersed throughout the forest, but the nest searches were restricted to within 100 m of a road/trail.

While the results of the PCA provided insight into the habitat variables that best summarized the total variation of the sample, the CDA derived canonical variables (linear combinations of the quantitative variables) that summarized the between-class variation of the sample. CDA is utilized as an exploratory technique to aid in graphically interpreting group differences (Rao 1973). The distribution of the canonical scores obtained for the vegetation plots

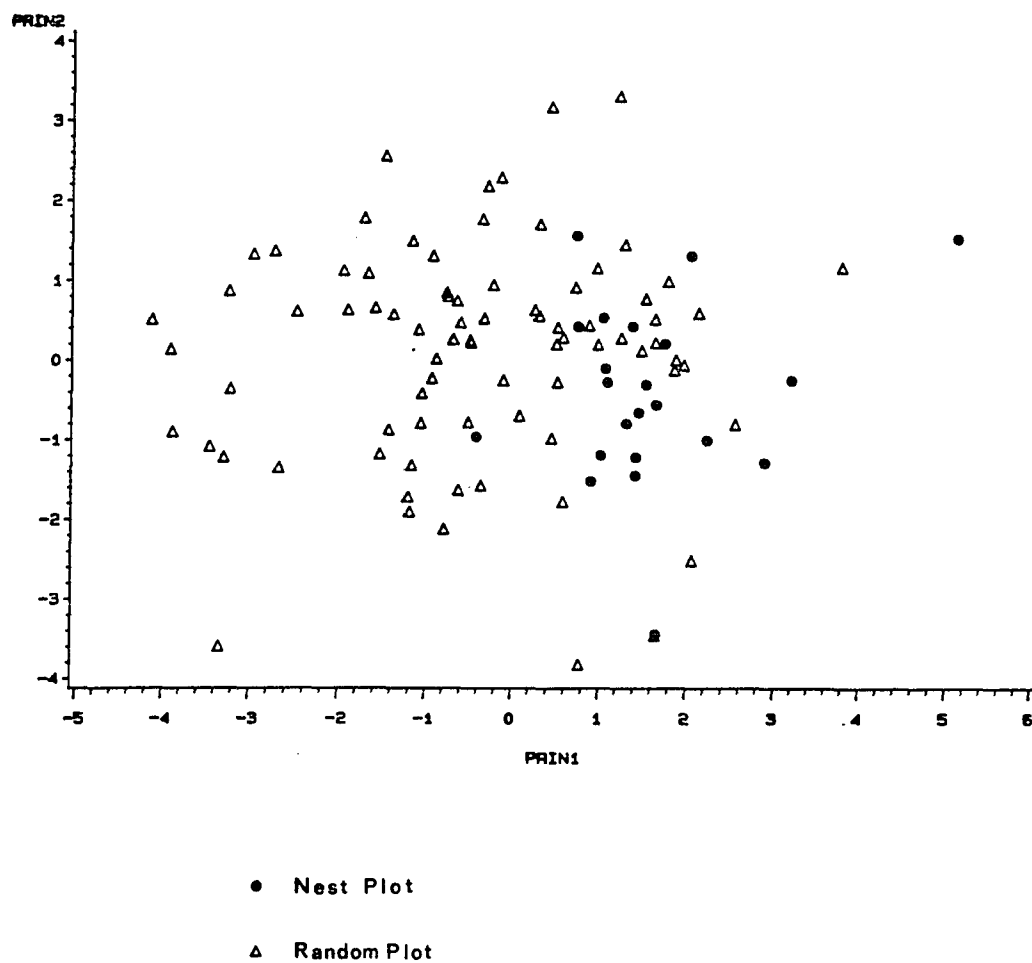


Figure 9. Plot of structural habitat data matrix projected from principal component 1 (PRIN 1) and principal component 2 (PRIN 2).

indicated the nest sites represented a discrete subgroup within the total sample (Fig. 10). The differences between random and nest plots were most affected by leaf litter biomass, amount of cover 50 cm above the plot center, understory density, and density and species richness of the midstory. Sites that have abundant leaf litter, protective cover directly above the nest, an open understory and midstory, and a relatively high number of tree species in the midstory, constitute optimal nightjar nesting habitat. Breeding nightjars apparently selected structural habitat features associated with the first 2 m above the forest floor. Other attributes such as elevation and structure of the overstory did not seem to contribute to the variation between nest and random sites. However, at Guanica Forest the availability of leaf litter and structural complexity of the vegetation are known to increase with elevation and soil development (Lugo et al. 1978).

Nesting nightjars selected sites with a well developed layer of leaf litter (Table 6). Available leaf litter varied greatly at Guanica Forest. Lugo et al. (1978) reported the highest amounts of total litter at Guanica Forest were found in the evergreen-plantation forest followed by the deciduous forest. Loss of leaf litter due to washouts that occurred during heavy rains has been reported at Guanica Forest (Gonzalez-Liboy et al. 1976). Above normal precipitation

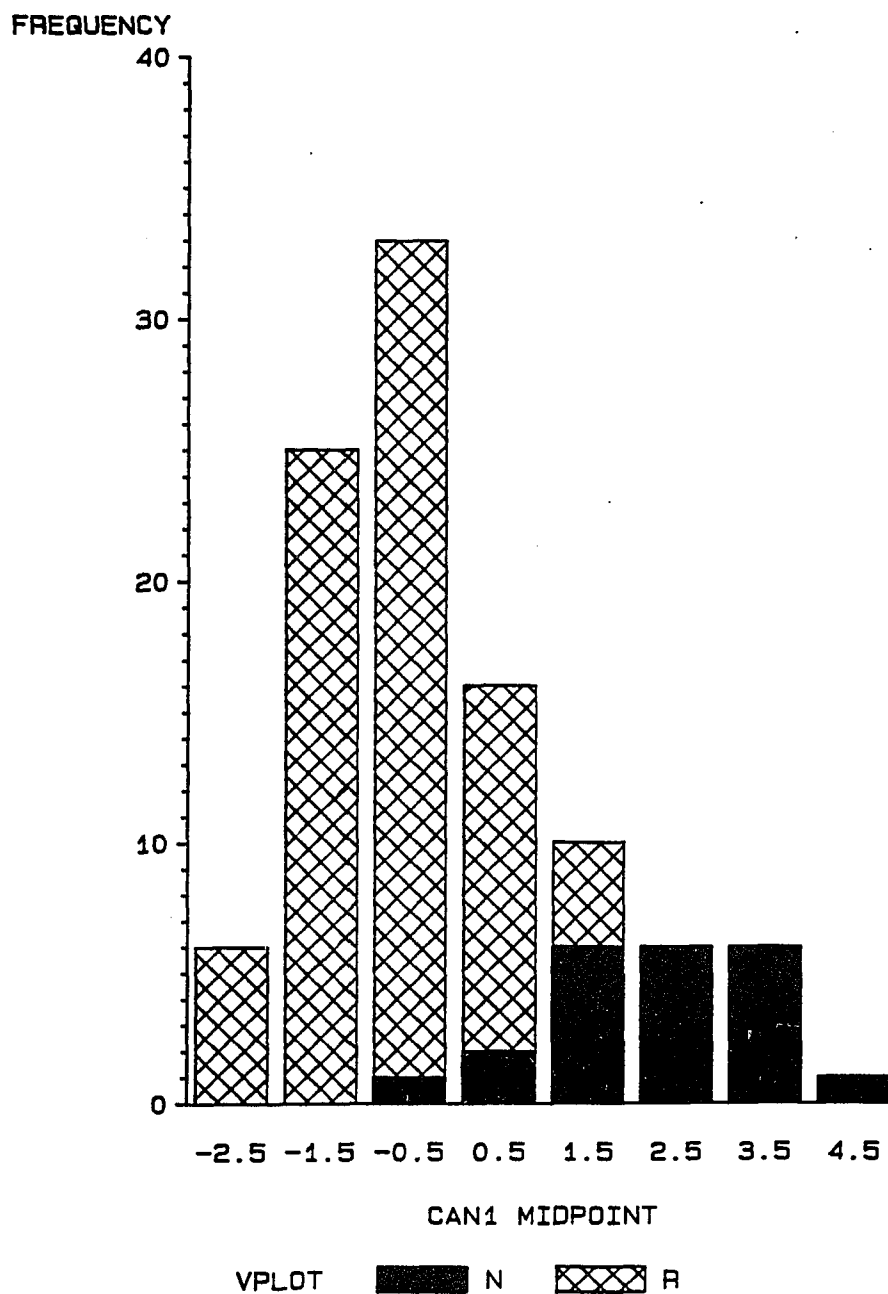


Figure 10. Frequency chart of the vegetation samples plotted by distance from the canonical midpoint.

during the nightjar's breeding season may negatively impact the reproductive output of the species (Fig. 11). Total precipitation during the 1986 breeding season was above average, with a major peak of rain occurring in May (252.5 mm). Nest searching efficiency for the study was lowest during 1986. Only 4.5 % of the areas searched had nesting pairs, compared with 10.6 % for 1985 and 11.2 % for 1987. Furthermore, all instances of predation observed throughout the study occurred during 1986. Perhaps in years of heavy rains, the resulting washouts can cause loss of eggs and/or young. Further, lack of adequate leaf litter camouflage cover could result in increased predation.

The openness of the lower layers of the forest, as well as the species richness of the midstory, appeared to constitute a major requirement of suitable nightjar nesting habitat. Nightjars foraged primarily in these layers. Foraging nightjars always fed well below the canopy and flew about in a slow, moth-like manner. Foraging efficiency may be inversely related to the density of the vegetation within these forest layers. Breeding nightjar pairs apparently selected areas in which to forage most efficiently in order to assure sufficient food for their chicks. Areas of open vegetation near the ground also offered suitable foraging habitat to the fledged young; these were observed to remain within the male's territory for up to a

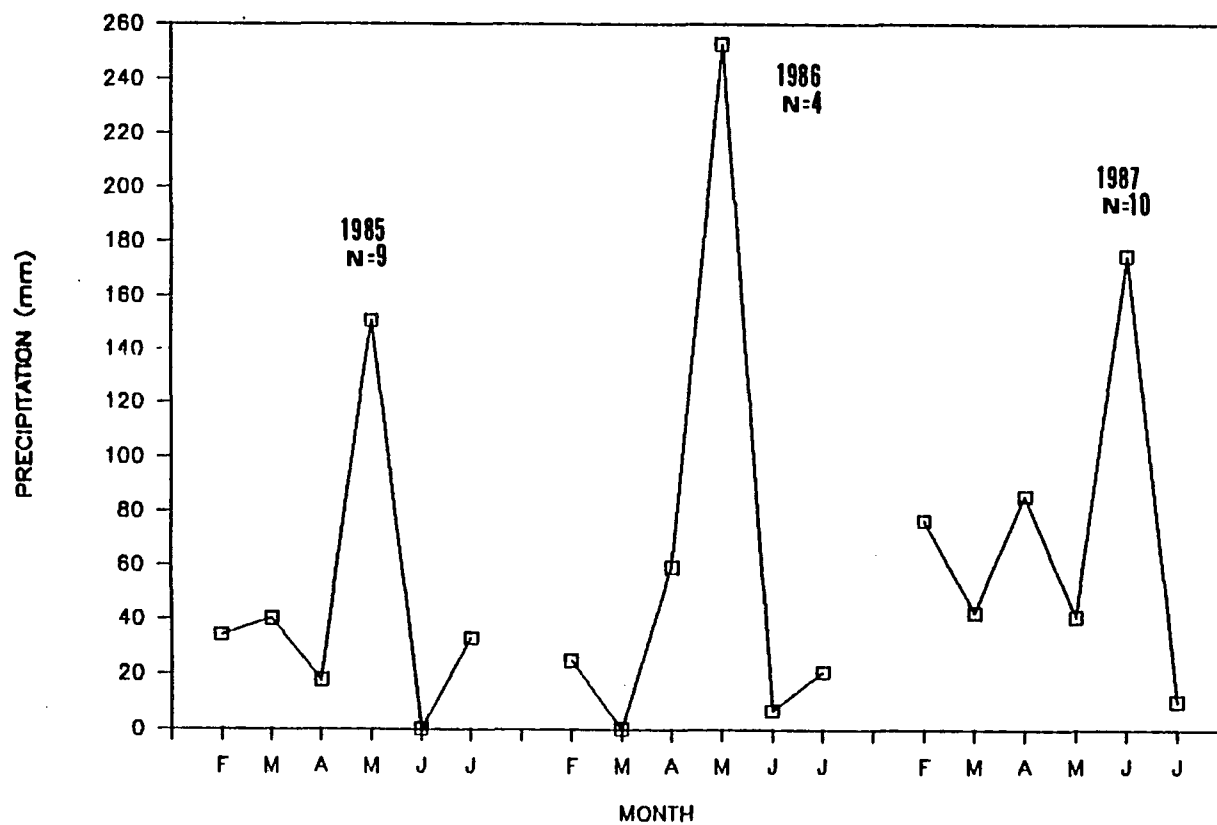


Figure 11. Mean monthly precipitation during nightjar breeding seasons 1985-1987 at Guanica Forest, Puerto Rico. Number of nests located during each year is included (N).

month after fledging. The abundance and quality of available food (aerial insects) could be related to the taxonomic richness of the forest midstory. Blair (1982) reported the number and abundance of nocturnal aerial insect taxa in forested environments was directly related to the species richness of the vegetation.

Many locations searched in the forested uplands of Guanica Forest (e.g. Fig. 2, trails 7, 8, 10) had a continuous canopy with abundant leaf litter. Nightjars were abundant in these areas, and a considerable number (53) of these locations were searched during the study. However, no evidence of nesting activity (breeding/roosting pairs) was ever found at any of these. These areas were all characterized by a dense, tangled understory and midstory. Small trees and shrubs typical of severely disturbed areas such as Lantana involucrata and Croton rigidus dominated the lower layers of the forest. Therefore, I suggest that breeding nightjar pairs were primarily responding to the density of the vegetation and the openness near the ground. At Guanica Forest, the structure of the lower layers of the forest is believed to be directly related to the intensity of past disturbance, and the amount of time a given area has been protected (Canals 1984). The main nightjar nesting areas (Fig. 3) at Guanica Forest were located in what is presently considered to be the best example of climax coastal dry forest in Puerto Rico and possibly

the West Indies (Lugo 1983). This area included approximately 446 ha, 87 % (386 ha) of which occurred in the higher elevation region of Guanica Forest (Fig. 12). Approximately 20 % (89 ha) of these areas are presently located on private property.

At the time of its discovery in 1493, the island of Puerto Rico was almost 100 % forested (Wadsworth 1950). However, by the early decades of the present century, only 3 % of the island remained forested. Guanica Forest was heavily cut during this period, and available nightjar nesting habitat was reduced. Nightjar numbers must have been critically low during this period.

Ironically, it is possible that the small spatial requirements of successful nightjar breeding pairs helped the species survive this period of severe habitat destruction. Plantations of mahogany and logwood (Haematoxylum campechianum) had been established during the 1930's in Guanica Forest (Fig. 13). These were probably the sole continuous canopy fragments found after Guanica Forest had been cut. These stands provided the requirements for nightjar breeding habitat; areas of abundant leaf litter, with little or no vegetation near the ground. At present, these evergreen-plantation areas provide the best known nightjar nesting habitat in Puerto Rico (Fig. 14). Suitable nesting habitat also existed at Guanica Forest in naturally regenerated areas of evergreen and deciduous forest.

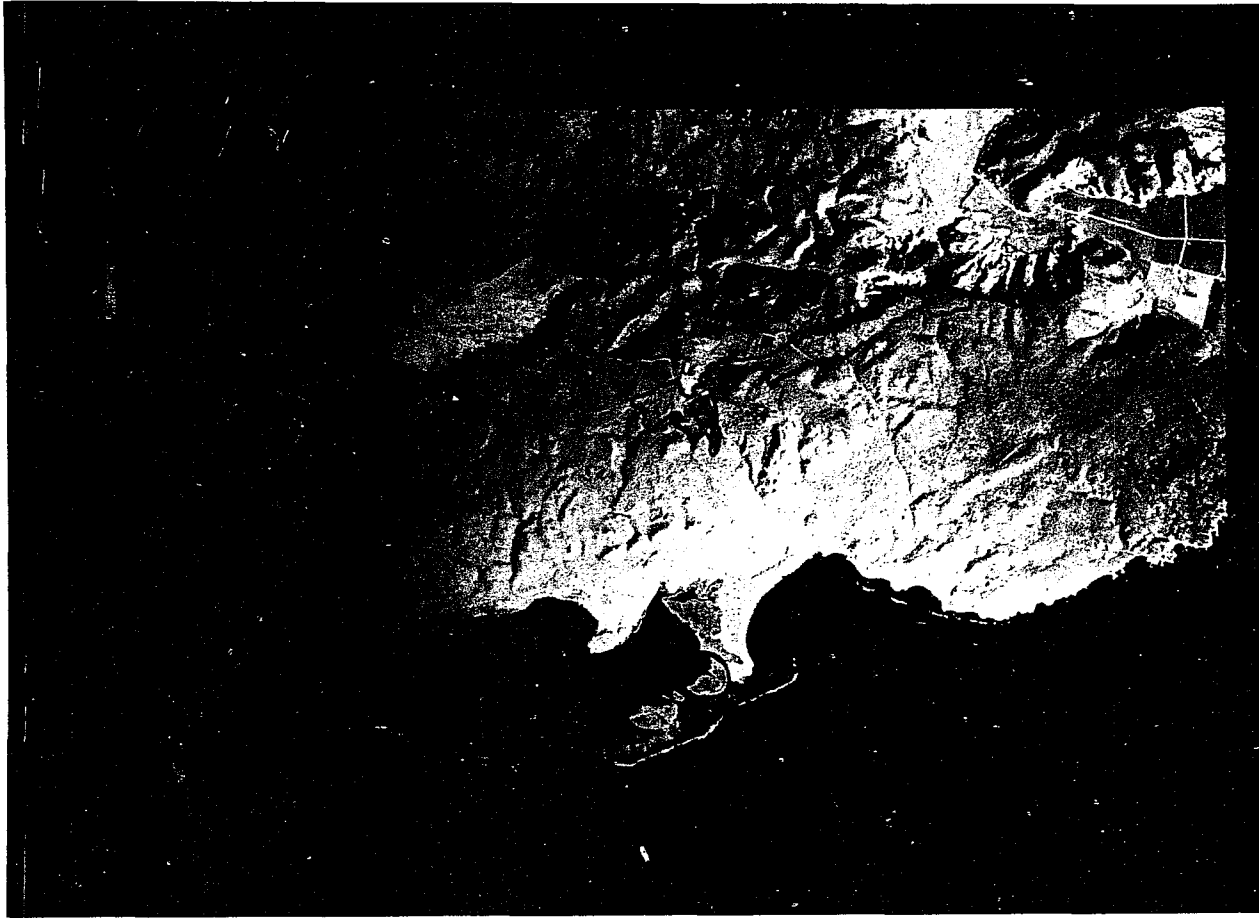


Figure 12. High-altitude, color infrared photograph of the Guanica Forest region. Highlighted areas represent regions of optimal nightjar nesting habitat.

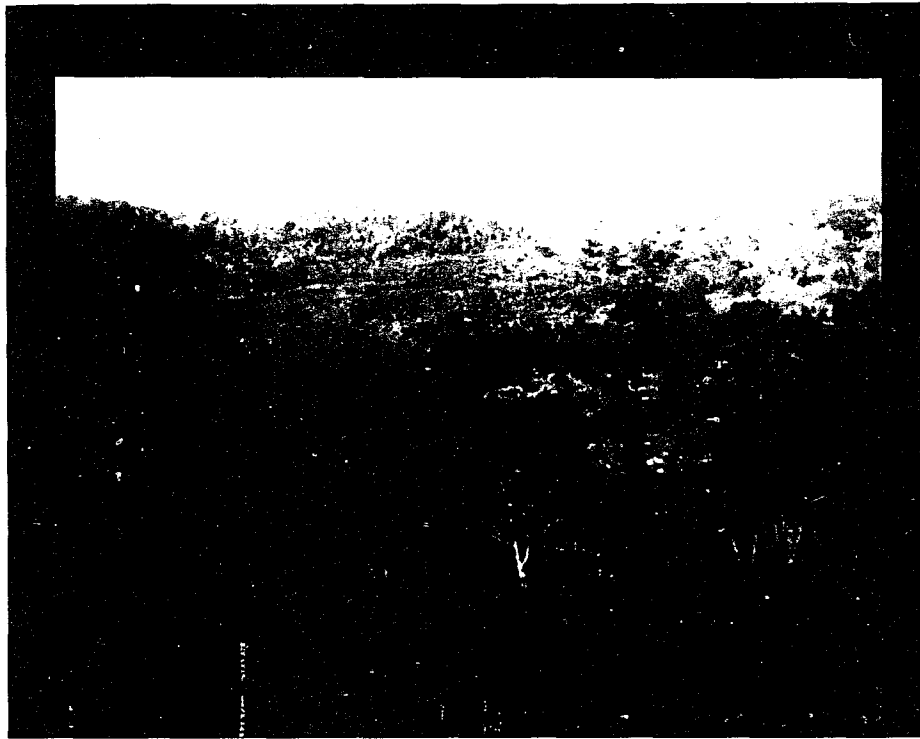


Figure 13. Photograph of the Guanica Forest in 1931 looking southwest from the present day forest headquarters. The forested area in the lower half was a mahogany plantation.

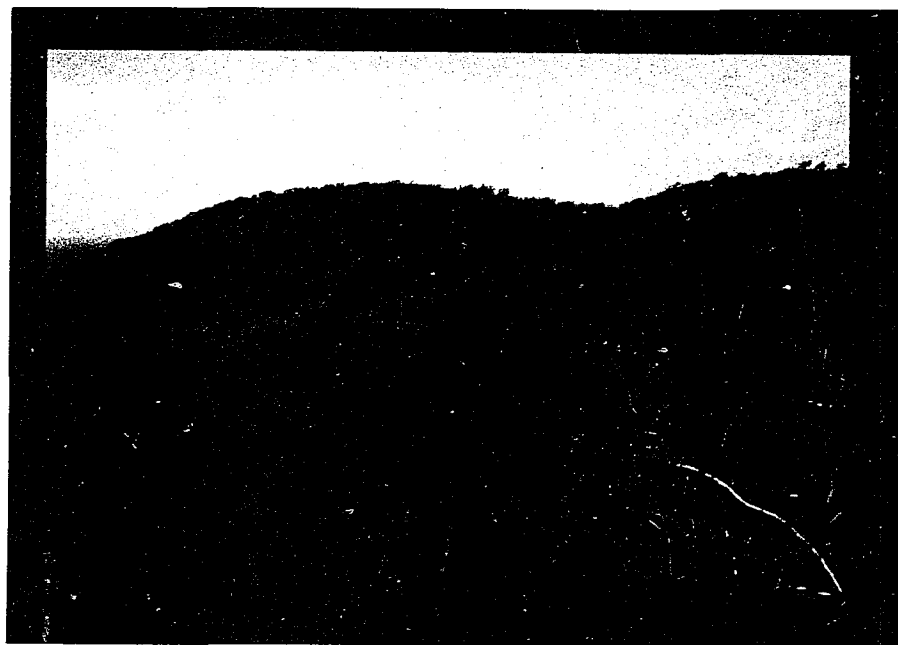


Figure 14. Guanica Forest in 1987. This photograph was taken from the same angle as Figure 13. The dark green trees located to the left are the remaining section of the mahogany plantation, now overgrown by evergreen forest.

Chapter 4. Biology of the Small Indian Mongoose in a Coastal Dry
Forest of Southwest Puerto Rico with Implications for
Possible Interactions with the Puerto Rican Nightjar.

Introduction

The small Indian mongoose Herpestes auropunctatus (Mammalia: Viverridae), hereafter termed mongoose, is a small carnivore originally distributed from northern Arabia, to southern China, India, the Malay Peninsula, Indochina, Sumatra and Java. The species was first described as Mangusta auropunctata and later revised to Herpestes javanicus auropunctatus (Hodgson 1836, Pocock 1937). The latest revision refers to the mongoose introduced into the West Indies as Herpestes auropunctatus auropunctatus (Ellerman and Morrison-Scott 1951, Pearson and Baldwin 1953, Hinton and Dunn 1967).

Mongoose are long and slim, with short legs and a tapered tail. The head is elongated with a pointed muzzle. The ears are small and rounded, and lie close to the head. The claws are long, sharp and non-retractile. Hair is short, alternately banded grey-brown and yellow and gives a speckled appearance to the fur. Females have three pairs of mammae; males have a baculum. Both sexes have an extensible anal pad with ducted glands lateral to the anus (Pocock 1916).

The mongoose was introduced into the West Indies during the 1870's, a period in which the economy of the majority of the Caribbean islands was based on the production of sugarcane. Damage to this vital crop by rats was severe, amounting to 150,000 pounds sterling per year, a considerable sum by 19th century standards. Following the unsuccessful introduction of various animals as biological controls, such as Bufo marinus from Surinam and Formica omnivora from Cuba, an unstated number of mongooses were brought to Trinidad from India in 1870 (Urich 1914).

However, most of the New World mongooses are derived from five females and four males brought from Calcutta to Jamaica in 1872 by W. Bancroft Espeut, a jamaican sugar producer. The idea to introduce mongooses came to Mr. Espeut from his wife, who lived for several years in Ceylon (Sri Lanka) and had there possessed a mongoose as a pet (Espeut 1882). Within 6 months of their introduction there was a noticeable reduction in cane damage, and within 3 years their estate was almost free of rodents.

Following this apparent success, all Caribbean islands with a major sugar industry had acquired mongooses within 30 years (1872 to 1900). The mongoose was also introduced on the mainland of South America in the agricultural areas near the coast. There, it has not extended its range into the interior rain forests or past swampy

coastal areas (Husson 1960). Mongooses were introduced to North America, but eliminated before becoming established (Nellis et al. 1978, Van Gelder 1979).

The impact by the mongoose on the terrestrial vertebrate fauna was quickly noticed in all islands where introductions occurred. Within 15 years of its introduction, it was considered an agricultural pest, and in succeeding years several islands introduced legislation to destroy the mongoose or prohibit its importation (Urich 1914). Many investigators, based on anecdotal information, attributed the decrease in abundance of several reptile species to the introduction of the mongoose (Myers 1931, Lewis 1953). The extinction of the snake Alsophis ater from Jamaica and the extirpation of A. rufiventris from St. Kitts and Nevis are believed to be due to mongoose predation (Westermann 1953). However, A. portoricensis is still common in Puerto Rico where mongooses are abundant.

Although the extirpation of many species has occurred on major islands having mongooses, remnant populations frequently continue to exist on small adjacent cays. The lizard Ameiva polops has been extirpated from St. Croix, but still thrives on nearby Green and Protestant Keys, the latter being less than 122 m from the shore (Philobosin and Ruibal 1971).

The impact of the mongoose on the West Indian avifauna is poorly documented. Mongooses are known to prey on eggs and young of domestic fowl. The decrease of quail doves (Geotrygon sp.) on several islands is believed to have followed mongoose introductions (Allen 1911). In Fiji, the Barred-wing Rail (Nesoclopeus poecilopterus) was generally distributed before the mongoose was introduced in the 1880's, but is now presumed extinct. Four other genera of rails now survive only on islands free of the mongoose (Gorman 1975). Nevertheless, in the West Indies, there are no documented cases of avian extinctions in which the mongoose played a prominent role.

The ornithological survey conducted by Alexander Wetmore (1927) was the first thorough work on the Puerto Rican avifauna completed after the introduction of the mongoose into the sugar producing areas of Puerto Rico in 1877. In it, Wetmore attributed the scarcity of certain species to the presence of the mongoose. The rarity of both species of quail dove, Short-eared Owl (Asio flammeus) and West Indian Nighthawk (Chordeiles gundlachii), all ground nesters, was according to Wetmore, "... without a doubt to be attributed to the mongoose". On the nightjar, whose status he presented as "possibly now extinct", he wrote "The species must have been decimated by the mongoose, since whippoorwills nest and rest on the ground in dense thickets during the day and are active only at night" (Wetmore 1927).

Methods and Materials

I studied the biology of the mongoose during 1987 on the section of Guanica Forest east of Guanica Bay. There, I utilized a removal trapping method and linear trap transects to estimate mongoose density. I used Leslie's depletion method to estimate the total number of mongooses within each transect (Leslie and Davis 1939). This method involves regressing the cumulative catch (Y) against trapping period (X). The intercept (b_0) of the regression line represents the estimated number of mongooses for each transect.

Trap transects were chosen at five different locations along established roads and trails in the forest (Fig. 1). Two transects were located at the lower elevations of the forest (0-75 m MSL) where the predominant vegetation is coastal scrub forest (Gonzalez-Liboy 1976). The remaining three transects were at higher elevations (100-200 m MSL) where the predominant vegetation type is deciduous forest (Gonzalez-Liboy 1976). I placed a Hav-a-hart trap (50x17x17 cm) baited with a fresh egg and a piece of cotton soaked with a fermented egg scent every 50 m along each 0.45 km transect.

Three trapping periods (6-13 May, 28 June-7 July, 1-8 Aug.) were conducted during 1987; each trapping period consisted of from 7 to 10 days. The first 2 days I prebaited the traps and allowed mongooses to

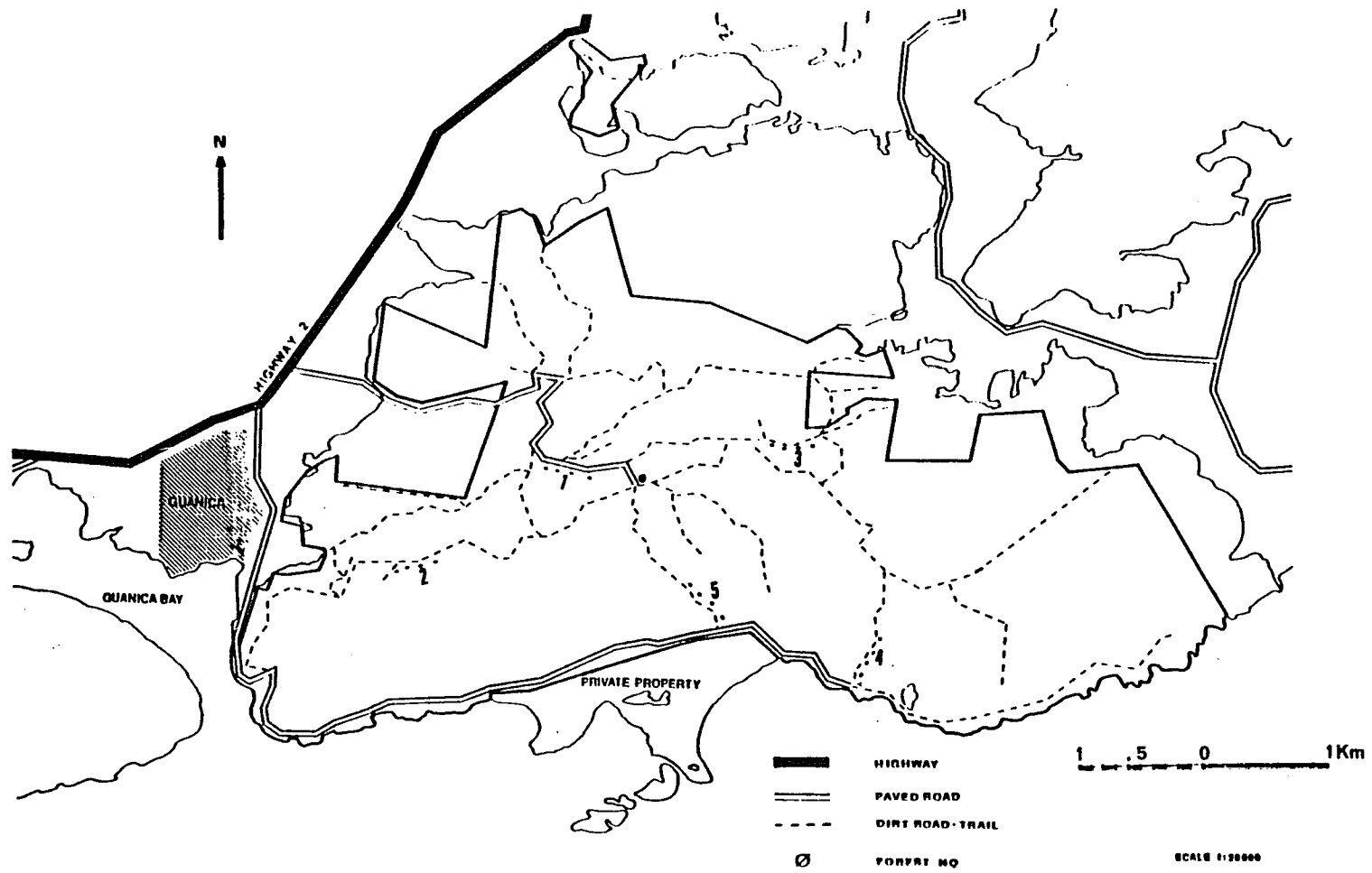


Figure 1. Map of the Guanica Forest and locations of trap transects. Numbers correspond to transects in Table 1.

enter the traps and remove the bait without being captured. During this period, I recorded daily bait removal. Beginning on day 3, traps were set and animals were trapped for 5 to 7 days. Because the mongoose is known to be strictly diurnal (Nellis and Everard 1983), traps were opened at dawn and closed at dusk to prevent rats from setting off the traps at night. Mongooses were euthanized by placing them and the trap with a towel soaked in anesthetic (Halothane) inside a large plastic bag for approximately 2 minutes.

In the field, I recorded sex, total length, tail length and weight of each mongoose captured. Pairwise comparisons of length and weight by sex was analyzed by Student's t-test (Steel and Torrie 1980). Secondary sexual characteristics, pelage and tooth condition were also recorded.

Scats were obtained from some traps. Samples of this fecal material were washed and then suspended in 70 % ethanol. Samples were then washed again and dried in an oven overnight. The samples were then examined under a dissecting microscope to separate food items and under a light microscope for identification.

During morning crepuscular hours of each mongoose trapping day, the number of singing nightjars heard along each trap transect was recorded. Procedures were to walk the transect beginning 30

minutes before sunrise and record the number of nightjars heard. The highest number of nightjars heard was recorded as the minimum number of nightjars within the 0.45 km trap transect. Call counts of nightjars were conducted at least twice for each transect during each trapping period to obtain an estimate of nightjar abundance at each trap transect.

Results

A total of 34 mongooses were trapped during 24 days of trapping (720 trap days) at Guanica Forest from May through August 1987 (Table 1). No mongoose was captured on transect 3 located in deciduous forest, during the entire study. The sex ratio of the sample slightly favored females over males (1.1:1.0), but this difference was not significant ($t = -1.62$, $df = 32$, $P < 0.26$). Males outnumbered females following the first trapping period.

Mean capture rate (Table 2) for the study was 0.08 ± 0.02 mongoose/trap day. Trapping efficiency differed by elevation (above/below 75 m) ($t = 6.19$, $df = 32$, $P < 0.0001$). However, there was no significant difference in capture rate by trapping period (ANOVA; $F = 2.90$; $df = 1,13$; $P < 0.11$). Mean number of mongooses caught per transect declined with repeated trapping (Fig. 2).

Table 1. Results of mongoose trapping on Guanica Forest, Puerto Rico, 1987.

Transect	Elevation (m)	Period 1		Period 2		Period 3	
		Males	Females	Males	Females	Males	Females
1	190	0	2	1	0	1	0
2	130	0	1	1	0	0	0
3	190	0	0	0	0	0	0
4	10	3	5	4	2	2	3
5	40	1	5	2	0	1	0
Total		4	13	8	2	4	3

Table 2. Trapping efficiency during three trapping periods on Guanica Forest,
Puerto Rico, 1987.

Location	Period 1	Period 2	Period 3
Above 75 meters			
Mongoose/trap day	0.014	0.007	0.005
Number of transects	3	3	3
Trap days/mongoose	70	150	210
Below 75 meters			
Mongoose/trap day	0.067	0.027	0.029
Number of transects	2	2	2
Trap days/mongoose	15	37	35

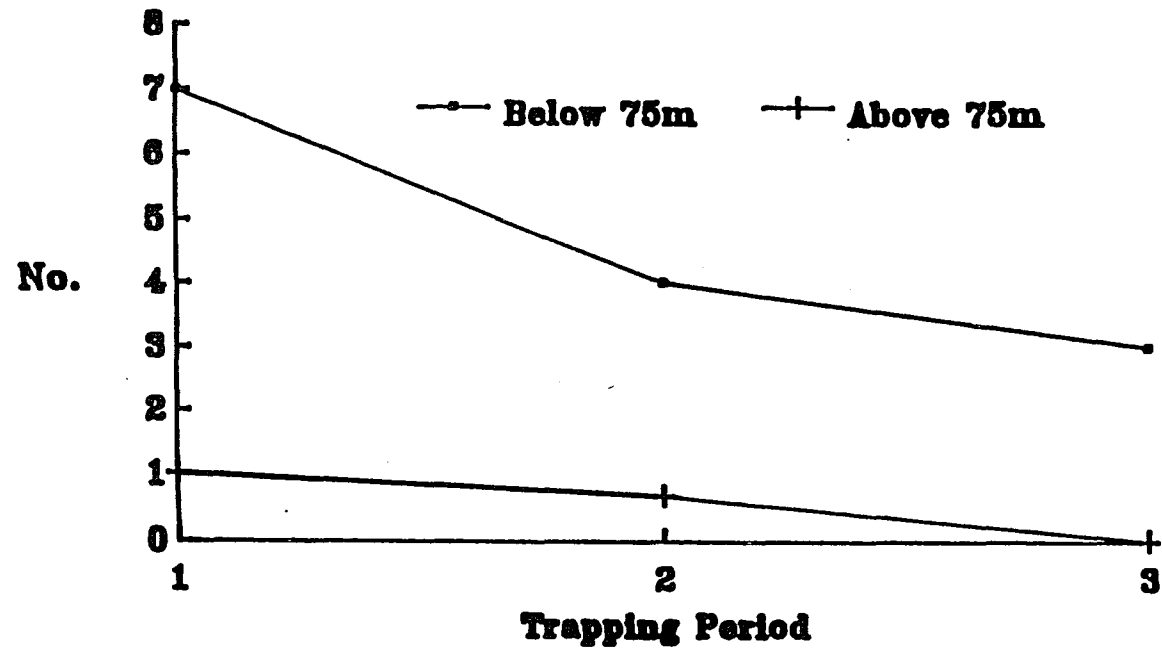


Figure 2. Mean number of mongooses captured by trapping period at Guanica Forest, Puerto Rico.

Estimated density ranged from 0 to 25.7 mongoose/transect ($\bar{x} = 9.3 \pm 9.15$ mongoose/transect) for the entire study area (Table 3). In Guanica Forest, mongooses were significantly more abundant at lower elevations ($t = 5.31$, $df = 32$, $P < 0.0001$). Below 75 m, mongooses averaged 19.0 ± 9.4 mongoose/transect compared to 2.8 ± 2.6 mongoose/transect above 75 m.

Mongooses trapped at Guanica Forest ranged from 51 to 64 cm in length ($\bar{x} = 55.4 \pm 3.6$ cm) (Fig. 3). Males averaged 58.2 ± 3.1 cm and were larger ($t = 6.55$, $df = 32$, $P < 0.0001$) than females which averaged 52.8 ± 1.5 cm. Weights of mongooses appeared to be more evenly distributed by sex (Fig. 4). Weights ranged from 340 to 750 g ($\bar{x} = 555.3 \pm 113.2$ g). Males averaged 587.4 ± 123.9 g and females averaged 526.8 ± 97.5 g. Weights were not significantly different between the sexes ($t = 1.59$, $df = 32$, $P < 0.12$).

All stomachs collected during the study were empty. Most likely, the mongoose's high metabolic rate coupled with the stress of capture and time spent in the trap were responsible for digestion of any food material in their stomach at the time of capture.

The scats from 10 mongooses trapped were analyzed for presence of food items. Of 56 items in the feces, approximately 85 % by volume were animal and 15 % were plant material (Table 4). Insects, of the

Table 3. Estimated number of mongooses by transect on Guanica Forest, Puerto Rico, 1987.

Transect	Area ¹	No	p ²
1	1	5.33	0.0741
2	1	3.00	0.0001
3	1	0.00	0.0001
4	2	25.66	0.0309
5	2	12.33	0.1270

¹₁= above 75 m
²₂= below 75 m

²_{H₀}: b₁=0 (Leslie and Davis 1939)

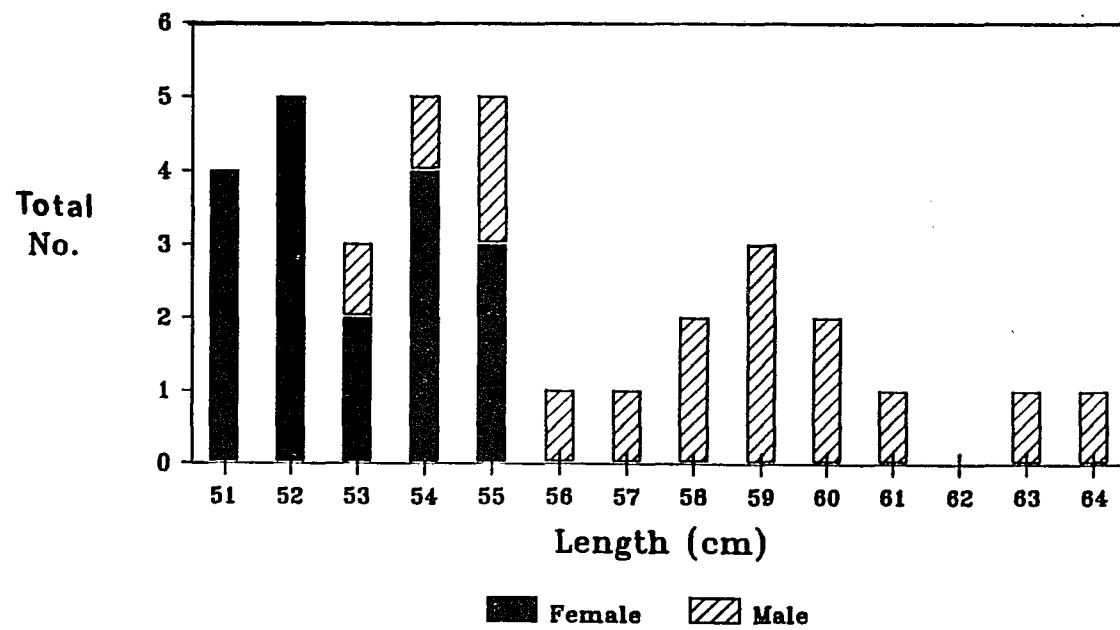


Figure 3. Length distribution of mongooses trapped at Guanica Forest, Puerto Rico.

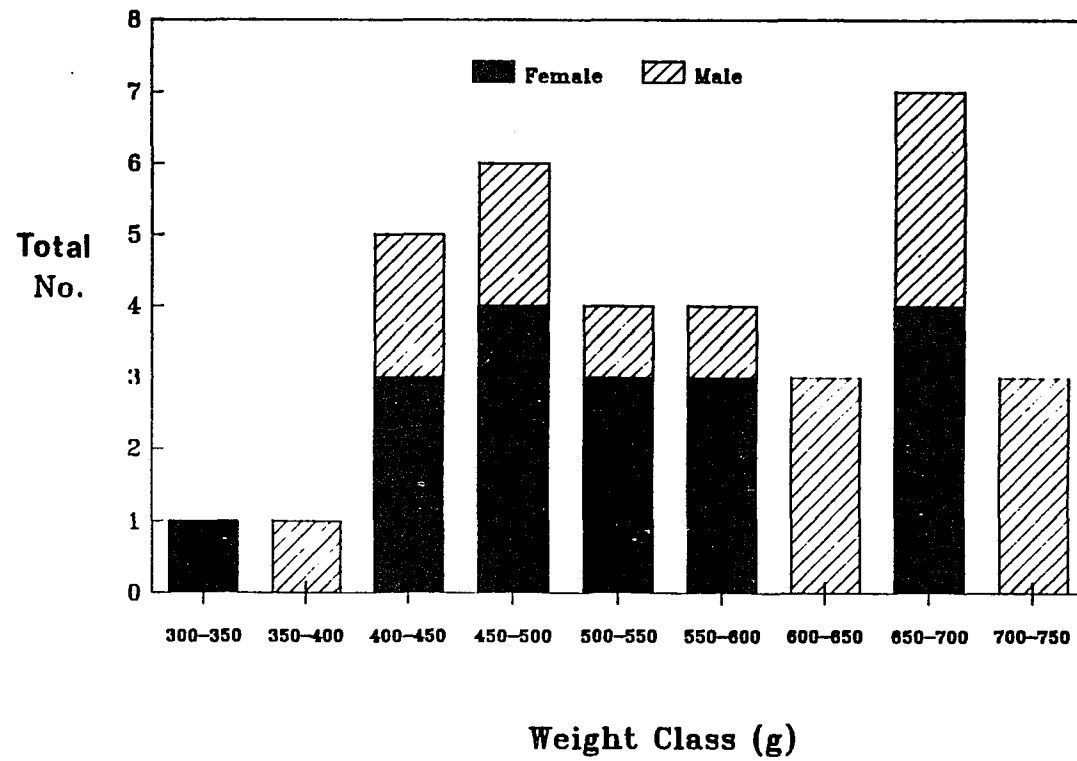


Figure 4. Weight distribution of mongooses trapped at Guanica Forest, Puerto Rico.

Table 4. List of food items identified from scats of mongooses trapped on Guanica Forest, Puerto Rico, 1987.

Items	% by volume
Plant Material	15
<u>Argemone mexicana</u>	9
<u>Panicum maximum</u>	3
<u>Pithecellobium unguis-cati</u>	3
Animal Matter	85
<u>Scolopendra</u> sp.	20
Orthopterans	35
Coleopterans	15
<u>Ameiva</u> sp.	8
<u>Anolis</u> sp.	2
<u>Rattus</u> sp.	5

order Orthoptera and Coleoptera made up about 50 % of the animal specimens. The remainder included centipedes (20 %) (Scolopendra sp.), lizards (10 %) (Ameiva sp. and Anolis sp.) and rats (5 %) (Rattus sp.). The plant material identified was seeds and fruit remains belonging to several species. The most common were mexican poppy (Argemone mexicana), guinea grass (Panicum maximum) and black bead (Pithecellobium unguis-cati).

A total of 44 nightjars were heard singing within the established trap transects (2.25 km) (Table 5). The number of nightjars heard per transect ranged from 3 to 15 ($\bar{x} = 8.8 \pm 4.0$ nightjars/transect). Nightjars were more numerous along the transects found at higher elevations ($t = 8.73$, $df = 42$, $P < 0.0001$). Above 75 m, nightjars averaged 10.4 ± 2.3 nightjars/transect while at lower elevations the mean was 3.5 ± 0.6 nightjars/transect. The number of mongooses and nightjars per transect was inversely related (Fig. 5) ($r = -0.86$, Pearson's r^2).

Discussion

The few mongooses captured on Guanica Forest may have been due to the low trapping effort invested and limited number of locations trapped (Table 1), but the mongoose number on Guanica Forest may

Table 5. Number of mongooses trapped and nightjars heard by transect on Guanica Forest, Puerto Rico, 1987.

Trapping Period	Transects ¹									
	1		2		3		4		5	
	M ²	N ³	M	N	M	N	M	N	M	N
1	2	10	1	11	0	8	8	4	6	3
2	1	7	1	11	0	15	6	3	2	3
3	1	10	0	10	0	12	5	4	1	4
Totals	4	10	2	11	0	15	19	4	9	4

¹1-3= above 75 m

4-5= below 75 m

²M= number of mongooses trapped

³N= highest number of nightjars heard

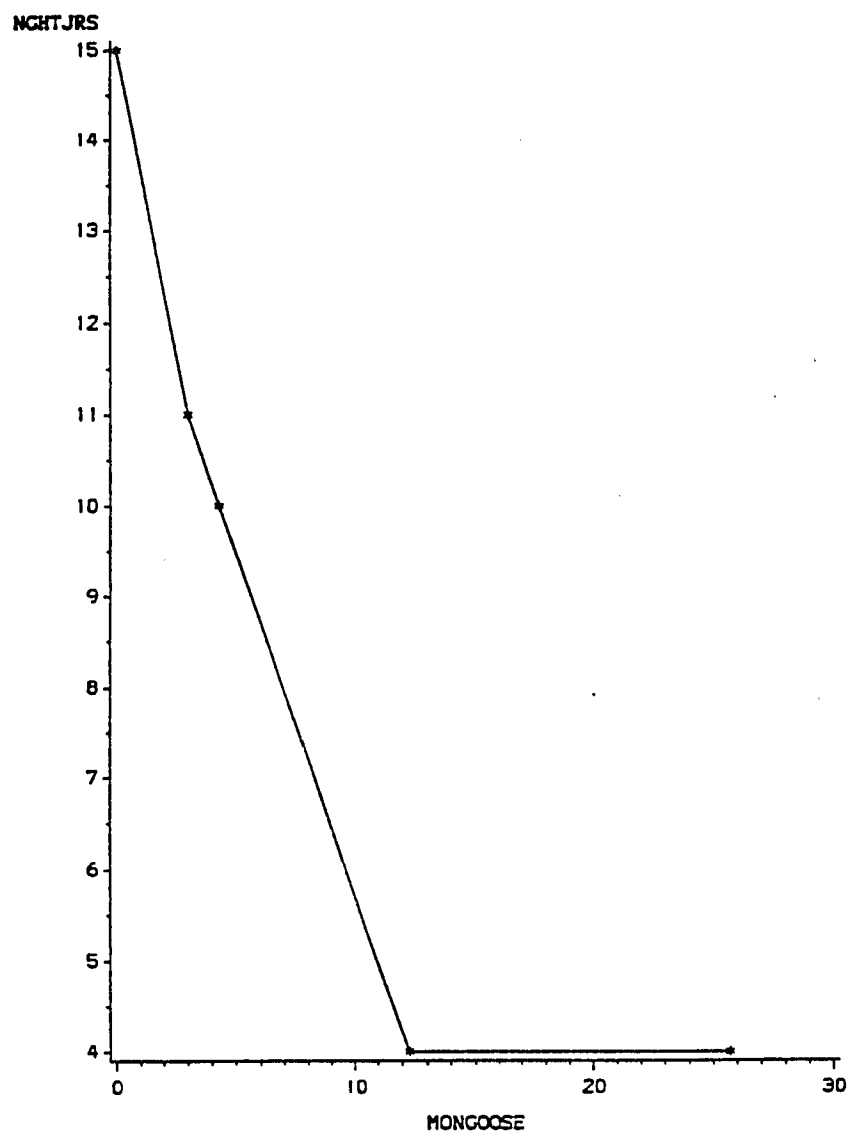


Figure 5. Plot of total number of mongooses captured and highest number of nightjars heard for each 0.45 km trap transect at Guanica Forest, Puerto Rico.

actually be low, because trapping efficiency (catch per unit effort) was one of the lowest reported to date (Nellis and Everard 1983, Coblentz and Coblentz 1985).

Mongoose on Guanica Forest apparently prefer the lower elevations, this may reflect the mongooses's preference for open grasslands and savannas with nearby sources of water in coastal lowlands of Puerto Rico (Pimentel 1955, Nellis and Everard 1983). Above 75 m, Guanica Forest was heavily forested with few water sources. The only sources of water were natural depressions in the limestone and intermittent streams along drainage areas that were available for only a few months following the rainy season. Furthermore, below 75 m there were year-round sources of water, both natural and man made. A cave system north of transect 4 contained underground streams that flowed to the coast year-round. I commonly observed mongoose tracks at the cave entrances. There were also several sinkholes leading to the same underground spring system south of transect 5. In addition, artificial sources of water existed adjacent to the forest along the coast because nearby private property had been developed into a hotel, small marina and private homes (Fig. 1). Garbage bins at lower elevations also provided food that the mongoose could exploit; mongooses are known to regularly feed from garbage bins (Coblentz and Coblentz 1985).

Differences in vegetation due to elevation may also have contributed to the elevational differences in mongoose abundance on Guanica Forest. Grassland areas created by periodic fires and historical overgrazing by goats were common at low elevations in Guanica Forest. Pimentel (1955) found mongoose density in Puerto Rico to be lowest in forested areas, even when water supplies were abundant. The largest densities were found in grass dominated regions, particularly near small streams in the coastal lowlands.

Of the 18 female mongooses trapped, 13 (72 %) were found to be either pregnant or lactating when caught. Pimentel (1955) found mongooses breeding in Puerto Rico from January to October. On the Guanica Forest, social groups consisting of a female and two young were seen during May and June. Every time these groups were observed the female was posted as a sentry above a fallen log or a limestone outcrop while the young foraged about.

Weight and length of all mongooses trapped were well within the range previously obtained for the species in the West Indies (Nellis and Everard 1983). All individuals appeared to be in excellent condition; none showed signs of tooth wear and all had clean well groomed pelages. Mongoose populations previously sampled on Hawaii and several other Caribbean islands excluding Puerto Rico, had a large

proportion of individuals with badly worn teeth and pelage (Baldwin et al. 1952, Nellis and Everard 1983). Thus, while not abundant, mongooses at Guanica Forest were very healthy animals.

The diet of the mongoose in coastal dry limestone forest of Puerto Rico was similar to that found on other islands (Table 4). The bulk of the animal matter consumed consisted of centipedes and insects in the orders Orthoptera and Coleoptera. Wolcott (1953) examined the stomach contents of 98 mongooses collected from St. Croix and Puerto Rico and found centipedes and tarantula spiders (Cyrtopholis sp.), together with insects in the orders Orthoptera, Coleoptera and Diptera to be most common.

In Guanica Forest, the seeds of the mexican poppy were the most common plant material consumed. This herbaceous plant, common throughout the forest, produces large seed heads that were apparently consumed whole by the mongoose as remains of the capsules were found in some scats examined. Mongooses consume a variety of plant material that may represent an important source of nutrients (Gorman 1975, Nellis and Everard 1983).

Vertebrate prey was uncommon in the fecal samples. Bone fragments belonging to lizards from the genera Ameiva and Anolis were detected in only 3 of the 10 scat samples and only 2 of the samples

contained small masses of rat hair. Although no remains of birds were found in the scats, the mongoose apparently does prey upon birds at Guanica Forest. I saw mongooses in the field carrying birds between their jaws on two occasions during the course of the project. On 27 May 1986 at 1015 hrs, a mongoose crossed a forest trail carrying a Greater Antillean Grackle (Quiscalus niger). The mongoose was holding the bird by the back of the neck as it moved casually across the trail. The observation occurred on a trail leading to the coast, at about 25 m elevation. Later that same year, on 11 August at 1330 hrs, I saw a mongoose crossing the road leading to the forest headquarters while holding a Common Ground-Dove (Columbina passerina) in a similar fashion. This observation took place on deciduous limestone forest at approximately 175 m elevation. Further, the first nightjar nest located during 1986 was probably destroyed by a mongoose.

Nightjar and mongoose numbers were inversely related on Guanica Forest. This relationship is correlational and no inference on causality can be made. Thus, no definitive statement can be made on whether nightjars are limited by mongooses. Predation by the mongoose could have eliminated the nightjar from its former range and currently limit the species to dry areas unable to support large mongoose numbers.

An alternative hypothesis is that the habitat requirements of each differs and each may be limited by the availability of suitable habitat. Apparent avoidance of the higher elevation areas of the forest by the mongoose may be due to the low availability of surface water and the dense vegetation of the forested uplands. Reduced numbers of nightjars at lower elevations reflects the species need for a closed canopy environment. To add support to this hypothesis, nightjars occur in the highly disturbed forestlands of the Guayanilla hills. There, the presence of streams, grazing and agriculture allows dense mongoose numbers, yet the nightjar is still to be found, albeit in small numbers.

Chapter 5. Summary and Management Recommendations

Project Summary

I surveyed nightjars in the moist coastal forests of northern Puerto Rico and found none. Previous estimates of the distribution of the species suggested that the nightjar had been limited to 3 % of its former range (Kepler and Kepler 1973), but the evidence available on the nightjar's past presence in northern Puerto Rico is scant and the former status of the species cannot be definitely ascertained. Nevertheless, nightjars did exist in some areas of the moist coastal forests of Puerto Rico until the early decades of the present century.

Based on the available biogeographical information on the flora and fauna of the West Indies during Pleistocene climatic cycles, arid conditions prevailed during the last glaciation because of a reduction in rainfall and humidity (Bonatti and Gartner 1973). Furthermore, as indicated by fossils, caprimulgids already formed part of the West Indian avifauna at this time (Olson 1978).

During the late Pleistocene, xeric environments extended throughout the lowlands of the Puerto Rican Bank. This insular platform extended from Puerto Rico to Anegada, with the exclusion of Mona and St. Croix.

Coastal dry forest was the dominant life zone of this region. About 7,000 years ago, the Puerto Rican Bank became fragmented by rising sea level at which time the Virgin Islands were separated from each other and from the Puerto Rican mainland (Heatwole and MacKenzie 1967).

In the West Indies, global climatic changes resulted in numerous extinctions of plant and animal species typical of arid life zones. Therefore, with the retreat of the coastal dry forests in Puerto Rico, small relict nightjar populations may have continued to survive in the moist coastal forests now predominant in all but the southwestern portion of the island. These small, isolated populations may not have tolerated the combined effect of massive deforestation and introduced ground predators that followed the discovery of the island.

Nevertheless, I found nightjars in several areas of dry limestone forest in southwestern Puerto Rico. Potential available habitat was determined from ground and aerial surveys. Nightjars were readily detected by utilizing playback recordings of singing males. The number of singing nightjars heard along the survey routes was significantly greater in winter (Jan.-Feb.) than summer (July-Aug.). The presence of nightjars was documented at a number of new locations, most of which were within privately owned lands. In the lower cordillera forest region of Susa and Maricao, 141 nightjars were

detected in 2,744 ha surveyed. Approximately 18.5 % (506.8 ha) of the area surveyed was privately owned. Nightjars occurred in disturbed areas, although in small numbers. In this region, nightjars were densest in the southern regions of Susua Forest and rare in the wetter, higher elevations of Susua and Maricao forests.

In the Guanica Forest region, nightjars were found both east and west of Guanica Bay. However west of Guanica Bay, nightjars occurred in low numbers and were mostly restricted to small areas that totaled 803.8 ha of coastal dry forest located at higher elevations in both public and private lands. Nightjar distribution in this region was centered in the forested uplands east of Guanica Bay that had the highest recorded densities of singing nightjars (5.0 ha/nightjar). Additionally, birds were often heard singing at low elevations (< 25 m) near the coast.

A total of 2,700 ha of privately owned forestland was surveyed in the Guayanilla hills region. Nightjars were most common in the western section of this region. Approximately 700 ha of mature dry forest currently exist. However, forested areas presently occupied by nightjars in the Guayanilla hills region are rapidly being converted to other uses. Some forestlands located within the areas surveyed were being cleared during the study period.

The nightjar surveys conducted throughout southwestern Puerto Rico covered approximately 70 % of the existing available habitat; some forested areas within, or adjacent to, the study regions were never surveyed because of accessibility and/or time limitations. A total of 676 singing nightjars were recorded in 9,838.7 ha surveyed. However, based on the total estimated area of available habitat, as many as 1,200 birds may have been occupying 15,000 ha of forestland throughout southwestern Puerto Rico.

The reproductive ecology of the nightjar was studied at the Guanica Forest from 1985 to 1987. Nightjar males sang and appeared to maintain territories year-round. Calling rates and territorial encounters increased by December, reached a peak by mid-May, then decreased by late July. From August to November, singing and calling decreased considerably.

A total of 23 nesting pairs were located during the study. Courtship activity occurred 2-3 days before the eggs were laid. Nests were initiated between 24 February and 2 July. Courtship and laying activities were most common during the last quarter and new moon phases. Clutch size was 1-2 eggs, these were incubated on a scrape in the leaf litter for 18-20 days. Incubation was mostly performed by the males; some females would relieve their mates during twilight peak singing hours after an elaborate nest relief ceremony. Hatching dates

were centered around the last 3-5 days of the first quarter and during the full moon phases.

Semiprecocial chicks averaged 4.13 ± 0.02 g when hatched, and were capable of short distance movements within hours of hatching. Chicks were fed by regurgitation during twilight and night hours and mostly by the male. Chicks fledged after 14-16 days and could fly short distances by this time; they remained on the male's territory for up to a month after fledging. Predation on eggs, chicks, juveniles, and breeding adults was documented for Pearly-eyed Thrasher, fire ants, Short-eared Owl and small Indian mongoose, respectively.

The movements of breeding nightjar males were investigated by monitoring two males fitted with radiotransmitters for 2-3 weeks during the breeding season. On average, breeding nightjar males covered between 57 m and 66 m with every move. The maximum distance covered in a single move by an instrumented male nightjar was 360 m. The primary areas utilized by each male at any one time were 4.8 ha (N6) and 5.6 ha (N18). Number of movements was higher during twilight than night periods and was higher during dusk compared to dawn. Females, infrequently seen within 50 m of the nest site, roosted on the ground or perched sideways on a low branch during the day.

Nightjar nests were located in the dominant plant associations of the forested upland areas at Guanica Forest. Nests ranged in elevation from 50 m to 220 m and were found in evergreen forest, deciduous forest, and mahogany plantation areas located at higher elevations in the reserve. On average, I found successful breeding pairs on 8.5 ± 3.5 % of the areas searched. Searching efficiency along roads and trails ranged from 4.5 % to 11.2 %. The primary areas of breeding activity at Guanica Forest were within the oldest and most pristine tracts of coastal dry forest. These areas corresponded to those parts of Guanica Forest that have been protected from disturbance for the longest period of time (since 1919).

I used multivariate analysis of the structural habitat data collected at nest and random sites and found that nesting sites had larger amounts of leaf litter biomass, more overhanging nest cover, and more openness of the understory and midstory than randomly selected sites. However, within the forested upland areas found at higher elevations, the openness of the lower layers of the forest appeared to be the main factor to which nightjar pairs were responding when selecting a nest site. The loss of leaf litter from the forest floor during years of high precipitation probably negatively affected reproductive output due to loss of protective cover, nest washouts, and increased predator activity.

Density estimates and habitat utilization of the small Indian mongoose at Guanica Forest were investigated during 1987. Mongooses were trapped on 3 separate occasions for 5-7 days from May through August along five 0.45 km trap transects established in different regions of the forest. Concurrently, nightjar call counts were conducted along each trap transect during every trapping period. Mongooses were found to be significantly more abundant at elevations below 75 m than above. Trapping efficiency differed by elevation and declined with repeated trapping. Males outnumbered females following the first trapping period. Males were found to be significantly longer than females. However, no significant difference was found in weight between the sexes.

The diet of the mongoose at Guanica Forest was analyzed from the contents of fecal samples. Orthopterans and Coleopterans made up about 50 % by volume of the animal matter identified. Remains of centipedes, lizards, and rats were also detected. Seeds and fruit were the most common plant material found; seeds of the mexican poppy appeared to make up the majority of the plant matter consumed.

A strong negative correlation was obtained between number of mongooses and number of nightjars at Guanica Forest. Nightjar numbers were significantly greater above 75 m than below. This inverse

relationship may be due to predation on nightjars by the mongoose or to the particular habitat requirements of each species. Mongooses apparently avoided the heavily forested regions of Guanica Forest. This was probably because of the low availability of surface water and the presence of a closed canopy.

Management Recommendations

The ultimate goal of endangered species management should be the eventual recovery and delisting of the organism in question. If the objectives of the recovery plan approved for the nightjar (Diaz 1983) are to be met, several habitat management alternatives should be pursued.

The habitat management options available for the nightjar at present depend primarily on whether the birds are found on private or public lands. Management on private lands is more restricted by the limitations in accessibility and control over land use practices than on public lands. I therefore present separate management alternatives for the species in private and public lands.

Private Lands

The most pressing conservation need for nightjar habitat within privately owned land is habitat acquisition. Nightjars occurred at moderate to high densities on a number of privately owned areas of dry limestone and lower cordillera forests in southwestern Puerto Rico. Of these, the most critical areas are in the Guayanilla hills because at present, no protected areas exist. Acquisition of approximately 500 ha of dry forest would insure the protection of the best nightjar habitat found within this area (Chapter 2, Fig. 5 routes 8, 9, 12, 13). This region also includes life zones found in limestone gorges that are presently not represented in any protected area of southwestern Puerto Rico (Cintron and Beck 1977). Similarly, private lands adjacent to the southern boundaries of Susua Forest (Chapter 2, Fig. 3 route 6) should also be considered for acquisition. These privately owned lands are some of the few remaining areas of coastal dry-lower cordillera ecotonal forest. Approximately 150 ha appear to constitute the most suitable nightjar nesting habitat. Additionally, small sized (30 ha) tracts of privately owned forestland located on the northeastern boundary of the Guanica Forest were found to possess some of the most pristine examples of mature deciduous forest. This area is located on the highest elevations of the reserve at the eastern end of survey route 11 (Chapter 2, Fig. 4).

It is unrealistic to assume that all of the best remaining tracts of coastal dry forest will be acquired and preserved. Therefore, provisions should be taken to mitigate the impacts of changes on areas that presently possess nightjars and will likely remain under private ownership. Information on the status of the nightjar and the desirability of conserving the region's coastal dry forests should be made available to the pertinent landowners through the Puerto Rico Department of Agriculture's extension service. Additionally, agroforestry practices that promote the establishment of mahogany plantations and use of native deciduous tree species (e.g. Bucida buceras) for reforestation should be strongly encouraged. Conversely, land uses such as industrial and residential development that promote forest clearing of privately owned nightjar habitat should be discouraged.

Public Lands

The most effective measures to insure the continuing existence of the species can be applied on those lands presently under public ownership, namely the Susua and Guanica forests. The designation of both reserves, particularly Guanica Forest, as critical habitat by the

federal government would provide additional protection and insure the species continued existence. Major improvements would be obtained if Susua Forest were designated as critical habitat and lands on the southern boundaries of the forest were acquired. Similarly, special designation of Guanica Forest would help to protect the area from existing developmental threats. The opening and development of the forest road system has been proposed several times to provide a direct access for residents of the Yauco and Guayanilla municipalities, both located northeast of Guanica, to the recreational areas on the coast. However, the importance as nightjar nesting habitat of those areas located along the forest roads and trails has been clearly demonstrated by the results reported here and it is imperative that the present state of the Guanica Forest system of trails remains undisturbed. Additionally, no further development of the private property located on the southern boundary of the forest can be permitted if the latter requirement is to be met.

The above mentioned measures apply to the Guanica Forest as a whole; however, some local management alternatives should also be explored. The main factors associated with the use of some areas by breeding nightjars in the uplands regions of the forest were the presence of dense, tangled vegetation within 2-3 m of the ground. These results were utilized in an exploratory way to illuminate

ecologically meaningful relationships and serve as a basis for future experimental work. Thus, further research should concentrate on experimental testing of the hypotheses raised by this study.

For example, the effect on nightjar habitat use of experimental manipulation of the vegetation in the lower layers of the forest should be investigated. Depending on the location of the forest where this is done, either mechanical removal or small scale, controlled burns could be utilized. This may help to increase the productivity of nightjars at Guanica Forest. Finally, mongoose trapping from April to June at the forest headquarters and surrounding visitor facilities may help to reduce the risk of losing breeding adults (e.g. N10) to predation because the refuse generated by visitors and forest personnel could be attracting mongooses to these areas.

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APPENDIX A

Species dominance (stems/ha) in nightjar nesting areas on the deciduous forest associations on Guanica Forest, Puerto Rico. Data are based on 0.05 ha nested circular plots.

Appendix A. Species dominance (stems/ha) in nightjar nesting areas on the deciduous forest associations on Guanica Forest, Puerto Rico. Data are based on 0.05 ha nested circular plots.

Species	Nest											
	1	2	3	4	5	9	11 ¹	14	19	20	21	22
<u>Exostema caribaeum</u>	920	40	140	80	240		160	40		100	80	100
<u>Pisonia albida</u>		20			40	20	40		20		60	60
<u>Bourreria succulenta</u>				20	220					20	200	
<u>Cephalocereus royeri</u>	60		20	20	20		60	60				
<u>Leptocereus quadricostatus</u>		40							20			
<u>Amyris elemifera</u>	80	160	20	40		120	60	40	20	40		40
<u>Krugiodendron ferreum</u>			20						20	60		20
<u>Pictetia acuelata</u>	120	20	20					20	40		20	20
<u>Thouinia portoricensis</u>	60	180	240	160	40	20	140	80	80	20		180
<u>Capparis cynophallophora</u>			40				20					
<u>Zanthoxylum flavum</u>		40		20								20
<u>Pithecellobium unguis-cati</u>			20	40			80	40	40			40
<u>Guaiaacum officinale</u>	60				60		20					

Continued.

Appendix A. Continued.

Species	Nest											
	1	2	3	4	5	9	11 ¹	14	19	20	21	22
<u>Bucida buceras</u>		100	120	60		140	120	80	240	220	100	40
<u>Bursera simaruba</u>	20	20	20			40	20		60	100	40	40
<u>Guettarda krugii</u>	40		20	20			40					
<u>Antirhea acutata</u>	80	60		100			40		20		100	80
<u>Hematoxylum campechianum</u>	40			120				240				
<u>Randia aculeata</u>		80		20	80	60						
<u>Eugenia foetida</u>		20		120	60	80	100		160			
<u>Eugenia rhombea</u>						80		60		240	60	
<u>Eugenia floribunda</u>									60	40		
<u>Coccoloba diversifolia</u>		100	20									
<u>Helicteres jamaicensis</u>				60		20			20			
<u>Erythroxylum aerolatum</u>				60						40		
<u>Schaefferia frutescens</u>				20	20							

Continued.

Appendix A. Continued.

Species	Nest											
	1	2	3	4	5	9	11 ¹	14	19	20	21	22
<u>Crescentia linearifolia</u>				100	40			40	20	20		
<u>Reynosa uncinata</u>					20	60	20		100			
<u>Reynosa guama</u>								60				
<u>Sapindus saponaria</u>					40		20				20	40
<u>Colubrina arborescens</u>							20					
<u>Gymnanthes lucida</u>							40	80	20			
<u>Plumeria alba</u>							40					
<u>Adelia ricinella</u>						60						
<u>Clusia rosea</u>									40			
<u>Sweetenia mahogany</u>				40	280							

Continued.

Appendix A. Continued.

Species	Nest											
	1	2	3	4	5	9	11 ¹	14	19	20	21	22
<u>Albizia lebbeck</u>			20	100	160		80	60				
<u>Leucaena glauca</u>						20						
<u>Sabal causiarum</u>						120						
<u>Thrinax morrisii</u>									100			
<u>Croton rigidus</u>	40	180	180		100	40	180	120			180	160
<u>Lantana involucrata</u>	20		40								20	
<u>Comocladia dodonea</u>									20		60	
Total	1540	1060	940	1200	1420	880	1300	1020	1100	900	940	840

¹Nest 11 and Nest 16

APPENDIX B

Species dominance (stems/ha) in nightjar nesting areas on the evergreen and plantation associations on Guanica Forest, Puerto Rico. Data are based on 0.05 ha nested circular plots.

Appendix B. Species dominance (stems/ha) in nightjar nesting areas on the evergreen and plantation associations on Guanica Forest, Puerto Rico. Data are based on 0.05 ha nested circular plots.

Species	Nest									
	6	7	8	10	12	13	15	17	18	23
<u>Exostema caribaeum</u>	20	20		120	380	100	740			
<u>Pisonia albida</u>	20									20
<u>Bourreria succulenta</u>	20		60		180	160	60			40
<u>Cephalocereus royenii</u>	20			80	20					100
<u>Opuntia rubescens</u>										260
<u>Amyris elemifera</u>	60	80		20	200		100			
<u>Bucida buceras</u>				140		20	20			160
<u>Bursera simaruba</u>				20			20			80
<u>Guettarda krugii</u>	40		20			180	40			
<u>Antirhea acutata</u>				60		60	40			
<u>Hematoxylum campechianum</u>	140								340	
<u>Randia aculeata</u>		40	180					60		
<u>Eugenia rhombea</u>	100		20	60		100	40		20	

Continued.

Appendix B. Continued.

Species	Nest									
	6	7	8	10	12	13	15	17	18	23
<u>Coccoloba diversifolia</u>		60								
<u>Coccoloba microstachya</u>	40	20						40	40	
<u>Helicteres jamaicensis</u>							20			
<u>Erythroxylum aerolatum</u>		220						140	20	
<u>Schaefferia frutescens</u>					20			40		
<u>Reynosa uncinata</u>		40		20	40					
<u>Sapindus saponaria</u>					20					
<u>Plumeria alba</u>				20						
<u>Sweetenia mahogany</u>	820	1320	860	20	240	460		1060	940	
<u>Guaiacum officinale</u>			40			20			40	20
<u>Pimenta racemosa</u>								20		
<u>Euphorbia petiolaria</u>										280
<u>Canella winterana</u>	20									

Continued.

Appendix B. Continued.

Species	Nest									
	6	7	8	10	12	13	15	17	18	23
<u>Comocladia dodonea</u>	20			20						
<u>Croton rigidus</u>	140			180	280	60	40		60	
<u>Lantana involucreta</u>				60						
<u>Pictetia aculeata</u>	20	60					20			60
<u>Thouinia portoricensis</u>	100		20	100				20		
<u>Reynosa guama</u>		20								
<u>Capparis cynophallophora</u>		20	40				40			
<u>Zanthoxylum flavum</u>		20				160	60		60	
<u>Albizia lebbeck</u>			200				100	120		40
<u>Pithecellobium unguis-cati</u>				20	20		20			
<u>Eugenia monticola</u>				100	580					
<u>Adelia ricinella</u>					20					
Total	1580	1920	1440	1040	2000	1320	1360	1500	1560	1020

VITA

Francisco Jose Vilella was born on September 25, 1955 in the city of Arecibo, on the northwest coast of the island of Puerto Rico, West Indies. At the age of four his family move to San Juan, where he attended primary and secondary school, graduating from the latter in May, 1973.

He attended the University of Puerto Rico-CAAM, Mayaguez, Puerto Rico, and received a Bachelor of Science Degree in Zoology in May, 1978. After graduation, he worked as a National Science Foundation Student Originated Research Fellow at the Water Resources Research Institute of the University of Puerto Rico-CAAM from 1978 to 1979. In November, 1979 he joined the Puerto Rico Department of Natural Resources Office of Coastal Zone Management where he worked as a Natural Resources Technician.

In August, 1981 he was admitted to the graduate program in biology at Hofstra University, Hempstead, New York, where he obtained a Master of Arts Degree in Biology in August, 1983. That same year, he was accepted into the Graduate School of Louisiana State University where he is a candidate for the Doctor of Philosophy Degree in Wildlife and Fisheries Science.

On September 24, 1988 he was married to Dr. Ana Beatriz Arnizaut of Rio de Janeiro, Brazil. Upon completion of his doctoral degree he will join the U.S. Fish and Wildlife Service.

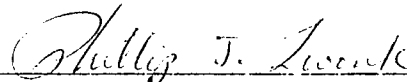
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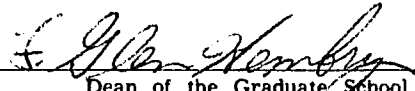
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Major Field: Wildlife and Fisheries Science

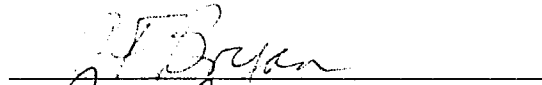


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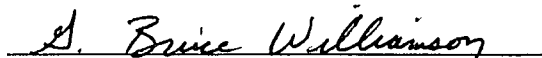
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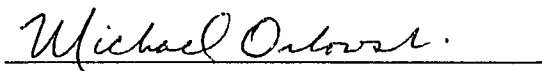

Major Professor and Chairman


Dean of the Graduate School

EXAMINING COMMITTEE:





Date of Examination:

15 December 1988