A Contribution to the Ecological Understanding of Bats in the Natural Metropolitan Park, Panama

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In collaboration with: El Parque Natural Metropolitano

PANAMA

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Host Institution

Parque Natural Metropolitano, Avenida Juan Pablo II, final.

The Natural Metropolitan Park is located in Panamá City, Panamá, and is the only wildlife refuge in Panamá located within city boundaries. The park itself consists of 232 hectares of protected space, and is part of the 'Biological Corridor' which exists along the east shore of the Panamá Canal, coupled with the Camino de Cruces and Soberania National Parks (Viquez & Denvers 2006). This protected area is one of the last refuges of the threatened Pacific Dry Tropical Forest in Central America, and provides a habitat for native flora and fauna species that require a large forested area (Viquez & Denvers 2006). The Park's objectives include providing opportunities for people to enjoy outdoor recreation, promoting environmental education and nature interpretation, facilitating ecological research and related scientific-cultural activities in addition to protecting the Curundu river's biological integrity and the buffer zone of the Panamá Canal Watershed (Viquez & Denvers 2006).

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Introduction

The order Chiroptera comprises one quarter of all extant mammals (Jones *et al*. 2002) and its approximately 1,100 species (Shutt & Simmons 2006) are characterized by being the only mammals to have developed powered flight, making them completely unique in the animal kingdom. The earliest records of modern bats in North America, Europe, Africa, and Australia date from the early Eocene between 53 mya to 49 Mya (Speakman 2001; Gunnell & Simmons, 2005). Evolution of Chiroptera remains controversial in part because no transitional fossils have been found to explain their evolution (Simmons 1995; Sears et al., 2006). It is believed that a gliding, nocturnal, insectivorous mammal developed flight, and afterwards evolved echolocation using low-frequency signals (Arita & Fenton, 1997). The majority of scientists consider Chiroptera to be a monophyletic taxa including two recognized suborders, Megachiroptera and Microchiroptera. Megachiroptera are the old world fruit bats (Jones *et al*., 2002) relying on their visual acuity (Teeling *et al*., 2000) and olfactory system (Safi & Dechmann, 2005) to navigate and forage, while Microchiroptera taxa use complex laryngeal echolocation (Teeling *et al*., 2000).

Bats are the most ecologically diverse and geographically widespread mammal (Ratcliffe, Fenton, & Shettleworth, 2006). They usually feed at night and rest in roost during the day. Some species create specialized roosts for themselves by cutting the leaves of palm trees to build a house-like structure, while most species rest in natural areas ranging from hollow trees, logs, caves, crevices, bridges, tunnels, culverts, and buildings (Reid 1997). Their feeding habits are quite diversified and their diet may include combinations of insects, fish, fruits, nectar, pollen, flowers, blood, birds, and other vertebrates (Samudio and Carrion de Samudio 1989) depending on the species. Their presence plays important roles in the ecosystems where they are found.

Ecologists consider Chiroptera to be the most important mammal order in neotropical rainforests because its contribution in pollination and seed dispersal is essential for the maintenance of plant biodiversity and regeneration (Santamaría and Méndez 2001). In spite of their ecological role and efficacy in insect control, people most commonly associate them with evil, darkness and a source of diseases (Fenton 1997). This association, along with their non-charismatic appearance, leads to a lower public support in many areas for their conservation.

The Natural Metropolitan Park is located in the transition zone between the tropical dry and humid forests of the region, and is part of the Biological Corridor of the east shore of Panamá, and therefore it is an important refuge for a diversity of animals including 27 species of bats (Viquez & Denvers 2006). In Panamá, 114 species of bats have been identified and according to previous studies 26 were found in the park (Viquez & Denvers 2006; Samudio 2002). As part of its mandate, the park aims to protect the resident species while providing information and environmental education to the public. Since information regarding the importance of food and roosts in bat population ecology is not well understood for a majority of the 26 identified species in the park, it affects the ability to produce effective management plans for their conservation (Fenton 1997). The aims of this project are to increase knowledge of resident bat populations and help promote understanding and conservation of these species through public education.

Specific Objectives

1. Investigate natural and artificial habitats that exist for different species in the park
2. Identify and characterize species living around these sites
3. Perform an habitat survey to compare the conditions of each site and how it affects bat richness
4. Create document that analyzes the population of bats sampled in the park
5. Map the capture sites and areas where each species are found
6. Create an educational pamphlet of the resident bat species

The general objectives are to establish a database of information about a sample of the population of bats living in the park, and make the appropriate correlations between the different habitats and their presence at these sites. An artificial site has also been selected to identify the diversity of species roosting in the building and thereby help the park create better management plans for the building and the bats living there. With these data, an informative guide will be designed to provide visitors of the park with detailed information describing the bat species present in the park for touristic and educational purposes.

Methods

AREA OF STUDY

The Parque Natural Metropolitano (PNM) was founded in 1988 to protect 115 943 m^2 of highly endangered pacific dry forest in the heart of Panama City. It joins the Camino de Cruces and the Parque Nacional Soberanía in the Biological Corridor of the east shore of Panamá (Viquez & Denvers 2006). The park is located in the transition zone between the tropical dry and humid forests, and therefore consists of a mixture of these two biomes. This protected area is one of the last refuges of the threatened Pacific Dry Tropical Forest in Central America, and provides a habitat for native flora and fauna species that require a large forested area (Parque Metropolitano 2008).

Figure 1: Map of the Natural Metropolitan Park, with specific study sites indicated

STUDY ORGANISMS

Based on the Management Plan of the park (Viquez & Denvers 2006); and a later study by Samudio *et al*. (*unpublished data*) 26 bat species from five families were found in the park (see Appendix IV).

SITE SELECTION

This study was performed for four months in the Metropolitan National Park of Panamá City, Panamá. Sites were selected by a first inspection on foot of the forest surrounding the Sendero (trail) Momótides and accessible areas of the park. Six sites were chosen to have a representative sample of areas of humid and dry tropical forest and different percentages of canopy cover. The proximity to possible roost site was also taken into account during the selection process. Once located, these sites were re-visited for the capture of bats and habitat characterization. For each site, the GPS coordinate, the forest type (humid or dry), the average height of the canopy of trees, the percent canopy cover and the possible roost sites visible from the netting site were recorded. Dominant tree species were identified at each site by the help of an experienced park employee. Canopy cover was estimated in percentage, 0% representing no tree cover, 50% signifying that sunlight can penetrate to the ground for 50% of the area and 100% representing a habitat without sunlight penetration to the ground.

The first site is an active artificial roost site, an abandoned building named “El Castillo” located in the junction of the path leading to the canopy crane and Camino Mono Titi and the road Juan Pablo II (Figure 2). Previous studies found a greater diversity of bats in the area of the Sendero Momótides (*Castillo pers. communication*) than other areas in the park, so three sites were chosen 200m apart in this area, at a quarter (site 2; Figure 3), half (site 5; Figure 6), and three-quarter (site 4; Figure 5) of the trail to maintain independence of treatment. An area near an abandoned building in an open area at the limit of the park was chosen as third site (Figure 4). Lastly, the sixth site was chosen near a pond on the Sendero “El Roble” because it offered an entirely different habitat than the other sites due chiefly to the presence of stagnant water (Figure 7).

Figure 2: Capture site 1: el Castillo

Figure 3: Capture site 2: Momótides ¼ trail

Figure 4: Capture site 3: Open Area/Abandoned building


Figure 5: Capture site 4: Momótides ¾ trail


Figure 6: Capture site 5: Momótides ½ trail

Figure 7: Capture site 6: Laguito site

HABITAT CHARACTERIZATION

Selection of a mapping method

In order to characterize the selected sites according to available geographic data such as soil type, height above sea level, and spatial dispersion, the compilation of various sources of data was required using a Geographic Information System (GIS). Ultimately, it was decided that for a number of reasons, this GIS system would use the Google Earth interface as its backbone. One reason for selecting Google Earth as opposed to a more sophisticated program such as ESRI's ArcGIS was that the park itself and its employees did not have knowledge of, or access to, this type of expensive software. In contrast, Google Earth may be downloaded for free by any computer user and features a simpler interface in addition to many hundreds of online tutorials in multiple languages. Another factor in this selection was that the map files that the park supplied were in a document format, with no spatial data attributed to them whatsoever. An attempt was made early on to solve this problem by digitizing photocopied GPS coordinates of sites in the park (the spreadsheet version of which can be found in Appendix II) to use as spatial control points, but this initiative failed because the datum in which this data had been collected had not been recorded and was evidently not any of the most common systems. The absence of geo-referencing control points but the available spatially accurate and valuable maps therefore made the Google Earth's 'overlay' tool the most sensible way of garnering the required information.

Overlaying maps using Google Earth

In order to produce a coherent set of overlays using Google Earth, all four source layers had to be converted from their original format as Microsoft Publisher files into more useful .jpg and .tiff image files at a high resolution (300dpi), which was performed using Microsoft Publisher (these image files can be found in Appendix III). These images were then added to Google Earth's free software version 5.0 as image overlays, saved as .kmz files compatible with Google Earth, and by increasing their transparency and using the provided base satellite imagery at a straight overhead view, the boundaries of the park were lined up for the first map image. Each subsequent image was then added to the interface and lined-up with the first image, with further minor adjustments bringing each overlay to an identical spatial location.

Creating spatial files and determining habitat characteristics

The transformation of field-collected locational data (using a Garmin 'Blue Moon' hand held GPS unit) to a format compatible with the Google Earth interface was done in a two-step process. First, the coordinates in the Latitude/Longitiude system using the WGS 1984 datum were entered into an Excel spreadsheet with the site's name and the GPS accuracy (Appendix II).

The file was then modified to include a pre-existing Google Earth icon number for each site and an online resource called "Excel to KML" provided by Earth Point at www.earthpoint.us/ExcelToKml.aspx was used to convert the Excel file to a .kml file. The transfer was then made permanent by saving the resulting file within the Google Earth itself. The resulting file, when combined with the spatially corrected map image overlays, allowed one to determine the elevation as well as the soil type of each site.

CAPTURE AND SAMPLING

This study was performed in the Metropolitan National Park of Panamá from January to April 2009. Bats were captured by mist-net according to the techniques described by Kunz & Kurta (1988). To maintain a uniform sampling effort across sites, a mist-net was put up for a total five hours (± 15 minutes) at each site between 18h00 and 22h00 which is recognized as the first activity peak for bats in this region (Thies, Kalko, & Schnitzler 2006; *Castillo pers. comm.).* For this study, thirty hours were dedicated to mist-netting in the field. Three nets were used alternatively between sites; two had a similar surface area of 14 m^2 while the last only covered 8.26m^2. Verification of the net was done every 30 minutes except for nights when two nets were set up and the time spent removing bats in one did not allow enough time to verify the other net with this frequency. In these cases, nets were verified as soon as removal was finished at the other site. All species caught were extracted and carefully manipulated for identification of the species, sex, level of maturity, reproductive stage, presence of parasite, and forearm length. Once all data were recorded, pictures of the animal were sometimes taken and then it was released to minimize stress associated with the capture and handling (Widemaier *et al.* 1994). The weather conditions (temperature, humidity, time at sunset, moon phase) as well as time of capture and date were also recorded for comparison purposes.

Figure 8: Bat capture and extraction using a mist-net. Supervised by bat expert Jorge Castillo.

SPECIES IDENTIFICATION

Each bat captured was identified using the "Key to the bats of the Lowlands of Panamá" by Handley and Samudio (see Appendix V) to which some modifications were made. When identification was uncertain, a brief description of important characteristics was recorded and multiple photos were taken of the individual. Other references were used and the additional information (description and pictures) was sent to bat specialists for accurate identification.

AGE DETERMINATION

As suggested by Anthony (1988), the bats caught for this ecological study were placed into broad relative age groups defined as juvenile, sub-adults and adults. Age category was determined visually by the observing the epiphyseal-diaphyseal fusion finger bones. Cartilaginous epiphyseal plates in finger bones (Fig 10: I) are present in juvenile bats (Andersen

1917; Anthony 1988) while adult bats have mineralized bones producing knobby and unevenly tapered finger joints (Figure 10: III). By flashing a light through the wing membrane, cartilaginous areas of young bat's fingers are lighter and barely visible while ossified areas for adults do not let as much light shine through and appear bulkier. All individuals without clearly mineralized bones and thick knobby joints were classified as sub-adults (Fig 10: II).

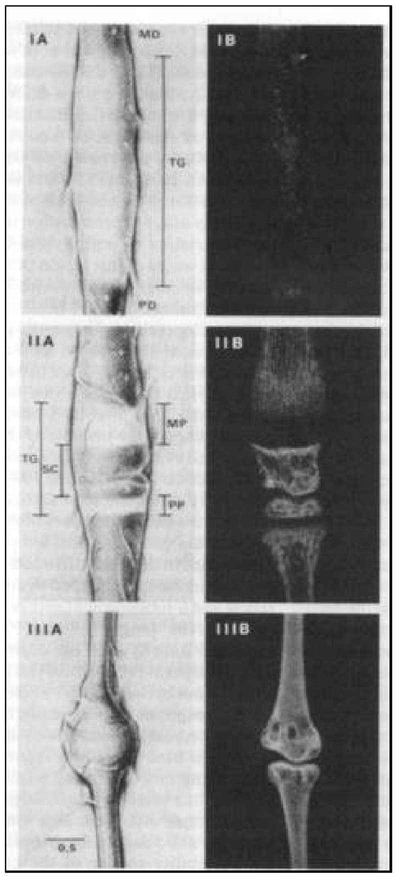


Figure 10: Growth progression of the fourth metacarpal-phalangeal joint of *Myotis lucifugus* from the neonatal stage (I) to sub-adult stage (II) and adult stage (III) . Image A shows the growth of the bone seen by transilluminating the wing while B shows the X-ray. (Illustration taken from Kunz and Anthony 1982)

SEXUAL DETERMINATION AND MATURITY

The sex of the bats captured was identified according to the presence of sexual organs. The presence of a penis distinguished the males (Figure 11) while for females a combination of traits was used. Females were recognized by a vaginal opening (Figure 12) and the presence of nipples (Figure13). Many species such as *Artibeus jamaicensis*, males experience seasonal descent of the testes during the reproductive season (Racey 1988). Other males are classified as reproducing by the swelling of testes during spermatogenesis which make them more conspicuous (Racey 1988). During this study all males with obvious testes were noted to be in the reproducing season and mature. Female pregnancies were determined by palpation of the abdomen. Parity was also established by the appearance of the nipples. A mature female will retain enlarged nipple size and a keratinize appearance while immature or non-parous females have smaller nipples covered by hair (Racey 1988).

Figure 11: Male *Artibeus jamaicensis* showing pronounced genetalia

Figure 12: Female *Artibeus jamaicensis*

Figure 13: Mature female with nipple found underneath the arm close to the wing membrane.

LIMITATIONS

Roost-site identification

An initial objective for this study was to identify the inhabited roost-sites of bats in the park. During the day, transects were performed to identify possible roost-sites such as hollow trees, palm leaves, caves, culverts, buildings, etc. However, several problems were experienced with this methodology. First, it was nearly impossible to access all the possible roosting sites due to lack of adequate equipment. Some bats use the under-branch of trees to roost (Kunz & Kurta, 1988), but with the canopy being so high, it was impossible make observations with the naked eye or binoculars, because the light source available did not provide sufficient contrast to see bats. Secondly, our focus was on the readily accessible roost sites, like culvert, buildings, hollow trees, palm leaves, but it also proved impossible to visually identify the presence of bats in these locations. When a camera was used to take pictures where access was difficult, no bats were found. In other areas, for example hollow trees, the angle of the photograph could not provide a clear enough photo of the interior of the roosts to determine if they were occupied. Powell & Wehnelt (2003) also found daytime colony counts to be difficult and often underestimated population density, implying that population assessments are not as reliable when done during the day.

Another methodology was explored where roost-site were re-visited at dusk in order to observe the bats leaving them. It was found by Warren & Witter (2002) that the time of first emergence of bats varied depending on the site, the date, and weather conditions for a same species; this implies observers must calculate an appropriate time-range to account for these variations. It was also noted that different species emerged at different times, therefore the assessment of the roost sites of many species requires a larger time frame than what was possible. Also, visibility was very limited at dusk. Bats were observed around the trees yet it was impossible to certify they originated from the roost-site or if they came from another location. Most roost-site studies require more than two researchers and often use volunteers (Warren & Witter, 2002; Jaberg & Blant, 2003) or a team of experts to locate them (Powell & Wehnelt, 2003). Other studies only looked at known roost-sites (Warren & Witter, 2002; Petit, Rojer & Pors, 2006) and artificial sites such as houses and barns. Sophisticated equipment such as telemetry where captured bats, mainly breeding females, are radio-tagged (Jadber & Blant, 2003) can be used. Given the restricted material, manpower and time frame of this project, this objective was abandoned.

Population density

Another initial goal was to estimate population density. Safe and short-term marking techniques of fur clipping were determined as the best method to assess this. Many population estimates require several counts by several people or the use of ultrasonic equipment (Allen

1996; Warren & Witter 2002). Due to this, and because the number of bats captured needs to be high enough to at least recapture some of the marked bats, this initiative was also deemed to not be feasible.

The most adequate sites for a population analysis of roost-sites that could be determined were the artificial sites “El Castillo”, “el bunker” and “la casa de agua” (see Appendix II for GPS locations) because they were accessible and easy to monitor. Visits during the day successfully accounted for the presence of bats at these sites. Furthermore, other signs of bat presence such as guano and remnants of seeds could serve as valuable information to infer or study life history and ecology of the bats living there for future studies.

Mist-netting

Considering this project was the first time we had dealt with bats, we both lacked knowledge about the techniques and methodologies to capture, extract, and identify bats. This lack of experience in handling bats imposed a few limitations on our research. First and foremost, several nights of practice were required before becoming confident with the handling bats and extracting them from the mist-net. Though experience was gained with each night in the field, we were not sufficiently efficient to use more than two nets at once because we could not process the bats fast enough for their safety and our own. The longer a bat spent in the net, the more entangled it became and thus it was increasingly arduous to retrieve them. In some cases it was necessary to cut the net to free a bat, which damaged the equipment and caused stress to the bat. Fruit-eating bats are especially vulnerable because their diet does not permit them to build large fat reserves and cannot tolerate periods of food restriction (Thies, Kalko, & Schnitzler 2006). Though it is more likely to be problematic over a long time scale, bats have a fast metabolic rate (White & Seymour 2003) and require constant feeding to remain active (Allen

1996). A handling error during the first night caused the death of a bat. To avoid further loss, we determined that it was best to keep the capturing method simple.

Bats are known to frequent a diverse range of habitats and this includes the exploitation of different altitudes during flight (Allen 1996). Since some insectivorous bats were found to fly 100m high on Barro Colorado Island (Allen 1996), the area and height at which the mist-net is installed can certainly affect the diversity of bats captured. Due to our limited equipment, it was impossible to put nets at different altitudes, and the capture area was therefore restricted to the height of the net from the ground, approximately 2-3m high. Insectivorous bats posed another problem; they were often observed actively avoiding the net. On one hand, this could be due to the condition of the net. Some nets had large holes, while others were repaired with knots, making the net more conspicuous than it would normally be. To reduce this bias the best nets were used and were repaired by hand with sewing threads. On the other hand, some bats are known to use a better signal that provides them with a clearer depiction of their surroundings. Bats using FM signals demonstrated the ability to distinguish between two separate targets even when the targets were less than half a millimeter apart (Jones & Teeling 2006; Simmons & Stein 1980). This signal offers a better resolution and these bats receive a continuous stream of information of the surrounding objects.

This idea was supported by the personal observations of bats flying towards the net and then veering off less than an inch before it. Other bats seemed to aim and fly through the larger holes that were a result of cut mesh. For these reasons, the mist-netting technique used may be selective in the species caught and provide an incomplete view of the species richness of the park.

Lastly, in the methods we fixed the verification of the net at 30 minutes, though sometimes unexpected events altered this time frame slightly. During this time period, bats were observed flying into the net but escaping it before the time of next verification, or while extracting other bats. Yet, if extraction was more frequent, the presence of the personnel and their lights may drive off bats and interfere with capture. The waiting time between net verification is therefore an important factor and can affect the results obtained.

Health and safety

Most bat studies require the handling of the animal and thus require appropriate safety measures. In this case, rabies vaccinations were mandatory to handle bats. Considering this fact became known to us after the beginning of the project, it was not possible to manipulate bats from the start of the project. In fact, the last vaccine was administered on March 2nd 2009, a month before the end of the project. Any bat handling before that period required the use of leather gloves and towel, making the process less efficient.

The host institution also required a guard to be present for each field night, thus the schedule of sampling was dependent on the availability of the park staff. Later on during the course of the project, the park buildings were broken into, and it was asked that the field time be restricted before 21h00, which greatly reduced the sampling effort.

The study of artificial sites or any roosts where bats gather at high density are known to pose significant health risks. Such sites usually have high concentration of ammonia, carbon dioxide and methane that may cause health problems if someone is exposed to these compounds for a long time period (Kunz & Kurta 1988). Bats are also zoonotic disease carriers and can transmit leptospirosis by coming in contact with their urine or histoplasmosis (Kunz & Kurta 1988) an airborne infection carried in their feces. There are always potential risks of infection and it is recommended to use respiratory masks or face pieces when working in conditions susceptible to transition. The visits to the interior of “El Castillo” and other artificial sites were therefore limited or avoided. The host institution has stated that it would provide the material if more explorations of these sites were projected. The limited time frame and health risk associated with this type of work provided us with another reason to omit the roost-site survey from this study.

DATA ANALYSIS

In conservation biology different indices and modelling can be done to represent the structure of a community and design the appropriate management strategy to help maintain its populations. To help monitor the effects of environmental change on such populations, it is important to recognize their biological diversity. Defining alpha diversity helps to describe the species richness of a specific community that is considered homogenous. Both test of dominance, Simpson’s index and Shannon-Weiner’s test of evenness are performed for each site sampled to assess the alpha-diversity and allow rapid comparison. The Simpson’s index measure the probability that two randomly selected individuals in a sample will belong to the same species (Moreno 2001). It can be calculated according to the following formula:

Simpson’s index of dominance

$$D = \frac{\sum_{i=1}^{s} n_i (n_i - 1)}{N(N-1)}$$

where S is the number of species, N is the total number of organisms, and n_i is the percentage of species or the number of organisms of species i. The index value obtained decreases as the diversity of the community increases, so a value of zero signifies infinite diversity while a value of one represent no diversity (Moreno 2001). The Shannon-Wiener index expresses uniformity of species across two samples and is represented by the equation below.

Shannon-Weiner's index of evenness

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

Where p_i is the relative abundance of each species which can be calculated by $\frac{n_i}{N}$ and all other variables have the same signification as for the Simpson's index. The value of the index increases when there are more unique species or the highest value occurs when all species are equally represented in the population.

Moreover, beta-diversity is used to determine the similarity of the species composition of two communities or sub-communities. A simple index used for this is the Jaccard index of similarity. When the value obtained is zero, it implies there is no similarity between the set of species found between the two sites sampled, while a value of one indicate that the two sites have the same species composition (Moreno 2001).

An ordination analysis is used to graphically represent the similarity and differences among sites according to the co-occurrence of species in an area. From these graphs, the presence and abundance of species at each site was noted in order to later establish possible environmental gradients associated with the cluster found. This graphical representation was chosen because if clusters exist in nature they will be shown by this analysis.

Results

Approximately 61 hours, or an equivalent of 7.6 days, were spent in the field either for capturing and identifying bats or for habitat survey. A little more than 26 days were required by each author to produce finalize this report and the complementary educational pamphlets and presentations. A total of 303 hours (38 days) were required to complete the goals set for this internship project, including field work, and writing of reports and the educative pamphlet for the host institution (see Appendix VI).

A total of 65 bats from 13 different species were identified during the course of this project. Seven individuals could not be identified because they escaped before net extraction was performed. The species accumulation curve, Figure 14, shows that the bat population of the park consists of more rare species and fewer very common species, as is generally the case for most populations (Rabinowitz 1981). The most common species captured and identified with 38 individuals was *Artibeus jamaicensis*.

In terms of the presence of parasites in the total population, it is clear from Table 1 that the occurrence of parasite was highest at capture site 1 for this study, with more than double the number of bats collected with parasites than without. The second highest occurrence of parasites was at site 5, followed by site 4 then site 6. Interestingly, none of the bats collected at either site 2 or site 3 had parasites. Overall, the incidence in parasites for bats collected was 33%.

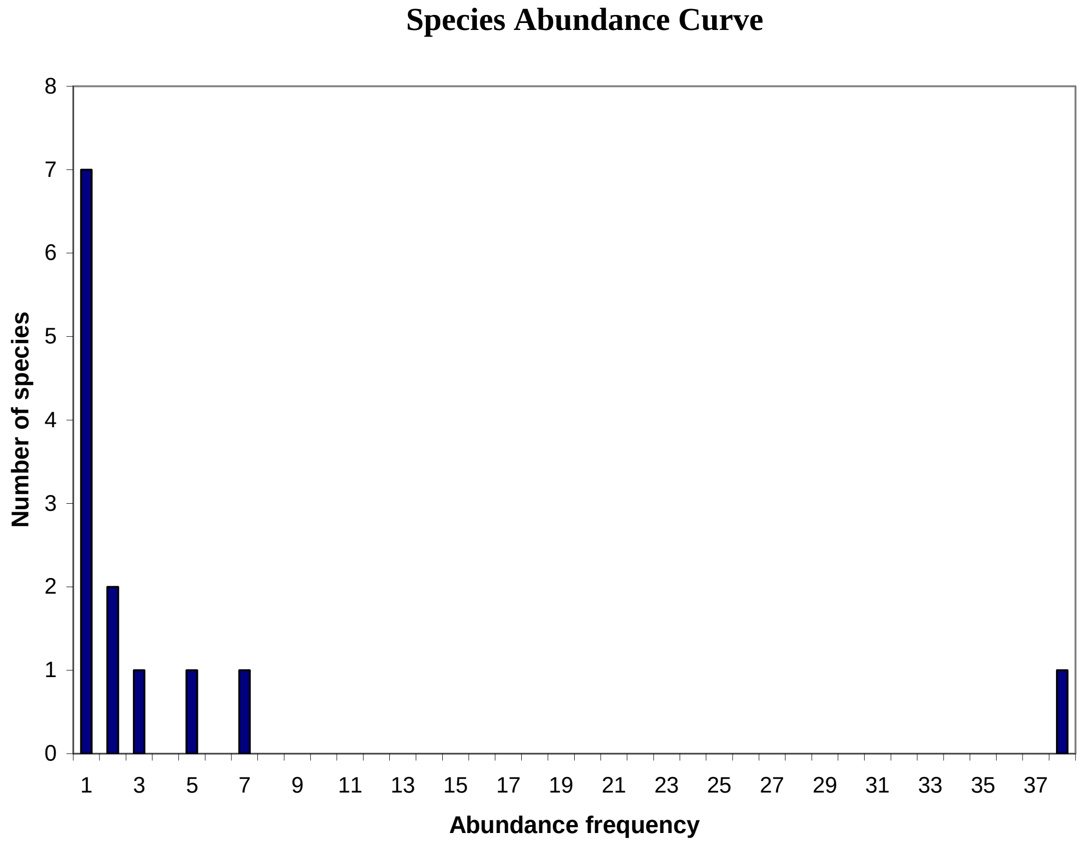


Figure 14: Species Abundance curve showing rare species are common while abundant common species are rare.

Table 1: Parasite presence in bats according to capture site

Site	# of Bats with parasites	# of Bat Without Parasites	Ratio of Parasites/No Parasites
Lagito	1	5	0.20
¾ trail Momótides	4	15	0.27
½ trail Momótides	3	6	0.50
¼ trail Momótides	0	14	0.00
Open Area	0	5	0.00
El Castillo	9	4	2.25
Total:	16	49	0.33

Focusing on the most abundant species, Table 2 shows that the most *Artibeus jamaicensis* individuals were captured at site 4, with a total of 15 individuals, followed by site 2 with a total of 12. For this species, all bats that were carrying parasites were captured in natural habitats, which conflicts with the compiled species data shown above (Table 1). Of the bats captured, 97.37% were adults and 50% were male (Table 2, Figure 15). In terms of reproduction activity, 89.5% of the females captures were gravid and 36.8% of the males were in their reproductive period (Table 2). Forearm length of bats collected has a mean value of 62.9mm, with female specimens having a noticeably smaller range of lengths than males, with both the overall maximum and minimum forearm lengths recorded being from male specimens (Figure 16).

Table 2: Key characteristics of *Artibeus jamaicensis* bats collected during the study

Bat No.	Date	Site	Adult	Gender	Forearm length (mm)	Parasites	Breeding Details
1	29/01/09	¼ trail Momótides	A	M	62	No	
2			A	M	67	No	
3			sA	M	62	No	
4			A	F	62	No	Gravid
5			A	F	62	No	Gravid
6			A	M	61	No	
7	12/02/09	¼ trail Momótides	A	M	65	No	Reproductive period
8			A	M	65	No	Reproductive period
9			A	M	67	No	Reproductive period
10	19/02/09	Open Area	A	M	57	No	
11	05/03/09	Open Area	A	M	66	No	
12			A	F	64	No	Gravid
13			A	M	62.5	No	
14		¾ trail Momótides	A	F	64	Yes	Gravid
15			A	F	63	No	Gravid
16			A	M	63	No	
17			A	M	63	No	Reproductive period
18			A	M	63	No	Reproductive period
19			A	F	62	No	Gravid
20			A	M	57	Yes	
21			A	F	63	No	
22			A	F	60	No	Gravid
23			A	F	64	No	Gravid
24			A	M	65	No	Reproductive period
25			A	M	58	No	
26			A	F	60	No	Gravid
27			A	M	61	No	Reproductive period
28	12/03/09	El Castillo	A	F	62	No	Gravid

29			A	F	66	No	
30	16/03/09	½ trail Momótides	A	F	66	No	Gravid/teats
31			A	F	64	No	Gravid/teats
32	18/03/09	½ trail Momótides	A	M	67	Yes	
33			A	F	63	No	Gravid/teats
34	19/03/09	El Castillo	A	F	62	No	Gravid
35	20/03/09	¾ trail Momótides	A	F	63	Yes	Gravid
36		¼ trail Momótides	A	M	63	No	
37			A	F	62	No	Gravid/teats
38			A	F	62	No	Gravid/teats

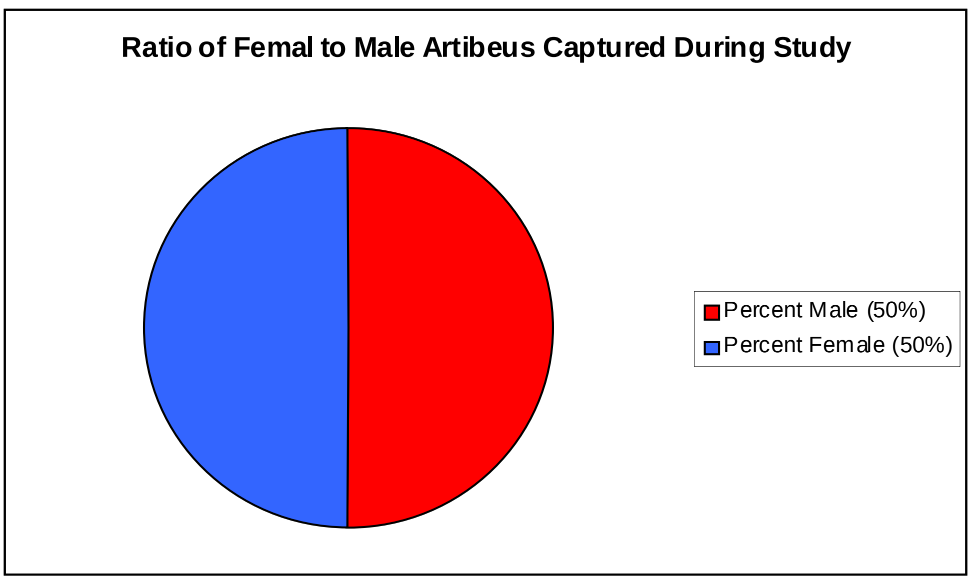


Figure 15: Sex ratio of *Artibeus jamaicensis* bats collected during the study

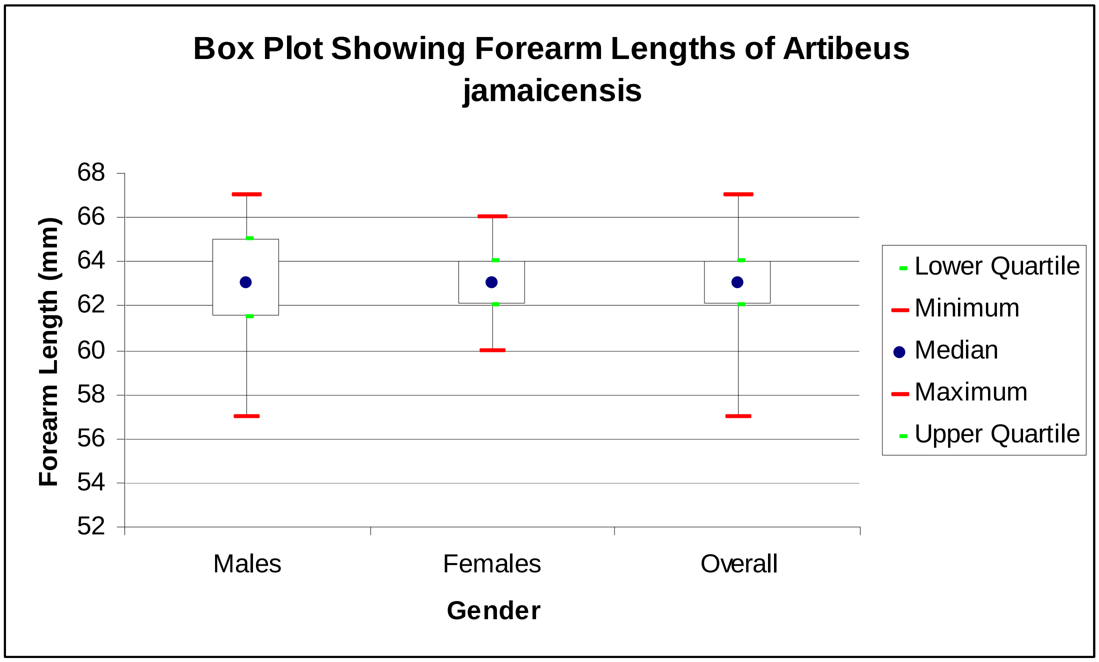


Figure 16: Box Plot showing the forearm length of *Atibeus jamaicensis* bats collected by gender

Habitat survey

Bats were sampled with the same sampling effort at the six sites established. The vegetation, abundance and diversity of bats species caught are summarized in Table 3. The results of the habitat surveys, shown in Table 4, indicate that the most noticeable difference between the six sites was the percent cover, that is, the percent of overhead canopy cover created by site-specific vegetation. The elevation varied to a maximum difference of 22m, with the highest elevation recorded at site 4 and the lowest at site 6 (Table 4). At one third of the sites there was dry tropical forest present, and this seems to partly correlate with the soil classification, with site 6 being a localized humid area due to the presence of the artificial pond (Table 4). The height of trees adjacent to the areas where the nets were placed ranged from a minimum of 14.8m at site to a maximum of 35.9m at site. Possible roosting locations identified included trees in all areas, palm trees and hollow trees in a few and the large artificial habitat created by the Castillo building itself (Table 4).

Table 3: Vegetation observations and bat captures according to location of capture

Site	Vegetation (Common Name)	Vegetation (Scientific Name)	Bats at Site	Number of Individuals
1 Castillo	Madroño	*Calycophyllum candidissimum*	*Carollia perspicillata*	6
	Sigua	*Nectandra lineata*	*Carollia castanea*	1
	Espavé	*Anacardium excelsum*	*Artibeus jamaicensis*	3
	Jobo	*Spondias mombin*	*Glossophaga soricina*	2
	Guácimo negrito	*Guazuma ulmifolia*		
	Guácimo colorado	*Luehea seemannii*		
	Indio desnudo	*Bursera simaruba*		
	Guarumo	*Cecropia peltata*		
	Jagua	*Genipa americana*		
	Cedro cebolla	*Cedrela odorata*		
	Pacito	*Muntingia calabura*		
	Frijolillo	*Albizia adinocephala*		
	Mongo	*Crateva tapia*		
	Chirimoya	*Annona spraguei*		
Site 2 Momótides 1/4 trail	Corotú	*Enterolobium cyclocarpum*	*Artibeus jamaicensis*	12
	Algarroba	*Hymenaea courbaril*	*Artibeus lituratus*	2
	Sigua blanco	*Cinnamomum triplinerve*		
	Harino de rio	*Andira inermis*		
	Zorro	*Astronium graveolens*		
	Candelo	*Pittoniotis trichantha*		
	Guasimo negrito	*Guazuma ulmifolia*		
	Espavé	*Anacardium excelsum*		
	Moñito rojo (flowering)	*Cojoba rufescens*		
	Siete negrito	*Lantana camara*		
	Higuerón	*Ficus insipida*		
	Bamboo	*Bambusa sp.*		
	Canotillo	*Piper reticulatum*		
	Mata palo	*Ficus obtusifolia*		
	Palma bejuco	Palma bejuco		
	Jobo (flowering)	*Spondias mombin*		
	Laurel	*Cordia alliodora*		
	Guasimo colorado	*Luehea seemannii*		
Site 3 Open Area	Ficus bejamina (Matapalo)	*Ficus benjamina*	*Myotis nigricans*	1
	Hinojo	*Piper reticulatum*	*Artibeus jamaicensis*	4
	Jobo	*Spondias mombin*		
	Siete negrito	*Lantana camara*		
	Guasimo colorado	*Luehea seemannii*		
	Moñito rojo	*Cojoba rufescens*		
	Zorro	*Astronium graveolens*		
	Balso	*Ochroma pyramidale*		
	Madroño/Alazano	*Calycophyllum candidissimum*		

	Indio desnudo	*Bursera simaruba*		
	Uvero de playa	*Coccoloba uvifera*		
	Bamboo	*Bambusa sp.*		
	Espavé	*Anacardium excelsum*		
Site 4 Momótides 3/4 trail	Algarroba	*Hymenaea courbaril*	*Artibeus jamaicensis*	15
	Guarumo de pava	*Schefflera morototoni*	*Artibeus phaeotis*	1
	Jobo (flowering)	*Spondias mombin*	*Saccopteryx leptura*	1
	Harino de rio	*Andira inermis*	*Carollia perspicillata*	1
	Guasimo colorado	*Luehea seemannii*		
	Siete negrito	*Lantana camara*		
	Espavé dominant	*Anacardium excelsum*		
	Moñito rojo (flowering)	*Cojoba rufescens*		
	Malagueto hembra	*Xylopia aromatica*		
	Zorro	*Astronium graveolens*		
	Hinojo	*Piper reticulatum*		
	Clavito	*Margaritaria nobilis*		
	Bamboo Carricillo	*Chusquea simpliciflora*		
	Camaroncillo	*Hirtella racemosa*		
Site 5 Momótides 1/2 trail	Higuerón	*Ficus insipida*	*Artibeus jamaicensis*	4
	Alazano	*Tachigali versicolor*	*Artibeus lituratus*	2
	Jobo	*Spondias mombin*	*Myotis nigricans*	2
	Harino de rio	*Andira inermis*	*Carollia castanea*	1
	Palma real	*Roynstonea regia*		
	Guarumo de pava	*Schefflera morototoni*		
	Maquenqué	*Oenocarpus mapora*		
	Espavé	*Anacardium excelsum*		
	Moñito rojo (flowering)	*Cojoba rufescens*		
	Huevo de gato	*Stemmadenia grandiflora*		
	Sigua blanco	*Cinnamomum triplinerve*		
	Hinojo	*Piper reticulatum*		
	Clavito (flowering)	*Margaritaria nobilis*		
	Guasimo colorado	*Luehea seemannii*		
	Cafeto	*Bunchosia nitida*		
Site 6 Pond/Laguito	Indio desnudo	*Bursera simaruba*	*Artibeus intermedius*	1
	Ficus benjamina (Matapalo)	*Ficus benjamina*	*Artibeus lituratus*	1
	Guarumo	*Cecropia peltata*	*Uroderma bilobatum*	1
	Pana canalera	*pennisetum purpureum*	*Myotis albescens*	1

	Mimosoideae		*Platyrrhinus helleri*	1
	Roble	*Tabebuia rosea*	Myotis riparius	1
	Cocobolo	*Dalbergia retusa*		
	Guarumo de pava	*Schefflera morototoni*		
	Camaroncillo	*Hirtella racemosa*		
	Vara santa	*Triplaris cumingiana*		
	Sigua	*Nectandra lineata*		
	Caoba	*Swietenia macrophylla*		
	Cortezo	*Apeiba tibourbou*		
	Espavé	*Anacardium excelsum*		
	Poro-Poro	*Cochlospermum vitifolium*		
	Machetito	*Erythrina rubrinervia*		
	Tronador	*Hura crepitans*		
	Arbol de Panama	*Sterculia apetala*		

Table 4: Capture site characteristics

Site	Dates of Netting	Av. Height of Trees	% Cover	Type of Forest	Elevation	Roosts	Soil Type
Castillo	22/01/2009 12/3/2009 19/03/2009	14.81m	5%	Bosque seco- Dry tropical forest	49m	abandoned building, trees	Arable muy severas limitaciones en la seleccion de las plantas o requiere un manejo muy cuidadoso
Momótides (1/4)	29/01/2009 12/2/2009 20/03/2009	22.39m	40-50%	Bosque humido- Tropical forest	44m	trees	No arable con limitaciones severas, con cualidades para pastos, bosques y tierras de reserva
Momótides (1/2)	16/03/2009 18-03-2009	20.59m	60%	Bosque humido- Tropical forest	54m	trees	No arable con limitaciones severas, con cualidades para pastos, bosques y tierras de reserva
Momótides (3/4)	5/3/2009 20/03/2009	35.94m	80%	Bosque humido- Tropical forest	56m	trees, palm trees, hollow trees	No arable con limitaciones severas, con cualidades para pastos, bosques y tierras de reserva
Open Area	19/02/2009	27.78m	40%	Bosque	38m	trees, palm	Combinacion de los dos tipos

	5/3/2009			seco- Tropical dry forest		trees, hollow trees	
Laguito	3/17/2009 3/19/2009	19.47	5%	Bosque humido- Tropical humid	34m	trees, palm trees, hollow trees	Arable muy severas limitaciones en la seleccion de las plantas o requiere un manejo muy cuidadoso

Diversity indices

Alpha diversity is lowest at site 2, 4, and 3 respectively where the Simpson index resulted in values closer to one, which implies dominance of one species at these sites (Table 5). Table 3 shows that at these sites *Artibeus jamaicensis* is the most abundant species. In contrast, site 6 shows infinite diversity with its value of zero (Table 5). Table 3 shows that five out of the six species caught at this site were singletons. The Shannon-Weiner index support these observations by computing higher values for site 6, 5, and 1 respectively which imply a stronger evenness in the species richness at these sites (Table 5). The number of each species found is about the same for these sites as noted in Table 3. The results of the Jaccard index of similarity indicate the beta-diversity between sites. For three different pair of sites, (1&6, 3&6 and 4&6) species composition was entirely different (Table 6). The Jaccard index further suggest that the highest level of similarity in terms of species composition is shared between site 2&5 and 3&5, where 33% of the species are common (Table 6). This generally low set of indices suggests high beta diversity among sites.

Table 5: Indices of alpha diversity calculated for each of the six samples. A value of zero for the Simpson's index indicates infinite diversity and a value of one shows no diversity at the site sampled. A high Shannon-Weiner value indicates species are equally represented in the population.

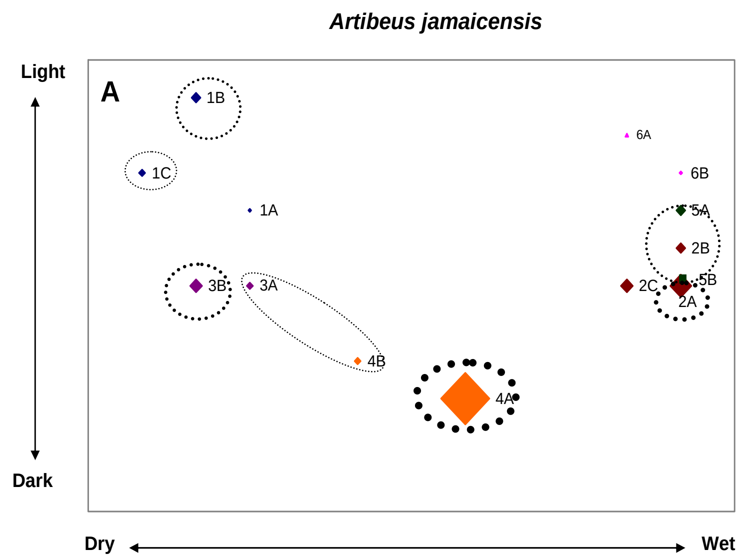
Alpha diversity		
Sites	Simpson Dominance index	Shannon Weiner Evenness Index
Castillo (1)	0.288	1.198
Momótides (2)	0.736	0.410
Opened area (3)	0.600	0.500
Momótides (4)	0.614	0.652
Momótides (5)	0.222	1.273
Laguito (6)	0.000	1.792

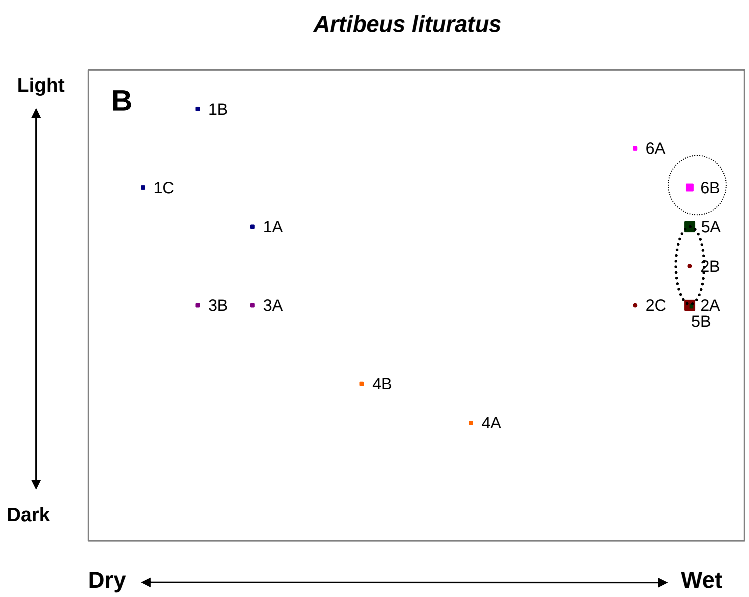
Table 6: Results of the Jaccard index where higher values indicate more similarity in the species composition of the two sites tested.

Beta diversity	
Sites	Jaccard
1 & 2	0.167
1 & 3	0.167
1 & 4	0.250
1 & 5	0.250
1 & 6	0.000
2 & 3	0.250
2 & 4	0.167
2 & 5	0.333
2 & 6	0.125
3 & 4	0.167
3 & 5	0.333
3 & 6	0.000
4 & 5	0.125
4 & 6	0.000
5 & 6	0.100

Ordination

The most commonly found species that had at least 3 individuals, and were found in at least three sites were used in the ordination to find the environmental gradients that affected the most their abundance and distribution. The two most important environmental gradients differentiating each site sampled were considered as axes and superimposed onto the abundance of the dominant species plotted. Light penetration was chosen for the y-axis. Three aspects were considered to establish the gradient: percent coverage, moon phase and cloud cover during each sampling. On the x-axis, the forest type in terms of humidity was calculated. In the case that sites had the same forest type, the percent humidity for each collection date was taken into account (for more details see Appendix VII). Figure 17 illustrates the impact of these environmental gradients on the most common species, *Artibeus jamaicensis*. A few clusters appear but do not seem associated with any particular section of any of these two gradients. In comparison, *Artibeus lituratus* is predominantly found in wetter areas, humid neotropical forest, and where light penetration varies between partial coverage and almost open area (Figure 17B). In the last figure, (17C), *Carollia perspicillata* clusters in more open areas with dryer conditions. This condition is predominant at site 1, the only artificial site studied.





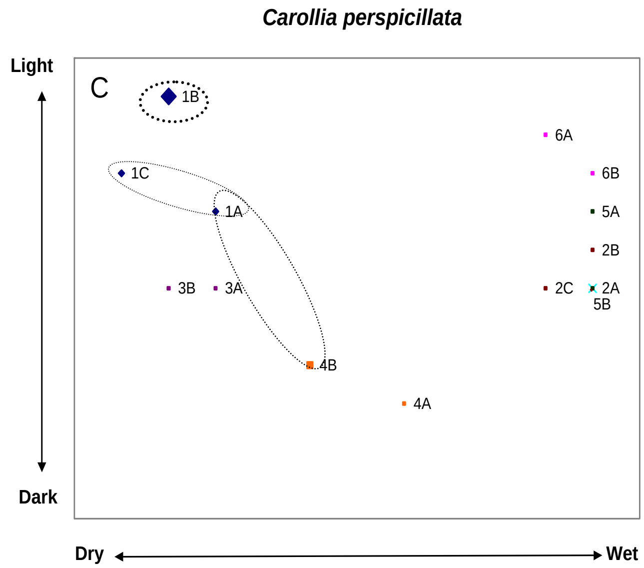


Figure 17: Ordination for the three most abundant species and their respective distribution according to light and humidity gradient. Sites are identified by their assigned number, the letters are used to represent different sampling times of each site and the size of the markers is proportional to the abundance. Contour lines are drawn to show the areas in which the species were found.

Discussion

For a natural park like the Metropolitan Park, questions relating to the abundance and diversity of their species are very important. Managers must know what is there and at what frequency in order to devise strong and efficient management plans. Since bats are the second largest of the mammalian orders, and have somewhat of a bad public image, their study creates more knowledge surrounding this group of animals and perhaps ultimately more acceptance.

Rarity and Commonness of species

Past studies (Viquez & Denvers 2006; Samudio *et al. unpublished data*) sampled a total of 26 different species of which this study found 12. *Myotis albescens*, a species present in Panamá, yet so far unknown to inhabit the park was been found at site 6. Our analysis further discovered most species are rather rare, seven species being singletons, (Figure 14) and only one, *Artibeus jamaicensis*, is very abundant. Rabinowitz (1981) identified three criteria of rarity based on the local population size, the geographic range and the level of specificity of a species to occupy a habitat. Common species are said to have a high population size, a large geographic range, and to occur in a broad range of habitats. In the case of *A. jamaicensis*, the Simpson's index of dominance was highest where this species was most abundant, suggesting that it is dominant. The fact that it was present at all sites but site 6, also supports the idea that this species is common. Supporting this finding, during a one year study on Barro Colorado Island, Panamá, the most common species captured by far was *A. jamaicensis* (Gardner *et al.* 1991).

Indeed, most studies have found that most species are rare in a population (Rabinowitz 1981), as seen in our study. However, the observations of singletons in our research may be attributed to low sampling effort. Though, Figure18 shows a positive correlation, only 39% of the variation in abundance is explained by the sampling effort. This does not suggest higher abundance of species necessarily occurs as more time is spent sampling one particular site. Results from the species accumulation curve (Figure19) nonetheless indicate that the amount of sampling was not enough to recover all species present at the park because the curve has not flattened out (Roberts-Pichette & Gillespie 2001). It is therefore likely that the sampling size was not large enough to encompass more individuals of the more uncommon species.

The analysis of beta-diversity by the Jaccard index shows species composition is different between the Castillo and Laguito sites, the Open area and Laguito sites, and the Momótides ¾ trail and Laguito sites. When contrasting these low indices with the ordination graph (Figure 17) these sites are distributed in different areas, and therefore have different environmental conditions. Given light and humidity differs greatly among these sites, this could explain why

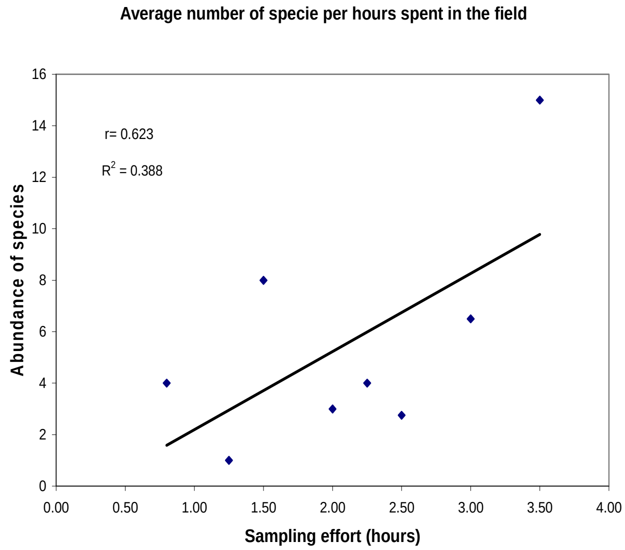


Figure 18: Average number of species found per time spent in the field

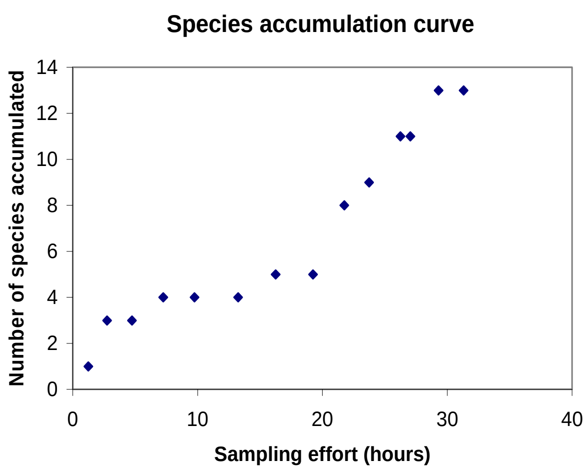


Figure 19: Species accumulation curve shows the efficiency of the sampling methods. The breaking point, where the curve asymptotes is usually used to determine the effective number of sampling sites (or effort) required to recover a representative portion of species richness in an area. Here, data suggest it has not yet reached this point.

entirely different species are found at each pair of sites. Since there are many singletons, however, it is more difficult to draw conclusions from the results obtained. More sampling effort at each site could provide clearer patterns in species richness and composition.

The park is located in the transition zone between the tropical dry and humid forests, therefore some trees experience seasonality and lose their leaves during the dry season. A last factor that can explain why all of the 27 species present were not caught, aside from those mentioned in the limitation section of this work, is the temporal scale of sampling. Our project was restricted to the dry season, and sampling was undertaken from the end of January to the end of March. During the last few field outings, many trees and plants had recovered their leaves, others were flowering and more were fruiting than in the initial weeks of sampling. These conditions were different at the beginning of the sampling period where only seeds were present. Some trees like *Cecropia pelatata* flower early from January to March (Silander and Lugo 2009), others like *Anacardium excelsium* flower later from March to May (Fournier 2009) and *Piper reticulatum* can produce flowers and fruits year-round (SDPR 2009). Since different bats have diverse feeding habits and can be frugivores, nectarivores, or seed eaters, the flowering of their preferred food source will determine whether or not a species is present in an area or not.

Characteristics of A. jamaicensis

The sex ratio results shown in Figure 15 can be considered atypical, since one would expect based on previous studies to encounter more female than males of this species. Gardner *et al*. (1991) report that in a sample of almost 17,000 records of *A. jamaicensis,* both adult and subadult females outnumbered adult and subadult males 55:45, though juvenile females were outnumbered by juvenile males. These data are supported by Pino and Winford (2006) who found that for both habitats in their study, the total sex ratio was 274:209 females to males. The data discrepancy may be a result of the relatively small sampling size of this study, as it is not likely that the ratio reported here is representative of the population of *A. jamaicensis* in the park.

The difference of forearm lengths between male and female specimens in our study are semi-consistent with other works produced on this species, though the objective ‘truth’ of the matter may be impossible to determine without further comprehensive studies on this species. One study by Pino and Winford (2006) found that there were no significant differences between the forearm lengths of female and male *A. jamaicensis*, although supporting our findings the male specimens showed the highest and lowest forearms lengths of the overall range of both sexes. However, scientists working on Barro Colorado Island found that at one site that forearm lengths in females were larger (though not significantly so) than males, but at a different colony site there was less of a difference in the forearm lengths of adult males and females (Handley *et al*. 1991). This suggests that the small differences observed in forearm lengths by gender may vary with the area being studied, and therefore may not be solely and artifact of sampling in our study.

Site Vegetation and the presence of bat species

One would expect that bats would most commonly be captured in areas where they are feeding during mist netting efforts, since they require a large amount of food each night to maintain themselves (Allen 1996), although it is also possible that they simply use the park's trail system as a convenient open airway; some bats are known to fly great distances to get food, or even traveling to resting sites on tree species completely unrelated to their diet (Kunz & Kurta

1988). The data presented here suggests that during the capture period of this study, all of these reasons may be applicable.

Supporting the hypothesis that bats will tend to be generally present where there are available food sources is the case of the *Uroderma billobatum* specimen that was captured at site 6 (Table 3). These bats are primarily frugivorous but may also feed on pollen, nectar and insects. It has been shown by analyzing the stomach contents of 320 bats that 76% of their diet is plant material (Baker and Clark 1987). This species is known to consume the fruits of at least three species of *Ficus* (Baker and Clark 1987), and multiple actively fruiting *Ficus benjamina* were recorded at the pond site where this species was captured (Table 3), thus explaining its presence. It is interesting that no *Uroderma billobatum* were captured at the Open Area site (site 3), which also featured many *Ficus* trees and a similar habitat of open space and canopy coverage (Tables 3, 4).

Similarly, *Platyrrhinus helleri*, a known fig specialist (Ferrell and Wilson 1991), was present at the Laguito site (site 6) where *Ficus* were also present (Table 3, 4). One study which analyzed the stomach contents of six specimens revealed 67% of the material was *Ficus*, with the most important species being *Ficus insipida* (Ferrell and Wilson 1991). Knowing this, one would have perhaps expected to capture this species at the Momótides ½ trail site (site 5) where *Ficus insipida* is present (Table 3). It is important to note, however, that this species is a canopy and sub-canopy forager (Ferrell and Wilson 1991), and the Laguito site may have been the only area sufficiently open to capture these bats using a ground-level mist net.

All of the seven *Carollia perspicillata* netted during our study were present in the same locations as their food sources. These bats were found at both the Castillo (six bats) and the ¾ Momótides trail sites (one bat)(Table 3). The Castillo site included two known secondary food sources, *Cecropia* and *Anacardium excelsum* (Cloutier and Thomas 1992)(Table 3). At the ¾ trail Momótides site, where only one bat was captured, three possible sources of food were observed. Cloutier and Thomas (1992) report that the genera *Piper*, found at this site, forms the mainstay of the diet of these bats, which also includes the *Anacardium excelsum* and *Hymenaea courbaril* trees also located there (Table 3). The number of bats present at each site is therefore initially surprising, given *Piper* is a more important food source but fewer bats were present where it is found. This apparent discrepancy may be explained, however, by the bat's recorded preference for free internal spaces, and that it has been observed roosting with at least 35 other species in eight families (Cloutier and Thomas 1992). Taking into account that the Castillo net was placed outside of a known roost entrance, it is likely that the *Carollia perspicillata* captured at this location were leaving from or returning to their roost and not actively foraging. These explanations further support the cluster seen in Figure 17C and better explain the presence of *C. perspicillata* than the environmental gradients. Yet it should be noted that this species does prefer open clearings and secondary growth forest (Reid 1997), which are present near the Castillo. Given this bat is a ground story frugivore (Cloutier and Thomas 1992) it is surprising that it was not recorded at the Open Area, the ¼ or the ½ Momótides sites, since at all three of these sites *Piper* was present. It is important to note, however, that *Piper* was observed fruiting only during our last few visits, so may have been a food source the time these sites were sampled.

As would be expected from its nature as a generalist feeder (Ortega and Castro-Arellano 2001), at all of the sites where *Artibeus jamaicensis* was captured several of its possible food sources were present. This factor explains the more random distribution of the species across sites, and why it does not show strong association to the environmental gradients tested in Figure

17A. Supporting these results, a study performed in the Chagres National Park of Panama did not find significant difference in abundance between evergreen and deciduous forest in terms of the presence of *Artibeus jamaicensis* (Pino &Winford 2006). This species is primarily a frugivore and a fig specialist (Ortega and Castro-Arellano 2001); at nearby Barro Coloado Island, *Ficus* plants form approximately 78% of the annual fruit consumed by this bat (Ortega and Castro-Arellano 2001). At the Castillo site, food sources included *Anacardium excelsum, Spondias mombin, Cecropia peltata,* and *Muntingia calabura* (Ortega and Castro-Arellano 2001)(Table 3). At the Open Site *Anacardium excelsum* and *Spondias mombin* were again present, in addition to *Ficus benjamina, Piper reticulatum,* and *Coccoloba uvifera* (Ortega and Castro-Arellano 2001)(Table 3). All of the Momótides trail sites had *Spondias mombin, Piper reticulatum, Anacardium excelsum,* and *Andira inermis* as likely food sources (Ortega and Castro-Arellano 2001). *Hymenaea courbaril* was only present at the ¼ trail and ¾ trail site, *Ficus insipida* at the ¼ and ½ trail sites, and the ¼ trail site was the only site with *Ficus obtusifolia* (Ortega and Castro-Arellano 2001)(Table 3). Although *Ficus benjamina, Cecropia peltata,* and *Anacardium excelsum* were present at the Laguito site, no *Artibeus jamaicensis* bats were captured there, which may be related to their relative scarcity at the other more open capture sites including the Castillo and Open Area site (Table 3).

Artibeus literatus is another example where the location of capture matches well with the presence of likely food sources. *Artibeus literatus* has been reported to feed on *Piper* species (Reid 1997) and seeds of *Cecropia* and *Ficus* have been found in their feces (Gardner 2008). At both the ¼ and ½ trail Momótides sites where *literatus* were netted, two of these species, *Ficus insipida* and *Piper reticulatum* were present, and at the ¼ trail site *Ficus obtusifolia* was also observed (Table 3). Although there are no *Cecropia* trees at the trails locations where nets were set up, there are *Cecropia* trees in the Momótides section of forest, meaning that all three of these food sources are available in the immediate area (i.e. without having to cross the roadways isolating this section of forest). Furthermore, the limited presence of *A lituratus* at these three sites can be correlated to the environmental characteristics of these sites. In fact, this species is common in humid forests and avoids dry areas (Reid 1997), which is well represented in Figure 17B. All of the sites at which the species was found are known to have a humid neotropical climate, vegetation and soil conditions. Though Momótides ¾ site is located in humid tropical forest, it is at the limit of it and dry forest conditions lie a few meters away and hence could deter *A. literatus* from occupying the area.

For the bats of the species *Carollia castanea,* single individuals were captured at the Castillo and Momótides ½ trail site (Table 3). The pioneer plant *Piper* is its main food source (Theis *et al*. 2006) although it also feeds on *Dipteryx panamensis* in the wet season (Reid 1997). However, *Piper reticulatum* was only present at the Momótides ½ trail site, and *Dipteryx panamensis* is only planted as singleton on the other side of the park behind the administrative buildings (Table 3). Important for future research efforts is the fact that park employees are actively planting *Dipteryx panamensis* seedlings throughout the park, so feeding habits of these bats and others may be altered in the near future.

For the single *Artibeus phaeotis* captured at the ¾ Momótides site and both *Glossophaga soricina* at the Castillo, no likely food source vegetation were found at these sites (Table 3). *Artibeus phaeotis* has been shown to be primarily frugivorous (Timm 1985) with a diet including *Ficus, Cecropia,* and *Spondias* spp. (Reid 1997) which are located relatively close to the capture site (Table 3). None of the plants that *Glossophaga soricina* feeds on, including bananas, *Muntingia, Acnistes*, flowers of bombacaeous and leguminous trees such as *Ceiba, Igna* and

Hymenaea (Reid 1997) were observed in neighboring sites, although *Hymenaea courbaril* is found in the Momótides forest patch (Table 3). The capture of two of these bats at the Castillo may be explained by the observation that about 30 species of bats roost in association with *G. soricina* and in many cases is reported to roost with *Carollia perspicillata* (Alvarez et al. 1991). Even though its preferred food sources were not found at the site, this bat could have been captured once it was done feeding and was returning to its roost.

Additional Information

The Open Area site is an excellent area for viewing bats, especially for the park's educational programs. One can observe bats flying at this location as early as 5pm, with peak hours between 5:30 and 6:30pm, which allows for easy viewing opportunities being that there is still enough natural light to see by. As well, the bats observed during this time period at this location were small, likely *Myotis* spp. and thus are not visually threatening for those children or adults who may have a fear of bats.

Additionally, although we did not ultimately perform a habitat survey in the park, we did happen upon one specific habitat for bats within the park. The first was directly beside the ¾ Momotides trail in the wet-dry transition area, and consisted of a semi-furled banana-like plant leaf in which three small dark-coloured bats were roosting. When disturbed during daylight hours by accident, these bats fled the site but there was a great deal of feces present in this site, indicating that it may have been a site used for many nights. Having seen this type of roost, we then proceeded to examine similar semi-furled leaves in the Jardin Bonsia area beside the Laguito and disturbed a group of three bats which were roosting approximately 3ft down inside a larger semi-furled leaf. When we continued to examine leaves nearby, we again disturbed this group of bats and they returned to their previous site in the same leaf. This shows a preference for an establish roost site, and the fact that we found two very different looking bats in each site, when the only difference in the roost was the size, is interesting in itself. The bats in this second group were larger, and though identification was impossible it was observed that their stomach hair was significantly lighter than their dorsal fur.

Finally, it is important to note the cycle of the bambusa vines on the Momotides trail forest in particular. It was explained to us by a park employee, Sixto Maquizama, that this plant has a five year cycle, and this year happened to be the peak year where the vines are at their largest and the forest appears very enclosed. Next year, these plants will be present only as seedlings and the forest will become significantly more open. This may have important implications for our project data, being that it was recorded in a year where the forest understory was at its most dense, and for future data since different bats seem to show a marked preference for different habitat types.

Conclusion

This study has illustrated that by far the most common species recorded in the park was *Artibeus jamaicensis*, with 38 out of a total of 65 individuals captures. This can be attributed to both their broad range of available foods at capture sites, their generalist nature, as well as their lack of preference for a particular habitat type. It has been illustrated that there are many 'rare' species recorded as singletons in the park, with the only common species being *A. jamaicensis*. Although this study represented a relatively small sample of bats, the data collected on the forearm lengths supports previous studies and contributes data to an existing debate on which sex is both larger and has the widest range of forearm lengths. The habitats chosen as capture sites were in fact distinct enough to capture 13 out of 26 previously recorded species in the park, including one species previously unrecorded there, *Mytois albascens*. In order to improve the park's capacity for bat population management, further studies are recommended. Future studies would ideally include an identification and classification of roost sites, likely requiring the use of ultrasonic equipment that was not available for this study. To obtain a reliable account of true population abundance, telemetry would be a recommended technique for future research, although the risks of bat mortality and morbidity it entails should always be considered, as the park exists to protect these animals. It would make an interesting comparison some years in the future if a population inventory was performed which included the other trails, Cienaguita and Los Caobos, especially considering that the park is actively planting *Dipteyx panamensis* which is an import food source for many fruit eating bats recorded in the park. The type of study detailed in this report, as well as scaled-up versions of it, are of vital importance for conservationists in the face of both global climate change and encroaching local urbanization; if one does not know what there is, one cannot know what there has been lost. It is the hope of the authors that the bat education pamphlet created for the host institution will be successful in improving the bat's public image in the eyes of park visitors and student groups, and may lead new minds to become more interested in conservation and the natural world around them.

Acknowledgements

We would like to offer our sincere gratitude to all of the people at our host institution that helped us every step of the way. The first of these people is Licenciada Dionora Víquez - Directora General, who is responsible for allowing us to do a project in the parque, and who always had a few words or encouragement to give us whenever we met. We would also like to thank our wonderful supervisor, Licenciada Amelia Muñoz Harris, who is the Jefa de

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We could not have done this project without the help of Licenciado Jorge Castillo of SOMASPA, who taught us almost everything we know about how to chose mist netting sites, how to place a mist net, and how to extract, safely handle, and identify bats. The help of our professors Rafael Samudio and Roberto Ibáñez was invaluable as well, both in the initial period of communication and in getting our rabies vaccinations and in the final frantic days of this course. Our teaching assistant, Kecia Kerr was a great help with everything organizational and was always on top of things and willing to answer our many detailed questions about formats and requirements. Finally, we would like to thank the nurses at the Region Metropolitana de Salud,

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Appendix I. Plant species observed at capture sites

Table 6: Common and Scientific names of observed vegetation

Nombre Comun	**Nombre Cientifico**
Alazano	*Tachigali versicolor*
Algarroba	*Hymenaea courbaril*
Arbol de Panama	*Sterculia apetala*
Balso	*Ochroma pyramidale*
Bamboo	*Bambusa sp.*
Bamboo Carricillo	*Chusquea simpliciflora*
Cafeto	*Bunchosia nitida*
Camaroncillo	*Hirtella racemosa*
Candelo	*Pittoniotis trichantha*
Canelo	*Annona hayesii*
Canotillo	*Piper reticulatum*
Caoba	*Swietenia macrophylla*
Cedro cebolla	*Cedrela odorata*
Chirimoya	*Annona spraguei*
Clavito	*Margaritaria nobilis*
Cocobolo	*Dalbergia retusa*
Corotú	*Enterolobium cyclocarpum*
Cortezo	*Apeiba tibourbou*
Espavé	*Anacardium excelsum*
Frijolillo	*Albizia adinocephala*
Guácimo colorado	*Luehea seemannii*
Guácimo negrito	*Guazuma ulmifolia*
Guarumo	*Cecropia peltata*
Guarumo de pava o mangavé	*Schefflera morototoni*
Harino de rio	*Andira inermis*
Higuerón	*Ficus insipida*
Hinojo	*Piper reticulatum*
Huevo de gato	*Stemmadenia grandiflora*
Indio desnudo	*Bursera simaruba*
Jagua	*Genipa americana*
Jobo	*Spondias mombin*
Laurel	*Cordia alliodora*
Machetito	*Erythrina rubrinervia*
Madroño/Alazano	*Calycophyllum candidissimum*
Malagueto hembra	*Xylopia aromatica*
Mamon	*Melicoccus bijugatus*
Matapalo	*Ficus benjamina*
Mata palo	*Ficus obtusifolia*
Maquenqué	*Oenocarpus mapora*
Mongo	*Crateva tapia*
Moñito rojo	*Cojoba rufescens*
Pacito	*Muntingia calabura*
Palma bejuco	*Desmoncus orthoacantus*
Palma real	*Roynstonea regia*
Pana canalera (Elephant grass)	*pennisetum purpureum*
Poma Roza	*Syzygium jambos*
Poro-poro	*Cochlospermum vitifolium*
Roble	*Tabebuia rosea*
Siete negrito	*Lantana camara*
Sigua	*Nectandra lineata*
Sigua Blanco	*Cinnamomum triplinerve*
Tronador	*Hura crepitans*
Uvero de playa	*Coccoloba uvifera*
Vara santa	*Triplaris cumingiana*
Zorro	*Astronium graveolens*

Appendix II. GIS Data

Table 7: UTM locations within Parque Natural Metropolitano, datum used during collection unknown

Easting	Northing	Description	Trail
659752	993328	Sede Administrativa de PNM	
659720	993396	Edificio de Educacion Ambiental	
659751	993396	Edificio de Rescate y Rehabilitacion de Fauna Silvestre	
659933	993677	Vivero Bonsai Concesionario (Via Juan Pablo II)	
660090	994167	El Castillo	
660160	994366	La Grua	
659842	993490	Transformador de Alto Voltaje (929)	
659916	993597	Bunker (Via Juan Pablo II)	
660112	994335	Letrero a la entrada hacia la Grua	Camino Mono Titi
660030	994342	Letrero La Tierra es nuestra casa	Camino Mono Titi
659942	994443	Mirador Los Trinos	Camino Mono Titi
659732	994457	Siguiente curva en el Camino del Mono Titi despues del Area para Acampar	Camino Mono Titi
659437	994500	Mirador Cerro Cedro (Punta mas alto del PNM, 150msnm)	Camino Mono Titi
660009	994043	Entrada Sendero La Cieneguita (Detras de la Garita del Gaurdaparque)	Sendero La Cieneguita
659928	993916	Matamba (antes de los primeros escalones a mano izquierda)	Sendero La Cieneguita
659776	993968	Estacion N 6 (monumento de hierro marcado con el #6)	Sendero La Cieneguita
659608	994125	Cuipo (estacion 10)	Sendero La Cieneguita
659412	994286	Barrigon	Sendero La Cieneguita
659478	994355	Espave	Sendero La Cieneguita
659535	994402	Salida del Sendero la Cieneguita (conexion con el Camino Mono Titi)	Sendero La Cieneguita
659762	993327	Entrada del Sendero Los Momotides (frente a la Sede Administrativa del PNM)	Los Momotides
659785	993196	Cachito (tomando la desviacion hacia la derecha a la entrada del sendero)	Los Momotides
659854	993068	Corotu	Los Momotides
659919	993046	Parte Alta del Sendero Los Momotides	Los Momotides
		(Sitio en donde se presumia estaban ubicadas cierto tipo de barracas)	
659885	993165	Espave	Los Momotides
659819	993290	Matillo (Proximo al punto de inicio)	Los Momotides
659745	993470	Entrada del Sendero El Roble (a un costado del Edifcio de PRRFS)	Sendero El Roble
659811	993551	Cauce de agua (ubicado antes de llegar a La Lagunita)	Sendero El Roble
659830	993617	La Lagunita	Sendero El Roble
659903	993721	Conexion entre el Sendero El Roble y el Sendero Los Caobos	Sendero El Roble
659950	993865	Barrigon	Sendero El Roble
660014	994030	Salida del Sendero El Roble (a un costado de la Garita del Guardabosque)	Sendero El Roble
659651	993417	Entrada del Sendero Los Caobos (a un costado de la Sede Administrativa)	Sendero Los Caobos
659624	993452	Estacion N 2	Sendero Los Caobos
659617	993532	Estacion N 4	Sendero Los Caobos
659639	993593	Estacion N 5	Sendero Los Caobos
659665	993701	Estacion N 8 – Rancho	Sendero Los Caobos

659695	993719	Quiebre (esquina anterior a la estacion 9)	Sendero Los Caobos
659744	993766	Estacion N 9	Sendero Los Caobos
659758	993816	Estacion N 11	Sendero Los Caobos
659774	993836	Estacion N 12	Sendero Los Caobos
659821	993802	Estacion N 13	Sendero Los Caobos
659870	993769	Queibre en la escalera (conexion con el Sendero El Roble)	Sendero Los Caobos
659882	993736	Estructura 934 y Letrero	Sendero Los Caobos
659900	993736	Salida del Sendero Los Caobos (conexion con el Sendero El Roble)	Sendero Los Caobos
660070	994187	Bomba de Agua – Frente al Castillo	
659903	994670	Tanque de Reserva para los abrevaderos	Camino Mono Titi
659916	994554	Area para Acampar	
660030	994505	Cerro 66 – Monumento 66	
660040	994500	Trichera Antiaerea (ubicadas en el Cerro 66)	
660047	994505	Trichera Antiaerea (ubicadas en el Cerro 66)	

Table 8: Site coordinate data used to create Google Earth file with UTM added

Latitude	Longitude	UTM 17 P		Name	Description	Icon
08°58'59.3”N	79°32'45.2”W	659851	993306	¼ Site Momotides	12 ft accuracy	91
08°58'56.6”N	79°32'42.4”W	659938	993223	½ Site Momotides	8.8 ft accuracy	91
08°59'01.8”N	79°32'43.8”W	659895	993383	¾ Site Momotides	10 ft accuracy	91
08°59'7.68”N	79°32'46.0”W	659825	993534	Open Area Site	10.7 ft accuracy	91
08°59'15.3”N	79°32'44.8”W	659862	993797	Lagito Site	8.6 ft accuracy	91
08°59'34.9”N	79°32'37.2”W	660091	994400	El Castillo Site	10 ft accuracy	91

Appendix III. Image file maps of the park

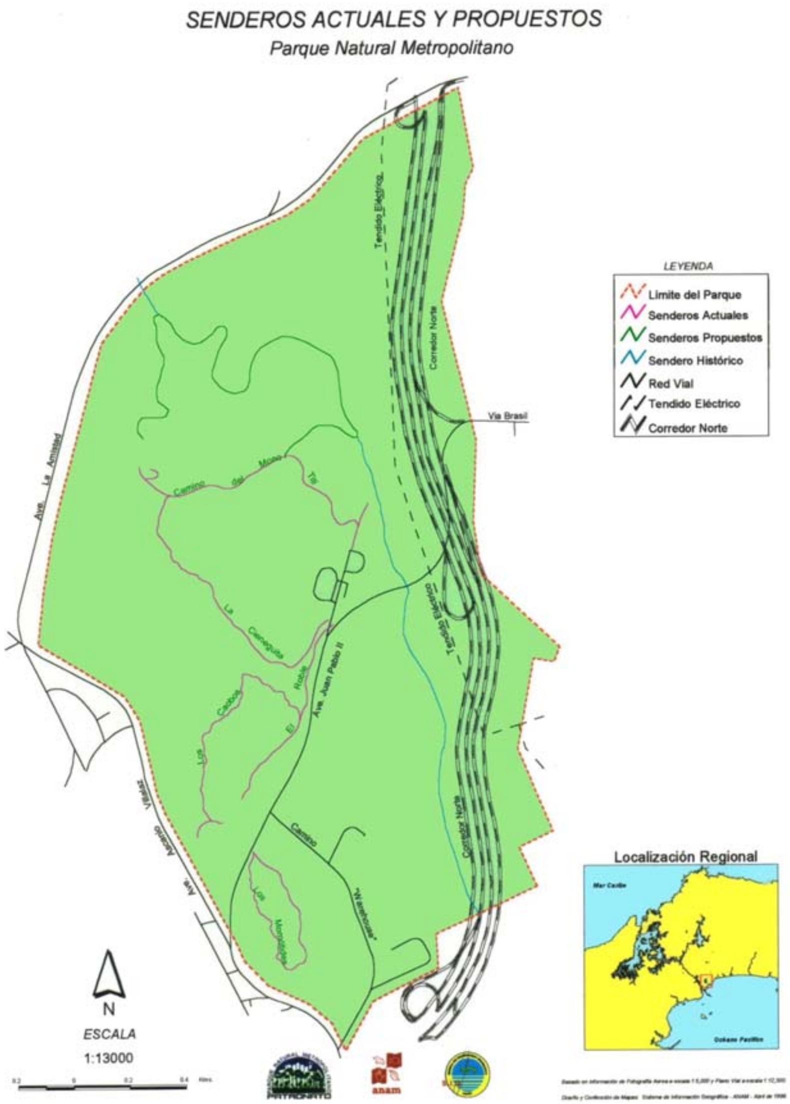

Figure 20: Map of The Parque Natural Metropolitano’s trail system

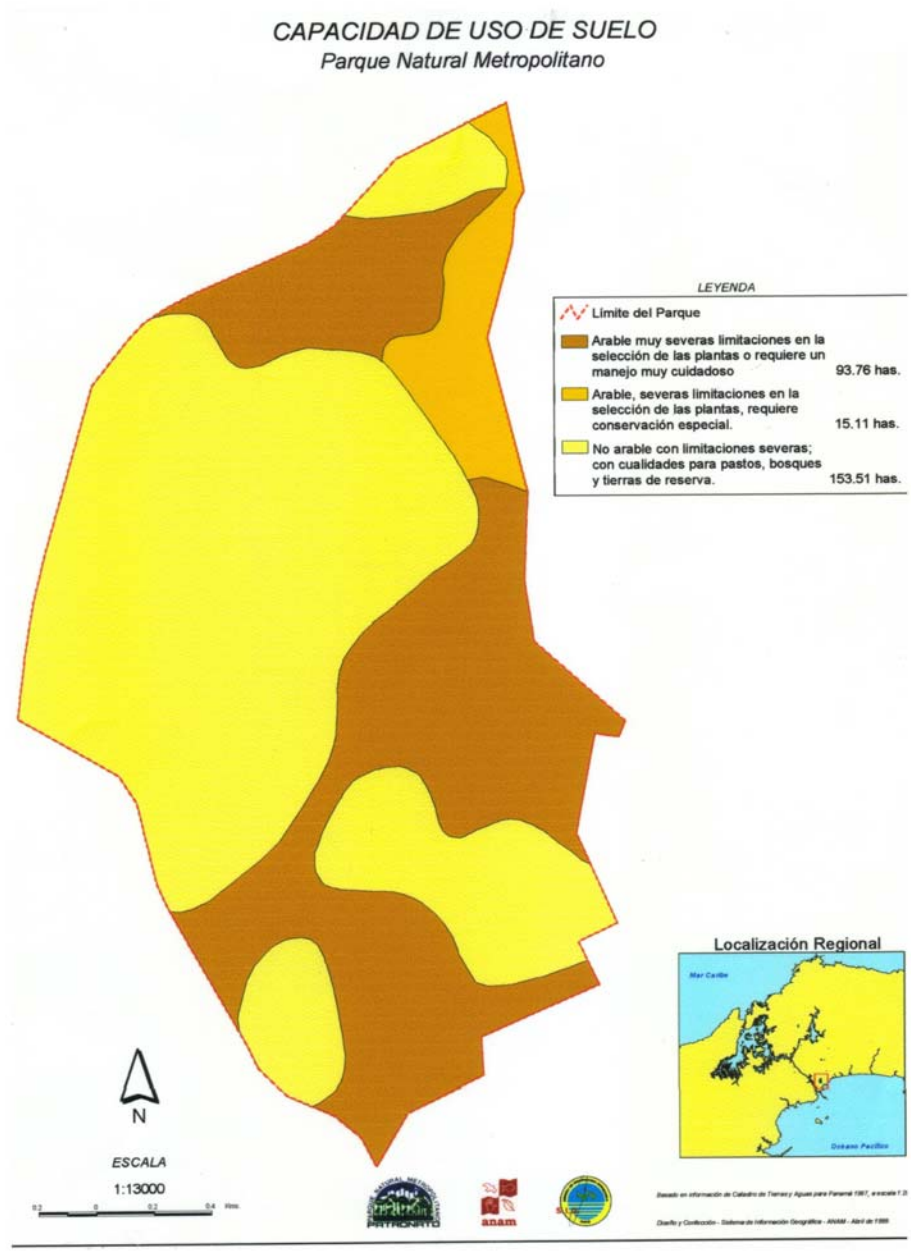

Figure 21: Map of the Parque Natural Metropolitano’s soil capacity

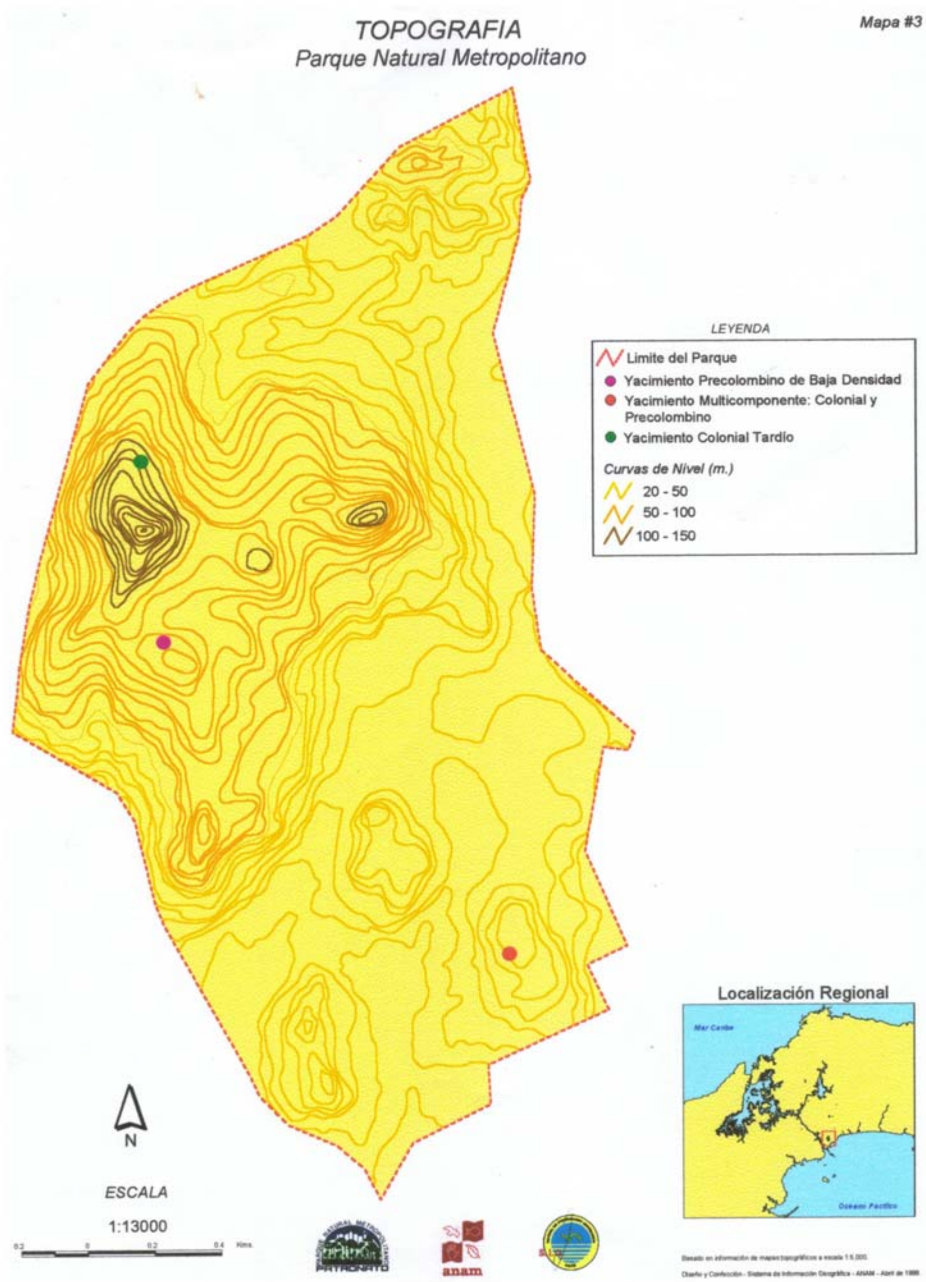

Figure 22: Map of general topography of the Parque Natural Metropolitano

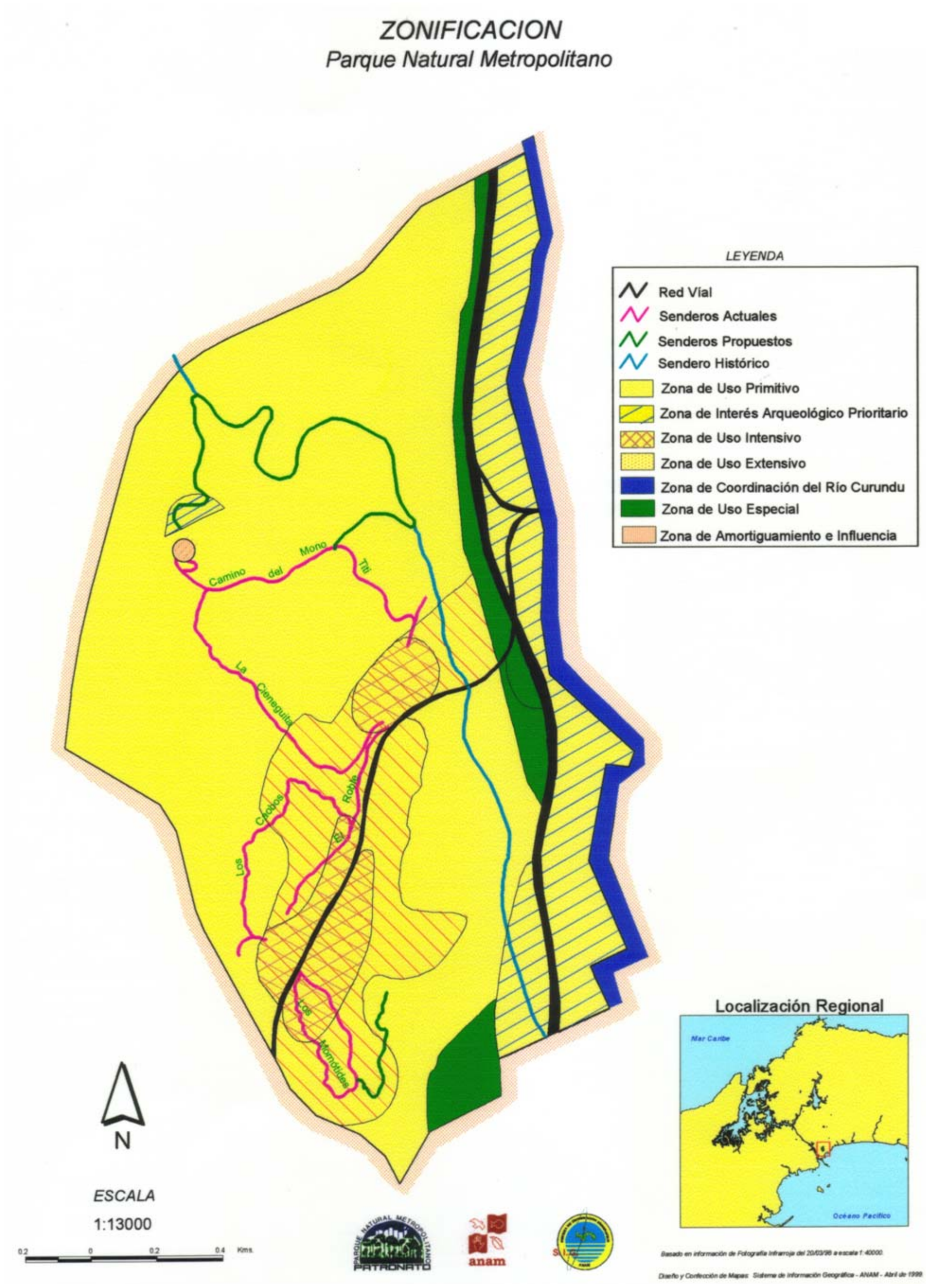

Figure 23: Map of the assigned zones of the Parque Natural Metropolitano

Appendix IV. List of bats found in the Natural Metropolitan Park in previous studies

Emballonuridae
- *Saccopteryx bilineata*
- *Saccopteryx leptura*
- *Cormura brevirostris*

Moormopidae
- *Pteronotus parnelli*

Molossidae
- *Molossus molossus*

Phyllostomidae
- *Micronycteris microtis*
- *Phyllostomus hastatus*
- *Glossophaga soricina*
- *Glossophaga commissarisi*
- *Artibeus jamaicensis*
- *Artibeus lituratus*
- *Artibeus watsoni*
- *Artibeus phaeotis*
- *Artibeus intermedius*
- *Carollia castanea*
- *Carolia perspicillata*
- *Carollia brevicauda*
- *Platyrrhinus helleri*
- *Vampyressa pusilla*
- *Vampyressa nymphae*
- *Chiroderma villosum*
- *Uroderma bilobatum*
- *Trinycteris nicefori*

Vespertilionidae
- *Myotis nigricans*
- *Myotis riparius*
- *Eptesicus furinalis*

Appendix V. Bat Identification Key used

Appendix. VI. Educational Pamphlet (Product for Host Institution)

Page 1, side 1

Bats of the Natural Metropolitan

The Natural Metropolitan Park is located in a transition zone between the tropical dry and tropical humid forests. As a part of the Biological Corridor of the east shore of Panamá, it is an important refuge for a diversity of animals, including 27 species of bats[3,4].

Heather Cray & Genevieve D'Avignon
McGill University 2009

About bats...

Bats are small, furry nighttime animals that are seen throughout the world. They represent one quarter of all mammals on earth[1] and there are over 1,100 species[2]. They are part of an animal group called Chiroptera, which is Latin for "winged hand," since they are the only mammals to have developed true flight.

Did you Know..?

Biologists have identified 114 species of bats in the Republic of Panama[3]

Evolution

Bats are very ancient creatures and were present on the planet during the early Eocene epoch between 53 million years ago to 49 million years ago[6,7]. Scientists are still puzzled by bat evolution, because no fossils have been found to show how the ancestors of bats developed wings or echolocation[8,9]. The bat was most likely a nocturnal mammal that used gliding to chase insects during the night. Over time it probably developed the ability to fly and later evolved echolocation[10]. The group Chiroptera is divided into two recognized suborders: Megachiroptera are the old world fruit bats[1], which use vision[11] and smell[12] to navigate and search for food; Microchiroptera use sound signals called echolocation to see in the dark.

Did you Know..?

When a bat emits a sound, it is reflected on the objects around it and like a submarine's sonar, the bat is able to see the location of these objects in the dark[8].

Ecology

Bats are found almost everywhere in the world, from islands to deserts[5] *and are known to have a specialized diet eating either insects, fish, fruits, nectar, pollen, flowers, birds, or other vertebrates*[14]. *Ecologists consider bats to be the most important mammal group in neotropical rainforests because they are essential to the pollination of plants and the dispersion of seeds*[15].

Did you Know..?

Of the over 1,100 species of bats in the world, only three species drink blood? And only one species will drink the blood of any mammal ... the others prefer birds[16].

Bats usually feed at night and rest during the day. Some species have specialized 'roosts' which they create themselves by cutting palm tree leaves to make a house-like structure. Most bats, however, rest at roosts ranging from hollow trees, logs, caves, crevices, bridges, tunnels, culverts, buildings[17].

Did you Know..?

There are a few species of bats in the world that actually fish for their food? Scientists believe that these amazing animals are able to detect slight ripples on the water where fish are swimming, then these bats use their long feet and claws to grab the fish out of the water[13].

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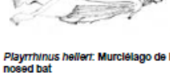
Page 1, side 2

Pteronotus parnellii: **Murciélago de Parnell- Mustached bat**

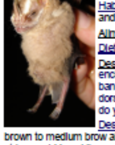
Antebrazo/ forearm: 49-65 mm
Hábitat Bosque o bosque alterado
Habitat: Forest, disturbed area
Alimentación: Insectívoro aéreo
Diet: Aerial Insectivore
Descripción: Mediano, Grisácea, cafezusco o café rojizo pelaje, ojos pequeños, labios con pliegues y surgos.

Mycronycteris microtis : **Murciélago orejitas- Common Big-eared Bat**
Antebrazo/ forearm: 31-38 mm
Hábitat: Bosque o bosque alterado
Habitat: Forest, disturbed area
Alimentación: Insectívoro de follaje; moscas
Diet: Gleaning insectivore; mainly flies
Descripción: Pequeño, café oscuro con la base de los pelos blancuzca, orejas grande y redondeadas unidas por una banda con muesca, pequeña hoja nasal.



Description: Small, dark brown hair with paler base, large rounded ears connected with a

Platyrrhinus helleri: **Murciélago de Heller- Heller's Broad-nosed bat**
Antebrazo/ forearm: 37-40 mm



Hábitat: Tierras bajas humidas, bosque primario y áreas alteradas
Habitat: Humid lowlands, primary forest and disturbed areas
Alimentación: Frugívoro, higos del dosel
Diet: Frugivore, canopy fig specialist
Descripción: Pequeño a mediano, café encima, café claro debajo, pelaje con dos bandas, rayas faciales y línea medio-dorsal, uropatagio con bordes delgado y peludo .
Description: Medium-small bat, buffy brown to medium brow above, paler below, white facial stripes, middorsal line, narrow tail membrane with furred edge.

Myotis nigricans: **Mioto negruzco- Black myotis**
Antebrazo/forearm: 31-39 mm
Hábitat: Diverso, tierras bajas hasta 3100m
Habitat: Diverse, lowland up to 3100m
Alimentación: Insectívoro aéreo Diet: Aerial Insectivore
Descripción: Muy pequeño, café oscuro a negro con puntas del pelaje un poco más pálidas.

Phyllostomus hastatus: **Murciélago punta de Lanza- Greater-spear-nosed Bat**
Antebrazo/forearm : 88-93 mm
Hábitat: Tierras bajas hasta 1000m, bosque o bosque alterado
Habitat: Lowland forest, disturbed area up to 1000m
Alimentación: Omnívoro. Insectos, invertebrados, frutas, flores, néctar y polen
Diet: Omnivorous; insects, invertebrates, fruits, flowers, nectar and pollen
Descripción: Muy grande, café oscuro a rojizo, pelaje corto, hoja nasal ancha y corta, orejas cortas y puntiagudas, verrugas en la barbilla.
Description: Very large, dark to reddish brown, short hair, nose-leaf wide and short, short pointed ears, beadlike warts on chin.

Glossophaga soricina: **Murciélago musaraña – Palla's Long-tongued bat**

Antebrazo/forearm: 32-37 mm
Hábitat: Tierras bajas, Bosque seco
Habitat: Lowland, Dry forest
Alimentación: Nectarívoro.
Diet: Nectarivore.
Descripción: Pequeño. Café pálido encima, claro por debajo, orejas y hoja nasal cortas, uropatagio y cola evidentes, con incisivos inferiores apiñados
Description: Small. Pale brown above, paler underneath, short ears and nose-leaf, tail membrane and tail evident, lower inci-

Myotis riparius: **Mioto riberino- Riparian Myotis**
Antebrazo/forearm: 31-39 mm
Hábitat: Bosque primero, tierras bajas hasta 2000m
Habitat: Primary forest, lowland up to 2000m
Alimentación: Insectívoro aéreo
Diet: Aerial Insectivore
Descripción: Muy pequeño, pelaje gris oscuro a canela. Pelaje corto y lanudo. Secundo pequeño premolar superior apiñado hacia adentro de la fila dientes.
Description: Very small, dark gray to cinnamon coloured bat. Hair short and woolly. Second small upper premolar crowded to inside of toothrow.

Epresicus furinalis: **Eptésico furioso- Argentine Brown Bat**
Antebrazo/forearm : 37-43 mm

Hábitat: Diverso, tierras bajas hasta 1000m
Habitat: Diverse, lowlands up to 1000m
Alimentación: Insectívoro aéreo
Diet: Aerial Insectivore
Descripción: Pequeño, pelaje café oscuro opaco y corto. Trago despuntado.

Glossophaga commissarisi: **Murciélago policía- Commissaris'Long-Tongued-Bat**

Antebrazo/ forearm: 32-36 mm
Hábitat: Diverso; tierras bajas hasta 3000m y tierras agrícolas
Habitat: Diverse; lowlands up to 3000m and agriculture field
Alimentación: Nectarívoro
Diet: Nectarivore
Descripción: Pequeño, gris cafezusco murciélago con hocico puntiagudo y bigotes. Orejas y hoja nasal cortas, con uropatagio y cola.
Description: Small, brownish-gray bat with pointed snout and whiskers. Short ears and nose leaf, with tail membrane and tail.

Uroderma bilobatum **- Murciélago bilobulado- Brown Tent-making bat**
Antebrazo/forearm: 39-46 mm
Hábitat: Tierras bajas
Habitat: Lowlands
Alimentación: Frugívoro
Diet: Frugivore
Descripción: Pequeño a mediano, grisáceo, rayas faciales y línea medio-dorsal, uropatagio ancho y sin orla (pelaje)
Description: Medium-small bat, grayish-brown, white facial stripes and middorsal line, wide tail membrane lacking fringe (hair)

Myotis albenscens: **Mioto blanquecino - Silver-tipped Myotis**
Igual que *M.riparius*, pero las puntas de los pelos del vientre son blancas.
Like *M. riparius* but has silver tipped hair on the ventral side.

Carollia castanea: **Carolia castaña – Chestnut Short-tailed bat**

Antebrazo/forearm: 35-39 mm
Hábitat: Tierras bajas, áreas alteradas
Habitat: Lowland, disturbed areas
Alimentación: Frugívoro, Piperacea
Diet: Frugivore, Piperacea
Descripción: Pequeño, café obscuro, pelaje dorsal con tres bandas poca distintivas, antebrazo desnudo, escaso pelaje en las patas. Tibia corta 13-17 mm
Description: Small, dark brown, tricoloured dorsal fur with little contrast between bands, naked forearm, little fur on feet . Tibia short : 13-17mm

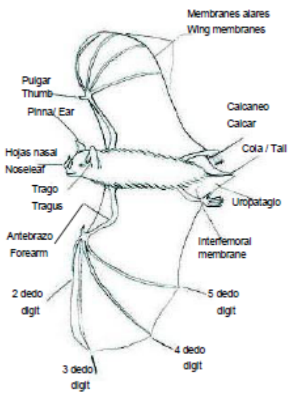
Carollia perspicillata: **Carolia transparente – Seba's short -tailed bat**

Antebrazo/ forearm: 40-45 mm
Hábitat: Tierras bajas hasta 1000m
Habitat: Lowland up to 1000m
Alimentación: Frugívoro, Piperacea
Diet: Frugivore, Piperacea
Descripción: Café, pelaje dorsal con tres bandas marcadas, cola corta, uropatagio presente, antebrazo ligeramente peludo, patas desnudas, la más grande del genero,tibia larga :19-21 mm
Description: Brown fur, distinct tricoloured dorsal fur, short tail, tail membrane present, forearm lightly furred, naked feet, long tibia: 19-21 mm

Carollia brevicauda: **Carolia de cola corta Silky Short-tailed bat**
Antebrazo/forearm: 38-41 mm
Hábitat: Tierras mediana hasta alta, bosque regenerado
Habitat: Medium to high elevation, regenerating forest
Alimentación: Frugívoro, Piperacea
Diet: Frugivore, Piperacea

Descripción: Mediano, gris cafezusco, pelaje dorsal con 3 bandas, la banda basal ancha y oscura, cola corta, uropatagio presente, antebrazo y patas peludos, tibia: 16-18 mm.
Description: Medium, brownish-gray bat, dorsal fur tricoloured, broad, dark basal band, short-tail, tail membrane present, forearm and feet hairy, short tibia: 16-18 mm

Page 2, side 1



***Molossus molossus*-Moloso moloso- Little Mastiff Bat**

Antebrazo/forearm: 38-41 mm

Hábitat: Tierras bajas hasta 1350 m, Costa Caribe y bosque seco

Habitat: Lowland to 1350m, Caribbean coast and dry forest

Alimentación: Insectívoro aéreo; escarabajos

Diet: Aerial insectivore; beetles

Descripción: Pequeño, café grisáceo a café obscuro con bases b;ancas. Pelaje y orejas cortas. Antetrago circular. Hocico abruptamente ondulado. Cerdas largas en el anca.

Description: Small, grayish brown to dark brown hair with white bases. Short hair and ears. Antitragus circular. Snout steeply ridged. Long bristle on rump.

Murciélagos del Parque Natural Metropolitano

El Parque Natural Metropolitano esta ubicado en la zona de transición entre el bosque tropical húmedo y bosque tropical seco. El parque es una parte del Corredor Biológico y es un refugio importante para una diversidad de animales incluyendo 27 especies de murciélagos[3,4].

PARQUE NATURAL METROPOLITANO PANAMA

Heather Cray & Genevieve D'Avignon
McGill University 2009

Los murciélagos...

Los murciélagos son pequeños animales nocturnos con pelos, que podemos encontrar en todo el mundo. Este grupo represente un cuarto de todos los mamíferos en el planeta[1] con cerca de 1100 especies[2]. Estos se llaman Chiroptera o 'manos volandoras' porque son los únicos mamíferos que desarrollaron vuelo verdadero.

¿Sabías que...?

Los biólogos han identifican 114 especies de murciélagos en la Republica de Panamá[5]

Evolución

Los murciélagos son criatura antiguas que estaban en la Tierra en la época del Eocena desde hace 53 a 49 millón de años[5,6]. Los científicos no entienden bien su evolución porque nunca descubrieron fósiles del antepasado de los murciélagos para demostrar si ellos desarrollaron alas o ecolocalización primero[7,8]. Los científicos sugieren que los murciélagos evolucionaron de un mamífero nocturno que se deslizaba para cazar insectos durante la noche. Con el tiempo mejoro su habilidad de vuelo y más tarde desarrollaron la ecolocalización[9]. Los Quiropteros son divididos en dos sub-ordenes: Megachiroptera que son los murciélagos frugívoros del Viejo Mundo[1] que usan la visión[10] y el olor[11] para navegar y buscar alimentos, y Microchiroptera que usan señales de sonidos llamados ecolocalización para ver en lo obscuro de la noche.

¿Sabias que...?

Cuando el murciélago emite el sonido, este se refleja sobre los objetos alrededor de el y como un sonar, el murciélago puede ver la ubicación de estos objetos[10] en la noche.

Ecología

Los murciélagos están en casi todo el mundo[13] y muestran una dieta especializada que incluye los insectos, peces, frutas, néctar, polen, flores, aves u otros vertebrados[5]. Los murciélagos están considerados como el grupo de mamíferos más importante en los bosques neotropicales porque son esenciales para la polinización de plantas y la dispersión de las semillas[15].

¿Sabias que...?

De los más de 1,100 especies de murciélagos en el mundo, solo tres especies se alimentan de sangre? Y solo una se alimenta de sangre de cualquier mamífero... las otras prefieren la sangre de las aves[16]

Usualmente se alimentan en la noche y descansan durante el día. Algunas especies fabrican su propia tienda con los hojas de las palmas pero la mayoridad se perchan en diferentes refugios como son los árboles huecos, troncos, cuevas, grietas, puentes, túneles y alcantarillas.

¿Sabias que...?

Hay algunas especies de murciélagos en el mundo que pescan su cena? Los científicos piensan que estos animales fascinantes pueden ver pequeñas ondas donde los peces están nadando, y entonces estos murciélagos usan sus largas patas con garras para agarrarlos en el agua[12].

Page 2, side 2

***Saccopteryx bilineata*: Greater White-lined Bat- Murciélago de lineas blancas**

Antebrazo/ forearm: 44-49mm

Hábitat: Tierras bajas, bosque de hojas perenne o caducas, borde

Habitat: Lowlands, evergreen and deciduous forest, edge

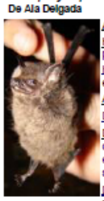
Alimentación: Insectivoro; escarabajos y mariposas nocturnas

Diet: Insectivore, beetles & moth

Descripción: Pelaje del espalda negra, con dos lineas paralelas onduladas blancas o cafe claro, vientre mas palido, casi gris, saco grande en el ala

Description: Upperparts blackish with two prominent, wavy cream-coloured stripes from neck to tail, underparts paler brownish-grey, wing-sac parallel to forearm, larger in males

***Saccopteryx leptura*: Lesser White-Lined Bat—Murciélago De Ala Delgada**



Antebrazo/ forearm: 37-43 mm

Hábitat: Tierras bajas, bosque de hojas perenne o caducas

Habitat: Lowland deciduous and evergreen forests

Alimentación: Insectivoro

Diet: Insectivore

Descripción: Más pequeño de bilineata, color café con bandas paralelas sobre la espalda café amarillento muy páldo y saco en el ala.

Description: Fur uniformly brown on upper and under parts, two wavy light-coloured stripes extending from neck to tail and a wing-sac parallel to its forearm.

***Cormura brevirostris*: Wagner's Sac-Winged Bat-Murciélago Chato**

Antebrazo/ forearm: 46-48 mm

Hábitat: Tierras bajas

Habitat: Lowlands

Alimentación: Insectivoro

Diet: Insectivorous

Descripción: De color café claro a negro, con saco grande en el ala

Description: Buffy brown to black colour, with large wing sac and no noseleaf

***Artibeus phaeotis*: Pygmy Fruit-eating Bat-**

Murciélago frutero pigmeo

Antebrazo/ forearm: 35-42 mm

Hábitat: Bosque secundariode hojas perenne, caducas o seco

Habitat: Secondary evergreen, deciduous or dry forest

Alimentación: Frugivoro; *Cecropia spp. y Sondias* spp. polen y insectos

Diet: Frugivore; *Cecropia* spp. y *Sondias* spp., pollen and insects

Descripción: Pequeño, café pálido a café grisáceo y con rayas faciales blancas marcadas, orejas y nariz bordeadas de amarillo

Description: Small, upperparts sandy brown, clearly defined

***Artibeus watsoni*: Thomas' Fruit-eating bat- Artibeo de Watson**

Antebrazo/ forearm: 35-41mm

Hábitat: Tierras bajas humidas, bosque secundario

Habitat: Humid lowlands, secondary forest

Alimentación: Frugivoro; *Cecropia* spp.

Diet: Frugivore; *Cecropia* spp

Descripción: Pequeno, muy parcecido a *A. phaeotis*

Description: Small with short muzzle, upperparts light brown and faintly tricolour, prominent white facial stripes

***Trinycteris [Micronycteris] nicefori*: Niceforo's Big-eared Bat- Murciélago de Niceforo**

Antebrazo/ forearm: 35-40 mm

Hábitat: Bosque secundario, de hojas perenne o caducas

Habitat: Secondary evergreen or deciduous forests

Alimentación: Insectivoro de follaje y frutas

Diet: Gleaning insectivore and fruits

Descripción: Dorso café claro ligeramente rojizo, con una raya blanca o gris en medio del dorso, negro alrededor de los ojos

Description: Back medium brown or slightly reddish, usually indistinct pale grey strip on rump, underparts buffy grey, indistinct dark mask around eyes, chin ornament simple, fur faintly tricoloured

***Artibeus jamaicensis*:,Jamaican Fruit-eating Bat- Artibeo Jamaiquino**

Antebrazo/ forearm: 55-67 mm

Hábitat: Bosque de tierras bajas y áreas alteradas

Habitat: Lowland forests and disturbed areas

Alimentación: Frugivoro, higos, floras, polen, hojas y insectos

Diet: Frugivore; figs, flowers, pollen, leaves and insects

Descripción: Café grisáceo por encima, las puntas blancuzcas del pelo por debajo parecen escarchadas y a menudo con rayas faciales blancas pero pueden ser no marcadas

Description: Stocky body, upperparts grey or greyish -brown, tips of hair frosted, white facial stripes usually faint, tail membrane and legs mostly naked

***Artibeus intermedius*: San Jose Fruit-Eating Bat- Artibeo Mediano**

Antebrazo/ forearm: 61-68 mm

Hábitat: Bosque de tierras bajas

Habitat: Lowland forests

Alimentación: Frugivoro

Diet: Frugivore

Descripción: De color cafe oscuro con rayas faciales blancas, pero el par inferior poco marcado, la mitad basal del uropatagio tiene pelaje (similar a *A.jamaicensis* pero con patas peludas)

Description: Medium to dark brown with distinct white facial stripes, tail membrane furred (like *A.jamaicensis* but with hairy feet)

***Chiroderma villosum*: Hairy Big-eyed Bat- Murciélago lanoso**

Antebrazo/ forearm: 42-50mm

Hábitat: Tierras bajas, bosque secundario y áreas abierta

Habitat: Lowlands, secondary forest, open areas

Alimentación: Frugivoro; higos

Diet: Frugivore; figs

Descripción: Ojos grandes, de colow cafe claro o gris, y con linea blanca medio-dorsal y rayas faciales que no se distinguen bien y uropatagio pelejado por arriba

Description: Large eyes, muzzle short, body grey, single white stripe on back and facial stripes indistinct, tail membrane hairy on upper surface

***Artibeus lituratus*: Great Fruit-eating Bat- Murciélago frutero gigante**

Antebrazo/ forearm: 69-78 mm

Hábitat: Bosque de tierras bajas humidas

Habitat: Humid lowlands forests

Alimentación: Frugivoro; higos, *Dipteryx* spp., *Piper* spp., insectos, polen, floras

Diet: Frugivore; figs, *Dipteryx* sp., *Piper* sp., insects, pollen, flowers

Descripción: De color café oscuro, con rayas faciales blancas y pelaje en la mitad basal del uropatagio (más grande que *A.jamaicensis* y patas peludas, rayas faciales marcadas)

Description: Stocky body with short muzzle, upperparts brown, white facial stripes usually distinct, tail membrane hairy (biggest of Artibeus, hairy feet, evidente facial stripes)

***Vampyressa nymphaea*: Striped Yellow-eared bat- Vampiresa Nimfia**

Antebrazo/ forearm: 35-40 mm

Hábitat: Tierras bajas hasta 900m

Habitat: Lowlands up to 900m

Alimentación: Frugivoro; higos

Diet: Frugivore; figs

Descripción: Pequeño, de color gris humo por encima y una franja tenue medio-dorsal que no siempre se distingue, con rayas faciales marcadas y hoja nasal amarillo o crema con orejas bordeadas de amarillo

Description: Small, upperparts grey-brown with very faint white stripe on back, very sharply defined white facial stripes, ears edged with yellow, noseleaf yellow or cream coloured

***Vampyressa pusilla*; Little Yellow-eared bat- Vampiresa Pequena**

Antebrazo/ forearm: 29-34 mm

Hábitat: Bosque de hojas perenne o caducas

Habitat: Evergreen to semi-deciduous forests

Alimentación: Frugivoro; higos

Diet: Frugivore; figs

Descripción: Muy pequeno, cafe claro rosaduzco, rayas faciales blancas que no se distinguen, bordes superiores de las orejas amarillo

Description: Very small, upperparts pale brown, white facial stripes usually indistinct, edges of ear yellow

Appendix VII. Data sheet for calculation of gradients for the ordination Graph

Sampling effort	tabulated	Abundance	accumulation	diversity	Species discovery		Site	Moon phase	cover	Cloud	Light value	Humidity	Temperature
1.25	1.25	1	1	1	1	1	Castillo (1)	1	6	1	8	69%	25
1.50	2.75	8	9	2	2	3	Momótides 1/4 (2)	1	3	2	6	54%	30
2.00	4.75	3	12	1	0	3	Momótides 1/4 (2)	3	3	1	7	52%	31
2.50	7.25	2	14	2	1	4	Abandonned (3)	1	4	1	6	74%	27
2.50	9.75	3	17	1	0	4	Abandonned (3)	2	4	0	6	60%	29
3.50	13.25	15	32	1	0	4	Momótides 3/4 (4)	2	1	0	3	60%	29
3.00	16.25	7	39	3	1	5	Castillo (1)	3	6	2	11	61%	26
3.00	19.25	6	45	3	0	5	Momótides 1/2 (5)	2	4	2	8	54%	28
2.50	21.75	3	48	3	3	8	Pond (6)	2	6	2	10	45%	29
2.00	23.75	3	51	2	1	9	Momótides 1/2 (5)	1	3	2	6	51%	28
2.50	26.25	3	54	3	2	11	Pond (6)	1	6	2	9	54%	29
0.80	27.05	4	58	4	0	11	Castillo (1)	1	6	2	9	54%	29
2.25	29.30	4	62	4	2	13	Momótides 3/4 (4)	1	1	2	4	47%	29
2.00	31.30	3	65	1	0	13	Momótides 1/4 (2)	1	3	2	6	47%	29

	light values
cloud	
full	0
partial	1
clear	2
moon	0
0	0
1/4	1
1/2	2
1	3
percent cover	
0-15%	6
15-30%	5
30-45%	4
45-60%	3
60-75%	2
75-90%	1
90%+	0

Appendix VIII. COMPILED DATA

Date	Time	Species	Sex	Age	Para-sites	Length of forearm (mm)	Site	Comments
1/22/2009	19h20	*Carollia perspicillata*	M	A	Yes	42	Castillo (1)	died
1/29/2009	19h00	*Artibeus jamaicensis*	M	A	No	62	Momótides 1/4 (2)	
1/29/2009	19h00	*Artibeus jamaicensis*	M	A	No	67	Momótides 1/4 (2)	
1/29/2009	19h00	*Artibeus jamaicensis*	M	sA	No	62	Momótides 1/4 (2)	
1/29/2009	19h00	*Artibeus jamaicensis*	F	A	No	62	Momótides 1/4 (2)	Pregnant
1/29/2009	19h30	*Artibeus jamaicensis*	F	A	No	62	Momótides 1/4 (2)	Pregnant
1/29/2009	19h30	*Artibeus jamaicensis*	M	A	No	61	Momótides 1/4 (2)	
1/29/2009	19h30	*Artibeus lituratus*	F	A	No	72	Momótides 1/4 (2)	Pregnant
1/29/2009	19h30	*Artibeus lituratus*	F	A	No	69	Momótides 1/4 (2)	Pregnant
2/12/2009	19h30	*Artibeus jamaicensis*	M	A	No	65	Momótides 1/4 (2)	reproductive period
2/12/2009	8h15	*Artibeus jamaicensis*	M	A	No	65	Momótides 1/4 (2)	reproductive period
2/12/2009	8h15	*Artibeus jamaicensis*	M	A	No	67	Momótides 1/4 (2)	reproductive period
2/19/2009	19h00	*Myotis nigricans*	M	J	No	28	Abandonned (3)	insectivorous
2/19/2009	19h25	unknown					Abandonned (3)	escaped
2/19/2009	19h55	*Artibeus jamaicensis*	M	A	No	57	Abandonned (3)	
3/5/2009	20h35	*Artibeus jamaicensis*	M	A	No	66	Abandonned (3)	
3/5/2009	20h35	*Artibeus jamaicensis*	F	A	No	64	Abandonned (3)	Pregnant
3/5/2009	20h35	*Artibeus jamaicensis*	M	A	No	62.5	Abandonned (3)	wart under chin
3/5/2009	19h40	*Artibeus jamaicensis*	F	A	Yes	64	Momótides 3/4 (4)	pregnant, bumps on wing bones
3/5/2009	19h40	*Artibeus jamaicensis*	F	A	No	63	Momótides 3/4 (4)	Pregnant
3/5/2009	19h40	*Artibeus jamaicensis*	M	A	No	63	Momótides 3/4 (4)	not reproductive period
3/5/2009	19h40	*Artibeus jamaicensis*	M	A	No	63	Momótides 3/4 (4)	Reproducing
3/5/2009	19h40	*Artibeus jamaicensis*	M	A	No	63	Momótides 3/4 (4)	Reproducing
3/5/2009	19h40	*Artibeus jamaicensis*	F	A	No	62	Momótides 3/4 (4)	Pregnant
3/5/2009	19h40	*Artibeus jamaicensis*	?	A	No	? (62-3)	Momótides 3/4 (4)	escaped pouch
3/5/2009	21h10	*Artibeus jamaicensis*	M	A	Yes	57	Momótides 3/4 (4)	
3/5/2009	21h10	*Artibeus jamaicensis*	F	A	No	63	Momótides 3/4 (4)	
3/5/2009	21h10	*Artibeus jamaicensis*	F	A	No	60	Momótides 3/4 (4)	Pregnant
3/5/2009	21h10	*Artibeus jamaicensis*	F	A	No	64	Momótides 3/4 (4)	Pregnant
3/5/2009	21h10	*Artibeus jamaicensis*	M	A	No	65	Momótides 3/4 (4)	reproducing
3/5/2009	21h10	*Artibeus jamaicensis*	M	A	No	58	Momótides 3/4 (4)	
3/5/2009	21h10	*Artibeus jamaicensis*	F	A	No	60	Momótides 3/4 (4)	pregnant, fruit in mouth
3/5/2009	21h10	*Artibeus jamaicensis*	M	A	No	61	Momótides 3/4 (4)	reproducing
3/12/2009	19h00	*Carollia perspicillata*	F	A	Yes	41	Castillo (1)	

Appendix VIII. COMPLIED DATA (CONTINUED)

3/12/2009	19h00	*Carollia perspicillata*	M	A	Yes	42	Castillo (1)	
3/12/2009	19h00	*Carollia perspicillata*	F	A	Yes	42	Castillo (1)	Reproductive period
3/12/2009	19h00	Carollia sp.					Castillo (1)	Escaped net
3/12/2009	19h00	*Carollia perspicillata*	F	A	Yes	43	Castillo (1)	
3/12/2009	20h30	*Artibeus jamaicensis*	F	A	No	62	Castillo (1)	Pregnant
3/12/2009	20h30	unknown					Castillo (1)	Escaped net
3/12/2009	20h30	unknown					Castillo (1)	Escaped net
3/12/2009	20h30	*Glossophaga soricina*	M	A	No	36	Castillo (1)	Reproductive period
3/12/2009	20h30	*Artibeus jamaicensis*	F	A	No	66	Castillo (1)	
3/16/2009	18h35	*Myotis nigricans*	M	sA	No	30	Momótides 1/2 (5)	
3/16/2009	19h00	*Myotis nigricans*	F	A	Yes	32	Momótides 1/2 (5)	
3/16/2009	20h00	*Artibeus lituratus*	M	A	Yes	73	Momótides 1/2 (5)	reproducing
3/16/2009	20h00	*Artibeus jamaicensis*	F	A	No	66	Momótides 1/2 (5)	pregnant/teats/ eating cachou nut
3/16/2009	20h15	*Artibeus jamaicensis*	F	A	No	64	Momótides 1/2 (5)	pregnant/ teats
3/16/2009	20h30	*Artibeus lituratus*	M	A	No	74	Momótides 1/2 (5)	reproducing
3/17/2009	19h30	*Uroderma bilobatum*	F	A	No	44	Pond (6)	Pregnant, bleeding on wing
3/17/2009	19h45	*Myotis riparius*	F	A	No	35	Pond (6)	
3/17/2009	20h10	*Artibeus intermedius*	M	A	No	65	Pond (6)	large & stocky, hairy feet, reproducing
3/17/2009	20h12	Large unknown bat					Pond (6)	escaped
3/17/2009	20h12	unknown					Pond (6)	escaped
3/17/2009	20h12	unknown					Pond (6)	escaped
3/17/2009	20h12	unknown					Pond (6)	escaped
3/18/2009	19h20	*Artibeus jamaicensis*	M	A	Yes	67	Momótides 1/2 (5)	reproducing, 54g
3/18/2009	20h20	*Carollia castanea*	M	A	No	35	Momótides 1/2 (5)	
3/18/2009	20h20	*Artibeus jamaicensis*	F	A	No	63	Momótides 1/2 (5)	pregnant/teats
3/19/2009	19h40	*Platyrrhinus helleri*	M	A	No	37	Pond (6)	reproducing
3/19/2009	20h50	*Myotis albescens*	M	A	Yes	33	Pond (6)	
3/19/2009	21h15	*Artibeus lituratus*	F	A	No	71	Pond (6)	pregnant/teats
3/19/2009	20h10	*Artibeus jamaicensis*	F	A	No	62	Castillo (1)	pregnant
3/19/2009	20h10	*Carollia perspicillata*	M	A	Yes	43	Castillo (1)	reproducing
3/19/2009	20h10	*Glossophaga soricina*	F	A	Yes	36	Castillo (1)	pregnant
3/19/2009	20h10	*Carollia castanea*	F	A	Yes	35	Castillo (1)	
3/20/2009	18h50	*Saccopteryx leptura*	F	A	No	42	Momótides 3/4 (4)	
3/20/2009	19h40	*Artibeus phaeotis*	F	A	No	38	Momótides 3/4 (4)	Pregnant+ teats
3/20/2009	19h40	*Artibeus jamaicensis*	F	A	Yes	63	Momótides 3/4 (4)	pregant + teats
3/20/2009	19h40	*Carollia perspicillata*	F	A	Yes	44	Momótides 3/4 (4)	hole in IM
3/20/2009	20h30	*Artibeus jamaicensis*	M	A	No	63	Momótides 1/4 (2)	
3/20/2009	20h30	*Artibeus jamaicensis*	F	A	No	62	Momótides 1/4 (2)	pregant + teats
3/20/2009	20h30	*Artibeus jamaicensis*	F	A	No	62	Momótides 1/4 (2)	pregant + teats
	20h30	unknown					Momótides 1/4 (2)	escaped