

OCCUPANCY AND ASSOCIATED HABITAT CHARACTERISTICS, FRUIT
PREFERENCES, AND NESTING BEHAVIORS OF THE BLUE-HEADED
QUAIL-DOVE (*STARNOENAS CYANOCEPHALA*) OF CUBA

By

Karen M. Leavelle

A THESIS

Presented to the Faculty of
The Graduate College at the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Master of Science

Major: Natural Resource Sciences

Under the Supervision of Professor Felipe Chávez-Ramírez

Lincoln, Nebraska

December 2008

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Karen Marie Leavelle, M.S.

University of Nebraska, 2008

Advisor: Felipe Chávez-Ramírez

The endangered Blue-headed Quail-dove (*Starnoenas cyanocephala*) is a ground dwelling bird endemic to the island of Cuba whose population has declined in the last century due to hunting pressures and habitat loss. The subtropical forest ecosystems in which the Blue-headed Quail-dove resides are so severely reduced that it is considered a rare species due to its restricted geographical range and low abundance. The population status and ecology of the Blue-headed Quail-dove remain understudied mainly due to quail-doves shy and illusive behavior.

This study examines the occupancy and habitat characteristics associated with the Blue-headed Quail-dove in the Loma de Cunagua wildlife refuge, a seasonally dry semi-deciduous forest in The Grand Humedal reserve in the northern coast of the province of Ciego de Avila, Cuba during the breeding season March - June 2006 to 2008. We also conducted a multiple offer “cafeteria” fruit preference experiment with captive Blue-headed Quail-dove at the National Zoo of Havana, Cuba in September of 2007 in order to understand the potential importance of particular choice foods. Finally we present first descriptions of Blue-headed Quail-dove nests and nestling growth at the Loma de

Cunagua as well as reproductive behaviors including incubation, nestling care, hatching and the first ever observation of hatchling predation.

Results indicate an average estimated 60% occupancy and a positive association with a proportion of leaf litter up to approximately 68% in which to forage for seeds, berries and animal prey, and the presence of a minimal proportion $\geq 30\%$ of exposed limestone rock which may hold water throughout the year, an important aspect in a dry forest environment. Results of fruit preference experiments suggest that Blue-headed Quail-dove preferred *Guazuma parvifolia* and *Hamelia patens* while they avoided *Ficus havanensis*, *Trema micrantha*, *Lagetta valenzuelana*, *Bursera simaruba*, *Metopium brownei*, and *Trichilia hirta*. *Ottoschulzia cubensis* may be a preferred fruit at a different level of ripeness. Lastly, two nests were found over two years (2006 and 2007). One nest was placed on a Bayua (*Zanthoxylum elephantiasis*) snag 2.55 m off the ground and fledged two young. The other was placed 4.30m up on a live Jocuma (*Mastichodendron foetidissimum*) trunk and hatchlings (n = 2) were depredated by a West Indian Racer (*Alsophis cantherigerus*). The nestling period is approximated to be 11 days.

ACKNOWLEDGMENTS

I would first like to thank all of the members of my committee for all their guidance and support throughout this project. First and foremost I want to extend my gratitude to my committee chair Felipe Chavez-Ramirez for giving me the opportunity to work with him in Cuba with not only this project but in helping to work towards a greater goal of training, science and conservation in the Gran Humedal del Norte de Ciego de Avila Reserve. I would also like to thank my committee Larkin Powell and Drew Tyre for all unending patience, guidance and support in all aspects of this project. Your doors were always open to me when I came calling and for that I am grateful.

A thank you also goes out to Jim Hines for all his assistance with using and understanding program PRESENCE, and to Milda Vaitkus at CALMIT for all the GIS assistance she provided. Thank you both for taking time out of your busy schedules to offer your assistance. Andy Mitchell eagerly provided me with his knowledge of Cuba, Blue-headed Quail-doves and sound recordings of all the dove species found on the island that we would not have been able to do without.

I am extremely grateful to all of our funding institutions without which none of this would have been possible: The International Crane Foundation, The Christopher Reynolds Foundation of New York, The National Geographic Society, and the John D. & Catherine T. MacArthur Foundation. We would also like to thank Optics for the Tropics for their generous donation of binoculars to all our field crew.

This project would not have possible without the approval of the Ministry of Agriculture of Cuba and the collaboration and support of the Empresa Nacional para la Protección de la Flora y la Fauna Nacional of Cuba and Flora y Fauna of Ciego de Avila

and the Loma de Cunagua Wildlife Refuge. In particular, recognition goes to Xiomara Galvez-Aguilera for approving the project and making it all happen and for your academic, logistical and emotional support whenever I needed you. A thank you also goes to Luis Alfaro, director of Flora y Fauna Ciego de Avila for your local support of the project and to Yarelys Ferrer-Sanchez for taking the helm in the second year. I especially want to thank my field technicians Oscar Ortiz-Cedeno, Albaro Espinoza-Romo, Osmani Jimenez-Perez, Niolber Verdecia-Quñone, Daniel Jimenez-Hernandez, Andres Tamallo and Ever Zambrano. Thank you for helping to make this project possible, for all the kilometers you walked, the masses of mosquitoes and wasp stings you endured, and your enthusiasm and desire to work with, conserve and protect this beautiful bird.

I would also like to thank all of my guarding angels at the Loma de Cunagua. Many people took care of me and watched over me during my stay in Cuba including Daysi and Lisandro, Jorge and Maida, Sonia, Francisco, Arley, and all my guys, but especially Osmani who made sure I had everything I needed at all times. I am indebted to you all.

The fruit experiment would not have been possible without the help of Dra. Daysi Rodriguez-Batista from the Instituto de Ecología y Sistemática, Tomas Escobar, director of the National Zoo of Havana, Yamilet Rodriguez who headed the experiment in my absence and to the governing bodies who approved all permits which allowed us to work with the captive of Blue-headed Quail-dove.

Various people supported me along the way throughout my time in graduate school: Kimberly Reynolds for keeping me grounded when things got difficult, and to

Luis Ramírez and Ingrid Barceló for lending an ear and propping me up when I needed it the most. Finally I would like to extend a huge thank you to Kirk Stodola for supporting me in this project from start to finish. Your belief in me, and not to mention the loads of project advice is what got me started and helped me through each and every day. And last but certainly not least, to my best friend and constant companion Jack for always greeting me at the door every night and never losing the wag in your tail.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	i
CHAPTER1. INTRODUCTION.....	1
LITERATURE CITED.....	6
CHAPTER2. OCCUPANCY AND HABITAT CHARACTERISTICS ASSOCIATED WITH THE BLUE-HEADED QUAIL-DOVE (<i>STARNOENAS CYANOCEPHALA</i>) IN CUBA	9
ABSTRACT.....	9
METHODS.....	12
<i>Methodological Considerations</i>	12
<i>Study Area</i>	14
<i>Bird Surveys</i>	15
<i>Vegetation Measurements</i>	18
<i>Data Analysis</i>	18
<i>Candidate Models</i>	21
RESULTS.....	23
<i>Detection</i>	23
<i>Local Extinction and Colonization Modeling</i>	25
<i>Habitat Modeling</i>	27
<i>Sample unit Occupancy</i>	31
<i>Abundance</i>	32
DISCUSSION.....	33
<i>Future Investigation and Long-Term Monitoring</i>	38

LITERATURE CITED.....	41
CHAPTER3. FRUIT PREFERENCES OF CAPTIVE BLUE-HEADED QUAIL-DOVE (<i>STARNOENAS CYANOCEPHALA</i>) IN CUBA.....	46
ABSTRACT.....	46
METHODS.....	49
<i>Captive Site</i>	49
<i>Fruit Species Tested</i>	49
<i>Seed Preference Trials</i>	52
<i>Statistical Analysis</i>	54
RESULTS.....	55
DISCUSSION.....	60
LITERATURE CITED.....	67
CHAPTER4. NOTES ON NESTING AND REPRODUCTIVE BEHAVIORS OF THE BLUE-HEADED QUAIL-DOVE (<i>STARNOENAS CYANOCEPHALA</i>) IN CUBA.....	72
ABSTRACT.....	72
METHODS.....	74
RESULTS.....	75
<i>Nest Description</i>	75
<i>Incubation</i>	77
<i>Nestlings</i>	78
<i>Hatching and Nest Predation</i>	80
DISCUSSION.....	81
LITERATURE CITED.....	84

CHAPTER5. CONCLUSIONS.....86

APPENDIX 1.....88

APPENDIX 290

CHAPTER 1: INTRODUCTION

CERTAIN REGIONS IN the world, particularly tropical islands, support large numbers of rare and unique endemic avifauna (Johnson and Stattersfield 1991, Stattersfield et al. 1998). The islands of the Greater Antillean chain are among the most affected with the loss of endemism due to their restricted areas (Stotz et al. 1996), and the destruction of habitat through deforestation (Stattersfield et al. 1998) making it a hotspot for conservation (Myers et al. 2000), and a region most at risk to future loss of endemic species (Brooks et al. 2000). Waves of species extinction are occurring in these biogeographical regions of endemism including the island of Cuba, especially for species that have had difficulty adapting to anthropogenic habitat changes.

Unique endemic species not only add to natural heritage but are also important to the function of a healthy ecosystem (Stotz et al. 1996). Many tropical island avian endemics are seed dispersers, seed predators and pollinators that play an important role in forest regeneration and ecosystem function (Strahl and Grajal 1991). They are also good indicators of overall quality of habitat (Diamond & Lovejoy 1985; Blake et al. 1990). Organisms that share characteristics such as endemism, habitat specialization, small population size, or sensitivity to habitat loss and change allow for identification of diversity of biological communities especially those in need of conservation and protection (Pimm et al. 1988, Stattersfield et al. 1998, Biber 2002).

The island of Cuba is considered an Endemic Bird Area of the World (EBA) and ranked “critical”, demonstrating the highest level of avian extinction concern (Stattersfield et al. 1998). Cuba is also home to 28 endemic species, nine of which are considered endangered (Biber 2002). Most of Cuba’s natural areas have been converted

to cash-crops and pasture with only approximately 18% still in its pristine state (Perera et al. 2004). Much of Cuba's avifauna is threatened by illegal logging, charcoal production, continued clearing for agriculture, tropical storms (Collar et al 1994; Baillie & Groombridge 1996) introduction of exotic species and chemical pollution (Garrido and Kirkconnell 2000).

The Blue-headed Quail-dove (*Starnoenas cyanocephala*) (A.O.U. 1998), alternatively known as the Blue-headed Ground-Pigeon and the Black-bearded Dove (Goodwin 1983), is one of Cuba's rare endemic avian species considered to be endangered with a high risk of extinction (BirdLife International 2008). It is one of Cuba's threatened species most affected by the alteration and loss of habitat (Collar et al. 1994; Baillie & Groombridge 1996; Stattersfield et al. 1998), but has also had the added threat of hunting and poaching as well as introduced predators (Gibbs et al. 2001, BirdLife International 2008).



Fig. 1.1. The Blue-headed Quail-dove (*Starnoenas cyanocephala*) locally known as the Paloma Perdiz, at the Loma de Cunagua Wildlife Refuge, Ciego de Avila, Cuba.

The Blue-headed Quail-dove, a member of the Columbidae family, is a new world quail-dove most closely related to members of *Geotrygon* genus. It is the largest Cuban Quail-dove (30 – 33cm) (Rafaelle et al. 1998), and co-occurs with the Gray headed Quail-dove (*Geotrygon caniceps*), The Key-West Quail-dove (*Geotrygon chrysie*) and The Ruddy Quail-dove (*Geotrygon montana*) on the island of Cuba. It is the only species within the monotypic genus *Starnoenas*, and is set apart from *Geotrygon* due to its black breast bib bordered in white, its hexagonal scales on the front of its legs and its white eggs (*Geotrygon* lay cream-colored eggs) (Goodwin 1983). It also has a striking cobalt blue head and the characteristic white facial stripe which sits below a black eye-line. The call note is a “uuuu-up”, a long first syllable followed by the last syllable which rises and stops quickly. Quail-doves as a group are so named because they are primarily long-legged forest ground-dwelling species similar to that of quail and partridge (Goodwin 1983). In Cuba the Blue-headed Quail-dove is commonly referred to as La Paloma Perdiz, or partridge dove, and is considered to be behaviorally similar to the European Gray partridge, (*Perdix perdix*) which may have led to the local name “Perdiz” (Raffaele et al 1998).

Very little data is available on the ecology and conservation status of the new world quail-doves, and beyond descriptive accounts, published ecological studies of The Blue-headed Quail-dove are limited. Original late 19th Century natural history accounts come from Dr. Jean Gundlach and Dr. Thomas Barbour in Bent (1963), and then later in the 20th century from Bond (1993), Goodwin (1983), Skutch (1949, 1991) and (Rodriguez and Sanchez 1993). Based on these accounts and subsequent observations a picture emerged indicating an association with lowland forest (Barbour in Bent 1963), in

particular dry lowland woods next to swamp areas, deciduous lowland forest, and deciduous second growth (Rompre et al 1999), but is also patchily distributed in highland forest (Bond 1993). Rodriguez and Sanchez (1993) add that the Blue-headed Quail-dove can be found in semi-deciduous and evergreen forests. All descriptions account for much of the forested vegetation types found on Cuba suggesting that the Blue-headed Quail-dove may be occupying a considerable part of the remaining available habitat on the island (Rodriguez and Sanchez 1993).

The Blue-headed Quail-dove forages within the leaf litter for seeds, berries, and small terrestrial snails in the forest undergrowth below a dense canopy with an open understory and a limestone forest floor (Gundlach in Bent 1963, Bond 1960), as well as peas and crop seeds from plantations (Gibbs et al. 2001). In spite of the fact it will readily eat grubs and other insects in captivity (Delacour 1959) information on specific animal prey in the natural diet is needed. According to Bendire (in Bent 1963) the Blue-headed Quail-dove is infrequently found on the forest edge in open prairies or cultivated fields, but Wells & Mitchell (1995) observed several individual Blue-headed Quail-dove foraging in a garden that the birds were known to frequent plus fifteen individuals around a water hole nearby in Bermejas near playa Giron within the Gran Parque Nacional de Montemar which protects the Zapata Swamp peninsula.

Reproductive ecology of the Blue-headed Quail-dove is another area of study in need of further attention. Direct observations of the Blue-headed Quail-dove in its natural environment indicate that nesting takes place primarily from March through June (Garrido and Kirkconnell 2000) or as late as July (Gundlach 1893 cited in Rodriguez and Sanchez 1993). Nests are made of twigs topped with fresh leaves placed within shrubs,

dead tree stumps (Bond 1993, Garrido and Kirkconnell 2000), and sometimes in on top of parasitic vines “*Tillandsia*” epiphytes (Bendire in Bent 1963). In addition, two eggs are generally layed and both parents share nesting responsibilities, a behavior typical of pigeons and doves (Goodwin 1986, Skutch 1949, 1991).

Due at least in part to its timid behavior the ecology of the Blue-headed Quail-dove still remains largely understudied. This species is inferred to have a small population estimated at approximately 550 – 1,850 individuals occupying an estimated area of less than 500km². These estimates however are taken from the lowest of three density estimates for the Ruddy Quail-dove (*Geotrygon montana*) (BirdLife International 2008). This limited information coupled with other potential limiting factors such as an increasingly fragmented habitat and possible hunting make this “jewel of the Caribbean” (Raffael et al. 1998) important for conservation and monitoring. Basic ecological and behavioral studies are a priority to understand exactly what may be directly threatening this population.

This study attempts to build upon the ecological foundation for the Blue-headed Quail-dove in a seasonally dry semi-deciduous sub-coastal habitat. The Loma de Cunagua Wildlife Refuge study area is a lowland subtropical forest located within the Gran Humedal wetland reserve on the northern coast in the central province of Ciego de Ávila, Cuba. The Loma de Cunagua, a 2,428 ha lowland forest (22° 06’N; 78°26’W) 340 m in elevation was at one time used heavily by locals to clear wood to make charcoal, and as a shade coffee and plantain plantation. In 1986 a high intensity fire burned much of the forest, destroying the agricultural base including the livelihood of many surrounding area residents, as well as much of the flora and fauna found there. The

loma was aerielly reseeded that following year and was officially designated as a protected wildlife refuge. It was however uncertain what wildlife remained. According to locals, prior to the fire hunting of many of the lomas fauna was a common event, and included the Blue-headed Quail-dove amongst others. After 22 years of forest regeneration and legal protection, local foresters and residents were uncertain as to the presence of the Blue-headed Quail-dove on the loma and wanted to determine the species status as part of an endangered species conservation and long-term monitoring and management program.

Considering the endangered status of the Blue-headed Quail-dove and the need for knowledge of the species ecology in its natural environment in order to affect proper management and protection, our primary objectives of this study were to 1) estimate occupancy, abundance and habitat characteristics associated with the Blue-headed Quail-dove in a semi-deciduous forest; 2) determine fruit preferences in a captive experimental setting; and 3) describe nesting and reproductive behaviors in the seasonally dry subtropical environment of the Loma de Cunagua wildlife refuge within the Gran Humedal del Norte de Ciego de Ávila, Cuba.

LITERATURE CITED

- AMERICAN ORNITHOLOGISTS' UNION. 1998. Check-list of North American Birds, 7th ed. American Ornithologists' Union, Washington, D.C.
- BAILLIE, J., AND B. GROOMBRIDGE, EDITORS. 1996. 1996 IUCN Red List of Threatened Animals. IUCN, Gland, Switzerland.
- BENT, A. C. 1963. Life Histories of North American Gallinaceous Birds. U.S. National Museum Bulletin. No. 162, pp. 456-458.
- BIBER, E. 2002. Patterns of endemic extinctions among island bird species. *Ecography* 25:661-676.

- BLAKE, J. G., B. A. LOISELLE, T. C. MOERMOND, D. J. LEVEY, AND J. S. DENSLOW. 1990. Quantifying Abundance of Fruits for Birds in Tropical Habitats. Pages 73-79 in *Studies in Avian Biology*.
- BOND, J. 1993. *Birds of the West Indies*, 5 ed. Houghton Mifflin, Boston.
- BROOKS, T. M., R. A. MITTERMEIER, C. G. MITTERMEIER, G. A. B. DA FONSECA, A. B. RYLANDS, W. R. KONSTANT, P. FLICK, J. PILGRIM, S. OLDFIELD, G. MAGIN, AND C. HILTON-TAYLOR. 2002. Habitat loss and extinction in the hotspots of biodiversity. *Conservation Biology* 16:909-923.
- COLLAR, N. J., M. J. CROSBY, AND A. J. STATTERSFIELD. 1994. *Birds to Watch 2. The World List of Threatened Birds*. BirdLife International. Page Bros Ltd., Norwich, UK.
- DELACOUR, J. 1959. *Wild Pigeons and Doves*. All-Pets Books, Fond du Lac, Wisconsin.
- DIAMOND, A. W., AND T. E. LOVEJOY. 1985. *Conservation of Tropical Forest Birds (Technical Publication #4)*. Princeton University Press.
- GARRIDO, O. H., AND A. KIRKCONNELL. 2000. *Field Guide to the Birds of Cuba*. Cornell University Press.
- GIBBS, D., E. BARNES, AND J. COX. 2001. *Pigeons and Doves: A Guide to the Pigeons and Doves of the World*. Yale University Press.
- GOODWIN, D. 1983. *Pigeons and Doves of the World*, 3rd ed. Cornell University Press.
- JOHNSON, T. H., AND A. J. STATTERSFIELD. 1991. A global review of island endemic birds. *Ibis* 132.
- MYERS, N., R. A. MITTERMEIER, C. G. MITTERMEIER, G. A. B. DA FONSECA, AND J. KENT. 2000. Biodiversity Hotspots for Conservation Priorities. *Nature* 403:853-858.
- PERERA, A., A. GONZÁLEZ, R. FERNÁNDEZ DE ARCILA, R. ESTRADA, AND A. MARTÍNEZ. 2004. *Las Áreas protegidas en Cuba*. Centro Nacional de Áreas Protegidas. Ministerio de Ciencia, Tecnología y Medio Ambiente. Playa.
- PIMM, S. L., H. L. JONES, AND J. DIAMOND. 1988. On the risk of extinction. *The American Naturalist* 132:757-785.
- RAFFAELE, H., J. WILEY, O. H. GARRIDO, A. KEITH, AND J. RAFFAELE. 1998. *A Guide to the Birds of the West Indies*. Princeton University Press, New Jersey.

- RODRIGUEZ, D., AND B. SANCHEZ. 1993. Ecología de las Palomas Terrestres Cubanas (géneros *Geotrygon* y *Starnoenas*). *Poeyana* 428:1-20.
- ROMPRE, G., Y. AUBRY, AND A. KIRKCONNELL. 1999. Notes on Some Cuban Birds. *Cotinga* 11:31-33.
- SKUTCH, A. F. 1949. Life History of the Ruddy Quail-dove. *The Condor* 51:3-19.
- SKUTCH, A. F. 1991. Life of the Pigeon. Cornell University Press. Ithaca, N.Y.
- STARNOENAS CYANOCEPHALA* (LINNAEUS). BLUE-HEADED QUAIL-DOVE. *COLUMBA CYANOCEPHALA* (LINNAEUS). 1758. *Syst. Nat.* (ed. 10) 1: 163. Based on "The Turtle-Dove from Jamaica" Albin, *Nat. Hist. Birds* 2: 45, pl. 49.
- STATTERSFIELD, A. J., M. J. CROSBY, A. J. LONG, AND D. C. WEGE, EDITORS. 1998. Endemic Bird Areas of the World: Priorities for Biodiversity Conservation. BirdLife International, Cambridge, UK.
- STOTZ, D. F., J. W. FITZPATRICK, T. A. PARKER, AND D. K. MOSKOVITS. 1996. Neotropical Birds: Ecology and Conservation. The University of Chicago Press, Chicago and London.
- STRAHL, S. D., AND A. GRAJAL. 1991. Conservation of large avian frugivores and the management of neotropical protected areas. *Oryx* 25:50-55.
- WELLS, L., AND A. MITCHELL. 1995. The Threatened Birds of Cuba Project. BirdLife International, Cambridge, UK.

**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

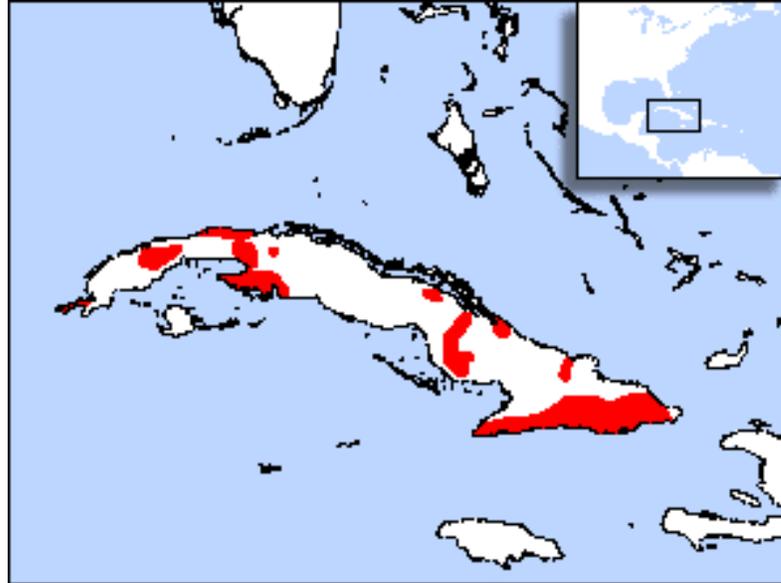


FIG. 2.1. Distribution map of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) in Cuba (BirdLife International 2008)

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 km^2 occupying an estimated island area of 500 km^2 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.

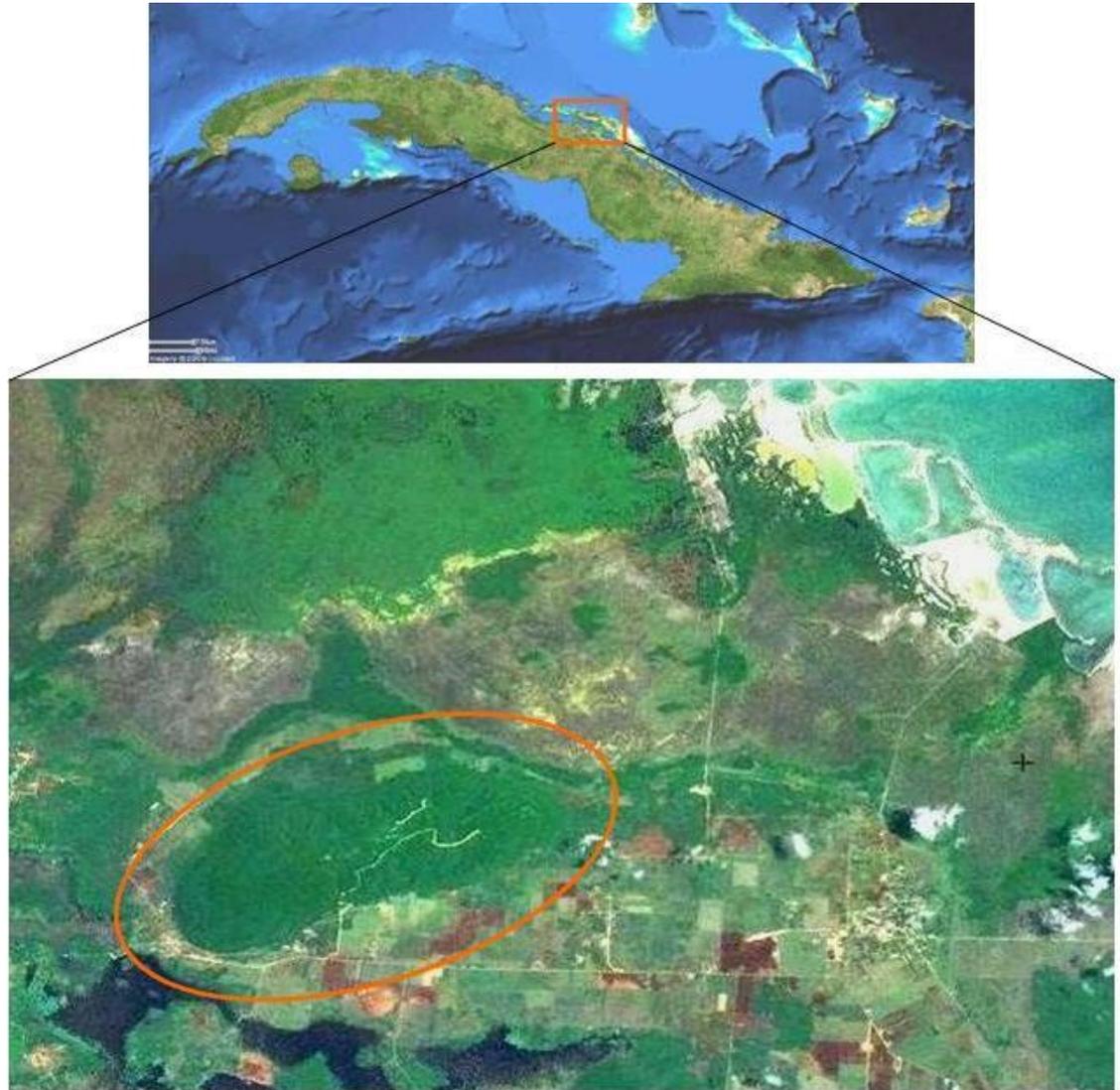


FIG 2.2. Loma de Cunagua Wildlife Refuge study area (outlined in red) in the Ciego de Ávila region of Cuba. The dry sub-coastal semi-deciduous forest was surveyed for presence of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) from 2006 – 2008.

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 2 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.

Multi-season model 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-dove may be preferring 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 AIC_c 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, abundance we estimated by including the total number of detections per 2 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.

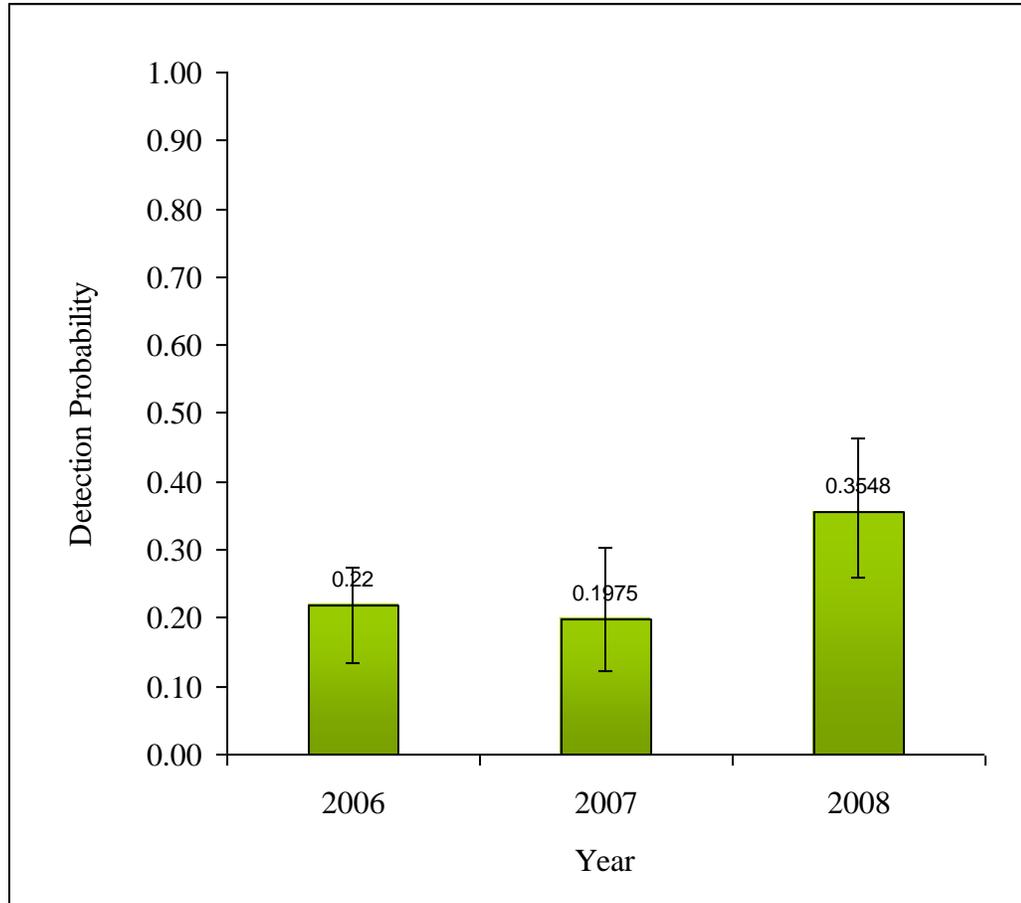


FIG. 2.3. Detection probabilities (p) for Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Refuge, Cuba 2006 - 2008. \pm 95% Confidence Intervals.

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.

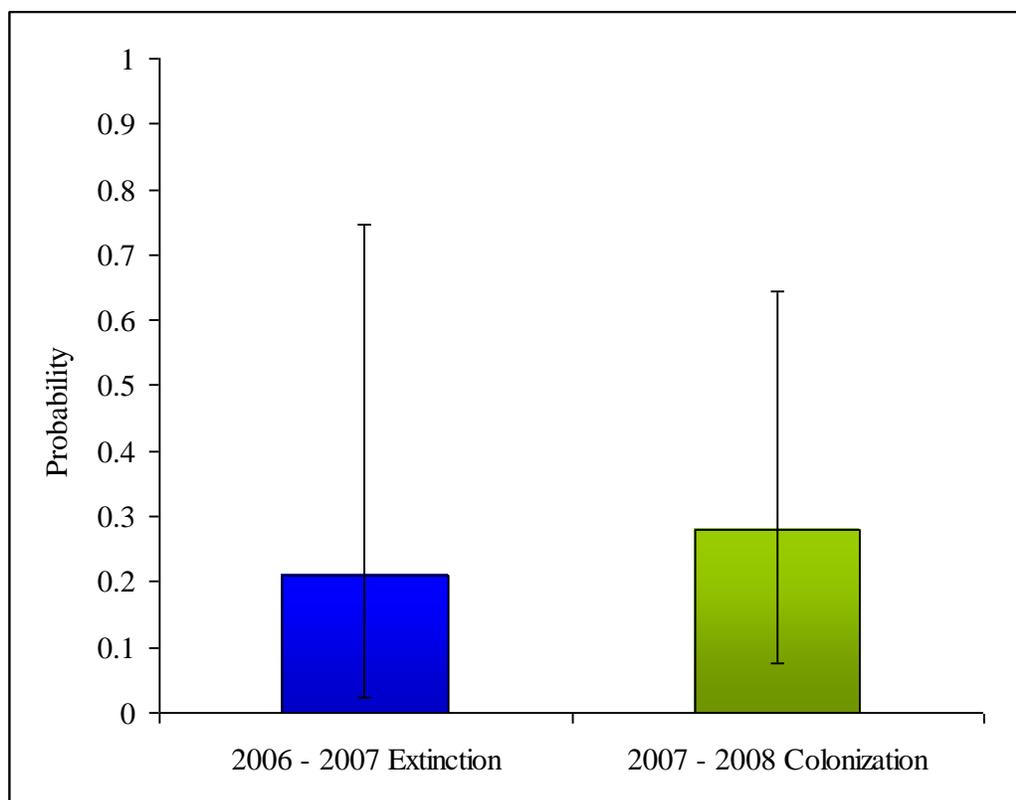


Fig. 2.4. Probability of extinction (ϵ) 2006 – 2007 and colonization (γ) 2007 – 2008 of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Refuge, Cuba \pm 95% Confidence Intervals.

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 ($\hat{c} = 0.95$). 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 [$\gamma(08)$] in 2008 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. Trees 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.

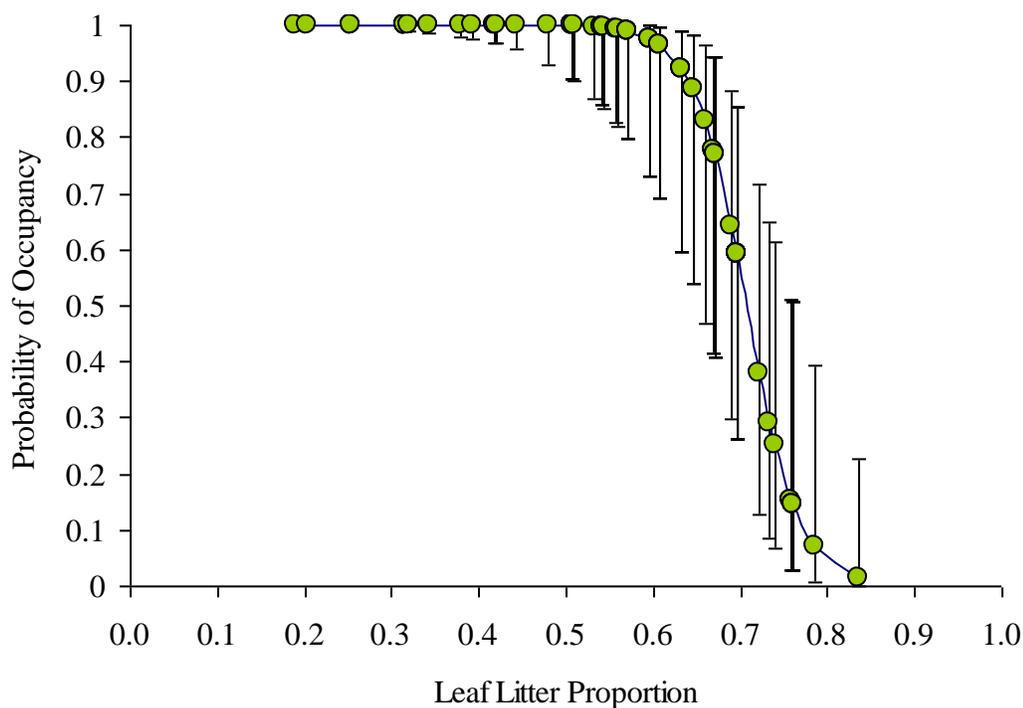


FIG. 2.4. Logistic curve describing the probability of sample unit occupancy \pm 95% confidence intervals as a function of the proportion of leaf litter ground cover of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Reserve, Cuba from 2006 – 2008.

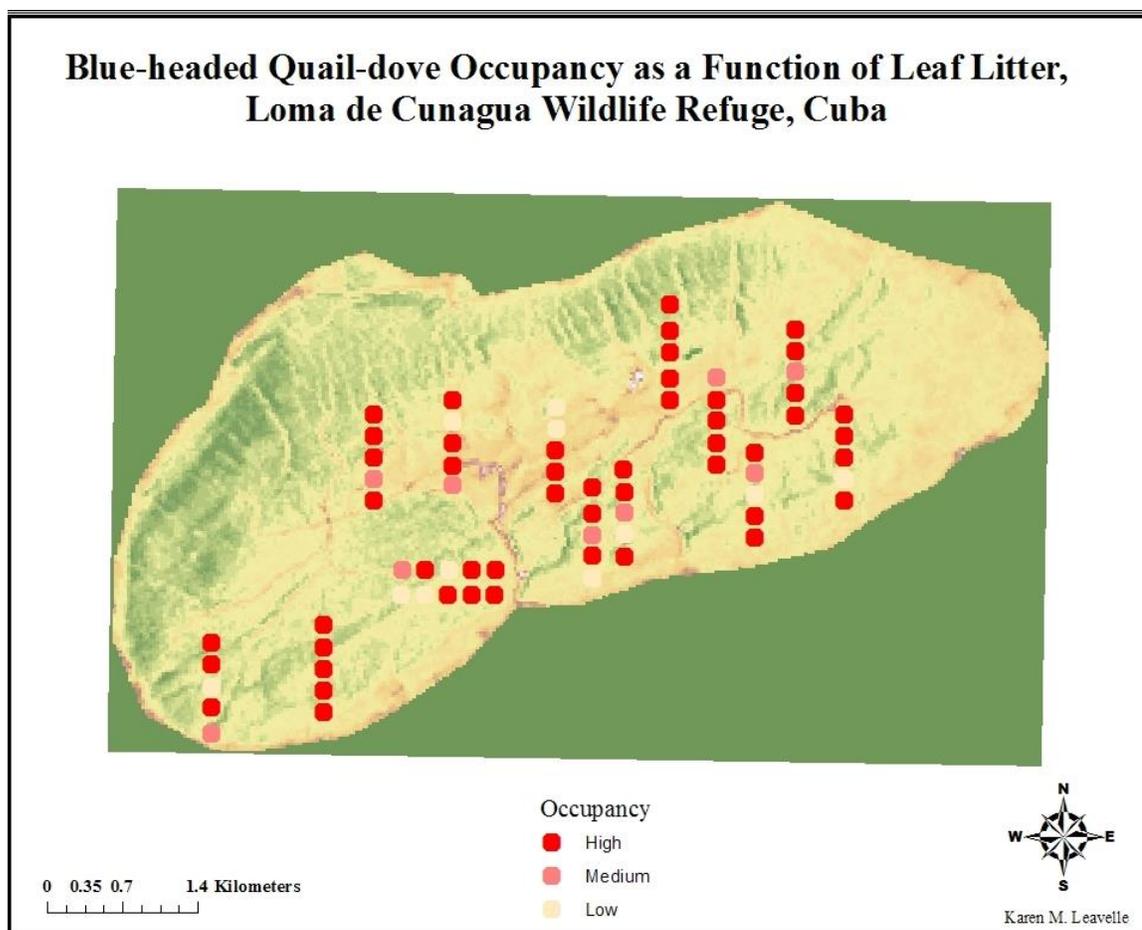


FIG. 2.5. Occupancy of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Refuge, Cuba as a function of leaf litter proportion. Areas of high occupancy ($\geq 70\%$) are in red, medium occupancy (40 – 69%) and low occupancy (0 – 39%). True color is not represented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

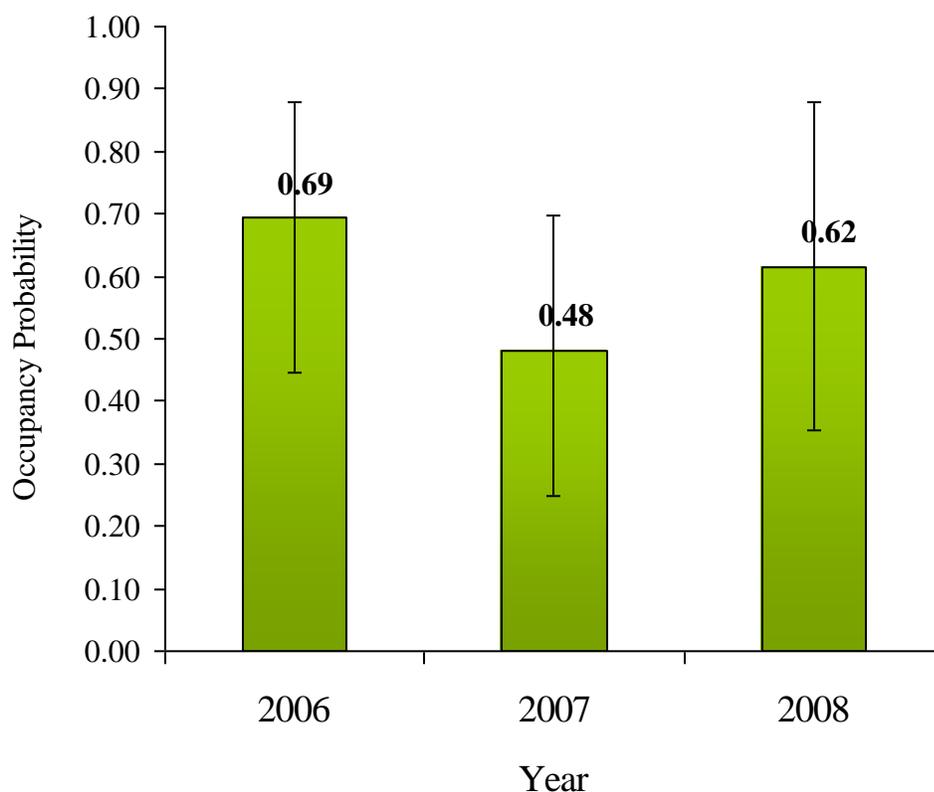


FIG. 2.6. The probability of sample unit occupancy of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) at the Loma de Cunagua Wildlife Refuge, Cuba from 2006 - 2008 \pm 95% Confidence limits.

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 (N_{hat}) 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. Our abundance estimates ($0.36 \text{ birds ha}^{-1}$) exceed those provided by BirdLife International ($0.01 \text{ ind ha}^{-1} - 0.04 \text{ ind ha}^{-1}$) or by Rodriguez and Sanchez (1993) at one study areas in the Cienaga de Zapata (0.05 ind ha^{-1}) and more closely agree with estimates from another (0.40 ind ha^{-1}).

TABLE 2.5. Abundance estimation from repeated count data formally allowing for detection probability (Royal 2004). Both detection (p) and average density/sample unit are transformed proportion estimates. Occupancy (ψ) and total abundance are derived parameter 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/ sample unit ($\hat{\lambda}$)	1.44	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>$8.74 \times 10^2 \text{ birds}^*$</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 is the first reported for a dry semi-deciduous forest and exceed low Ruddy Quail-dove population size estimates provided by BirdLife International (2008) as a proxy for Blue-headed Quail-dove estimates. The low end of our estimate more closely agrees with estimates given by Rodriguez and Sanchez (1993). Our estimates do have low precision, but they are generally higher than those of Rodriguez and Sanchez (1993). We incorporated detectability in our estimation process, which would be expected to provide a higher estimate, especially given our detectability rate 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. The average rock proportion for the loma is $0.185 (\pm 0.132)$. Though it is only a 10% difference, it may be a meaningful difference to the quail-dove.

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 (K. M. Leavelle pers. obs.) 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.

LITERATURE CITED

- AKAIKE, H. 1973. Information Theory and an Extension of the Maximum Likelihood Principle. Pages 267-281 in B. N. Petran and F. Csaaki, editors. International Symposium on Information Theory. Akademiai Kiado, Budapest, Hungary.
- BAILLIE, J., AND B. GROOMBRIDGE, EDITORS. 1996. 1996 IUCN Red List of Threatened Animals. IUCN, Gland, Switzerland.
- BARRIENTOS, Z. 2000. Population dynamics and Spatial Distribution of the Terrestrial Snail *Ovachlamys fulgens* (Stylommatophora: Helicarionidae) in a Tropical Environment. *Revista de Biologica Tropical* 48:
- BART J. AND S. EARNST. 2002. Double Sampling to Estimate Density and Population Trends in Birds. *The Auk* 119:36-45.
- BENT, A. C. 1932. Life Histories of North American Gallinaceous Birds. Dover Publications, New York.
- BIRDLIFE INTERNATIONAL (2008) Species factsheet: *Starnoenas cyanocephala*. Downloaded from <http://www.birdlife.org> on 12/7/2008
- BISSE, J. 1988. Arboles de Cuba. Editorial Cientifico-Tecnica, Ciudad de la Havana, Cuba
- BORHIDI, A. 1991. The Phytogeography and Vegetation Ecology of Cuba. Akademiai Kiado, Budapest.
- BUCKLAND S. T. AND D. A. ELSTON. 1993. Empirical Models for the Spatial Distribution of Wildlife. *Journal of Applied Ecology* 30:478-495.
- BULTMAN, T. L., G. W. UETZ. 1984. Effect of Structure and Nutritional Quality of Litter on Abundances of Litter-Dwelling Arthropods. *The American Midland Naturalist* 111:165-172.
- BURNHAM, K. P., AND D. R. ANDERSON. 2002. Model Selection and Multi-model Inference; A Practical Information-Theoretic Approach. Springer Science, New York, New York.

- CHAPMAN C. A., L. J. CHAPMAN, R. WANGHAM, K. HUNT, D. GEBO, L. GARDNER. 1992. Estimators of Fruit Abundance of Tropical Trees. *Biotropica* 24:527-531.
- CHIPLEY, R. M. 1991. Notes on the Biology of the Bridled Quail-dove (*Geotrygon mystacea*). *Caribbean Journal of Science* 27:180-184.
- CINTRA, R. 1997. Leaf Litter Effects on Seed and Seedling Predation of the Palm *Astrocaryum murumuru* and the Legume Tree *Dipteryx micrantha* in Amazonian Forest. *Journal of Tropical Ecology* 13:709-725.
- COLLAR, N. J., M. J. CROSBY, AND A. J. STATTERSFIELD. 1994. Birds to Watch 2. The World List of Threatened Birds. BirdLife International. Page Bros Ltd., Norwich, UK.
- CONCEPCIÓN, H. Y., AND R. P. TADEO. 1997. Registro de aves de la Sierra de Cubitas, Camaguey, Cuba. *El Pitirre* 10:93-94.
- DALSGAARD, B. 2007. Impacts of a volcanic eruption on the Forest Bird Community of Montserrat, Lesser Antilles. *Ibis* 149:298-312.
- FARNSWORTH, G. L., K. H. POLLOCK, J. D. NICHOLS, T. R. SIMONS, J. E. HINES, AND J. R. SAUER. 2002. A Removal Model for Estimating Detection Probabilities from Point-Count Surveys. *The Auk* 119:414-425.
- FOSTER, S. A. 1986. On the Adaptive Value of Large Seeds for Tropical Moist Forest Trees: A review and Synthesis. *Botany Review* 52:260-299.
- GARRIDO, O. H., AND A. KIRKCONNELL. 2000. Field Guide to the Birds of Cuba. Ithaca, NY: Comstock/Cornell University Press.
- GIBBS, D. G., E. BARNES AND J. COX. 2001. Pigeons and Doves: A Guide to the Pigeons and Doves of the World. Yale University Press, New Haven and London.
- GOODWIN, D. 1983. Pigeons and Doves of the World, 3rd edition. Cornell University Press, Ithaca, NY.
- GU, WEIDONG, AND ROBERT K. SWIHART. 2004. Absent or undetected? Effects of a non-detection of species occurrence on wildlife-habitat models. *Biological Conservation* 116:195-203.
- HINES, J. E. (2002). *PRESENCE2.0* - Software to Estimate patch occupancy rates and related parameters USGS-PWRC.
<http://www.mbr-pwrc.usgs.gov/software/presence.html>.
- HUTTO R. L., S. M. PLETSCHET, AND P. HENDRICKS. 1986. A Fixed-Radius Point Count Method for Non-Breeding and Breeding Season Use. *The Auk* 103:593-602

- JANZEN, D. H. AND T. W. SCHOENER. 1968. Differences in Insect Abundance and Diversity between Wetter and Drier Sample units during a Tropical Dry Season. *Ecology* 49:96-110.
- JAMES F. C. AND H. H. SHUGART JR. 1970. A Quantitative Method of Habitat Description. *Audubon Field Notes* 24:727-736.
- JANZEN, D. H. 1973. Sweep Samples of Tropical Foliage Insects: Effects of Season, Vegetation Types, Elevation, Time of Day, and Insularity. *Ecology* 54:687-708.
- LEVINGS, S. C., D. M. WINDSOR. 1984. Litter Moisture Content as a Determinant of Litter Arthropod Distribution and Abundance during the Dry Season on Barro Colorado Island, Panama. *Biotropica* 16:125-131.
- MCDONALD, L. L., 2004. Sampling Rare Populations. pp. 11-41 in W. L. Thompson, ed., *Sampling Rare or Elusive Species*. Island Press, Washington, D.C.
- MACKENZIE, D. I., JAMES D. NICHOLS, GIDEON B. LACHMAN, SAM DROEGE, J. ANDREW ROYAL, AND CATHERINE A. LANGTIMM. 2002. Estimating sample unit occupancy rates when detection probabilities are less than one. *Ecology* 83:2248-2255.
- MACKENZIE, D. I., AND A. J. ROYLE. 2005. Designing Occupancy Studies: General Advice and Allocating Survey Effort. *Journal of Applied Ecology* 42:1105-1114.
- MCSHEA W. J. AND J. H. RAPPOLE. 1997. Variable Song Rates in Three Species of Passerines and Implications for Estimating Bird Populations. *Journal of Field Ornithology* 68:367-375.
- MOILANEN A. 2002. Implications of Empirical Data Quality to Metapopulation Model Parameter Estimation and Application. *Oikos* 96:516-530.
- NICHOLS J. D, J. E. HINES, J. R. SAUER, F. W. FALLON, J. E. FALLON, AND P. J. HEGLUND. 2000. A Double Observer Approach for Estimating Detection Probability and Abundance from Point-Counts. *The Auk* 117:393-408.
- POLLOCK, K. H. 1982. A Capture-Recapture Design Robust to Unequal Probability of Capture. *Journal of Wildlife Management* 46:752-757.
- REED, L. L., L. B. MENDEL, AND H. B. VICKERY. 1932. The nutritive properties of the "crop-milk" of pigeons. *American Journal of Physiology* 101:285-292.
- RICHARDS, D. G. 1981. Environmental acoustics and censuses of singing birds. *Studies in Avian Biology* 6:297-300.

- ROYLE, A. J. AND JAMES D. NICHOLS. 2003. Estimating abundance from repeated presence-absence data or point counts. *Ecology* 84:777-790.
- ROYLE, A. J. 2004. N-Mixture models for estimating population size from spatially replicated counts. *Biometrics* 60:108-115.
- RIVERA-MILAN, F. F. 1992. Distribution and relative abundance patterns of Columbids in Puerto Rico. *The Condor* 94:224-238.
- RODRÍGUEZ, D., AND B. SÁNCHEZ. 1993. Ecology of Cuban Terrestrial Doves (Genus *Geotrygon* and *Starnoenas*). *Poeyana* 248:1-20.
- SAUER J. R., B. G. PETERJOHN, AND W. A. LINK. 1994. Observer Differences in the North American Breeding Bird Survey. *The Auk* 11:50-62.
- SCHILTHUIZEN, M., H. N. CHAI, AND T. E. KIMSIM. 2003. Abundance and Diversity of Land-Snails (Mollusca: Gastropoda) on Limestone Hills in Borneo. *The Raffles Bulletin of Zoology* 51:35-42.
- SCHMIDT B. R. AND J. PELLET. 2005. Relative Importance of Population Processes and Habitat Characteristics in Determining Sample unit Occupancy of Two Anurans. *Journal of Wildlife Management* 69:884-893.
- SCHUPP, E. W. 1989. Factors Affecting Post-dispersal Seed Survival in a Tropical Forest. *Oecologia* 76:525-530.
- SEAMAN, G. A. 1966. Foods of the Quail-Dove (*Geotrygon mystacea*) in the American Virgin Islands. *Caribbean Journal of Science* 6:177-179.
- SEASTEDT, T. R. 1983. A Two Year Study of Leaf Litter Decomposition as Related to macroclimatic factors and Microarthropod Abundance in the Southern Appalachians. *Holarctic Ecology* 6:11-16.
- SEIFRIZ, W. 1943. The Plant Life of Cuba. *Ecological Monographs* 13:375-426.
- SKUTCH, A. F. 1949. Life History of the Ruddy Quail-dove. *The Condor* 51:3-19.
- SKUTCH, A. F. 1991. Life of the Pigeon. Cornell University Press. Ithaca, N.Y.
- SMYTHE, N. 1970. Relationships between Fruiting Seasons and Seed Dispersal Methods in a Neotropical Forest. *American Naturalist* 104:25-35.
- SORK V. L. 1985. Germination Response in a Large-Seeded Neotropical Tree Species, *Gustavia superba* (Lecythidaceae). *Biotropica* 17:130-136.

- STATTERSFIELD, A. J., M. J. CROSBY, A. J. LONG, AND D. C. WEGE, EDITORS. 1998. Endemic Bird Areas of the World: Priorities for Biodiversity Conservation. BirdLife International, Cambridge, UK.
- SUTHERLAND, W. J., I. NEWTON, AND R. E. GREEN. 2004. Bird Ecology and Conservation: A handbook of techniques. Oxford University Press Inc., New York.
- THOMPSON W. L. EDITOR. 2004. Sampling Rare or Elusive Species. Island Press, Washington, D.C.
- TYRE, A. J., B. TENHUMBERG, S. A. FIELD, D. NIEJALKE, K. PARRIS, AND H. P. POSSINGHAM. 2003. Improving Precision and Reducing Bias in Biological Surveys: Estimating False-Negative Error Rates. *Ecological Applications* 13:1790-1801.
- WILSON D. M., AND J. BART. 1985. Reliability of Singing Bird Surveys: Effects of Song Phenology During the Breeding Season. *The Condor* 87:69-73.
- YOCOZ N. G., J. D. NICHOLS, AND T. BOULINIER. 2001. Monitoring of Biological Diversity in Space and Time. *Trends in Ecology and Evolution* 16:446-453.

**CHAPTER 3: FRUIT PREFERENCES OF CAPTIVE BLUE-HEADED
QUAIL-DOVES (*STARNOENAS CYANOCEPHALA*) of Cuba**

ABSTRACT. – We conducted a multiple offer “cafeteria-style” fruit preference experiment with captive Blue-headed Quail-doves (*Starnoenas cyanocephala*) at the National Zoo of Havana, Cuba in September of 2007 to understand the potential importance of particular choice foods and food aversions. Results of fruit preference experiments suggest that Blue-headed Quail-doves preferred *Guazuma parvifolia* and *Hamelia patens* while they avoided *Ficus havanensis*, *Trema micrantha*, *Lagetta valenzuelana*, *Bursera simaruba*, *Metopium brownei*, and *Trichilia hirta*. *Ottoschulzia cubensis* may be a preferred fruit at a peak level of ripeness.

Key Words: Blue-headed Quail-dove, Cuba, fruit preference, multiple offer experiment, *Starnoenas cyanocephala*

BLUE-HEADED QUAIL-DOVE (*Starnoenas cyanocephala*) is an endemic forest ground dove considered to be both endangered and rare on the island of Cuba (BirdLife International 2008). It has declined throughout its restricted island range during the last century due to hunting pressures and a loss of habitat from agricultural development, logging and charcoal production (Collar et al. 1994, Garrido and Kirkconnell 2000). The Blue-headed Quail-dove is thought to occur in much of Cuba’s remaining forests including swamp, mogotes, evergreen, and semi-deciduous forest habitats (Rodriguez and Sanchez 1993). However, the secretive nature of the quail-dove has led to uncertainty of its habitat associations, fruit preferences and its overall basic ecology, and conservation status. This information is critical for effective management of a species that is thought to be declining in its range with a high risk of extinction (BirdLife International 2008).

Much of the remaining 18% of forested land area in Cuba (Perera et al. 2004) that may be providing important habitat for the Blue-headed Quail-dove is patchily distributed and geographically isolated. Blue-headed Quail-doves are post dispersal seed predators (Moermond and Denslow 1985, Goodwin 1983), and seed predators are considered to be food generalists (Hulme 1998, Crawley 2000). This means that they may be able to take advantage of a variety of food resources if Blue-headed Quail-doves use multiple forest types in Cuba (Rodriguez and Sanchez 1993). Conversely, it is possible that Blue-headed Quail-doves may be able to access similar food sources if they are available across Cuban subtropical forests.

Blue-headed Quail-doves forage on the ground and shift the leaf litter substrate in search of seeds, berries, arthropods and terrestrial snails (Gundlach in Bent 1963, Goodwin 1983, Skutch 1991). There are, however no studies on diet, food preferences or specific fruit preferences in their natural environment to the best of our knowledge and published accounts of feeding observations are limited. Rodriguez and Sanchez (1993) report that Blue-headed Quail-doves and other quail-dove species in Cuba consume berries and seeds of *Crescencia cujete*, *Smilax* sp., *Vitis tiliaefolia*, *Bourreria* sp., *Wallenia laurifolia*, *Cupania* sp., *Tabebuia pentaphilia*, *Celtis iguanea*, *Comocladia dentata*, *Metopium* sp., *Erythroxylon* sp., and *Adelia ricinella* although forest associations for these observations were not provided. Leavelle (Chapter 2) found that Blue-headed Quail-doves are abundant at the Loma de Cunagua Wildlife Refuge in Ciego de Avila, a lowland semi-deciduous forest, and have been observed consuming seeds from *Bursera simaruba*, and *Byrsonima biflora* (K. Leavelle pers. obs.), two dominant fruiting trees in this seasonally dry environment.

Food resource use is primarily influenced by preference and availability. Availability of food resources, which is defined as accessibility and procurability, dictates what an animal is able to consume while preference determines which available food items are ultimately consumed (Frazer and McWilliams 2002). Knowledge of food resource use based solely on observations, crop or fecal analysis only provides a snapshot of consumption of available food and not necessarily what an animal prefers to eat (Cueto et al. 2001). Food preference experiments are an appropriate way to observe food choice under controlled conditions where availability of food items is known and a preference can be assessed (Cueto et al. 2001). Multiple offer experiments, also known as cafeteria trials, expose a test subject to more than one food item at a time to measure the use of each food item to determine preference when one is offered on an equal basis to others (Johnson 1980). In a natural setting an animal may encounter more than one potential food item simultaneously and makes a decision of which to consume thereby demonstrating a food preference (Peterson and Renaud 1989, Manly 1995, Cueto et al. 2001).

Leavelle (Chapter 2) conducted a concurrent study of abundance and habitat associations of the Blue-headed Quail-dove in a lowland semi-deciduous forest in Cuba. This study attempts to make the link between available fruit items from this dry seasonal forest and fruit preferences. Food preference studies were not practical *in situ* with the shy, elusive study species, so we used a captive setting with multiple offer experimental trials. Our primary objectives were to 1) determine fruit preference by observing consumption and; 2) assess aversion by observing rejection (non-consumption) of fruit.

METHODS

Captive site. – The National Zoo of Havana, Cuba maintains a captive population of five Blue-headed Quail-dove for captive breeding in the endangered species conservation program. All individual captive quail-doves were wild caught from the Zapata Swamp forest region of Cuba and had been zoo residents for a minimum of three years. We used four males from the Zoo's captive population for our experiment from 26 September to 29 September 2007, which was during their non-reproductive period. The individuals were housed separately in cages (4.45m length x 1.5m width x 2.5m height) under natural illumination, and were visually isolated from each other during the duration of the experiment. We received experimental approval from Cuba's Ministry of Agriculture, Empresa Nacional para la Protección de la Flora y la Fauna, and the National Zoo of Havana.

The Zoo's regular, daily feeding regimen for Blue-headed Quail-dove consisted of a prepared diet of wheat (20g), corn (20g), peas (20g), canary grass seeds (46g), and grit and fresh water *ad libitum*, which was left in the cage all day. This diet was maintained during experimental trials.

Fruit species tested. – Nine fruit species in total were included in experimental trials (Table 3.1). We obtained the fruit from Leavelle's (Chapter 2) study site at Loma de Cunagua, to associate fruit preferences with fruits available during the habitat association study. We defined fruit as the mature pistil of a single flower (Bold et al. 1980). Some fruits are dry containing multiple seed capsules while others are fleshy with a thick mesocarp which holds one to several seeds (Bold et al. 1980). Here, we refer to fleshy fruits as berries. *Ficus havanensis* (Moraceae) is a native tree of Cuba (Bisse

1988) belonging to the fig family. The fig fruit contains many tiny seed bearing flowers within the fruit's pulp, and is considered a keystone resource for some birds in the tropics including pigeons and doves (Terborgh 1986). *Lagetta valenzuelana* (Thymelaeaceae), the lace bark tree native to Cuba, produces ~7 mm diameter fleshy fruit encasing a single seed. *Trema micrantha*, (Ulmaceae) or guasimilla boba, occurs in subtropical forests at the extreme southern tip of Florida and in the Caribbean region. The reddish-orange ~10 mm diameter fruit is a drupe (fleshy fruit with a hard cover seed similar to a plum) commonly eaten by birds. It is known to grow along edges or disturbed areas (Vasquez-Yañes 1998). *Guazuma parvifolia* (Sterculiaceae) is the Cuban species botanically synonymous with *Guazuma ulmifolia* (Cristóbal 1989). *Guazuma ulmifolia* occupies dry lowlands from Central Mexico to Panama (Janzen 1983), and is native to tropical America and belongs in the cacao family. Trees are deciduous and produce 2 cm ovule hard fruit capsules with five interior cavities containing multiple ~2 mm seeds. Thirty fruits from *Guazuma ulmifolia* in Puerto Rico averaged 68 ± 4 seeds per capsule (Francis 1991). An average seed count is unknown in *Guazuma parvifolia* in Cuba. *Hamelia patens* (Rubiaceae), known as Firebush, is typically pollinated by hummingbirds, and produces fruit ~8 mm with many small seeds which are contained within a fleshy pulp. It is a shrub species found along edges or in disturbed areas, and is an important food resource for birds (Gilman & Meerow 1999). *Trichilia hirta* (Meliaceae), or Broomstick, is in the Mahogany family and is native to the West Indies. It is widespread but scattered throughout its range commonly found on rocky sites. Each fruit is ~12 mm in diameter and is a 2 chambered capsule with 2 seeds of ~7 mm per chamber, each covered with a thin red aril (seedcoat) (Francis 2002). *Ottoschulzia cubensis* (Icacinaeaceae) is in the

Rosewood family and is native throughout the Americas. The fruit is a drupe of approximately 20 - 25 mm in diameter (Bisse 1988). Caribbean *Ottoschulzia* species are commonly found on rocky limestone derived soils (Little et al. 1974). *Bursera simaruba* (Burseraceae), or West Indian Birch, is also known as the Almacigo Colorado, and is native to tropical America. It is one of the most common fruiting trees in the lowland tropics often found in secondary or disturbed habitats (Graham 2002). Blue-headed Quail-dove have been observed feeding on seeds from *Bursera simaruba* (Leavelle pers. obs.), the most abundant tree species at the Loma de Cunagua in Cuba (Leavelle Chapter 2). Fruits are ~10 mm diameter three-valved capsules encasing one seed which is covered in a fatty maroon-red aril rich in lipids (Greenberg et al. 1993). Seeds are commonly eaten by birds and *Bursera simaruba* is often planted in human altered habitats in Mexico for migrating birds (Foster & Mercedes 2007), and. *Metopium brownei*, (Anacardiaceae), or Black Poisonwood, is in the cashew or sumac family, and is native to the Greater Antilles, southern Mexico and Central America. Though it contains the secondary growth compound urushiol, an alkaloid that causes serious skin irritations, it is a common food source for many bird species (Frankel 1991). The fruit is an orange yellow drupe ~15 mm in diameter (Bisse 1988).

The Blue-headed Quail-dove is a common species on the Loma de Cunagua (Leavelle, Chapter 2), and the chosen fruit species are abundant and widespread. *Bursera simaruba*, (the most dominant species), *Metopium Brownei*, and *Ficus havanensis* (Appendix 1). We used fruits available from Leavelle's (Chapter 2) dry forest study site, because we speculated that seeds from one or more of these species could be important food sources for the quail-dove. We did not include other abundant tree species that

occur on the Loma such as *Byrsonima biflora*, *Nectandra coriacea*, *Oxandra lanceolata*, and *Mastichodendron foetidissimum*, because their fruits were not available during Leavelle's (Chapter 2) habitat association study. Mature seeds were taken from the host plant during June and July of 2007 and frozen until they were transported to Havana in September for the experimental trials.

Table 3.1. Seeds tested in September 2007 in a multiple offer experiment with Blue-headed Quail-dove at the National Zoo of Havana, Cuba.

Family	Species	Cuban Common Name
Anacardiaceae	<i>Metopium brownei</i>	Guao de Costa
Burseraceae	<i>Bursera simaruba</i>	Almacigo Colorado
Icacinaceae	<i>Ottoschulzia cubensis</i>	Cogote de Toro
Meliaceae	<i>Trichilia hirta</i>	Cabo de Hacha, Guaván
Moraceae	<i>Ficus havanensis</i>	Jagüey
Rubiaceae	<i>Hamelia patens</i>	Ponasí
Sterculiaceae	<i>Guazuma parvifolia</i>	Guasima
Thymelaeaceae	<i>Lagetta valenzuelana</i>	Daguilla de Loma
Ulmaceae	<i>Trema micrantha</i>	Guasimilla boba

Seed preference trials. – We conducted a multiple offer or “cafeteria” style experiment (Sutherland et al. 2004) using nine native fruit species. All nine fruits were presented simultaneously with each species in a separate container (12 cm x 12 cm x 6 cm). The seeds of fruits that were encased in pulp and the fruits with multiple seed capsules covered in an aril were left intact and displayed as one fruit as it would be found in nature. Five fig fruits of *Ficus havanensis* were opened up to display an estimated 100 seeds per fig for a total of approximately 500 seeds. Figs fall to the ground when mature and are soft and easily accessible to a dove when whole or broken open by the fall or by other animals, but were cut open by zoo technicians for display purposes only. Four fruit capsules of *Guazuma. parvifolia* were opened up and placed in a container with an estimated 68 seeds per capsule roughly equaling 272 seeds. In nature *Guazuma*

parvifolia falls and either ruptures or the shell becomes soft and slowly opens up after sitting on the moist ground becoming available to quail-doves that otherwise would not be able to open the fruit on their own. Pigeons and doves swallow their food whole whether it is a seed, fruit or invertebrate animal as they cannot de-husk foods as other birds can (Goodwin 1983). *Metopium brownei* was only offered on the final two days of trials, and *Bursera simaruba* was offered on days two, three and four due to their late arrival to the zoo. All nine containers were placed on the ground in the cage in a circular array in a haphazard order (Fig. 3.1). Because Blue-headed Quail-dove are sensitive to brusque changes in their diet (Y. Rodriguez, pers. comm.) they were given a mixture of their maintenance diet and fruit three days prior to start of experimental trials as a period of acclimation. All food was removed at noon the day before trials to fast before novel food was presented. Each trial began at 0900 h EST and trials lasted for 30 minutes to allow for selection and consumption of seeds before seeds were removed from the cage. This process was repeated for four consecutive days. We placed a digital camera in each cage for behavioral analysis, and we reviewed each digitized recording of the quail-dove trials. We consider each approach to a food bowl as a behavioral event, and we recorded: 1) start time 2) end time 3) fruit species; 4) number of times fruit was picked-at (pecked-at, but not picked up); 5) number of times fruit was spit out (picked up in the bill but then let go); 6) number of seeds or berries consumed (ingested), and 7) whether the fruit was consumed. We were able to clearly observe each moment of consumption, because the partial or full lifting of the head is followed by a distinct swallowing motion.



Fig. 3.1. Circular display array of test fruits in a captive Blue-headed Quail-dove multiple choice fruit preference experiment conducted at the National Zoo in Havana, Cuba in September 2007. Clockwise from the bird is *Hamelia patens*, *Trichilia hirta*, *Cogote de Toro*, *Bursera simaruba*, *Metopium brownei*, *Ficus havanensis*, *Lagetta valenzuelana*, *Trema micrantha*, and *Guazuma parvifolia*.

Statistical analysis. – Cafeteria trials were analyzed using logistic regression in PROC GLIMMIX (SAS Institute Inc. 2004); our data was not normally distributed, and PROC GLIMMIX allowed us to fit errors of binomial or Poisson distributions as well as random effects (Schabenberger 2005). We coded the response of quail-doves to each fruit species as a binomial response (1: success, 0: failure). We used the number of seeds eaten and the number of seeds offered to calculate the average proportion of seeds eaten across 16 total trials (4 individuals for 4 days). For each analysis, the explanatory fixed effect was the fruit species. Birds were already adjusted to captivity as permanent zoo residents and were allowed a 3 day period of adjustment to the fruit, so there was no expected increased foraging by day as a result of adjustment to captivity or to the novel

food. In addition, all quail-dove included in trials were males, and we did not expect variation in foraging by individual. Therefore, we considered both day and bird as random effects in order to account for extra-binomial variation among trial days and individual quail-dove. Finally, we assessed differences among fruit species for the number of seeds eaten, picked at, and spit out which was modeled using a Poisson distribution and log link function for our count-type data.

A final consideration was made regarding the comparison of fruits of unequal size and quantity. *Guazuma parvifolia* is a fruit with many small, 2 mm seeds ($n = 272$) as compared to seven fruit species much larger in size (7 mm – 15 mm diameter) and smaller in quantity ($n = 8$). If any one of these seven seeds and *Guazuma parvifolia* are consumed once in a trial, they each then have an equal probability of being eaten. Conversely, due to the difference in size and quantity of each fruit, consumption of one *Lagetta valenzuelana* berry, for example, would result in a greater proportion consumed than one 2 mm *Guazuma parvifolia* seed thereby masking the actual likelihood or probability that a particular species was consumed. In consideration of this it became important to test both the total proportion of fruit consumed, as well as the binary probability of fruit consumption. We then defined fruit preference as the fruit species with both the greatest proportion consumed and the highest probability of being consumed.

RESULTS

Each Blue-headed Quail-dove took, on average, 32.25 s (min = 0 s, max = 133 s) to make contact with the fruit with the exception of one individual that paced in the corner of the cage for 16 min before approaching the fruit on the first day of trials. *Guazuma*

parvifolia was the first fruit eaten in nine of 16 trials (56%), followed by *Hamelia patens* in three of 16 trials (19%). Out of a 30-min trial period, quail-dove fed on average 27.75 min (± 4.5) on day one, decreasing to 17 min (± 14.86) on day two, and 18 min (± 9.6) on day three, but increased again to an average 28 min (± 3.7) on the final day. The only anomaly was one individual which fed for only 1 min 46 s. An average percentage of fruit species investigated by Blue-headed Quail-dove increased with day (day 1 = 50%, day 2 and day 3 = 62%, and day 4 = 81%). Finally *Guazuma parvifolia* was the most frequently visited (42%) followed by *Ottoschulzia cubensis* (26%), while *Trema micrantha* was visited the least (3%).

Guazuma parvifolia and *Hamelia patens* were eaten at higher rates than the other fruit species ($F_{8,116} = 4.3$, $P < 0.0001$), and *Ottoschulzia cubensis* was the third most preferred fruit type (Fig. 3.2). All other species of fruits had much lower probabilities of consumption, compared to the top three species (Fig. 3.2).

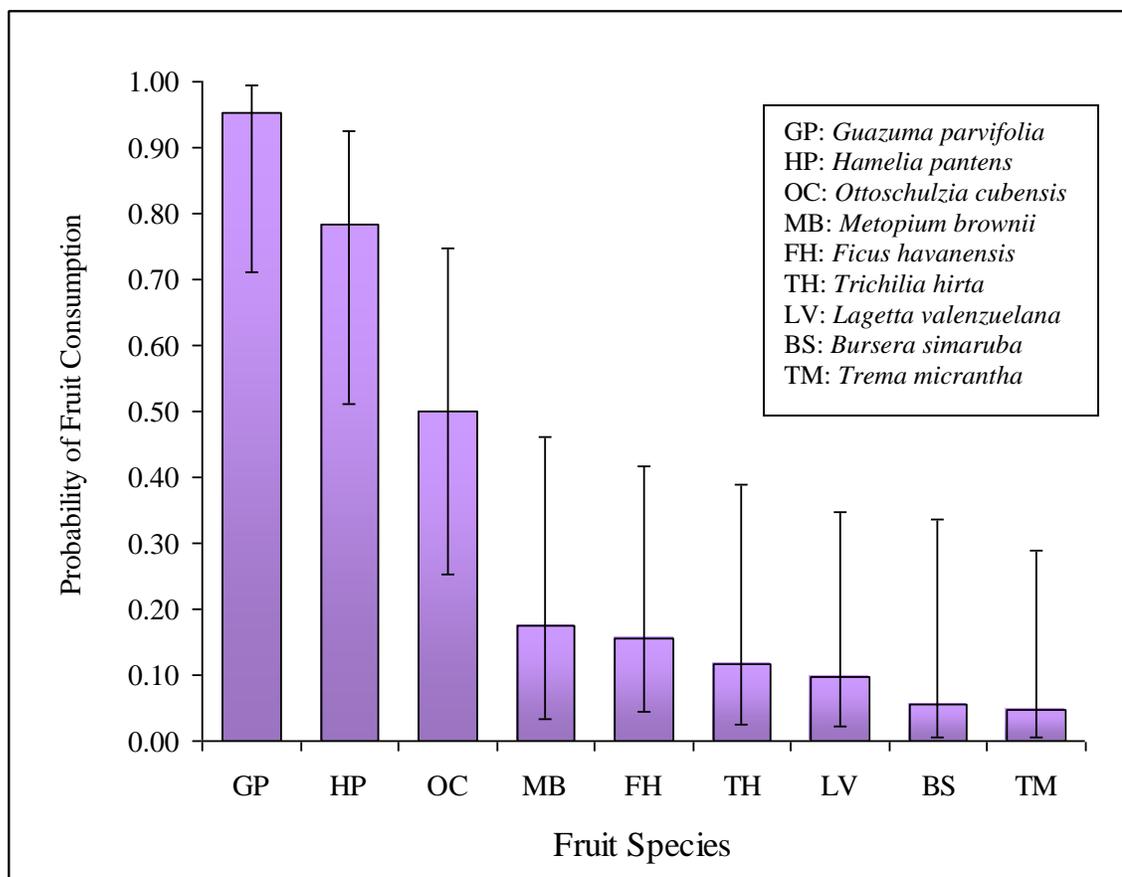


Fig. 3.2. The probability of fruit being eaten for each plant species in multiple offer fruit preference trials with captive Blue-headed Quail-dove in the National Zoo of Havana, Cuba in September 2007 \pm 95% Confidence Intervals. GP = Guasima, HP = Ponasí, OC = Cogote de Toro, MB = Guao de Costa, FH = Jagüey, TH = Guaván, LV = Daguilla de Loma, BS = Almacigo Colorado, TM = Guasimilla Boba.

There was a significant difference in the proportion of each fruit consumed by fruit species ($F_{8,122} = 101.3$, $P < 0.0001$). The mean proportion of fruit eaten was highest for *Hamelia patens* followed by *Guazuma parvifolia* and *Ottoschulzia cubensis*. The mean proportion of fruit eaten for all other fruits was < 0.10 (Fig. 3.3).

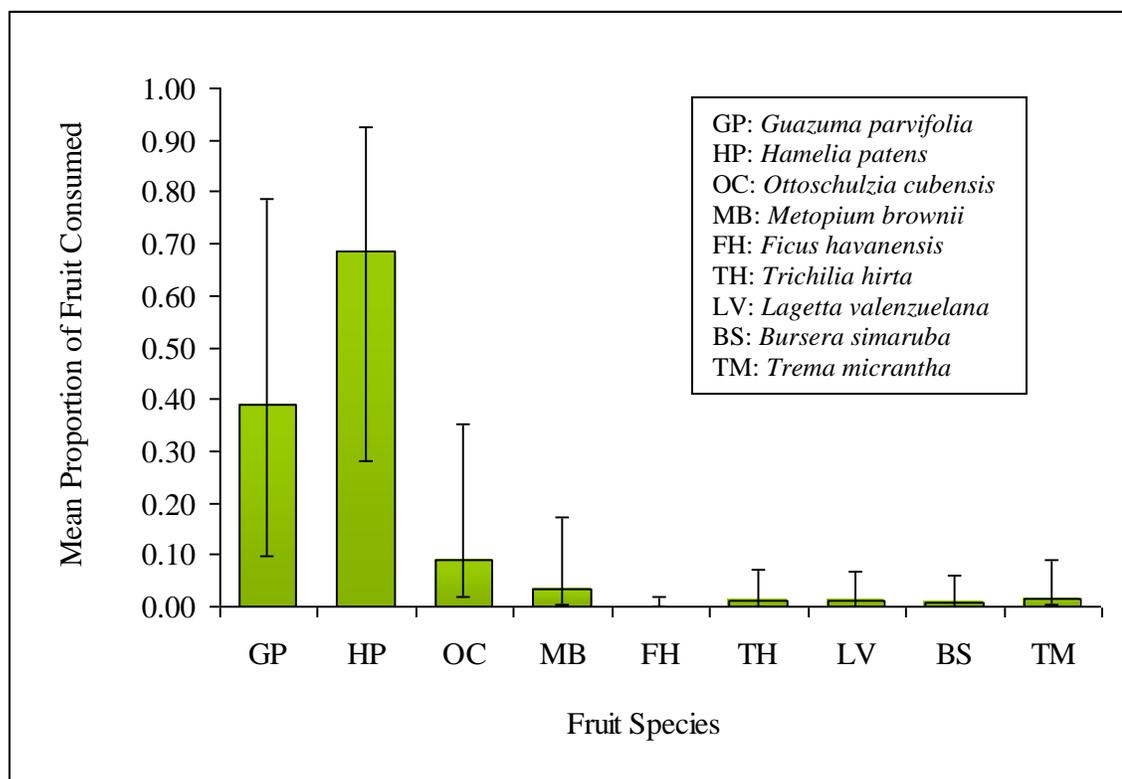


Fig. 3.3. Mean estimated proportion of fruit consumed for each species in multiple offer fruit preference trials with captive Blue-headed Quail-dove in the National Zoo of Havana, Cuba in September 2007 \pm 95% Confidence Intervals. GP = Guasima, HP = Ponasi, OC = Cogote de Toro, MB = Guao de Costa, FH = Jaguey, TH = Guavan, LV = Daguilla de Loma, BS = Almacigo Colorado, TM = Guasimilla Boba.

The fruit most picked-at by Blue-headed Quail-doves was *Guazuma parvifolia* (Fig. 3.4) followed by *Ottoschulzia cubensis*, *Hamelia patens*, and *Ficus havanensis* (Fig. 3.5). The two fruits most spit out were *Ottoschulzia cubensis*, and *Metopium brownei* (Fig. 3.5). *Ficus havanensis* was never spit out followed by *Guazuma parvifolia* and there were few feeding events (< 3) at *Trichilia hirta*, *Lagetta valenzuelana*, *Bursera simaruba* or *Trema micrantha* (Fig. 3.5).

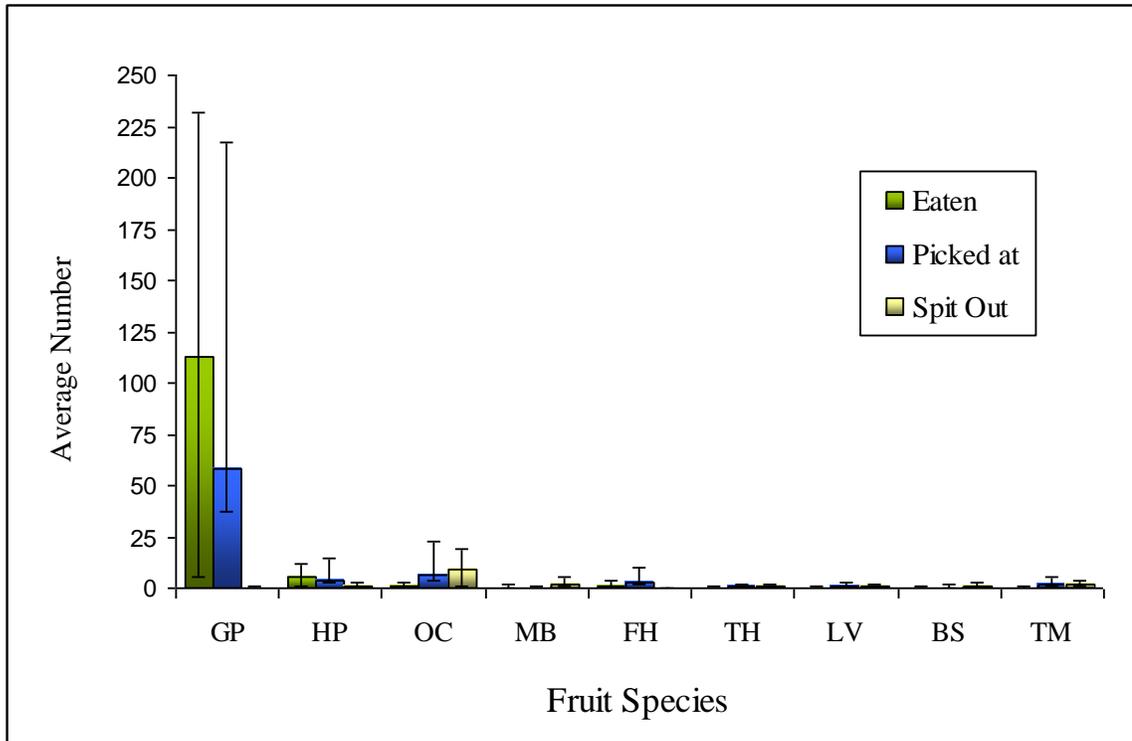


Fig. 3.4. Comparison of average number of fruits eaten, picked-at and spit out by captive Blue-headed Quail-dove in the National Zoo of Havana, Cuba during multiple offer feeding trials in September 2007 \pm 95% confidence intervals. GP = *Guazuma parvifolia*, HP = *Hamelia patens*, OC = *Ottoschulzia cubensis*, MB = *Metopium brownei*, FH = *Ficus havanensis*, TH = *Trichilia hirta*, LV = *Lagetta valenzuelana*, BS = *Bursera simaruba*, and TM = *Trema micrantha*.

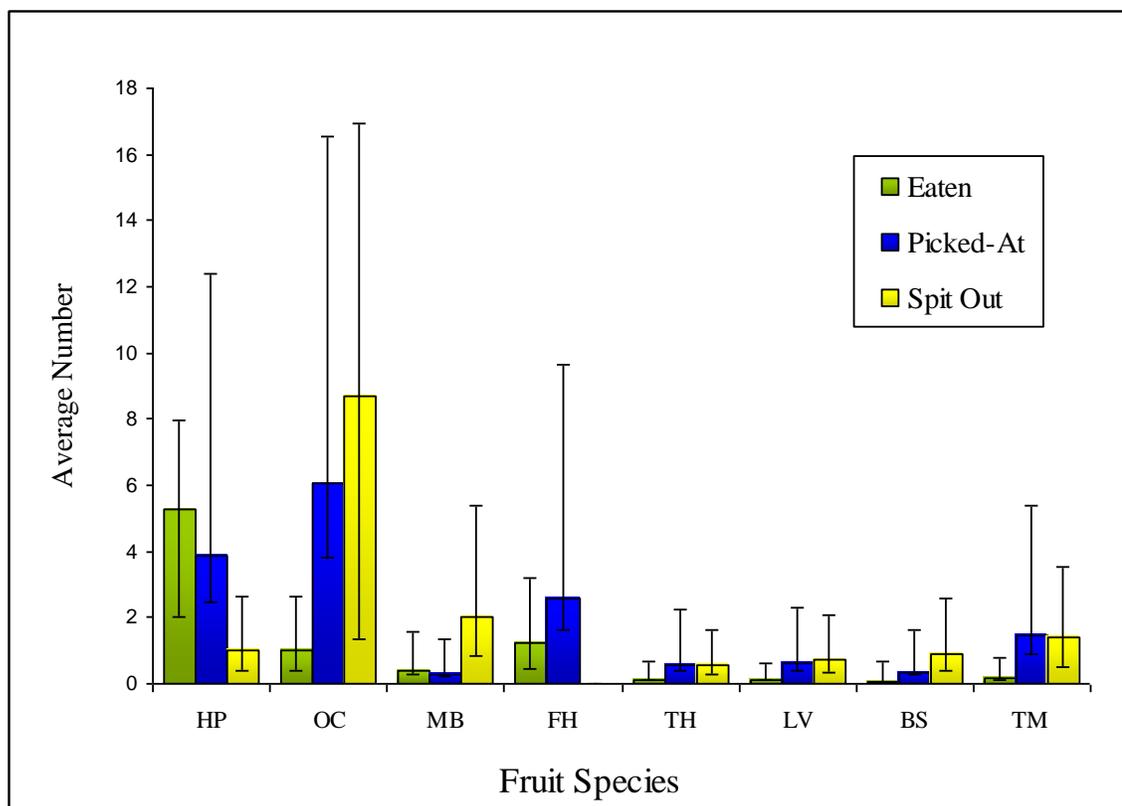


Fig. 3.5. Comparison of average number of fruits eaten, picked-at and spit out by captive Blue-headed Quail-dove in the National Zoo of Havan, Cuba during multiple offer feeding trials in September 2007 \pm 95% confidence intervals. (*Guazuma parvifolia* not shown) HP = *Hamelia patens*, OC = *Ottoschulzia cubensis*, MB = *Metopium brownei*, FH = *Ficus havanensis*, TH = *Trichilia hirta*, LV = *Lagetta valenzuelana*, BS = *Bursera simaruba*, and TM = *Trema micrantha*.

DISCUSSION

Results suggest that the Blue-headed Quail-dove in this study demonstrate a clear preference among the food items offered to them. The probability of eating *Guazuma parvifolia* was highest while the proportion of *Hamelia patens* was greater than *Guazuma parvifolia* and all other seeds tested. Each test quail-dove spent considerable time during the 30 min trial period both eating the 2 mm *Guazuma parvifolia* seeds that came loose when the fruit was opened, and trying to get seeds out of the capsule that did not initially come loose resulting in what appeared to be a clear preference for the tiny dry seeds.

Conversely, *Hamelia patens* berries, approximately blueberry (*Vaccinium sp.*) size, were easy and quick to pick up and eat.

Why did Blue-headed Quail-dove prefer these two fruit species? First, *Hamelia patens* and *Guazuma parvifolia* may be common to the Zapata swamp area where these captive individuals were originally brought from and the quail-doves may have already been familiar with them. However, information on the presence of these species in that region is needed. Second, neither color nor size should be a determinant of preference as *Hamelia patens* had the same dark purple coloration and size (5 mm and 7 mm) as *Ottoschulzia cubensis*, *Lagetta valenzuelana*, *Trichilia hirta* and *Trema micrantha*, all non-preferred fruits. Furthermore, the two preferred fruits *Guazuma parvifolia* and *Hamelia patens* were each different in size from the other (2 mm and 8 mm respectively). If frugivores are expected to choose the most profitable fruit (Morton 1973, Johnson et al. 1985) then Blue-headed Quail-dove fruit preferences may be determined by perceived nutrient composition (Levey 1987), caloric content (Sorensen 1984, Johnson et al. 1985), the presence of secondary compounds (Sorensen 1983, Cipollini and Levey 1997) and accessibility (Moermond and Denslow 1983, Stanley and Lill 2001). Fruit pulp is relatively high in lipid content, soluble carbohydrates (simple sugars) and water which varies by species (Crome 1975, Snow and Snow 1988), but low in protein and nitrogen (Morton 1973, Johnson et al. 1985). Seeds (without the pulp) are high in non-structural carbohydrates (starch, complex sugars and pectin) which provide a large proportion of energy (Wheelwright et al. 1984, Gautier-Hion et al 1985). Protein, nitrogen and minerals can be provided by minor amounts of animal prey; however it is possible that fleshy fruits provide sufficient amounts when animal foods are scarce (Jordano 2000).

Post-dispersal seed predators are considered to be food generalists (Janzen 1971, Hulme 1998, Crawley 2000), and thus able to feed on a wide variety of food items including both berries and pulpless seeds. *Hamelia patens* has fleshy pulp containing many small seeds, but *Guazuma parvifolia* does not. If *Guazuma parvifolia* seeds are rich in non-structural carbohydrates and high in calories as are *Guazuma ulmifolia* (Bressani and Navarrete 1959), yet deficient in lipids, soluble carbohydrates and water content due to the lack of pulp then quail-dove may be able to supplement their diet with the nutrient rich flesh of the berries which are produced by many plant species in the dry subtropical forest which characterizes the Loma de Cunagua in Ciego de Avila and presumably other forest habitats as well in Cuba. *Guazuma parvifolia* fruits are considered ripe when they fall to the ground, the time at which they were collected, and have a thin layer of sweet molasses on the outer surface of the capsule (Janzen 1982, 1983). Previous studies have shown that birds can differentiate fruits based on sweetness (Levey 1987, Lepczyk et al. 2000) and possibly use that sweetness as a primary indicator of fruit quality (Stiles 1980, Borowicz 1987). Fruits high in sugar content, and thus a higher nutrient reward, may also be a mechanism to attract bird dispersers during a time of high fruit availability (Stiles 1980) during the tropical rainy season. Blue-headed Quail-dove may have responded to the potentially higher nutritional quality of the seeds which may have been lacking in their captive diet however analysis of nutritional components of *Guazuma parvifolia* and all other test fruits is necessary.

Interestingly, *Guazuma ulmifolia* is a tree which grows in forest interiors, but is more commonly found in disturbed areas along fencerows and in pastures (Janzen 1982, Francis 1991). It is dispersed by livestock (Janzen 1982, 1983), however knowledge of

specific avian dispersers is lacking. In Central America it has been used as poultry feed for weight gain due to its high carbohydrate load (Bressani and Navarrete 1959). Mammals such as peccaries and agoutis commonly feed on and disperse *Guazuma ulmifolia* seeds but the only mammal found at the Loma de Cunagua is the Jutia (*Capromys pilorides*) which may be the only vertebrate capable of opening the hard capsule or dispersing the seeds other than horses (Janzen 1982, 1983) brought in by park guards. *Guazuma parvifolia* fruits are otherwise mechanically protected from seed predators by the hard exterior casing making it otherwise impossible for doves to eat the seeds due to their relatively weak beaks (Goodwin 1983). Furthermore, most *Guazuma parvifolia* trees at the Loma de Cunagua are found along edges where Blue-headed Quail-dove were never observed feeding but further study is required.

Hamelia patens is also an edge species with individuals that produce flowers and fruits throughout the year and is considered a preferred fruit of many bird species (Moermond and Denslow 1985, Levey 1987, Gilman and Meerow 1999). Though it is also unknown whether Blue-headed Quail-dove feed on *Hamelia patens* berries in its natural habitat, it may be an important food source during the seasonally dry winter months when fruit availability is diminished (Jordano 2000).

All four tested Blue-headed Quail-dove picked at and spat out *Ottoschulzia cubensis* more than the average number of berries they actually consumed. This was likely due to fruit unpalatability from the presence of a secondary compounds meant as chemical defense (glycosides, tannin, alkaloids or other toxins) against seed consumption and attack by pathogens (McKey 1979, Cipollini and Levey 1997), or microbes associated with decay (Janzen 1977, Cipollini and Stiles 1993). Microbial degradation

however is unlikely due to the prompt collection at fruit ripening, and careful handling prior to and during the experiment. *Metopium brownei* was also spit out often relative to how much was eaten and picked at. Species belonging to the family Anacardiaceae are known to have resins, gums and volatile oils associated with all parts of the plant, but are only known to be a skin irritant causing allergic dermatitis in humans (Anaya et al. 1999). It is on the other hand a common species in the diet of many bird species (Frankel 1991, Anaya et al. 1999), and is one of the five most dominant species found in the diet of white-crowned pigeon nestlings (*Columba leucocephala*) (Bancroft and Bownman 1994). It is possible that berries of *Metopium brownei* arrived to the Havana zoo unripe.

All test quail-dove approached the fruits of *Trichilia hirta*, *Lagetta valenzuelana* and *Trema micrantha*, yet no preference was shown as indicated by the low probability and proportions consumed. Not one of these species is dominant at the Loma de Cunagua and information on fruiting phenology is lacking. Furthermore, more information is needed on the ecology of with respect to nutritional quality, chemical defenses and avian consumption. As for *Bursera simaruba* and *Ficus havanensis*, it is surprising that no preference was shown for either fruit considering it has been cited in the literature that *Bursera simaruba* (Scott and Martin 1984, Trainer and Will 1984, Greenberg et al. 1993) and *Ficus spp.* (Jordano 1983, Coates-Estrada and Estrada 1986, Lambert 1989) are an important dry-season resource for birds throughout the tropics? Thirty nine avian species from 10 families were found eating fruits from *Bursera simaruba* on the Yucatan peninsula (Scott and Martin 1984), 21 wintering and migrant species in Panama (Griscom 2007), and 39 species in Los Tuxtlas, Veracruz, Mexico (Graham 2002) amongst others. *Bursera simaruba* is consistently visited throughout the

fruiting season (Graham 2002), and thought to provide fat reserves to both migrating and resident birds (Scott and Martin 1984). The *Bursera* seeds may have been green (immature) when presented to test quail-dove, or it is also possible that the high level of preference shown by the large proportions of *Hamelia patens* and *Guazuma parvifolia* eaten may have sufficiently satiated the birds.

The fruits of *Ficus havanensis* in the experiment were rarely touched. Though figs are not considered to be rich in nutrients, they are important in the dry season as a source of energy (soluble carbohydrates), water, fiber and some protein, and are probably supplemented with other fruits (Janzen 1979, Jordano 1983, Coates-Estrada and Estrada 1986). *Ficus havanensis* is a common tree species at the Loma de Cunagua, a seasonally dry environment, and is believed to produce mature fruit in the dry winter months (Leavelle pers. obs.) when many other plants are done fruiting. In spite of the fact that one *Geotrygon montana* individual was observed foraging on a fallen fig in Los Tuxtlas, Veracruz, Mexico (Coates-Estrada and Estrada 1986), a quail-dove's ability to mandibulate and eat figs and the ecological roll that *Ficus havanensis* has for these terrestrial birds is an area for further study.

Our study does not provide conservation biologists with information regarding the nutrient value of each fruits. This information is critical, if fruit is to be incorporated into the diet regimen of the endangered species program diet. Each fruit's seed and pulp materials should be tested for nutrient concentrations, caloric values and presence of secondary metabolites. Further field observations of wild quail-dove's foraging activities will be of great importance during both rainy and dry seasons in the dry semi-deciduous habitat as well as other forest vegetation types where the Blue-headed Quail-dove occur.

Captive experiments with both males and females conducted in the breeding and non-breeding seasons may also shed some light on behavioral feeding changes which result from physiological needs during the nesting cycle and for winter survival.

It is our hope that this project will initiate the process of investigation of the Blue-headed Quail-dove throughout Cuba. It is thought that this species occurs in many of the differing habitat types that are patchily distributed throughout Cuba from moist montane to lowland swamp forests, but future study will determine with greater clarity the actual distribution and relative abundance of the Blue-headed Quail-dove in each area. Making the link between quail-dove abundance and food availability and food preferences will be a start to understanding species ecology. More specifically, investigating dietary components through fecal and crop analysis will contribute tremendously to understanding food resource use in differing habitat types. Additionally, further captive experimentation of fruit preferences may confirm the Blue-headed Quail-dove as a fruit generalist able to take advantage of many sources of fruit in Cuba's forests. If dietary components and fruit preferences reveal specific fruit and/or food requirements in relationship to differing habitat types then that will go a long way in identifying remaining natural areas in need of protection. Finally, diet and preference information will serve to initiate and advance a captive silviculture program. Preferred fruit trees can be cultivated to assist biologists in maintaining a proper nutritional diet for the captive breeding population.

This study provided information on fruit preferences in a captive setting. It also provides suggestions regarding future investigations necessary to build a foundation of knowledge of Blue-headed Quail-dove feeding ecology. This information in conjunction

with habitat associations, abundance and island distribution is vital to the conservation and protection of this endangered endemic species in the geographically restricted subtropical island of Cuba.

LITERATURE CITED

- ANAYA, A. L., R. MATA, B. E. HERNANDEZ-BAUTISTA, D. CHAVEZ-VELASCO, AND A. GOMEZ-POMPA. 1999. Allelochemical potential of *Metopium brownei*. *Journal of Chemical Ecology* 25:141-156.
- BANCROFT, G. T., AND R. BOWNMAN. 1994. Temporal patterns in diet of nestling white-crowned pigeons: implications for conservation of frugivorous columbids. *Auk* 111:844-852.
- BENT, A. C. 1963. *Life Histories of North American Gallinaceous Birds*. Dover Publications Inc.
- BIRDLIFE INTERNATIONAL (2008) Species factsheet: *Starnoenas cyanocephala*. Downloaded from <http://www.birdlife.org> on 12/7/2008
- BISSE, J. 1988. *Arboles de Cuba*. Editorial Cientifico - Tecnica, Ciudad de La Havana.
- BOLD, H. C., C. J. ALEXOPOULOS, AND T. DELEVORYAS. 1980. *Morphology of plants and fungi*, 4th ed. Harper & Row, Publishers, New York.
- BOROWICZ, V. A. 1987. Fruit consumption by birds in relation to fat content in pulp. *American Midland Naturalist* 119:121-127.
- BRESSANI, R., AND D. A. NAVARRETE. 1959. Composicion quimica y digestibilidad del fruto del caulote o guacimo (*Guazuma ulmifolia* Lam.) y su uso en raciones para polluelos. *Turrialba* 9:12-16.
- CIPOLLINI, M. L., AND E. W. STILES. 1993. Fruit rot, antifungal defense, and palatability of fleshy fruits for frugivorous birds. *Ecology* 74:751-762.
- CIPOLLINI, M. L., AND D. J. LEVEY. 1997. Why are some fruits toxic? Glycoalkaloids in solanum and fruit choice by vertebrates. *Ecology* 78:782-798.
- COATES-ESTRADA, R., AND A. ESTRADA. 1986. Fruiting and frugivores at a strangler fig in the tropical rain forest of Los Tuxtlas, Mexico. *Journal of Tropical Ecology* 2:349-357.

- COLLAR, N. J., M. J. CROSBY, AND A. J. STATTERSFIELD. 1994. Birds to Watch 2: The world list of threatened birds. BirdLife International. Page Bros Ltd., Norwich, U.K.
- CRAWLEY, M. J. 2000. Seed predators and plant population dynamics. Pages 167-182 in *Seeds: The Ecology of Regeneration in Plant Communities* (M. Fenner, Ed.). CAB International, Oxford.
- CRISTÓBAL, C. L. 1989. Comentarios acerca de *Guazuma ulmifolia*. *Bonplandia*. *Corrientes* 6:183–196.
- CROME, F. H. J. 1975. The ecology of fruit pigeons in tropical Northern Queensland. *Australian Wildlife Research* 2:155-185.
- CUETO, V. R., L. MARONE, AND J. L. DE CASENAVE. 2001. Seed preference by birds: Effects of the design of feeding-preference experiments. *Journal of Avian Biology* 32:275-278.
- FRANCIS, J. K. 1991. *Guazuma ulmifolia* Lam. Guacima. SO-ITF-SM-47. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment station. 5 p.
- FRANCIS, J. K. 2002. *Trichilia hirta* L. (F. S. U.S. Department of Agriculture, Ed.). International Institute of Tropical Forestry, Jardín Botánico, San Juan Puerto Rico.
- FRAZER, K. I., AND S. R. MCWILLIAMS. 2002. Determinants of dietary preference in Yellow-rumped Warblers. *Wilson Bulletin* 114:243-248.
- FOSTER., AND S. MERCEDES. 2007. The potential of fruiting trees to enhance converted habitats for migrating birds in southern Mexico. *Bird Conservation International* 17:45-61.
- FRANKEL, E. 1991. Poison ivy, poison oak, poison sumac and their relatives. Boxwood Press, Pacific Grove, California.
- GARRIDO, O. H., AND A. KIRKCONNELL. 2000. *Field Guide to the Birds of Cuba*. Ithaca, NY: Comstock/Cornell University Press.
- GAUTIER-HION, A., J. M. DUPLANTIER, R. QURIS, F. FEER, C. SOURD, J. P. DECOUX, G. DUBOST, L. EMMONS, C. ERARD, AND P. HECKETSWEILER. 1985. Fruit characters as a basis of fruit choice and seed dispersal in a tropical forest vertebrate community. *Oecologia* 65:324-337.
- GILMAN, E. F., AND A. MEEROW. 1999. *Hamelia patens*: Fact Sheet. (I. o. F. a. A. Sciences, Ed.). University of Florida, Gainesville.
- GOODWIN, D. 1983. *Pigeons and Doves of the World*, 3rd ed. Cornell University Press.

- GRAHAM, C. 2002. Use of fruiting trees by birds in continuous forest and riparian forest remnants in Los Tuxtlas, Veracruz, Mexico. *Biotropica* 34:589-597.
- GREENBERG, R., D. K. NIVEN, S. HOPP, AND C. BOONE. 1993. Frugivory and coexistence in a resident and a migratory vireo on the Yucatan peninsula. *The Condor* 95:990-999.
- GRISCOM, H. P., E. K. V. KALKO, AND M. S. ASHTON. 2007. Frugivory by small vertebrates within a deforested, dry tropical region of Central America. *Biotropica* 39:278-282.
- GUAZUMA PARVIFOLIA*. 1845. Histoire Physique, Politique et Naturelle de l'Ile de Cuba ... Botanique. -- Plantes Vasculaires 190. (Hist. Phys. Cuba, Pl. Vasc.)
- HULME, P. E. 1998. Post-dispersal seed predation: consequences for plant demography and evolution. *Perspectives in Plant Ecology, Evolution and Systematics* 1:32-46.
- JANZEN, D. H. 1971. Seed predation by animals. *Annual Review of Ecology and Systematics* 2:465-492.
- JANZEN, D. H. 1977. Why fruits rot, seeds mold, and meat spoils. *The American Naturalist* 111:691-713.
- JANZEN, D. H. 1979. How to be a fig. *Annual Review of Ecological Systems* 10:13-51.
- JANZEN, D. H. 1982. Natural history of Guacimo fruits (Sterculiaceae: *Guazuma ulmifolia*) with respect to consumption by large mammals. *American Journal of Botany* 69:1240-1250.
- JANZEN, D. H. 1983. *Guazuma ulmifolia* (Guacimo, Guacima, Caulote, Tapaculo). in Costa Rican Natural History. The University of Chicago Press, Chicago.
- JOHNSON, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 61:65-71.
- JOHNSON, R. A., M. F. WILLSON, J. N. THOMPSON, AND R. I. BERTIN. 1985. Nutritional values of wild fruits and consumption by migrant frugivorous birds. *Ecology* 66:819-827.
- JORDANO, P. 1983. Fig-seed predation and dispersal by birds. *Biotropica* 15:38-41.
- JORDANO, P. 2000. Fruits and Frugivory. Pages 125-166 in *Seeds: the ecology of regeneration in plant communities* (M. Fenner, Ed.). CAB International, Oxford.

- LAMBERT, F. R. 1989. Pigeons as seed predators and dispersers of figs in a Malaysian lowland forest. *Ibis* 131:521-526.
- LEPCZYK, C. A., K. G. MURRAY, K. WINNETT-MURRAY, AND P. BARTELL. 2000. Seasonal fruit preferences for lipids and sugars by American Robins. *Auk* 117:709-717.
- LEVEY, D. J. 1987. Sugar tasting ability and fruit selection in tropical fruit eating birds. *The Auk* 104:173-179.
- LITTLE, E., R. O. WOODBURY, AND F. H. WADSWORTH. 1974. Trees of Puerto Rico and the U.S. Virgin Islands. vol. 2 (U. F. S. Handbook, Ed.).
- MANLY, B. F. J. 1995. Measuring selectivity from multiple choice feeding-experiments. *Biometrics* 51:709-715.
- MCKEY, D. 1979. The distribution of secondary compounds within plants. Pages 56-134 in *Herbivores-their interaction with secondary plant metabolites*. (G. A. Rosenthal, and D. H. Janzen, Eds.). Academic Press, New York.
- MOERMOND, T. C., AND J. S. DENSLow. 1983. Fruit choice in neotropical birds: effects of fruit type and accessibility on selectivity. *Journal of Animal Ecology* 52:407-420.
- MOERMOND, T. C., AND J. S. DENSLow. 1985. Neotropical avian frugivores: Patterns of behavior, morphology, and nutrition, with consequences for fruit selection. Pages 865-897 in *Neotropical Ornithology*. *Ornithologica Monographs* No. 36 (P. A. Buckley, M. S. Foster, E. S. Morton, R. S. Ridgely, and F. G. Buckley, Eds.). American Ornithologists' Union.
- MORTON, E. S. 1973. On the evolutionary advantages and disadvantages of fruit eating in tropical birds. *American Naturalist* 107:8-22.
- PERERA, A., A. GONZÁLEZ, R. FERNÁNDEZ DE ARCILA, R. ESTRADA, AND A. MARTÍNEZ. 2004. *Las Áreas protegidas en Cuba*. Centro Nacional de Áreas Protegidas. Ministerio de Ciencia, Tecnología y Medio Ambiente. Playa.
- PETERSON, C. H., AND P. E. RENAUD. 1989. Analysis of feeding preference experiments. *Oecologia* 80:82-86.
- RODRIGUEZ, D., AND B. SANCHEZ. 1993. Ecología de las Palomas Terrestres Cubanas (géneros *Geotrygon* y *Starnoenas*). *Poeyana* 428:1-20.
- SAS INSTITUTE INC. 2004. SAS/STAT GLIMMIX Procedure June 2006, V.9.1.3. SAS Institute Inc. Cary, NC. USA.

- SCHABENBERGER, O. 2005. Introducing the GLIMMIX Procedure for Generalized Linear Mixed Models. in Proceedings of the Thirtieth Annual SAS Users Group International Conference. SAS Institute Inc., Cary, NC.
- SCOTT, P. E., AND R. F. MARTIN. 1984. Avian consumers of *Bursera*, *Ficus* and *Ehretia* fruits in Yucatan. *Biotropica* 16:319-323.
- SKUTCH, A. F. 1991. Life of the Pigeon. Cornell University Press, Ithaca and London.
- SNOW, D., AND B. SNOW. 1988. Birds and Berries: a study of an ecological interaction. T & AD Poyser Limited, England.
- SORENSEN, A. E. 1983. Taste aversion and frugivore preferences. *Oecologia* 56:117-120.
- SORENSEN, A. E. 1984. Nutrition, energy and passage time: experiments with fruit preference in European blackbirds (*Turdus merula*). *Journal of Animal Ecology* 53:545-557.
- STANLEY, M. C., AND A. LILL. 2001. Accessibility as a factor influencing frugivory by silvereyes (*Zosterops lateralis*): field comparisons with aviary experiments. *Australian Journal of Zoology* 49:171-182.
- STILES, E. W. 1980. Patterns of fruit presentation and seed dispersal in bird-disseminated woody plants in the eastern deciduous forest. *The American Naturalist* 116:670-688.
- SUTHERLAND, W. J., I. NEWTON, AND R. E. GREEN. 2004. Bird Ecology and Conservation: A handbook of techniques. University Press, Oxford.
- TERBORGH, J. 1986. Keystone plant resources in the tropical forest. Pages 330-344 in Conservation Biology: The Science of Scarcity and Diversity (M. E. Soule, Ed.). Sunderland, MA.
- TRAINER, J. M., AND T. C. WILL. 1984. Avian methods of feeding on *Bursera simaruba* (Burseraceae) fruits in Panama. *Auk* 101:193-195.
- VASQUEZ-YANES, C. 1998. *Trema micrantha* (L.) Blume (Ulmaceae): A promising neotropical tree for site amelioration of deforested land. *Agroforestry Systems* 40:97-104.
- WHEELWRIGHT, N. T., W. A. HABER, K. G. MURRAY, AND C. GUINDON. 1984. Tropical fruit-eating birds and their food plants: a survey of a Costa Rican lower montane forest. *Biotropica* 16:173-192

**CHAPTER 4: NOTES ON THE BREEDING BEHAVIOR OF THE
BLUE-HEADED QUAIL-DOVE (*STARNOENAS CYANOCEPHALA*)
OF CUBA.**

ABSTRACT. – We examined nesting and reproductive behavior of the Blue-headed Quail-dove (*Starnoenas cyanocephala*) during the breeding season from April to June of 2006 and 2007 at the Loma de Cunagua Wildlife Refuge, a dry semi-deciduous lowland forest, located within the Gran Humedal wetland reserve in the north central coast in the province of Ciego de Ávila, Cuba. We present descriptions of nests (n = 2) and nesting substrates, incubation, hatching, and nestling (n = 2) development and morphometric measurements. Nests were made of small sticks and twigs lined with a sparse layer of freshly fallen leaves. One nest was placed on a Bayua (*Zanthoxylum elephantiasis*) snag 2.55 m off the ground and fledged two young. The other was placed 4.30 m up on a live Jocuma (*Mastichodendron foetidissimum*) trunk and hatchlings (n = 2) were depredated by a West Indian Racer (*Alsophis cantherigerus*). The nestling period is approximated at 11 days.

Key Words: Loma de Cunagua, Cuba, Blue-headed Quail-dove, nesting, reproduction, incubation, nestlings, dry semi-deciduous lowland forest, *Starnoenas cyanocephala*.

THE BLUE-HEADED Quail-dove (*Starnoenas cyanocephala*) is a Cuban endemic ground dwelling dove considered to be both a rare and endangered species (BirdLife International 2008). It is believed to occur in much of Cuba's remaining forests including dry woodland next to swamp areas and in semi-deciduous forests (Rodriguez and Sanchez 1993), dry deciduous lowland (Rompre et al. 1999), and evergreen forests

(Rodríguez and Sanchez 1993). The secretive nature of the Blue-headed Quail-dove however has resulted in the reproductive behavior being largely understudied in the species natural environment. To date, there have been no published studies on the reproductive behavior of the Blue-headed Quail-dove in the wild. Current information is limited to captive reproduction (Sanchez et al. 1992) and sparse observations in the wild (Bent 1963, Bond 1995). The primary breeding period takes place from March through June (Garrido and Kirkconnell 2000) or as late as July (Gundlach 1893 cited in Rodríguez and Sanchez 1993) commencing prior to the onset of the rainy season in May (Borhidi 1991). Overall, observations reveal that the nest is loosely made of sticks (Bendire in Bent 1963, Sanchez et al. 1992) and placed either on or near the ground, on top of parasitic vines, or epiphytic bromeliads (*Tillandsia spp.*) (Bendire in Bent 1963), on trunks (Garrido and Kirkconnell 2000), or in shrubs (Bond 1995). Bendire, in Bent (1963), describes one nest (2ft) off the ground and another in a small bunch of grass while Gibbs (2001) reports that nest placement is usually less than 1.75 m from the ground. Two eggs are typically laid per clutch (Bond 1995, Sanchez et al. 1992), and the female lays both eggs on alternating days commencing incubation after the final egg is laid (Sanchez et al. 1992). Both parents share incubation and feeding duties (Sanchez et al. 1992) as do other quail-dove species (Pérez-Rivera 1979, Goodwin 1986, Skutch 1991). Descriptions of nestling development of Blue-headed Quail-dove in captivity are given by Sanchez et al. (1992) but incubation and nestling periods are not yet described.

This study provides information into the breeding behavior of the Blue-headed Quail-dove in its natural environment, in a dry sub-coastal semi-deciduous forest. We

specifically present information on nest site, nest characteristics, nestling development, and notes on incubation and hatching.

METHODS

The study was conducted during from April to June of 2006 and 2007 at the Loma de Cunagua Wildlife Refuge, Cuba. The Loma de Cunagua is a subtropical 2,428ha dry sub-coastal semi-deciduous forest (22° 06'N; 78°26'W). It is a lowland forest rising to 326 m in elevation and is located within one of Cuba's largest wetland reserves El Gran Humedal Norte in the province of Ciego de Ávila. The loma is a seasonally dry environment with a defined rainy period between May and October (Borhidi 1991). Dominant tree species are Almacigo Colorado (*Bursera simaruba*), Sigua (*Nectandra coreacea*), Sangre de Doncella (*Byrsonima biflora*), Yaya (*Oxandra lanceolata*), and Jocuma (*Mastichodendron foetidissimum*) (Appendix 1) with emergent canopy species such as Yagruma (*Cecropia paltata*) and Ceiba (*Ceiba pentandra*) (Borhidi 1991).

We systematically searched for nests four to five days per week from 20 March to 30 June 2006 and 2007. As many as 10 field technicians were spaced 5 m from one another and walked slowly in a line for up to 1 km. Nests were discovered by flushing adults from the nest. Once located, behavioral observations were conducted daily during the nesting cycle from a natural blind. We described incubation, parental care, and other related behaviors and occurrences. Morphometric measurements including weight, wing cord, tail length, and beak width and length were taken on each nestling twice before fledging, and measurements of nest characteristics were taken after fledging had taken place.

RESULTS

Nests. – Two nests were located, one in 2006 (nest 1) (Fig. 4.1), and the other in 2007 (nest 2) (Fig. 4.2). Each nest was in a different stage of the nesting cycle. Nest 1 was placed within a natural cavity of a dead and bowed over Bayua snag (*Zanthoxylum elephantiasis*) with a trunk slope from the nest to the ground of 35° (Fig. 4.1). Nest height was 2.55 m, tree diameter at the nest was 24 cm, and nest dimensions were 13 cm x 22 cm. It appeared that any water collected within the cavity during the rainy portion of the breeding season would have drained out from underneath the nest from the slight slope on which the nest was placed (Fig. 4.1a). The nest was placed on top of collected leaf litter which would have also assisted in water drainage and keeping the nest from inundation during the period of heavy rains. Nest 2 height was 4.3 m and was placed on top of a live bowed over Jocuma (*Mastichodendron foetidissimum*) tree, nestled within cactus vines which were draped over the top of the trunk (Fig. 4.2). The slope of the trunk from the nest to the ground was 40° and tree diameter at the nest was 100 cm.

Both nests were built with a base of twigs and a thin lining of green leaves placed on top (Figs. 4.1 and 4.2). The slopes of the trees provided a walking platform for both pairs in both years. The parents were observed walking down the slope but never back up. Nest 1 was found on 17 May 2006 with two chicks approximately three days old. We assumed three days because the chicks eyes opened on day four, the number of days it takes for captive Blue-headed Quail-doves to open their eyes (Rodriguez and Sanchez 1993). The chicks fledged successfully eight days later on 25 May after an estimated 11 day nestling period. Nest 2 was found on 22 May 2007 with two eggs (Fig. 4.6). Hatch

occurred eight days later on 30 May, but was depredated later the same day by a West Indian Racer (*Alsophis cantherigerus*) locally known as the Jubo Sabanero.



FIG. 4.1. Blue-headed Quail-dove (*Starnoenas cyanocephala*) nest 1, 2006. Bayua (*Zanthoxylum elephantiasis*) tree nest substrate and height (A), nest platform with dimensions (B), and a parent brooding its nestlings (C) at the Loma de Cunagua Wildlife Refuge, Ciego de Avila, Cuba.



FIG. 4.2. Blue-headed Quail-dove (*Starnoenas cyanocephala*) nest 2, 2007. Jocuma (*Mastichodendron foetidissimum*) tree nest substrate with a parent incubating 2 eggs May 25th (A), the nest platform (B) and a full clutch of two eggs (C) at the Loma de Cunagua Wildlife Refuge in Ciego de Avila, Cuba.

Incubation. – Two eggs from nest 2 were incubated by both members of the Blue-headed Quail-dove pair. The parent incubating at night was replaced each morning ($n = 5$ mornings) at 0910 EST \pm 12 min by the other parent. At 0855 h on day one, out of the five days the nest was observed, the parent on the night shift gave out a soft low utterance, *ooo*, potentially calling to attract its mate, and at 0906 h the quail-dove's mate silently flew up to switch places with the incubating parent. On the other four mornings, the parents made a direct non-overlapping switch with one another and the night incubating parent left immediately. In all cases the parent either coming or going did so without making any sound related to wing movement. One observation revealed an

evening nest switch at 1736 h during the incubation period. In captivity the Blue-headed Quail-dove male incubates during the day and the female at night (Sanchez et al. 1992), and is also a behavior found in other Columbiformes in their natural environment (Skutch 1991, Goodwin 1986). The pairs in this study were not banded however it may be reasonable to assume the same gender role with respect to incubation. While incubating, adults generally sat very still keeping the head down and flush with the body (Fig. 4.1c and 4.2a), and only occasionally moving to stretch a wing or adjust position. The full length of the incubation period of the nesting cycle was not determined as a result of discovering the nest an unknown number of days after both eggs were laid.

Nestlings.— The nestlings from nest 1 in 2006 were found at approximately three days old at which time the skin was black with sparse plumes on the head and back, and the eyes were closed. The eyes with blue irises were opening on approximately day four and wing pinfeathers were emerging, which agrees with findings from Sanchez and Rodriguez (1992). On approximately day six, pinfeathers were present on the back and emerging tail, and the tips of the primary feathers were emerging from the pinfeather sheaths (Fig. 4.3a). Both birds weighed the same on day six and had the same fat score, but varied slightly in bill, wing, and tarsus length (Table 4.1). On approximately day 10 nestlings already had their characteristic white facial stripe and unique black bib with a slight white border on the breast. Cobalt blue contour feathers on the head were just emerging from their sheaths but otherwise nestlings were already well feathered (Fig. 4.3b). Fledging took place on 25 May when the chicks were approximately 11 days old. The fledgings young spent the morning walking back and forth on the nest tree until at least one of the parents led them down the trunk at approximately 1053 h.



FIG. 4.3. Approximately five to six day old Blue-headed Quail (*Starnoenas cyanocephala*) nestlings (A), and a nine day old nestling (B) at the Loma de Cunagua Wildlife Refuge in Ciego de Avila, Cuba 2007.

TABLE 4.1. Morphometric measurements taken on approximately day six of two Blue-headed Quail-dove (*Starnoenas cyanocephala*) chicks from nest 1 found in 2006 on the Loma de Cunagua Wildlife Refuge, Ciego de Avila, Cuba. *Fat is a score referencing the visible fat in the tracheal pit. 2 = pit one third full.

	Chick #1	Chick #2
Weight	82g	82g
Tarsus	29.4mm	28.2mm
Fat*	2	2
Wing Length	88mm	95mm
Beak Length	9.5mm	9.8mm

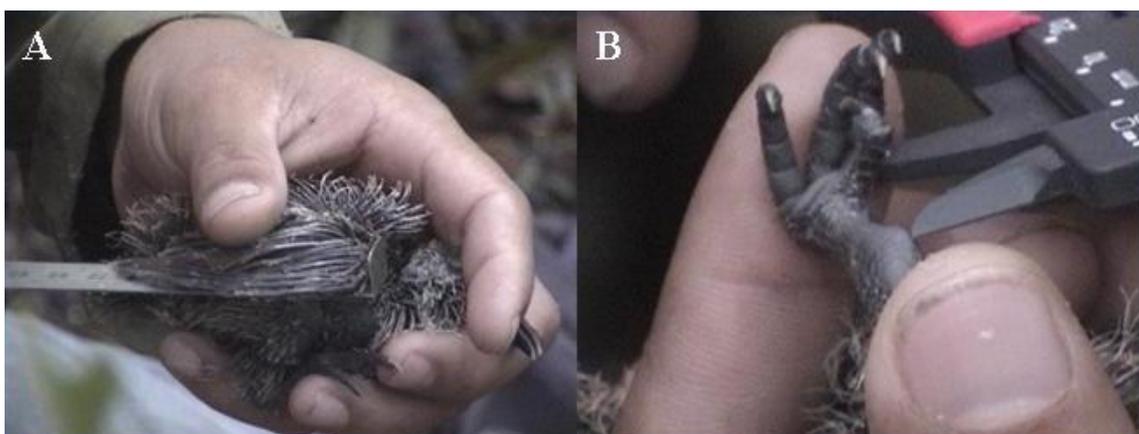


FIG. 4.4. Wing length (A) and tarsus length (B) measurements taken on approximately five to six day old Blue-headed Quail-dove (*Starnoenas cyanocephala*) nestlings in the Loma de Cunagua Wildlife Refuge in Ciego de Avila, Cuba 2007.

Hatching and nest depredation. – Both eggs from nest 2 hatched on 30 May, 2007. The regular nest switch did not occur on this day. Instead a West Indian Racer (*Alsophis cantherigerus*) approached the nest at 0930 h. The incubating Blue-headed Quail-dove took on a defensive posture by fluffing up its feathers appearing larger in size, but leaning its body putting weight to one side. The quail-dove directly faced the snake that then left after 1.5min. The observer was in a blind approximately 9 m away from the nest so some of the activity may have been hampered by obscuring vegetation. The quail-dove returned to its normal incubating posture but from 1107 to 1200 hours the parent assumed the defensive posture again becoming extremely agitated. The snake was not seen by observers at this time. At 1200 h the snake was seen trying to enter the nest from underneath the quail-doves tail, but she hit it with one of her wings three times causing it to move away again. At 1203 h the quail-dove got up from the nest and picked up an egg shell and walked the shell down the sloping tree trunk to discard it. In the next 10 min she took away shell fragments on four occasions, and was away from the nest between 2 – 3min each time. On two of those occasions the quail-dove walked down the trunk and the other two she dropped down to the ground directly from the nest. She returned to the nest by flying directly up to it without making a sound. During those 10 min she called twice to her mate with a soft *ooo* utterance only this time she increased the volume. At 1213 h the snake returned for a third time. The quail-dove confronted the snake directly again face to face until it left. Her posture remained defensive for the next 45 min but we did not have a visual of the snake. At 1303 h she got up from the nest and dropped to the ground and disappeared into the vegetation. At 1312 h a regular call was

heard from within a few meters of the nest tree, but neither the quail-dove nor its mate ever returned again. The nestlings were eaten by the snake at 1400 h.

DISCUSSION

Nestling descriptions and incubation behaviors of the Blue-headed Quail-dove are the first non-captive accounts for this species and represent the first description of nest sample unit substrates in a lowland semi-deciduous forest in particular in the Loma de Cunagua Wildlife Refuge in Ciego de Ávila, Cuba. Furthermore, nest heights are the greatest distances from the ground reported to date. Descriptions of hatch are the first descriptions as well however normal hatching behavior may have been influenced by the depredation of the nest by the West Indian Racer (*Alsophis cantherigerus*).

The fact that we only found two nests over a two year period underscores the difficulty in studying this endangered species. However, abundance estimates for this species at the Loma de Cunagua Wildlife Refuge (0.72 birds ha⁻¹; K. M. Leavelle and F. Chavez-Ramirez unpubl. data) indicate that the species is wide spread. A simple explanation for finding so few nests may be that Blue-headed Quail-dove are very good at hiding them. Quail-dove nests in Puerto Rico have low detection probabilities (Rivera-Milan 2001) as a response to predators (Perez-Rivera 1979, Rivera-Milan 1996) causing parents to resist flushing from the nests are approached. Indeed, the parent that was flushed from each nest did not budge until we were within approximately one meter of attending parent. Another possibility is that breeding amongst pairs may be separated by months (asynchronous breeding) (Stutchbury and Morton 2001) as a result of a long reproductive season (6 – 9 months) associated with subtropical and tropical forest habitats and fruit resource availability (Skutch 1950, Stutchbury and Morton 2001).

Asynchronous breeding of a secretive species over a protracted period of time would present a tremendous challenge with respect to both the logistical implications and prolonged effort to locate nests. The period of greatest nest searching effort in this study occurred from April to June, the period of peak nest density for quail-dove species in Cuba (Rodriguez and Sanchez 1993) and Puerto Rico (Rivera-Milan 1996) during a reproductive period that may be extended from February to August for (Rivera-Milan 1996, D. Rodriguez pers. comm.). Possible confounding factors such as asynchrony or limited search effort with respect to time may help explain our narrow results. We feel confident that there were no nests placed on the ground in the areas we looked, but grassy substrates and dense shrubs capable of holding a quail-dove nest are lacking in this forest. The nests that were found are the highest recorded for the Blue-headed Quail-dove but that is likely due to the inadequate data for this species.

Overall, the best way to gain more complete information on reproductive behaviors is to continue an extended search. One way to possibly increase the likelihood of finding a nest would be to track Blue-headed Quail-dove through radio telemetry. Chipley (1991) was able to successfully track two radioed Bridled Quail-dove (*Geotrygon mystacea*) in Puerto Rico to their nests which provided information about the species biology and reproduction not previously known.

Once a nest is found it becomes important to have information available on complete incubation and nestling durations to effectively back-date the start of each period if a nest is found midway through the nesting cycle. In light of the lack of nestling development information from the time of hatch in the wild, we believe that assuming that eyes open on day four, which corresponds to captive bred individuals (Sanchez et al.

1992), is a reasonable starting point until a complete incubation cycle is established in this forest environment. This assumption allowed us to estimate the duration of the nestling period at 11 days. The duration of the incubation period could not be estimated though Skutch (1949) estimates an 11 day incubation period for the Ruddy Quail-dove in Costa Rica which would merely serve as a point of comparison in future studies.

This study presents the first occurrence of Blue-headed Quail-dove nest predation by any animal predator. The hatchlings were eaten by the West Indian Racer (*Alsophis cantherigerus*) within 48min from the time of nest abandonment, and within 1 h and 47 min after the parent discarded the egg shells. The West Indian Racer is known in the Caribbean for bird nest predation and its ability to wind its way up trees in search of a meal (Henderson and Powell 1999). Other nest predators likely include the Cuban boa (*Epicrates angulifer*) and several bird species: The Red-legged Thrush (*Turdus plumbeus*), the Great Lizard Cuckoo (*Saurothera merlini*) and the Cuban Trogon (*Priotrulus temnurus*). These potential avian predators were all observed exhibiting agonistic behavior towards the incubating adult, and one individual Red-legged Thrush (*Turdus plumbeus*) was observed standing on the edge of nest 2 when there was no quail-dove adult present. In this instance the thrush was flushed off the returning Blue-headed Quail-dove parent. Few people own cats in this area and no domestic or feral cat was ever observed on the Loma. Rats on the other hand may pose a problem for nesting birds, but their role in avian nest predation is unstudied. Finally, introduced mongooses are considered important in avian declines in Cuba (BirdLife International 2008), but no observations were made during the study and local knowledge is nonexistent. This is an important area for further study.

It is clear that further descriptions and information on behaviors associated with reproduction is needed in order to both compare and contrast findings with other nesting studies in differing forest types (dry versus moist or lowland versus montane), and to increase our overall ecological knowledge of this rare endemic species. Further knowledge in unstudied aspects of reproduction would provide a clearer understanding of factors that may be limiting the Blue-headed Quail-dove population (e.g., nesting success, predation effects or food resource availability). Finally, it would provide some of the necessary inputs for effective planning and execution of actions for species conservation management and protection of what is currently considered one of Cuba's most endangered species.

LITERATURE CITED

- BENT, A. C. 1963. Life Histories of North American Gallinaceous Birds. Dover Publications Inc.
- BIRDLIFE INTERNATIONAL (2008) Species factsheet: *Starnoenas cyanocephala*.
Downloaded from <http://www.birdlife.org> on 12/7/2008
- BISSE, J. 1988. Arboles de Cuba. Editorial Cientifico - Tecnica, Ciudad de La Habana.
- BOND, J. 1993. Birds of the West Indies, 5 ed. Houghton Mifflin, Boston.
- BORHIDI, A. 1991. The Phytogeography and Vegetation Ecology of Cuba. Akademiai Kiado, Budapest.
- CHIPLEY, R. M. 1991. Notes on the biology of the Bridled Quail-dove (*Geotrygon mystacea*). Caribbean Journal of Science 27:180-184.
- GARRIDO, O. H., AND A. KIRKCONNELL. 2000. Field Guide to the Birds of Cuba. Cornell University Press.
- GIBBS, D., E. BARNES, AND J. COX. 2001. Pigeons and Doves: A Guide to the Pigeons and Doves of the World. Yale University Press.
- GOODWIN, D. 1983. Pigeons and Doves of the World, 3rd ed. Cornell University Press.

- HENDERSON, R. W., AND R. POWELL. 1999. West Indian Herpetoecology. Pages 223-268 in Caribbean Amphibeans and Reptiles (B. I. Crother, Ed.). Academic Press, San Diego.
- PÉREZ-RIVERA, R. A. 1979. Trabajo preliminar sobre la biología y el ciclo de vida de la perdiz pequeña (*Geotrygon montana montana*). Science-Ciencia 6:85-90.
- RIVERA-MILAN, F. F. 1996. Nest density and success of Columbids in Puerto Rico. The Condor 98:100-113.
- RIVERA-MILAN, F. F. 2001. Transect surveys of Columbidae nests on Puerto Rico, Vieques, and Culebra islands. The Condor 103:332-342.
- RODRIGUEZ, D., AND B. SANCHEZ. 1993. Ecología de las Palomas Terrestres Cubanas (géneros *Geotrygon* y *Starneonas*). Poeyana 428:1-20.
- ROMPRE, G., Y. AUBRY, AND A. KIRKCONNELL. 1999. Notes on Some Cuban Birds. Cotinga 11:31-33.
- SANCHEZ, B., D. RODRIGUEZ, AND M. ACOSTA. 1992. Algunos aspectos de la reproducción de la Paloma Perdiz (*Starneonas cyanocephala*) en cautiverio. in Reporte de Investigación del Instituto de Ecología y Sistemática. Ecología y Sistemática Academia de Ciencias de Cuba, Habana, Cuba.
- STUTCHBURY, B. J. M., AND E. S. MORTON. 2001. Behavioral Ecology of Tropical Birds. Academic Press, San Diego.
- SKUTCH, A. F. 1949. Life History of the Ruddy Quail-dove. The Condor 51:3-19.
- SKUTCH, A. F. 1950. The nesting seasons of Central American birds in relation to climate and food supply. Ibis 92:185-222.
- SKUTCH, A. F. 1991. Life of the Pigeon. Cornell University Press, Ithaca and London.

CHAPTER 5: CONCLUSIONS

Our results indicate that the Blue-headed Quail-dove is widespread across the Loma de Cunagua Wildlife Refuge, a semi-deciduous lowland forest located in the Gran Humedal wetland reserve in Ciego de Avila, Cuba. The estimated probability of occupancy averaged 60% over three years while abundance was 0.36 birds ha⁻¹, the largest abundance estimate for this species anywhere in Cuba. The Blue-headed Quail-dove responded positively to leaf litter ground cover but only up to a proportion of 70% at which time occupancy decreased to zero precipitously. Because the proportion of exposed rock was negatively correlated with the proportion of leaf litter, the quail-dove was responding to an increase in the proportion of exposed rock.

A Fruit preference experiment with captive Blue-headed Quail-doves at the National Zoo in Havana, Cuba suggest a preference in both *Guazuma parvifolia* in the probability of consumption and *Hamelia patens* in the proportion eaten. Conversely, Blue-headed Quail-dove showed an aversion to *Ottoschulzia cubensis* and to a lesser degree *Metopium brownei* possibly due to secondary metabolites, or other compounds associated with unripe or spoiling fruit. The Blue-headed Quail-dove did not show any preference at all for *Lagetta valenzuelana*, *Trema micrantha*, *Ficus havanensis*, or *Trichila hirta*. No preference was shown for *Bursera simaruba* which was surprising considering that we observed the quail-dove eating seeds from this tree at our study area.

Considering our small sample size of nests found at the loma we were able to add to the already limited existing knowledge of reproductive behaviors of this species. The Blue-headed Quail-dove appears to follow behaviors typical of other columbid species in nest construction and clutch size (n = 2) as well as the shared parental incubation duties.

Nests ($n = 2$) were the highest ever reported at 2.55 m and 4.30 m, and first reports of nests in both a Bayua (*Zanthoxylum elephantiasis*) or Jocuma (*Mastichodendron foetidissimum*) tree. The nestling period was estimated to be 11 days in this environment and nestling weights were the same for both squabs (82 g) at day six suggesting equal attention given by both parents. We also presented the first report of both a hatching event and predation event by a West Indian Racer (*Alsophis cantherigerus*) which occurred simultaneously. These two nests were very difficult to find and so patience and perseverance are recommended.

This was the first study of the endangered endemic Blue-headed Quail-dove in a semi-deciduous lowland forest, also known as a sub-coastal saline dome, which evaluated abundance and the probability of occupancy while taking the probability of detecting this very shy species into account. Sanchez et al. (1992) provided valuable information on the ecology of all four quail-dove species found in Cuba including the Blue-headed Quail-dove within the swamp forest of the Zapata peninsula. Their work along with observations made in the wild and the work done with these birds in captivity by Daysi Rodriguez and her colleagues provided the foundation for our study at the Loma de Cunagua Wildlife Refuge. We hope that the results of this study inspire biologists to continue the process of investigation of the ecology of the Blue-headed Quail-dove for the purposes of both science and conservation of this “Jewel of the Caribbean”.

APPENDIX 1. Tree species (≥ 10 cm DBH) at selected sample unit points at the Loma de Cunagua Wildlife Refuge, Cuba. Percentage of species dominance (species N/total individuals = (%)) at all sample unit points (4 ha) combined. Tree species mean, standard deviation and range 4 ha⁻¹ sample unit.

Tree Species	Common Name	Family	%	Mean	St. Dev.	Range	
						Min	Max
<i>Bursera simaruba</i>	Almacigo Colorado	Burseraceae	13.04	5.04	2.09	2	11
<i>Nectandra coriacea</i>	Cigua	Lauraceae	10.39	3.94	2.0	0	10
<i>Oxandra lanceolata</i>	Yaya	Annonaceae	7.79	2.93	1.99	0	10
<i>Byrsonima biflora</i>	Sangre de Doncella	Malpighiaceae	7.42	2.93	1.8	0	8
<i>Mastichodendron foetidissimum</i>	Jocuma	Sapotaceae	7.42	2.9	1.64	0	7
<i>Metopium brownei</i>	Guao	Anacardiaceae	6.72	2.57	2.21	0	10
<i>Gymnanthes lucidus</i>	Aite	Euphorbiaceae	5.00	1.87	1.99	0	8
<i>Cecropia peltata</i>	Yagruma	Moraceae	4.06	1.5	1.68	0	6
<i>Caesalpinia violacea</i>	Yarúa	Caesalpinaceae	3.87	1.49	1.57	0	7
<i>Cupania glabra</i>	Guarana	Sapindaceae	3.75	1.47	1.41	0	6
<i>Chrysophyllum oliviforme</i>	Caimito	Sapotaceae	3.60	1.37	1.33	0	5
<i>Calophyllum antillanum</i>	Ocuje	Clusiaceae	3.40	1.27	1.70	0	9
<i>Cedrela odorata</i>	Cedro Hembra	Meliaceae	3.07	1.17	1.19	0	5
<i>Cordia sp.</i>	Varía	Boraginaceae	2.11	0.80	0.91	0	4
<i>Colubrina ferruginosa</i>	Bijaragua	Rhamnaceae	1.60	0.63	0.87	0	3
<i>Pseudocarpidium multidentis</i>	Chicharrón	Melastomataceae	1.60	0.69	0.89	0	4
<i>Trophis racemosa</i>	Ramon de Caballos	Moraceae	1.50	0.57	1.04	0	7
<i>Zanthoxylum martinicensis</i>	Ayúa	Rutaceae	1.37	0.50	0.81	0	3
<i>Ocotea cuneata</i>	Canelón	Lauraceae	1.02	0.37	0.75	0	3
<i>Allophylus cominia</i>	Palo de Caja	Sapindaceae	0.90	0.39	0.62	0	3
<i>Erythroxylum confusum</i>	Árabo	Erythroxylaceae	0.88	0.39	1.01	0	5
<i>Phyllanthus juglandifolius</i>	Grosella Cimarrona	Euphorbiaceae	0.70	0.27	0.74	0	5
<i>Picramnia pentandra</i>	Águedita	Simarubaceae	0.70	0.26	0.83	0	6
<i>Clusia rosea</i>	Cupey	Clusiaceae	0.61	0.23	0.49	0	2
<i>Ficus havanensis</i>	Jaguey	Moraceae	0.61	0.23	0.46	0	2

Species richness (Total number of species) = 47. Total families = 29. Sapotaceae and Moraceae families have the greatest representation with 5 genera each.

APPENDIX 1. Continued

Tree Species	Common Name	Family	%	Mean	St. Dev.	Range	
						Min	Max
<i>Eugenia axillaris</i>	Guairaje	Myrtaceae	0.59	0.21	0.51	0	2
<i>Trema micrantha</i>	Guasimilla Boba	Ulmaceae	0.57	0.24	0.58	0	3
<i>Trichilia havanensis</i>	Siguaraya	Meliaceae	0.55	0.20	0.47	0	2
<i>Pera bumeliaefolia</i>	Jiquí	Euphorbiaceae	0.55	0.20	0.50	0	2
<i>Ateleia sp.</i>	Rala	Fabaceae	0.55	0.20	0.81	0	6
<i>Eucalyptus sp.</i>	Caoba	Myrtaceae	0.47	0.17	0.88	0	7
<i>Manilkara grisibachii</i>	Acana	Sapotaceae	0.43	0.16	0.37	0	1
<i>Zanthoxylum elephantiasis</i>	Bayúa	Rutaceae	0.35	0.13	0.41	0	2
<i>Pseudolmedia spuria</i>	Macagua	Moraceae	0.35	0.13	0.51	0	3
<i>Vitis sp.</i>	Uvita	Vitaceae	0.31	0.11	0.36	0	2
<i>Erythroxylon havanense</i>	Jiva	Erythroxylaceae	0.27	0.11	0.32	0	1
<i>Aeschynomene americana</i>	Tamarandillo	Leguminosea	0.27	0.10	0.30	0	1
<i>Ottoschulzia cubensis</i>	Cogote de Toro	Icacinaceae	0.25	0.10	0.42	0	2
<i>Laurocerasus occidentalis</i>	Cuajani	Amygdalaceae	0.23	0.09	0.37	0	2
<i>Pouteria serpentaria</i>	Canistel	Sapotaceae	0.20	0.07	0.26	0	1
<i>Guazuma parvifolia</i>	Guasima	Sterculiaceae	0.20	0.07	0.26	0	1
<i>Pisonia sp.</i>	-	Nyctaginaceae	0.20	0.09	0.28	0	1
<i>Casearia hirsuta</i>	Jia	Flacourtiaceae	0.16	0.06	0.23	0	1
<i>Lysiloma sabicú</i>	Sabicu	Mimosaceae	0.14	0.06	0.23	0	1
<i>Zuelania guidonia</i>	Guaguasi	Flacourtiaceae	0.12	0.04	0.20	0	1
<i>Pseudolmedia spuria</i>	Macaguilla	Moraceae	0.08	0.03	0.24	0	2
<i>Sideroxylon salicifolium</i>	Cuya	Sapotaceae	0.04	0.01	0.12	0	1

Species richness (Total number of species) = 47. Total families = 29. Sapotaceae and Moraceae families have the greatest representation with 5 genera each.

APPENDIX 2. Table showing vegetation measurement differences between the eastern side of the loma de Cunagua Wildlife Refuge where vegetation is in a stage of secondary succession (SU 35-55) and the remaining more mature areas (SU 1-34 & 56-70).

Sample units 1 – 34 & 56 – 70 (n = 50)			Range		Sample units 35 – 55 (n = 20)			Range	
Variable	Mean	St. Dev	Min	Max	Mean	St. Dev	Min	Max	
Slope	18.960	7.660	0.000	32.000	16.900	14.200	0.000	50.000	
Canopy Cover (%)	0.713	0.142	0.304	0.987	0.580	0.156	0.253	0.886	
Leaf Litter (%)	0.597	0.139	0.203	0.835	0.341	0.182	0.190	0.760	
Rock (%)	0.175	0.112	0.000	0.510	0.213	0.174	0.000	0.532	
# Perches	5.420	2.935	0.000	13.000	1.300	1.559	0.000	5.000	
Sapling Abundance	31.640	12.000	14.000	66.000	30.550	10.050	17.000	67.000	
Shrub Abundance	23.040	14.330	2.000	100.000	29.600	12.230	13.000	75.000	
Avg. Shrub Cover	0.800	0.100	0.413	0.965	0.769	0.158	0.475	0.975	
<i>Avg. Tree DBH*</i>	<i>39.150</i>	<i>7.870</i>	<i>20.060</i>	<i>50.190</i>	<i>19.353</i>	<i>1.755</i>	<i>14.938</i>	<i>22.100</i>	
Tree Abundance	39.160	7.940	21.000	51.000	37.100	7.580	16.000	49.000	
Doncella Abundance	3.280	1.896	0.000	8.000	2.050	1.356	0.000	4.000	
Almacigo Abundance	4.960	2.338	2.000	11.000	5.250	1.293	3.000	8.000	

*Avg. Tree DBH (Diameter at breast height) Means indicate two areas in differing stages of succession. Occupancy was unaffected.