

**CHAPTER 2: OCCUPANCY AND HABITAT CHARACTERISTICS
ASSOCIATED WITH THE BLUE-HEADED QUAIL-DOVE
(*STARNOENAS CYANOCEPHALA*) OF CUBA**

ABSTRACT. – When endangered endemic species are faced with population decline from loss of habitat or other anthropogenic pressures, it becomes extremely important to have current information on population status and trends for species management and conservation. The Blue-headed Quail-dove of Cuba is one such species which remains largely understudied at least in part due to its shy and illusive behavior resulting in a species which has been very difficult to detect. We examined the occupancy, abundance and habitat characteristics associated with the endangered endemic Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Refuge from 2006 to 2008. The study area is a 2,428 ha dry semi-deciduous forest located in the Gran Humedal del Norte de Ciego de Ávila reserve in north-central coastal Cuba. We estimated occupancy, abundance and detection probability using multiple sample unit visits, and we modeled occupancy as a function of habitat characteristics. First time population size estimates of this ground dwelling dove in a sub-coastal loma indicate abundance at 0.36 birds ha⁻¹ and an averaged estimated 60% probability of sample unit occupancy. Occupancy models suggest an association with a proportion of leaf litter not exceeding 68% and a positive correlation with the presence of exposed limestone rock outcropping which may retain water during seasonally dry months of the year.

Key Words: Blue-headed Quail-dove, Cuba, Loma de Cunagua, detection, occupancy, abundance, habitat characteristics, semi-deciduous. Paloma Perdiz, *Starnoenas cyanocephala*

THE BLUE-HEADED Quail-dove or La Paloma Perdiz (*Starnoenas cyanocephala*) is a non-migratory terrestrial dove monotypic in its genus and is one of Cuba's rare endemic endangered species with a high risk of extinction (BirdLife International 2008). It is the only endemic quail-dove species on the island and is often found in habitats occupied by related *Geotrygon* species the Ruddy Quail-dove (*Geotrygon montana*), the Key-West Quail-dove (*Geotrygon chrysis*) and the Grey-headed Quail-dove (*Geotrygon caniceps*) (an endemic subspecies also found in the Dominican Republic; BirdLife International 2008). It was once reported as widespread with a range from Pinar del Rio on the western end of the island to Guantanamo at the far eastern corner opposite Haiti (Fig. 2.1) at the later part of the 19th century (Bent 1963), but is now considered rare. Rodriguez & Sanchez (1993) and Garrido & Kirkconnell (2000) consider it likely extinct on the Isle of Youth off the south west coast of the main island (Fig. 2.1), however local biologists reported seeing the Blue-headed Quail-dove in the southern portion of the small island in 2007 (F. Chavez-Ramirez pers. comm.). Populations are now locally restricted and patchily distributed across the island (Fig. 2.1) with substantial numbers in the mountains at La Güira National Park in Pinar del Rio, and the Guanahacabibes peninsula (Garrido & Kirkconnell 2000). The population decline has been principally a result of anthropogenic alterations to the landscape and subsequent loss of habitat owing in part to the development of the sugar industry and widespread forest removal during the neocolonial era (Rodriguez & Sanchez 1993), as well as hunting for food and trade, and possibly natural disasters (Gundlach in Bent 1963, Collar et al. 1994, Baillie & Groombridge 1996, Stattersfield et al. 1998). In particular, hurricanes may affect the Blue-headed

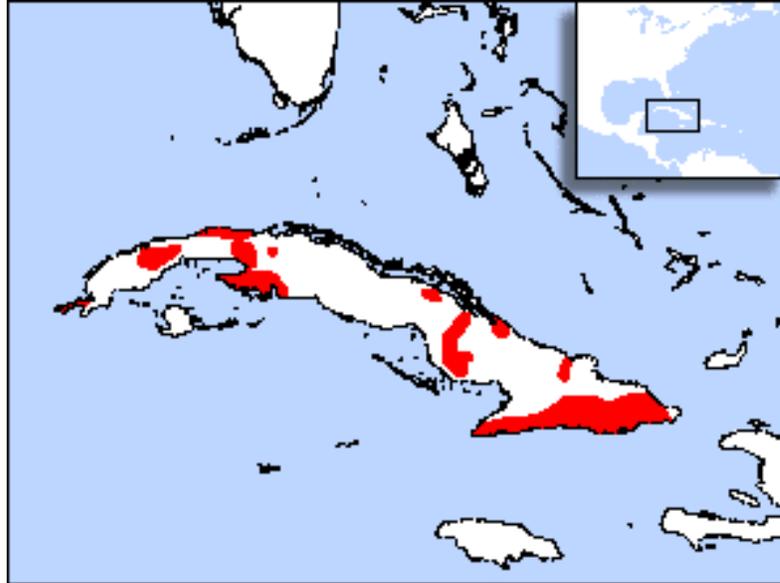


FIG. 2.1. Distribution map of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) in Cuba (BirdLife International 2008)

Quail-dove and related species with the loss of large forest tracks as was the case in the Cienega de Zapata in 1996 (Michell 1998).

All four quail-dove species are generally associated with subtropical/tropical lowland moist forest, montane moist forest, and swamp forest (BirdLife International 2008) with a closed canopy, and a high density of saplings and small diameter trees (Rodriguez & Sanchez 1993). Anecdotal evidence suggests, however that each species may be spatially partitioned within those habitats (Rodriguez & Sanchez 1993) although specific habitat associations for the Blue-headed Quail-dove remain unknown.

Population estimates from the year 2000 were 1.1 – 3.7 individuals km² occupying an estimated island area of 500 km² for a total 550 – 1850 individuals, however estimates were derived indirectly taken from the lowest of three population estimates for the Ruddy Quail-dove (BirdLife International 2008). The only empirically estimated population size comes from two forested swamp locations at Cienega de Zapata

where estimates were on average 0.05 and 0.40 birds ha⁻¹ (Rodriguez & Sanchez 1993), however the authors feel this could be an underestimation due to the cryptic nature of the species and the difficulty associated with its' detection. No direct estimates of size exist for this species in a dry semi-deciduous or evergreen forest habitat.

Attaining accurate population estimates are critical for highly endangered species; long-term management and conservation decisions can be improved with information that associates habitat with affects on populations. Sources of uncertainty can affect management of a species, and decisions based on biased information can potentially be harmful to conservation efforts. Endangered endemic species are often the ones of highest management priority due to limited distribution and a lack of reliable information on population status or trends. Consequently, our objectives were: 1) to obtain reliable, unbiased population estimates of the Blue-headed Quail-dove in a subtropical semi-deciduous forest; and 2) to investigate specific habitat features that are associated with species presence. Habitat is defined as the vegetation variables and physical geographic variables associated with the Blue-headed Quail-dove at the local site scale during the breeding season.

METHODS

Methodological Considerations. – Quail-doves are generally timid and elusive in nature making them difficult to detect and observe (Skutch 1949 1991, Seaman 1966, Chipley 1991, Rodriguez & Sanchez 1993, Rivera-Milan 1992, Robinson 2001, Dalsgaard et al. 2007). The Blue-headed Quail-dove is no exception and because it is also considered rare (BirdLife International 2008) they present a special challenge in estimating abundance. Traditional abundance counts where a sample unit is typically visited once

often produce erroneous estimates of population size or trends because they are subject to bias when detection is imperfect (Hutto 1986, Buckland 1993, Yoccoz 2001, Nichols 2002, Tyre et al. 2003, Gu and Swihart 2004, MacKenzie 2002).

Similarly, abundance counts may fluctuate over time or across sample units due to random variations or changes in detectability making inferences about the species ambiguous (MacKenzie et al., 2002 2003). Possible factors of variation in detection may come from: Season or time of day (MacKenzie 2002, 2005), temperature (Schmidt 2005), variations in singing proportion during a breeding season (Wilson and Bart 1985), variations in singing proportion with habitat type and distance to the observer (McShea and Rappole 1997), skill or observer anomalies (Sauer et al. 1994), variations in singing due to seasonal rainfall (Rivera-Milan 1992), and habitat attributes such as foliage density (Richards 1981).

Methods have been developed that account for detection probability as a result of the problems associated with species detectability. Distance Sampling (Buckland 1993), Double Observer sampling (Nichols 2000 et al.), Double Sampling (Bart and Earnst 2002), and removal methods (Farnsworth et al. 2002) are all examples. However these methods are mainly geared towards conspicuous and relatively abundant species, and may not work well with cryptic enigmatic animals (Thompson 2004) due to large amounts of non-detections in the data (McDonald 2004).

How does one then achieve accurate abundance estimates for an elusive species? Occupancy methods developed by MacKenzie et al. (2002) account for detection probabilities to be estimated when sample units are surveyed multiple times, and account for false negative observations when a species is present but goes undetected (Moilanen

2002, Tyre et al. 2003) which traditional abundance counts do not. These methods also allow for the inclusion of sampling and habitat covariates that could affect either the probability of detection or the probability of occupancy, thus providing an unbiased estimate of habitat specific effects and population size. This involves a shift in methodology from estimating numbers of animals to estimating the proportion of sample units occupied by animals (MacKenzie 2002, Royle and Nichols 2003). We thus employed occupancy as a surrogate for abundance estimation and habitat modeling.

Study Area. – We surveyed Blue-headed Quail-doves in the Loma de Cunagua Wildlife Refuge in Cuba (Fig. 2.2). It is a subtropical 2,428 ha forest (22° 06'N; 78°26'W) 340 m in elevation located within one of Cuba's largest and newly established wetland reserves El Gran Humedal located in the islands north central province of Ciego de Ávila. It is one of several regional sub-coastal semi-deciduous forests (lomas), characterized by porous limestone outcroppings and soils that have little ability to retain water (Bisse 1988, Borhidi 1991). Dominant plant species are Almacigo Colorado (*Bursera simaruba*), Sigua (*Nectandra coreacea*), Sangre de Doncella (*Byrsonima biflora*), Yaya (*Oxandra lanceolata*), and Jocuma (*Mastichodendron foetidissimum*) (Appendix 1). Shrub species common to the loma have not yet been identified by local biologists. These lomas, also known as coastal saline domes, are typically low in stature and small in area. The loma is a biogeographical island land mass surrounded by wetlands, savannahs, agriculture (predominantly sugarcane), and urban areas. The study area is located 15 km east from the province's second largest city of Moron and 9.6 km from coastal waters. According to residents, the loma experienced a high intensity fire in

1986 and was followed by aerial reseeding. It is unknown how much of the seed bank was destroyed or whether reseeding altered species composition.

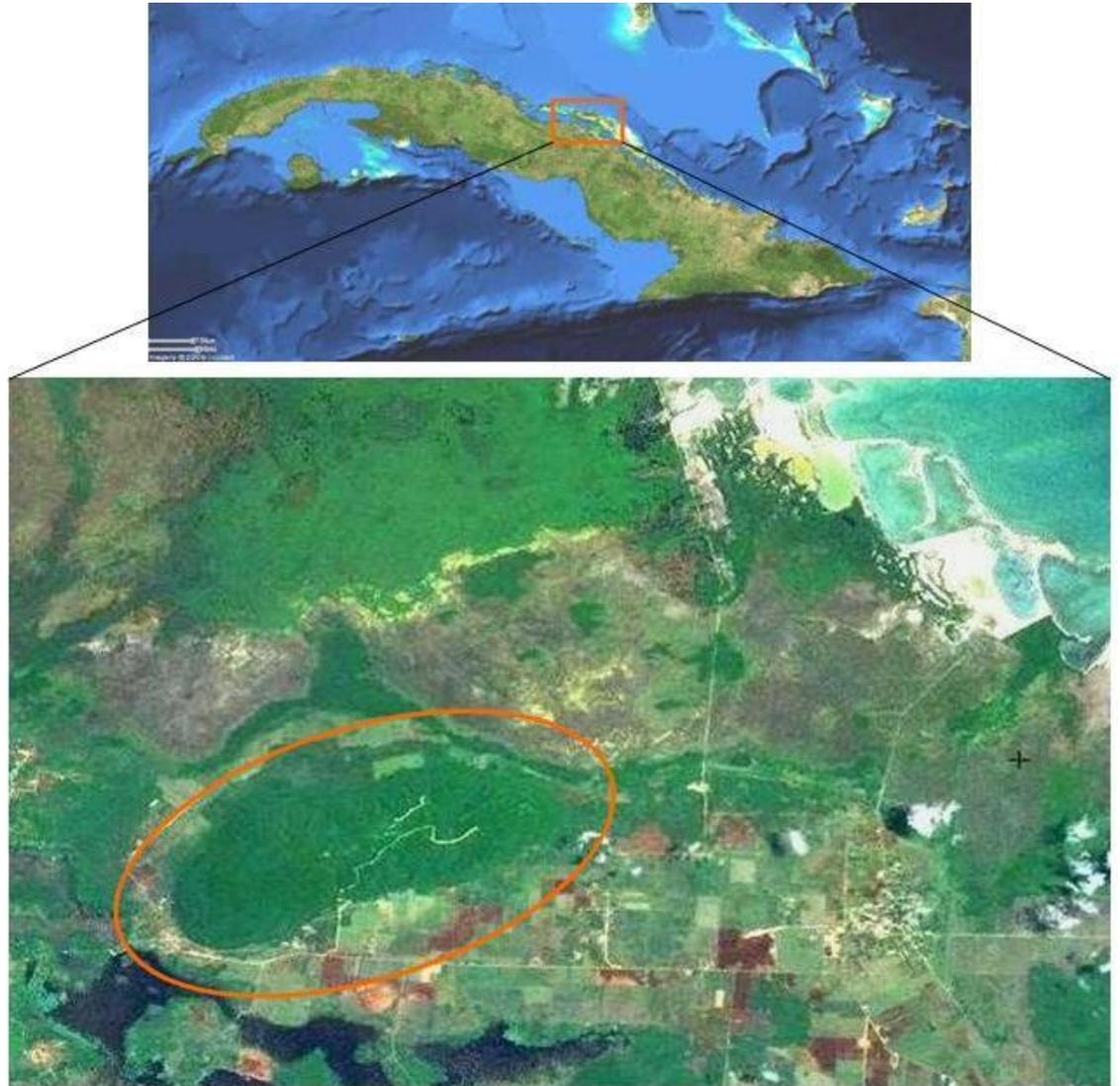


FIG 2.2. Loma de Cunagua Wildlife Refuge study area (outlined in red) in the Ciego de Ávila region of Cuba. The dry sub-coastal semi-deciduous forest was surveyed for presence of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) from 2006 – 2008.

Bird Surveys. – Blue-headed Quail-dove were surveyed from 2006 -2008 at the Loma de Cunagua Wildlife Refuge during March and April, the known peak reproductive period for this species in its natural habitat (Goodwin 1983) in order to assess occupancy

and habitat associations in this forest type. Due to the presumed severely reduced population of this species it was unclear to what extent it still inhabited this protected area after 22 years of forest regeneration resulting from a devastating fire in 1986. Thus, a pilot count was initiated on 23 March 2006 to investigate both species presence and the onset of singing behavior related to the reproductive period. On 1 April 2006 singing commenced across the study area and the three weeks that followed were utilized for familiarization with the quail-doves song in this environment. Official bird surveys were conducted from 23 April – 3 May 2006, 9 April – 19 April 2007 and 1 April – 9 April 2008. Singing tapers off precipitously during early May, thus surveys must be conducted within this relatively small window to allow for maximum detection and to avoid false absences.

We systematically placed 11 1 km lines every 500 m with a random start at the east end of the loma in 2006. We were not able to stratify our sampling regime because we had no information regarding the vegetation heterogeneity and possible stratification of habitat types, or species distribution within the loma. We therefore used systematic sampling to ensure coverage of all vegetation types within the study area (Sutherland et al. 2004). We allowed 500 m between each 1 km line to assure independence of sample units between lines.

Each 1 km line was divided into 200 x 200 m (4 ha) block sampling units for a total of $n = 55$ sample units, 5 sample units per 1 km line in 2006. Because both territory size and auditory detection distance for this species was unknown we estimated 100 m as the horizontal distance at which auditory detection ceased. We then doubled that amount

to 200 m as the length and width of each sample unit to avoid double counting individuals along the 1 km line and ensure independence of each sample unit.

Three repeat surveys (K) were conducted at each sample unit over the course of the sampling period. In order to obtain a usable probability estimate of species presence a minimum of three repeat visits is suggested (Tyre et al. 2003, MacKenzie and Royle 2005). In 2007 we increased the number of 1km lines by three for a total of 14 (n = 70 sample units) and the number of repeat visits increased to (K = 4) per day. Due to the species timid nature and limited daily singing, the probability of obtaining a false negative observation is increased and an increased number of visits are recommended (Tyre et al. 2003). We increased our sampling effort due to a lack of sample unit representation on the north-west portion of the loma during 2006. To reduce the effect of heterogeneity (potential sources of variation in detection probability) as a result of observer differences, observers were rotated amongst sample units and sample unit visits were changed each day (MacKenzie and Royle 2005).

Each sample unit along the 1 km line was walked slowly (5 min 25 m⁻¹) beginning at sunrise from 0630 until 1000 hours EST and observers recorded audible and visual quail-dove detections. The Blue-headed Quail-dove sings intermittently throughout the day however it is more physically active in the cooler morning hours (K. M. Leavelle pers. obs.) increasing the probability of a visual sighting. This species also makes a loud and abrupt flight exit when it takes flight resulting from being startled unlike that of any other quail-dove or bird in this forest, and thus flushes were also considered in our observations. Finally, in order to estimate population abundance we

counted all individuals observed within each sample unit during each replicated survey count.

Vegetation Measurements. – We modified methods described by James and Shugart (1970) to measure vegetation and physical feature variables within a 20 m radius plot at a randomly chosen point within each 4 ha sample unit. Vegetation variables measured within the circle included tree diameter at breast height (DBH), tree abundance (≥ 10 cm DBH), and tree species abundance. Variables measured within a 2 m x 4 m quadrat from the center of the plot were sapling abundance (≥ 2 cm & < 10 cm DBH), and shrub abundance (woody stems < 2 cm). Average shrub cover (%) was estimated 10 m from the center in each cardinal direction. Finally, I measured the percent cover of leaf litter, exposed rock and canopy cover with an ocular tube at each meter along the meter tape (James and Shugart 1970). I also measured topographic features of slope (the angle of the surface relative to the horizon), and aspect (the compass direction of the slope's orientation).

Data Analysis.– I used a maximum likelihood based approach to estimate model parameters and the proportion of sample units occupied by the Blue-headed Quail-dove because we believed the probability of detection at a sample unit was < 1 . Sample unit occupancy models were developed by MacKenzie et al. (2002) and analyzed in Program PRESENCE2.0 (Hines, J. E. 2002). I used a logit link function to model the probability of occupancy (success) as a function of sample unit covariates. A linear combination of covariate values was transformed to a probability scale between 0 -1. The logit link is defined as:

$$\log \text{it}(\theta_i) = \ln\left(\frac{\theta_i}{1-\theta_i}\right) = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \dots + \beta_u x_{iu}$$

where θ_i is the probability for the i th sampling unit, the term $\frac{\theta_i}{1-\theta_i}$ is the odds of success, and $x_{i1}, x_{i2}, \dots, x_{iu}$ are the values for the U covariates. The regression coefficients $\beta_1 + \beta_2 + \dots + \beta_u$ determine the size of the effect of the covariates and β_0 is the intercept.

I used a multi-season analysis which combines data from the 2006 - 2008 breeding seasons. The analysis resulted in estimates of occupancy (ψ), detection (p) and the dynamic processes of extinction (ϵ), and colonization (γ) which explicitly govern changes in occupancy. The time frame for a multi-season model is considered at two temporal scales: a primary and secondary sampling period. The primary period refers to three breeding seasons between March and July from 2006 - 2008. The primary period assumptions are: 1) each breeding season is common to all sample units and; 2) the occupancy state is open to change or population movement between seasons. The secondary sampling periods refer to the within-season surveys of N sample units, K times and is essentially a sequence of single season studies conducted at the same sample units for multiple breeding seasons (Pollock 1982, MacKenzie et al. 2005). This model could also be extended to determine habitat use in other seasons. Specific assumptions for the secondary period are: 1) a closed population over each 2 week survey period with no immigration or emigration due to assumed sedentary breeding behavior and territoriality. In other words occupancy does not change at a sample unit during the set of surveys; 2) detection of the target Blue-headed Quail-dove at a sample unit was independent of

detections at other sample units; and 3) the target species was never falsely detected at a sample unit when absent.

I used a three-step approach to select the best model of accuracy. First we determined which factors explained detection probabilities while keeping sample unit occupancy probability, extinction and colonization parameters constant across sample units [$\psi(\cdot)$, $\gamma(\cdot)$, $\epsilon(\cdot)$]. Four detection models were constructed: 1) The probability of detection was constant across sample units [$p(\cdot)$]. Species at all sample units per sample are detected with a single probability (detection is not heterogeneous across sample units), and is the estimated probability of detecting a species at least once during a set of surveys (given the species is present); 2) Detection probabilities were survey (sample unit) specific [$p(t)$] where the detection probability at all sample units varies, sample #1 = $p(1)$, sample #2 = $p(2)$, sample #3 = $p(3)$; 3) The detection probability was a function of temporal year differences [$p(\text{year})$]; 4) Detection was a function of observer variation among years [$p(\text{obs})$], and; 5) Detection was a function of an increase in singing due to call playback [$p(\text{call playback})$].

I then used the best model for detection probabilities in the second step to determine sample unit extinction or colonization from 2006 to 2007 or from 2007 to 2008. In datasets of multiple years > 2 it is possible to allow them to vary to detect year differences and test hypotheses about populations either being in equilibrium (colonization = extinction) or non-equilibrium (colonization \neq extinction). Finally, I used the best model for detection, extinction and colonization probabilities to determine probabilities in occupancy (ψ) which was allowed to vary as a function of habitat covariates.

Candidate Models. – We developed an *a priori* set of candidate models based on either known biological information or information gained from direct observations obtained from this study hypothesized to be important for the Blue-headed Quail-dove. Eight models contained vegetation variables. 1) A closed canopy (CANOPY COVER PROPORTION) may be a possible mechanism for aerial predator avoidance. An open understory with low shrub cover (AVERAGE SHRUB COVER) may be important for visual clarity and an ease of predator escape. 2) A large percentage of leaf litter (LEAF LITTER PROPORTION) would be important to this terrestrial dove as it only feeds on the ground moving leaf litter with its beak in search of fallen fruit and invertebrates hiding within the leaves. 3) A large percentage of limestone rock outcroppings (EXPOSED ROCK PROPORTION) could be advantageous to a dove species which requires large amounts of water for the production of crop milk. Water collects in these tide pool-like structures during the rainy season (May-Oct) providing an important water resource to all animals. In addition, incipient rains coincide with the later part of the quail-dove breeding season when chicks are being fed crop milk, a substance which is 64.3% water (Reed et al. 1932). 4) Fallen trees, limbs or bent over trees (PERCHES) used as perches would provide possible resting and nesting substrates. The Blue-headed Quail-dove has been observed on many occasions sunning, resting, singing and preening on natural perches and is often found in areas with large amounts of fallen tree matter. Two nests were also found in bowed over tree trunks with a flat horizontal place for a nest. 5) Larger trees (AVG. TREE DBH) would be indicative of a mature forest producing a greater abundance of fruit (Chapman et al. 1992). 6) Fewer trees (TREE ABUNDANCE) would also represent a mature forest and a greater ability to flee predators. 7) Fruiting tree species

(ALMACIGO COLORADO) (*Bursera simaruba*) and (SANGRE DE DONCELLA) (*Byrsonima biflora*) may potentially be important for the quail-dove in this system. Quail-doves have been observed feeding on fallen fruit of these tree species which may indicate an important dietary component providing nutritional requirements during the breeding season. A model combining AVG. TREE DBH and TREE ABUNDANCE was included to represent fewer larger trees suggestive of a mature forest plus a model with ALMACIGO COLORADO, SANGRE DE DONCELLA and ASPECT as quail-doves may prefer fruiting trees on south facing slopes.

Two other models contained physical topographical variables. 1) Blue-headed Quail-dove may be associated with south facing areas (ASPECT) (compass degrees) which receive more sun at this latitude throughout the day and may cause earlier fruit production in certain plant species. 2) Blue-headed Quail-dove may be associated with increasing degree in incline (SLOPE) (horizontal degrees) as trees may have more of a tendency to fall in the direction of the downward slope increasing the number of potential available fallen trees for perches or nesting sites.

We considered 14 competing models with one or two parameters constructed from 12 predictor variables. More complex models with additional parameters are of less practical value for conservation of this species and make less biological sense (Burnham and Anderson 2002). Preliminary analyses in Program PRESENCE2.0 revealed a lack of convergence of global and sub-global models which were thus excluded from analysis.

We used Akaike's Information criterion with a small sample size correction (AIC_c) for model comparison (smallest AIC_c = the best model; Table 2.4). Burnham and Anderson (2002) recommend the use of AIC_c when $n/K < 40$, n = sample size and K =

the number of sample unit covariates used; ($70/12 = 5.83$). High ranking models were given substantial empirical support if the AICc difference ($\Delta_i = AIC_i - AIC_{\min}$) was greater than two (Burnham and Anderson 2002). Models were averaged across all model parameters to reduce potential model selection bias effects on beta coefficient estimates (Burnham and Anderson 2002).

Finally, we estimated abundance by including the total number of detections per 4 ha sample unit which estimates population size while accounting for detection probability from spatially replicated counts (Royle 2004). We ran a Pearson's Goodness of Fit test to assess the fit of the global model to our data. Transformation of data was done by dividing parameter values by a constant of 100 in order to avoid over dispersion and to allow program PRESENCE to work with values between zero and one (Hines 2002).

RESULTS

Detection. – Quail-dove were detected on 91% of the 11 1 km lines in the first year, 86% of 14 1 km lines in 2007, and 93% of 14 1 km lines in 2008 indicating species presence throughout the study area. The proportion of sample units where Blue-headed Quail-dove were detected at least once (naïve occupancy) decreased by 8% in 2007 but increased by 14% in 2008 (Table 2.1). The amount of birds detected aurally was 16 (57%) in 2006, 20 (62.5%) in 2007 and 25 (61%) in 2008. Visual detections accounted for 7 (25%) in 2006 and 9 (28%) in 2007, and flushes accounted for 5 (18%) and 3 (9%) of the detections in 2006 and 2007 respectively. The amount of visual detections including flushes was 16 (39%) in 2008. Finally an average of 10.6 birds \pm 0.57 were detected h^{-1} from 0700 – 1000 hours decreasing to 4.5 \pm 0.71 after 1000 h.

TABLE 2.1. Number of sample units where Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Refuge, Cuba 2006 – 2008 were detected at least once, number of detections and naïve occupancy not accounting for detection probabilities.

Year	Sample Unit Detections (Total Sample Units)	Naïve Occupancy	Detections
2006	21 (55)	38%	28
2007	21 (70)	30%	32
2008	31 (70)	44%	41

In the first of the two-step approach, the model including year best explained detection probabilities (Table 2.2). We found no evidence for heterogeneity in detection using call-playback, between surveys, or when detection was held constant. The model including differences in observer as explaining detection did not converge when 2008 was added but did not explain detection when 2006 and 2007 were analyzed alone. We therefore allowed detection to vary by year p (year) in all subsequent models. Detection was low in the first two years (p 2006 = 0.22, SE = 0.038; p 2007 = 0.19, SE = 0.06), and increased in 2008 (p 2008 = 0.35, SE = 0.05), but were not statistically different as illustrated by overlapping confidence intervals (Fig. 2.3).

TABLE 2.2. Factors explaining detection probabilities for the Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Refuge, Cuba 2006 - 2008 from a multi-season model. Models are ranked using Akaike's Information Criterion with a small sample size correction (AIC_c).

Model	AIC_c	ΔAIC_c	AIC_w	NPar	-2L
$\psi(\cdot), p(\text{Year})$	507.83	0.00	0.834	6	495.80
$\psi(\cdot), p(\text{CallPlayback})$	511.50	3.67	0.133	6	499.50
$\psi(\cdot), p(t)$	514.72	6.89	0.026	14	486.71
$\psi(\cdot), p(\cdot)$	517.45	9.62	0.006	2	513.44
$\psi(\cdot), p(\text{obs.})^*$	-	-	-	-	-

*The model for observer (obs.) as explaining detection did not converge in program PRESENCE2.0.

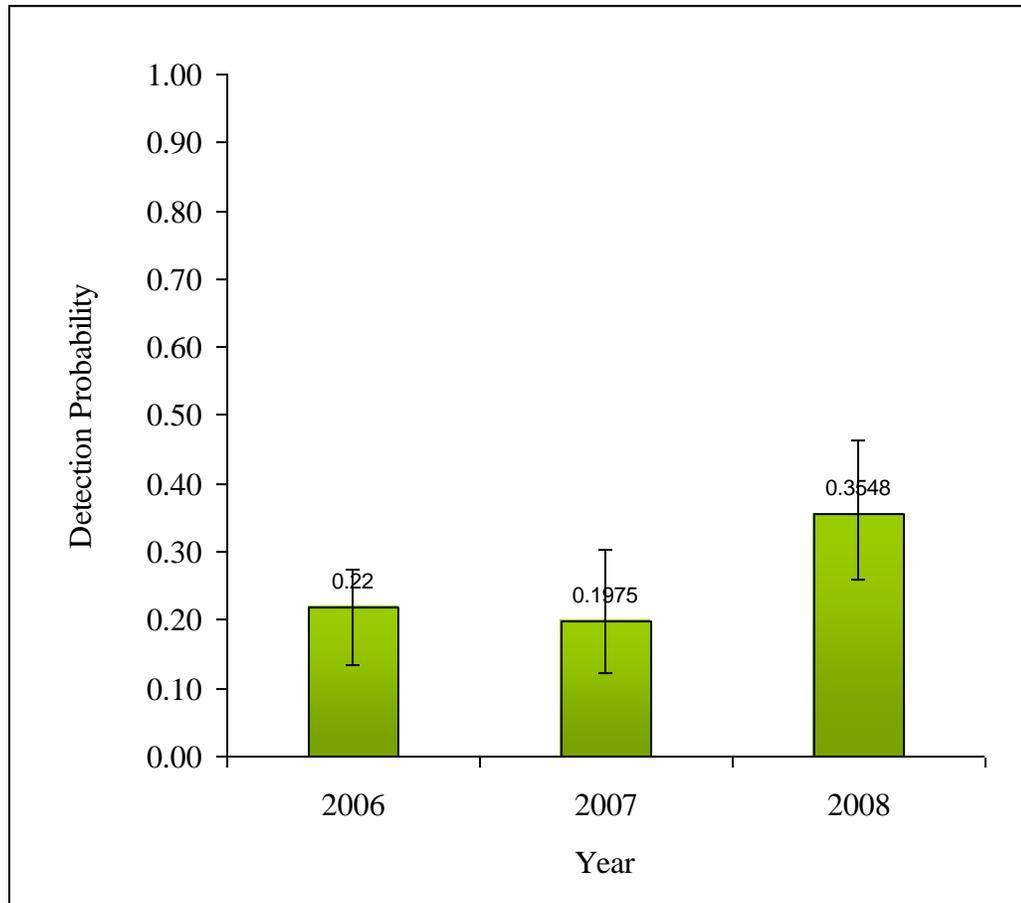


FIG. 2.3. Detection probabilities (p) for Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Refuge, Cuba 2006 - 2008. \pm 95% Confidence Intervals.

Local Extinction and Colonization Modeling. – There was information in the data to suggest extinction in 2007 and colonization in 2008, however there was no statistical evidence for either extinction ($\hat{\beta} = -0.95$, SE = 0.79, CI = -2.49 – 0.59) or colonization ($\hat{\beta} = -1.31$, SE = 1.21, CI = -3.7 – 1.11) as indicated by the large standard errors and confidence intervals which overlapped with zero (Fig. 2.4). The best model [$\epsilon(07)$, $\gamma(08)$] was used in all habitat models.

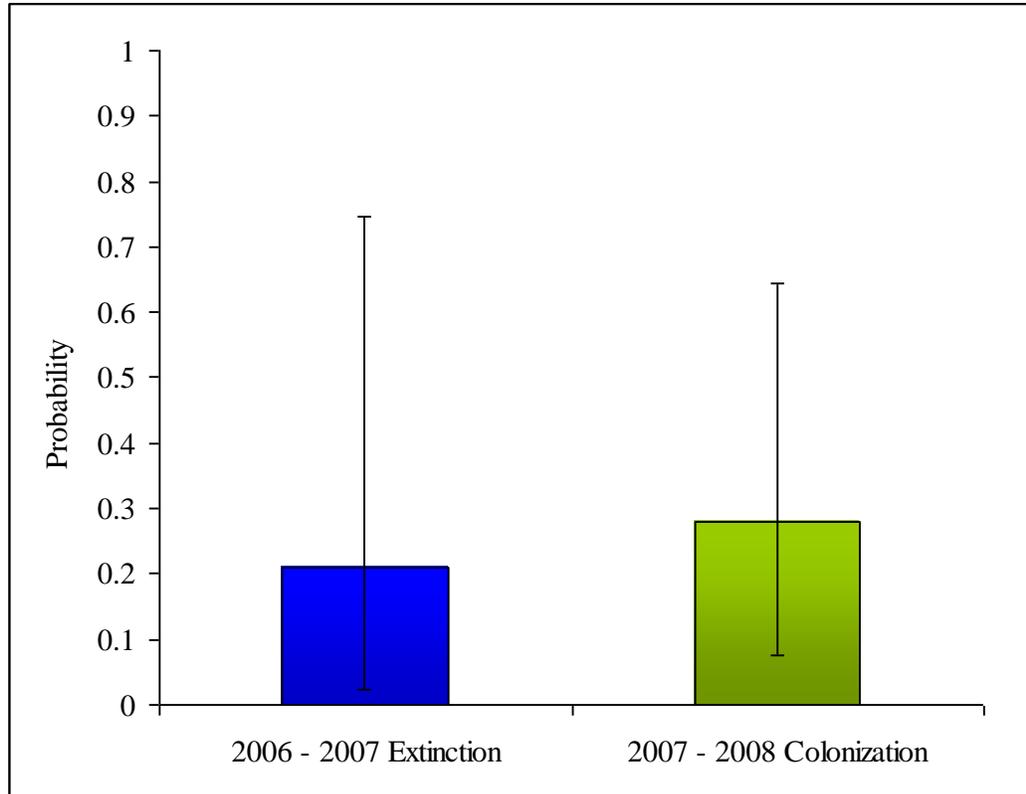


Fig. 2.4. Probability of extinction (ϵ) 2006 – 2007 and colonization (γ) 2007 – 2008 of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Refuge, Cuba \pm 95% Confidence Intervals.

Vegetation Variables. – Vegetation measurements varied widely at the Loma de Cunagua Wildlife Refuge (Table 2.3). The amount of between sample unit variation was high for all variables but highest for canopy cover proportion, proportion of leaf litter, slope, and shrub abundance.

TABLE 2.3. Vegetation and physical feature sample unit (4 ha) parameter measurements (Mean 4 ha⁻¹) at the Loma de Cunagua Wildlife Refuge, Cuba. Measurements were taken in 2007.

Variable	Mean	Median	St. Dev.	Range	
				Min	Max
Leaf Litter Proportion (%)	0.57	0.60	0.16	0.19	0.83
Canopy Cover Proportion (%)	0.68	0.67	0.16	0.25	0.99
Rock Proportion (%)	0.19	0.19	0.13	0.00	0.53
Sangre de Doncella Abundance	3.00	3.00	1.80	0.00	8.00
Almacigo Colorado Abundance	5.00	5.00	2.10	2.00	11.00
Tree Abundance	39.00	39.00	7.84	16.00	51.00
Avg. Tree DBH*	33.49	36.00	11.22	14.94	50.19
Slope (°)	18.37	19.00	9.90	0.00	50.00
# Perches	4.24	4.00	3.21	0.00	13.00
Sapling Abundance	31.33	30.00	11.41	14.00	67.00
Shrub Abundance	24.91	23.50	14.00	2.00	100.00
Avg. % Shrub Cover	0.79	0.81	0.13	0.41	0.98

*DBH = Diameter at Breast Height. Vegetation variables including all proportions, everything related to trees and perches were measured within a 20 m radial circle. Slope was measured at the randomly chosen point, shrub abundance and sapling abundance were measured within a 1 m radial circle around the point, and avg. shrub cover was taken 10 m from the point in every cardinal direction. n = 70.

Habitat Modeling. – The goodness-of-fit test for a global model did not indicate lack of fit ($c\text{ hat} = 0.95$). The parameters of leaf litter and exposed rock were negatively correlated ($r^2 = -0.56$, $p < 0.0001$) and could not be included together in the same model or in competing models. The model for exposed rock was chosen as the parameter which was thought to be most biologically meaningful however it did not converge in program PRESENCE2.0. Therefore a model for leaf litter was included instead as a proxy for the proportion of exposed rock. The model for leaf litter best fit the data and received nearly nine times more support than the next best model that included Sangre de Doncella abundance and is given considerable empirical support by the 4.36 difference in AIC_c (Table 2.4).

Occupancy decreased with increasing leaf litter ($\beta_0 = 23.60$, $\beta_{\text{leaf litter}} = -33.37$, $SE = 10.78$, $CI = -54.93 - -11.81$). However, the model averaged estimate for leaf litter, conditional on all 14 models, indicate little evidence for any directional effect ($\tilde{\beta}_0 = 17.47$, $\tilde{\beta}_{\text{leaf litter}} = -24.44$, $SE(\tilde{\beta}) = 16.79$, $CI = -57.34 - 8.46$). No other habitat parameters or models combining multiple parameters received significant support.

TABLE 2.4. Models explaining the proportion of sample units occupied (ψ) by Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Refuge, Cuba from 2006 - 2008 as a function of habitat variables ranked by Akaike's Information criterion (AIC) with a small sample size correction (AIC_c). Best model for parameters extinction in 2007 [$\epsilon(07)$], and colonization in 2008 [$\gamma(08)$] are included in each model for occupancy. PRESENCE2.0 was used for analysis.

Model	ΔAIC_c	AIC _w	NPar	-2LL
$\psi(\text{Leaf Litter Proportion}), \epsilon(07), \gamma(08), p(\text{Year})$	0.00	0.732	7	487.60
$\psi(\text{Sangre de Doncella Abundance}), \epsilon(07), \gamma(08), p(\text{Year})$	4.36	0.082	7	491.96
$\psi(\text{Aspect}), \epsilon(07), \gamma(08), p(\text{Year})$	5.85	0.039	7	493.45
$\psi(\cdot), \epsilon(07), \gamma(08), p(\text{Year})$	6.23	0.032	6	495.83
$\psi(\text{Slope} + \text{Aspect}), \epsilon(07), \gamma(08), p(\text{Year})$	7.28	0.019	8	492.88
$\psi(\text{Tree Abundance}), \epsilon(07), \gamma(08), p(\text{Year})$	7.77	0.015	7	495.37
$\psi(\text{Average Tree DBH}), \epsilon(07), \gamma(08), p(\text{Year})$	7.80	0.014	7	495.40
$\psi(\text{Canopy Cover Proportion}), \epsilon(07), \gamma(08), p(\text{Year})$	7.85	0.014	7	495.45
$\psi(\text{Slope}), \epsilon(07), \gamma(08), p(\text{Year})$	8.06	0.013	7	495.65
$\psi(\text{Almacigo Colorado}), \epsilon(07), \gamma(08), p(\text{Year})$	8.13	0.012	7	495.73
$\psi(\text{Perches}), \epsilon(07), \gamma(08), p(\text{Year})$	8.22	0.012	7	495.82
$\psi(\text{Avg. Shrub Cover}), \epsilon(07), \gamma(08), p(\text{Year})$	8.23	0.012	7	495.83
$\psi(\text{Tree Abundance} + \text{Avg. Tree DBH}^*), \epsilon(07), \gamma(08), p(\text{Year})^{**}$	-	-	-	-
$\psi(\text{Aspect} + \text{Doncella.} + \text{Almacigo}), \epsilon(07), \gamma(08), p(\text{Year})^{**}$	-	-	-	-

*DBH=Diameter at Breast Height. **Models that did not converge in program PRESENCE2.0. Tree species listed are Sangre de Doncella (*Byrsonima biflora*) and Almacigo Colorado (*Bursera simaruba*). Slope (°) = the angle of the surface relative to the horizon, and Aspect (°) = the compass direction of the slopes orientation. All variables were measured within a 20 m radius circle.

Figure 2.4 demonstrates the probability of occupancy with respect to the proportion of leaf litter at a sample unit. Blue-headed Quail-doves were predominantly detected in areas with 30-65% leaf litter ground cover proportion (57% of sample units) and were detected most often at sample units with 49-59% leaf litter ground cover (33% of sample units). Occupancy was estimated at $\leq 50\%$ at leaf litter levels of $\geq 73\%$ (14% of sample units) while areas of highest occupancy (86% of sample units) were found with leaf litter between 20% -73%. Figure 2.6 illustrates the lack of spatial pattern of specific leaf litter proportions, thus a lack of pattern of occupancy which is high (99%) across the loma.

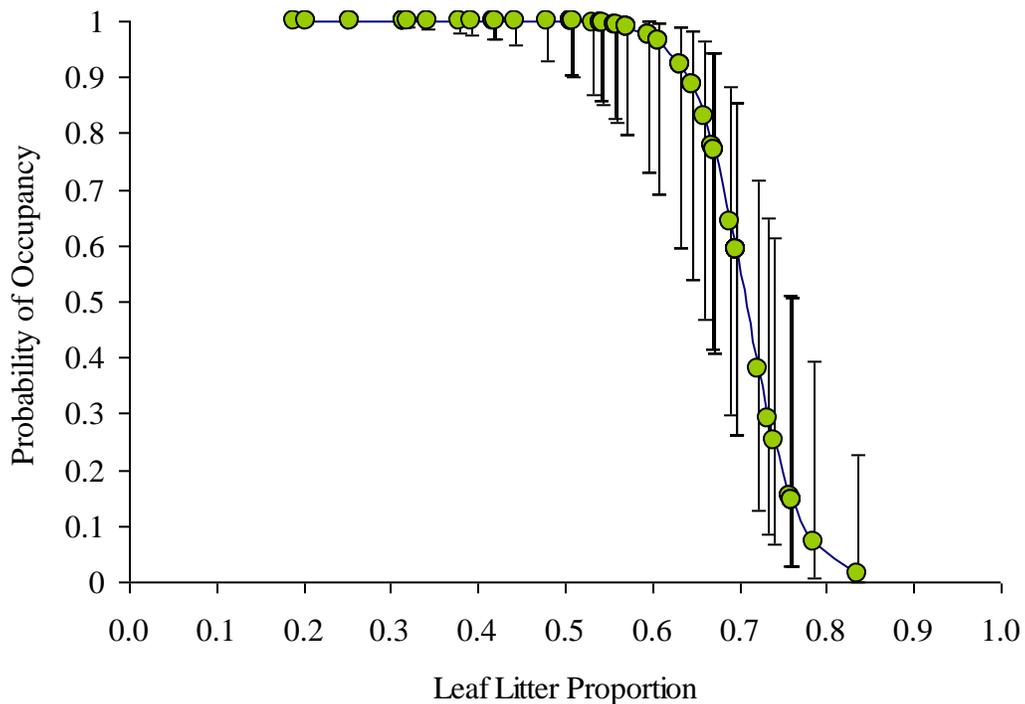


FIG. 2.4. Logistic curve describing the probability of sample unit occupancy $\pm 95\%$ confidence intervals as a function of the proportion of leaf litter ground cover of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Reserve, Cuba from 2006 – 2008.

Blue-headed Quail-dove Occupancy as a Function of Leaf Litter, Loma de Cunagua Wildlife Refuge, Cuba

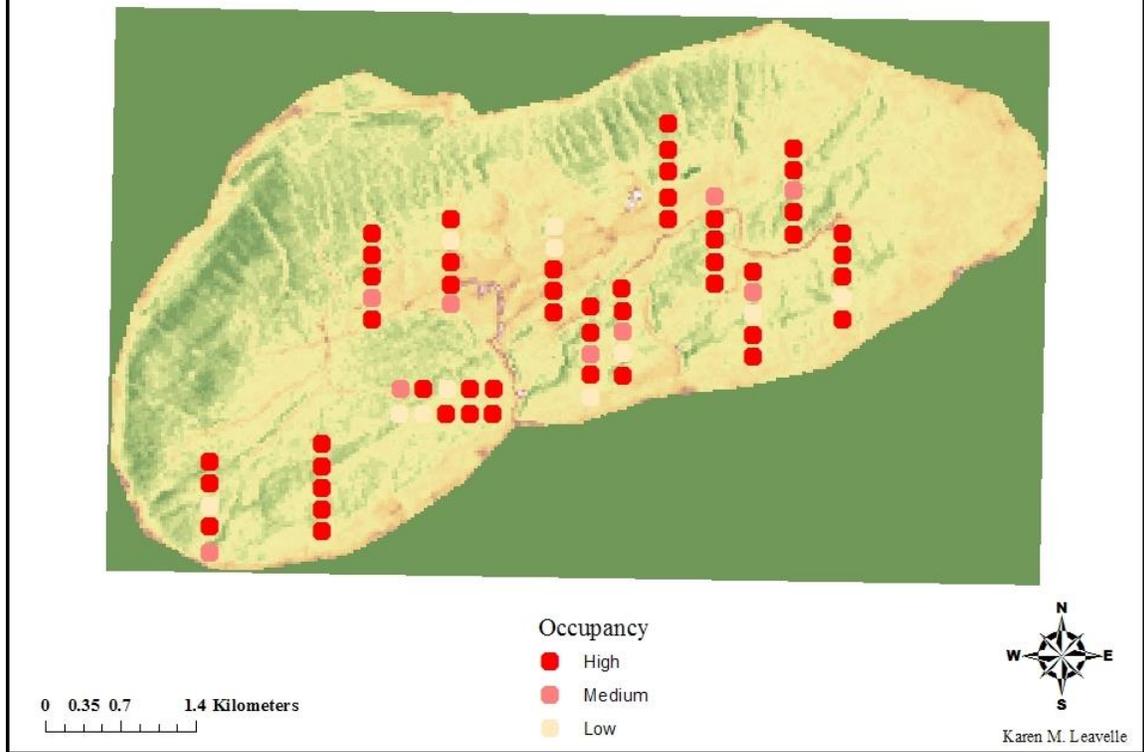


FIG. 2.5. Occupancy of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Refuge, Cuba as a function of leaf litter proportion. Areas of high occupancy ($\geq 70\%$) are in red, medium occupancy (40 – 69%) and low occupancy (0 – 39%). True color is not represented in the image.

Sample unit Occupancy Probabilities. – The probability of sample unit occupancy for each habitat model varied between 0.65 and 0.99 in all years, however high estimates near 1.00 may be over-estimates as a result of low detection probabilities < 0.30 (MacKenzie 2002). Thus, the probability of sample unit occupancy (ψ) of Blue-headed Quail-dove was taken from the constant model (2006: $\psi = 0.69$, SE = 0.11, CI = 0.47 – 0.90; 2007: $\psi = 0.48$, SE = 0.12, CI = 0.24 – 0.71; 2008: $\psi = 0.62$, SE = 0.14, CI = 0.34 – 0.90).

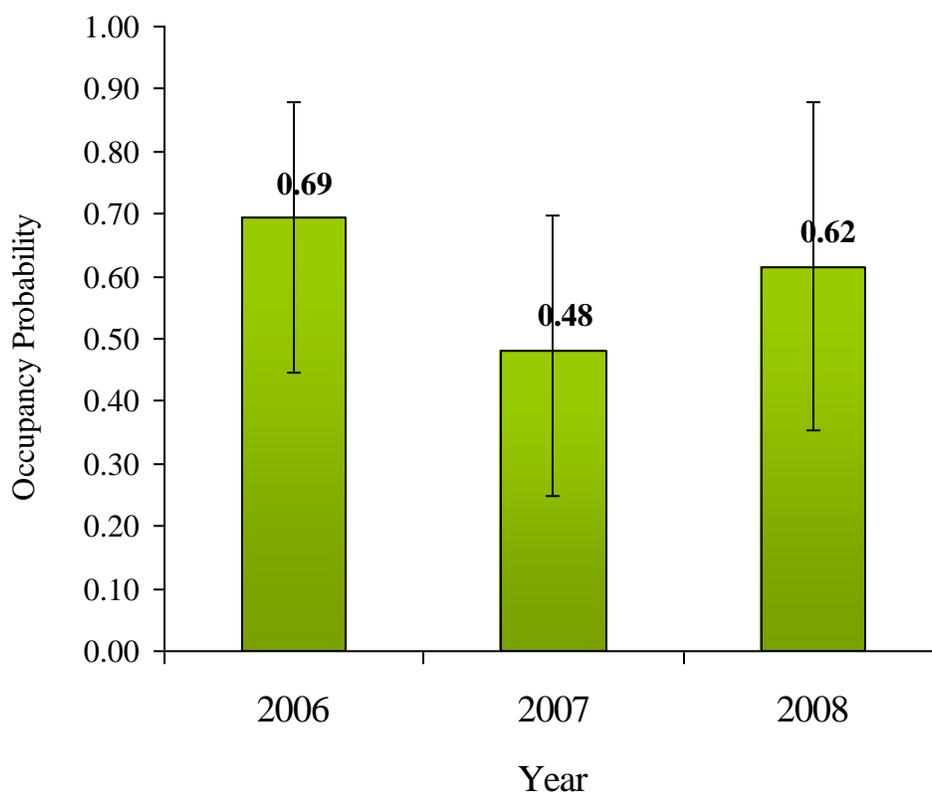


FIG. 2.6. The probability of sample unit occupancy of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Refuge, Cuba from 2006 - 2008 \pm 95% Confidence limits.

Abundance. – Average density (λ) per sample unit (4 ha) was 1.44 (SE = 0.59; 95% CI 0.29 – 2.58; Table 2.5). The average density per hectare was 0.36 birds (1.44/4ha). Total sample unit ($n = 70$) abundance (\hat{N}) was 1.0×10^2 with a low detection probability of 0.09. The total average estimated abundance (N) of Blue-headed Quail-dove at the Loma de Cunagua was 8.74×10^2 (0.36 birds ha^{-1} out of a total 2,428 ha) (Table 2.5). The data for 2008 when added to 2006 and 2007 did not converge in program PRESENCE therefore only 2006 and 2007 are used to obtain abundance estimates. Due to the fact that there was no between year statistical difference in the

probability of occupancy all seven visits were combined to obtain a more robust estimate of abundance.

TABLE 2.5. Abundance estimation from repeated count data formally allowing for detection probability (Royal 2004). Occupancy (ψ), detection (p) and average density/sample unit are transformed proportion estimates. Estimates are birds/sample unit. A sample unit = 4 ha.

Estimated Parameter	Estimate	St. Error	95% CI	
			Lower	Upper
Detection (p)	0.09	0.04	0.02	0.17
Occupancy (ψ)	0.76	0.14	0.49	1.03
Average Density per sample unit ($\hat{\lambda}$ /ha)	1.44 (0.36/ha)	0.59	0.29	2.58
Total Sample Unit				
Abundance (\hat{N})	1.0×10^2	40.96	20.26	1.8×10^2
<i>Total Abundance (N)*</i>	<i>8.74×10^2 birds*</i>		<i>1.76×10^2</i>	<i>1.6×10^3</i>

**Total abundance (N)* is derived from 1.44 birds/4 for a per hectare estimate. Abundance estimates reflect pooled data for 2006 and 2007 only.

DISCUSSION

Our study was the first to extensively examine occupancy of the Blue-headed Quail-dove, to incorporate estimates of detectability into quail-dove occupancy analysis, and to determine habitat associated with the presence of the species in a semi-deciduous forest in Cuba. In general, we believe that these methods developed by MacKenzie et al. (2002) are well suited for assessing populations of rare and elusive species and are worth the time spent to obtain unbiased estimates and is recommend for the study of any animal population. It is particularly well suited for the long-term monitoring of the Blue-headed Quail-dove at the Loma de Cunagua and other areas throughout Cuba.

Results for the proportion of sample units occupied far exceeded our expectations considering the fact that local biologists were uncertain as to the presence of the Blue-

headed Quail-dove within this protected area. Occupancy estimates indicate that occupancy is moderately high across the entire study area and its distribution is homogeneous. The local biologists' perception is, therefore, a result of low detectability, rather than low abundance, and this distinction is critical for future conservation decisions.

Our estimation of abundance ($0.36 \text{ birds ha}^{-1}$) is the first reported for a dry semi-deciduous forest and exceed low Ruddy Quail-dove population size estimates ($0.01 \text{ ind ha}^{-1} - 0.04 \text{ ind ha}^{-1}$) provided by BirdLife International (2008) as a proxy for Blue-headed Quail-dove estimates, or by Rodriguez and Sanchez (1993) at one study area in the Cienaga de Zapata (0.05 ind ha^{-1}). Our estimate more closely agrees with estimates given by Rodriguez and Sanchez (1993) from their second study site in Zapata (0.40 ind ha^{-1}). Because we incorporated detectability in our estimation process, it would be expected to provide a higher estimate, especially given our detectability rate estimates. We also have low precision in our estimates however increased years of data will increase statistical confidence in these estimates.

There was no statistical evidence for between year increases or decreases in detection, extinction, colonization or occupancy parameters due to a lack of precision in the estimates. The amount of error and lack of precision is a result of this small data set and highlights the need for additional years of data as well as an increase in surveys each year. Missing values from both 2006 and 2008 could also cause reduced precision in the estimates (MacKenzie et al. 2002).

Occupancy appears to vary as a function of leaf litter ground cover, though conditional model averaged estimates rendered it inconclusive. Two possible factors may

help explain the uncertainty in our results. First, our limited observations contributed to a lack of precision in the estimates, which is further amplified by the conditional model averaging process. However, some of the uncertainty is derived from the fact that our raw data shows that Blue-headed Quail-doves were fairly general users of habitat, as they were observed across the range of litter cover values in our sample units (19 - 83%).

We did not observe a clear spatial pattern of areas with large or small amounts of leaf litter on the loma, which led to the absence of a spatial pattern of occupancy. The only spatial vegetation pattern we observed is that the secondary growth seen on the eastern portion of the loma has smaller trees and reduced canopy and leaf litter cover (Appendix 2), which may indicate more recent disturbance or abiotic factors affecting the vegetation growth which is not seen on the rest of the loma. However, quail-dove occupancy was not determined by that pattern. Indeed, no other vegetation variable, slope, aspect, or tree species showed any clear spatial pattern on the loma, and the estimated probability of occupancy was high at all levels (low, medium, and high) of each variable. This is likely the main reason why no other model was able to explain occupancy of the Blue-headed Quail-dove as related to a particular vegetation or physical feature covariate due to the general vegetative association of the quail-dove in this semi-deciduous forest that characterizes the Loma de Cunagua Wildlife Refuge.

We did observe patterns in our data that suggest a negative effect of leaf litter on the occupancy when leaf litter exceeds 70% cover. The probability of occupancy remained high (99%) from 19% litter up to about 70% and precipitously declined to zero at approximately 83% (Fig. 2.4). Because the proportion of leaf litter ground cover was used as a proxy for the proportion of exposed limestone rock due to their negative

correlation, the Blue-headed Quail-dove may be responding positively to an increase in the proportion of rock which is exposed at sites with low leaf litter. In fact, the sample units with leaf litter greater than 70%, which are associated with low occupancy, have an average rock cover of 11%; 30% of those sample units (n = 20) have no rock at all. The rest of the sample units (n = 50) with low to medium levels of litter between 19 and 70% which are indicative of high occupancy had an average rock cover of 21%; less than 1% of those sample units had no rock cover. Though it is only a 10% difference, it may be a meaningful difference to the quail-dove. The average rock proportion for the loma is 0.185 (± 0.132).

Why is the probability of occupancy high at low to medium proportions of leaf litter? The presence of leaf litter on the ground is important to terrestrial species such as new world quail-dove which primarily feed on seed, berries and small snails (Gundlach, in Bent 1963). Seeds and berries are affected by the abiotic factors of humidity and temperature which may create the micro site conditions necessary for seed viability underneath the layers of leaf litter especially in drought years and during the dry season. Specifically, this protective cap in tropical forests provides a hydraulic balance between the seed and the soil (Sork 1985) protecting both berries and seeds from desiccation during the dry months and flooding in the wet season. Alternatively, temperatures can become too high in seasonal environments causing seed mortality and desiccation beneath the litter (Foster 1986). Leaf litter can also protect seeds from seed predators (Cintra 1997, except see Schupp 1989), but these factors may also create an environment which allows for an increase of activity of seed predators (Schupp 1989). Blue-headed Quail-dove, as well as species of the genus *Geotrygon*, are such ground dwelling seed

predators known for moving leaf litter substrate with both their feet and their beaks down to the bare soil (Skutch 1991, K. Leavelle pers. obs.) in search of berries and seeds which would allow them to take advantage of seed physiology and establishment mechanisms.

Invertebrates are considered to be a dietary element for the Blue-headed Quail-dove as they have been directly observed to take small terrestrial snails (Dr. Jean Gundlach in Bent 1963). Quail-dove are only part time fruit and seed eaters probably relying on a certain amount of invertebrate protein in their diets (Goodwin 1983). Captive Blue-headed Quail-dove have been known to “devoure” mealworms, snails, and slugs (Skutch 1991) suggesting that animal protein may be an important dietary component of doves. Low to mid elevations upwards of 1,000 m where quail-doves are typically found (Gibbs et al. 2001) have more prolonged dry spells and associated deciduousness with trees either dropping all of their leaves or reducing their leaf volume (Smythe 1970). Fallen leaves of these seasonal forests harbor many species of invertebrates which rely on litter fall for both structure and nutritional quality (Bultman & Uetz 1984), moisture during the dry season (Levings and Windsor 1984), abiotic factors of temperature and humidity (Janzen and Schoener 1968) and chemical properties of the soil resulting from litter decomposition (Seastedt 1983). In a subtropical seasonal forest in Costa Rica terrestrial snails are associated with secondary growth vegetation and increase with increasing leaf litter depth and proportion for thermic stability (Barrientos 2000).

The proportion of exposed limestone rock may not be important as much as the ability of these tide pool-like formations to retain water, a vital resource for many organisms in a seasonally dry environment especially during the dry winter months.

Blue-headed Quail-dove are frequent visitors during the breeding season to these small watering holes called “posetas” of which only 4 – 0.5 m diameter pools and several smaller cup size reservoirs have been identified at the loma. As many as five individuals have been observed at one time at a poseta to drink water during the month of May and as many as eight throughout the course of a day (K. Leavelle pers. obs). There may also be a connection between terrestrial snails, a potentially important dietary element of the Blue-headed Quail-dove, and limestone rock deposits characteristic of the island of Cuba (Seifriz 1943, Borhidi 1991). Interestingly, small terrestrial snails are more abundant on limestone hills in Borneo supporting two to five times more species than non-limestone plots possibly due to the calcium carbonate availability important for egg and shell formation (Schilthuizen et al. 2003). Terrestrial snails are indeed found at the loma de Cunagua refuge and may be playing an important role in the presence of the Blue-headed Quail-dove in this environment and in its feeding ecology.

Future Investigation and Long term Monitoring. – Blue-headed Quail-doves are ubiquitous at the Loma de Cunagua refuge; therefore, conservation efforts should protect the entire loma. If logistical constraints allow, additional years of surveys will be needed to increase the precision of our occupancy estimates of the Blue-headed Quail-dove at the Loma de Cunagua and will allow biologists to detect trends in occupancy as well as the dynamic processes of extinction and colonization probabilities. If there is a need to decrease the effort involved in multiple visits to a sample unit then it is reasonable to recommend a decrease in the number of sample units included in bird surveys due to the homogeneity of the habitat (MacKenzie et al. 2002) while maintaining the recommended minimum three visits per sample unit (MacKenzie et al. 2002, Tyre et al.

2003) though five is a more optimum number of visits to reduce bias and variance in the estimates (Tyre et al. 2003). Furthermore, occupancy surveys can be conducted every two to three years if survey effort needs to be decreased. When the old coffee plantation area and burned areas from the 1986 fire are identified, sample units can be stratified according to vegetation differences which resulted from disturbance which may provide more fine scale differences in occupancy estimates.

Because this species is extremely elusive and difficult to detect we believe that detection probabilities can be increased by adding call playback methods to population counts. In 2007 we tested a call playback method to lure the birds in and had better than expected results. We chose one 1 km line in particular where we believed the quail-dove to be present, but absent on all visits during the official bird surveys, and played the quail-dove call every 200 m for 5 min. Individuals either sang in response or walked into the area either alone or in a pair to investigate the playback at each point. Blue-headed Quail-dove are territorial during the breeding season and will respond to other individuals entering into their territory by approach, display or if that doesn't work, physical contact (K. Leavelle pers. obs.). Use of call playback at all sample units by all observers during bird surveys is therefore recommended to increase both detection and sample unit occupancy probabilities.

Occupancy, relative abundance and habitat associations of the Blue-headed Quail-dove should be investigated within remaining forest types throughout Cuba for the purposes of direct comparisons of relative abundance and to evaluate actual species distribution on the island. Specifically, we recommend investigating areas within the reserve such as Tres Galan, a mixed palm, broadleaf, semi-deciduous forest located at sea

level at the base of the loma, and Cayo Coco, a reserve with semi-deciduous trees, palmettos, black mangrove and coastal dunes which made this a perfect place for study of any species in a series of stratified sub-tropical habitat types. It would also be important to extend the study to areas outside of the reserve such as other neighboring lomas common to this region or other natural areas within the central region such as Cueva Lechusa in the Sierra de Cubitas where the Blue-headed Quail-dove has been sited (Concepción and Tadeo 1997). Finally, investigations should be initiated in La Güira National Park in Pinar del Rio, and the Guanahacabibes peninsula in the Eastern portion of Cuba where naturalists and biologists have previously reported the quail-dove, as well as the Zapata peninsula which would be a extension of an investigation previously conducted with all four quail-dove species which occur together in this area (Rodriguez and Sanchez 1993).

Investigation into species interactions will determine if and how each species influences the other with respect to occupancy, extinction or colonization (MacKenzie et al. 2005). We recommend a program to monitor the Key-West Quail-dove, the Ruddy Quail-dove and the Blue-headed Quail-dove to determine niche partitioning, ecological behaviors and effects of interactions they may have on each other. The Grey-headed Quail-dove was not observed at any time during this investigation but is reported in Cayo Coco, Ciego de Avila, Cuba.

Occupancy methods that account for the probability of detection are fundamental to the long-term monitoring of population trends of this endangered endemic species, and to gaining a better understanding of the species associations within differing habitat types. Results from our study at the Loma de Cunagua Wildlife Refuge should serve as

the basis for new investigations both locally and regionally, and should be used to update the current World Conservation Unions' records for Blue-headed Quail-dove estimated abundance in a semi-deciduous lowland forest in Cuba.

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