SIT Graduate Institute/SIT Study Abroad
SIT Digital Collections

Independent Study Project (ISP) Collection | SIT Study Abroad

Spring 2016

Wildlife Underpasses: Frequency of use by neotropic mammals in Parque Natural Metropolitano, Panamá City, Panamá

Kelly Russo
SIT Graduate Institute - Study Abroad

Follow this and additional works at: https://digitalcollections.sit.edu/isp_collection


Part of the Ecology and Evolutionary Biology Commons, Environmental Indicators and Impact Assessment Commons, Natural Resources and Conservation Commons, and the Natural Resources Management and Policy Commons

Recommended Citation
Russo, Kelly, "Wildlife Underpasses: Frequency of use by neotropic mammals in Parque Natural Metropolitano, Panamá City, Panamá" (2016). *Independent Study Project (ISP) Collection*. 2388.
https://digitalcollections.sit.edu/isp_collection/2388

This Unpublished Paper is brought to you for free and open access by the SIT Study Abroad at SIT Digital Collections. It has been accepted for inclusion in Independent Study Project (ISP) Collection by an authorized administrator of SIT Digital Collections. For more information, please contact digitalcollections@sit.edu.

Wildlife Underpasses:
Frequency of use by neotropic mammals in
Parque Natural Metropolitano, Panamá City, Panamá

Kelly Russo
University of Colorado at Boulder
School for International Training: Panamá
Spring 2016

Abstract

In a world of ever increasing globalization and urbanization, roads present wildlife with a number of challenges. They fragment habitats, disrupt animal movements, impact reproductive success and the fitness of individuals and populations, alter population dynamics, and cause unnatural levels of mortality. Fortunately, the numerous detrimental effects of roads can be alleviated by the proper implementation of mitigation structures, such as underpasses, sky bridges and vegetated overpasses. These mitigation structures are an important source of genetic connectivity, especially in a peri-urban reserve setting. This study seeks to understand what species of mammal utilize the wildlife underpasses below Via La Amistad, a road that divides Parque Natural Metropolitano from Camino de Cruces, and how frequently they do so. Mud traps were implemented within the tunnels and at two control locations. A species composition list was created, along with frequency and relative abundance index values for species by site, overall species, and overall sites. Seven species of mammals were detected at the study sites, six of which were present at the tunnel sites. Number of individuals observed per day at the study locations showed a significant difference between the sites. Relative abundance index values and frequency calculations did not yield significant results. *D. punctata* (Central American Agouti) and *D. marsupialis* (Common Opossum) had the two highest relative abundance and frequency values at the tunnel sites, while *P. semispinosus* (Tomes' Spiny Rat) and *D. novemcinctus* (Nine-banded Armadillo) were equally present at the controls. The baseline results of this study imply that wildlife underpasses have some success at providing genetic connectivity between fragmented habitats. Additional studies should be conducted to further expand upon and confirm the results from this study. If more extensive road ecology research is conducted and road mitigation structures are implemented, both around Parque Natural Metropolitano and in the Neotropics, the negative impacts of roads on wildlife can be decreased.

Acknowledgements

My project could not have been accomplished without the guidance, support, and knowledge of many people. The growth I have experienced as a part of this project would not be possible without them.

I am immensely grateful for both my advisor, Prof. Melva Olmos of PANTHERA, and Ezekiel Jakub of CONSERVACIÓN PANAMÁ Inc. Their direction and expertise were integral to the creation, implementation, and delivery of my project. Melva and Zeke pushed me in ways I had never expected, and my research and I flourished as a result. Furthermore, I thank them both for their time and energy in making sure I was able to construct my mud traps. Without them, I'd still be staring at the concrete-like dirt in my tunnels in disbelief.

I would like to acknowledge the guards of Parque Natural Metropolitano, who tirelessly accompanied me to the tunnels on Via La Amistad and whose knowledge of the mammals in the Park made identifying tracks much easier. I would also like to extend my thanks to Lic. Dionora Viquez, Directora General for allowing me to conduct my research in the Park.

To Aly Dagang, SIT: Panama's Academic Director, I owe a heartfelt thanks. Her guidance and encouragement throughout the semester was uplifting and inspiring. SIT: Panama would not be the same without her.

Much thanks to Daniel Bye, who helped me craft the visualization of the study sites and who was an unending source of support.

Finally, I would like to thank my fellow student and friend, Rachael Pruitt, for her help throughout this process. Her skill as a field assistant and a sounding board was unparalleled. I also greatly appreciated her moral support and unending cheerfulness on our long days in the Park. I couldn't have done my project without her.

Table of Contents

I. Abstract……2

II. Acknowledgements……..3

III. Introduction……5

a. *Background……5*

b. *Study habitat……5*

c. *Study area……6*

d. *Current study……6*

IV. Research Question……...6

V. Methods……7

a. *Mud trap construction and resets……7*

b. *Track identification……7*

c. *Visualizations……8*

d. *Analysis……8*

VI. Results……..9

a. *Visualization……9*

b. *Identified species composition……10*

c. *Track counts and individuals……10*

d. *Relative abundance indexes……10*

e. *Frequency……13*

VII. Discussion……....15

a. *Additional observations……16*

b. *Limitations and sources of error……16*

c. *Study recommendations……17*

VIII. Conclusion……..18

IX. Works Cited……...19

Introduction

Background

Roads present wildlife with a vast number of challenges. Roads fragment and destroy habitat, impede migration and dispersal patterns (Beben 2012; Gagnon et al. 2011; Goosem 2007), and impact reproductive success (Corlatti et al. 2009). Environmental disturbances include significant noise and light disturbances that can extend far beyond the normal range of edge effects, as well as pollution (Bond and Jones 2008; Goosem 2007). Roads open up an environment ideal for invasions of non-native flora, fauna, and diseases (Goosem 2007). As roads are barriers to animal movement, they can affect the behavioral patterns and habitat use of species, subsequently resulting in altered population dynamics (Ramp and Ben-Ami 2006; Goosem 2007). Vehicle-wildlife collisions, and subsequent mortality, is another major issue that has seriously impacted certain species (Glista et al. 2009; Goosem 2007).

Roads' detrimental effects trigger sharp reductions in gene flow within species. Declines in gene flow lead to several problems for wildlife, such as reductions in genetic diversity and fitness of individuals or populations, and increased inbreeding. Gene flow decline can also influence extinction risks (Corlatti et al, 2009). Therefore, wildlife populations in or near road-fragmented habitats may not be stable or viable, especially when considering the rapid increase in globalization, development, and expansion of urban areas, which result in an increase in the number of people travelling on roads worldwide (Ramp et al. 2006).

Peri-urban reserves are vital to conservation success because they provide wildlife with accessible, intact, and protected habitat. However, the effects of roads impact populations no matter their location. Fauna living within peri-urban reserve settings are under as much threat as those living near major highways (Ramp et al. 2006), especially if local populations of species are low (Ramp and Ben-Ami 2006). Moreover, tourism can be a source of income for peri-urban reserves and consequently, they generally have high rates of both foot traffic and road traffic. Communities can even be located within reserve borders (Ramp et al. 2006).

Despite these overwhelming challenges, there are ways to reduce the impact of roads on wildlife, within both peri-urban reserves and other road-impacted habitats. There is a growing body of literature illustrating that mitigation structures have direct affects on both reducing the number of wildlife mortality events, and increasing gene flow and genetic diversity of animal populations (Glista et al, 2009; Bond and Jones 2008; Corlatti et al. 2009). Initially, management strategies sought to prevent wildlife-vehicle collisions with roadside exclusion fencing, but the projects were only somewhat successful (Bond and Jones 2008). Moreover, when fences are the sole method utilized to keep wildlife away from roads, they often amplify barrier effects within habitats and species suffer from disrupted mobility between habitats (Ramp and Ben-Ami 2006; Goosem 2007). In order to circumvent the detrimental effects that roads and roadside exclusion fencing have on wildlife populations, wildlife overpasses and underpasses have been designed and constructed worldwide (Ramp and Ben-Ami 2006). As these structures are expensive, there is a community of researchers investigating their efficacy at supporting connectivity, biodiversity, and gene flow (Ramp and Ben-Ami 2006).

Study Habitat

Seasonal tropical dry forests are unique, important, and relatively unstudied habitats that present living organisms with a number of challenging environmental conditions. They are hot

and dry for a significant portion of the year, and as a result have highly inconsistent resources available for biota. Specifically, they have average temperatures of greater than 17 degrees Celsius and highly seasonal rainfall ranging annually from 250-2000 millimeters, as well as a low potential evapotranspiration to precipitation ratio (Stoner and Timm 2011).

Study Area

Parque Natural Metropolitano is a neotropic, peri-urban reserve located in the heart of Panama City, Panama. Along with Soberania National Park, Chagres National Park, and the Gatun Lake Recreation Area, Parque Natural Metropolitano was founded in the 1980s in an effort to help protect the Panama Canal watershed (ANAM 2006). The park itself encompasses 233 hectares and is one of the few surviving areas of secondary growth, tropical dry forest in Central America (McNaughton 2015; Cray and D'Avignon 2009). It is an integral piece of the Biological Corridor that runs along the east side of the Panama Canal, as it provides a key patch of habitat for native flora and fauna (McNaughton 2015; ANAM 2014; Cray and D'Avignon 2009). As of 2007, the park serves as habitat to 45 species of mammals, 227 species of birds, 36 species of reptiles and 14 amphibians (Carrión 2007). Additionally, it is recognized as a Key Biodiversity Area (KBA) and as an Area of Importance to Birds (IBA) (McNaughton 2015; ANAM 2014).

Central Panama has retained a large amount of forest cover close to many of its major cities. About half of these forests are under protection, while the rest mostly consist of unprotected fragments tied together with scattered regenerating second growth forests, pastures, and urban areas (Rómpre et al. 2007). As such, Central Panama and Parque Natural Metropolitano are vital, relatively unstudied sites for understanding the impacts that roads have on Neotropical wildlife populations.

Current Study

Over five years ago, an expansion project on Via La Amistad took place, turning the two lane road into a four lane road. The impacts of such a project have had both short-term and long-term consequences for the surrounding flora and fauna (Aippersbach et al. 2012). In an effort to help facilitate safe wildlife crossings, this expansion included the construction of aerial overpasses and terrestrial underpasses (Aippersbach et al. 2012). These wildlife underpasses provide a critical, safe corridor of connectivity between Parque Natural Metropolitano and Camino de Cruces National Park, a forest fragment that connects Parque Natural Metropolitano with Soberania National Park. This research seeks to provide a brief assessment of the frequency of use of wildlife underpasses by neotropic mammals below Via La Amistad, in the peri-urban setting of Parque Natural Metropolitano.

Research Question

What species of mammal frequent the Via La Amistad underpasses in Parque Natural Metropolitano, Panama City, Panama?

Methods

Mud trap construction and resets

For this study, four underpass and two control mud traps were constructed. Within each of the two tunnels, two mud traps were placed at least 1-2 meters within the entrances in accordance with a similar study conducted by Bond and Jones with sand traps (2008). Due to substrate quality, some traps had to be constructed further into the tunnels. Underpass traps spanned 50 centimeters wide and the entire width of each tunnel. Due to safety concerns, control traps were constructed on either side of Ave. Juan Pablo II, southwest of the visitor's center. Each of the two control traps were a square meter and were placed at least 2 meters from the road edge.

A tape measure was used to measure the appropriate dimensions for each trap, before the areas were cleared of leaf litter and other debris (Olmos Pers. Comm. 2016 based on Aranda 2012). The top 2 centimeters of soil were broken up with a trowel, and water was poured onto the broken soil and mixed into mud. Cement trowels were used to smooth the surface of the traps after the proper mud consistency was reached . Each trap was marked as "active" with a thumbprint in the bottom right corner (Olmos Pers. Comm. 2016 based on Aranda 2012). Traps were checked for tracks and reset from 10:30AM-1:30PM each day during the study period. Reset protocol included turning over the top 2 centimeters of soil, pouring enough water on the soil to return the traps to the proper consistency of mud, and smoothing the surface of the traps.

Traps were unable to be checked on days where guards from the Park were unavailable. Additionally, traps were unable to be checked on days with inclement weather due to safety concerns.



Top: Tunnel 1
Middle: Tunnel 1, Trap 2
Bottom: Control 2

Track identification

Every morning during the thirteen-day study period, mud traps were checked for tracks. Site name, date, time, track measurements, species, and whether individuals or groups were

present were recorded. Tracks were measured at their longest point and their widest point, and were photographed for reference (Olmos Pers. Comm. 2016 based on Aranda 2012). Unidentified mammal presence, defined as scratch marks and faint tracks of unfamiliar species, were recorded and numbered. Plaster of Paris was mixed with water, poured over tracks, and left to harden for 10 minutes before being removed and placed in plastic bags (Olmos Pers. Comm. 2016 based on Aranda 2012; Orjuela and Jiménez 2004). Tracks were identified using *A Field Guide to the Mammals of Central America and Southeast Mexico* (1997) and *Manual para el Rastreo de Mamíferos Silvestres de México* (2012) as references, and with the help of guards from Parque Natural Metropolitano.

Visualizations

A Garmin GPSMAP 64s unit was used to map the study area and measure the distance between mud trap locations. Satellites were checked for location errors before any GPS measurements were taken. Location error in meters was recorded. Waypoints were then dropped at the center of all mud traps to mark their location for later visualization.

Analysis

From the track data collected, an identified species composition list was created. Within the framework of this study, species presence was confirmed by their detected tracks (Simonetti and Huareco 1999). Individual animals were determined from the track data collected. Track length, width, and direction were evaluated in order to distinguish individuals of the same species from one another. These individual counts were used to calculate the following: the relative abundance index (RAI) and frequency values for species detected at each study site (1 and 4), the RAI and frequency values for species overall (2 and 5), and for RAI and frequency values at the sites overall (3 and 6). The study sites are defined as Tunnel 1, Tunnel 2, and Controls.

Following a study by Orjela and Jiménez (2004), RAIs were calculated with the following equations, where total number of active trap days is defined as number of active traps ∗ number of active days (Lyra-Jorge et al. 2008):

(1) $RAI_{\text{species by site}}$ =
tracks of individuals from species_i at site_X / total number of active trap days

(2) $RAI_{\text{species overall}}$ =
total tracks of individuals from species_i/ total number of active trap days

(3) $RAI_{\text{site overall}}$ =
total tracks of individuals at site_x / total number of active trap days

Frequency of use was calculated with the following equations, where active $\text{days}_{\text{site x}}$ is defined as the number of days where traps were able to pick up tracks during the study period:

(4) $FR_{\text{site by site}}$ = total individuals from species_i at site_X/ active $\text{days}_{\text{site x}}$

(5) $FR_{\text{species overall}}$ = individuals from species_i / active days

(6) $FR_{\text{site overall}}$ = total individuals at site_X / active $\text{days}_{\text{site x}}$

Kruskal-Wallis tests were used to determine significance between frequency values of identified individuals found per trap observation day at each of the three study sites, and between frequency values of species at each of the three study sites. This non-parametric statistical method was chosen because it accounts for the uneven distribution of data that generally characterizes small data sets.

Mapping of the study sites was conducted in Python with Python modules matplotlib and Basemap. The map image was taken from openstreetmap.org. Mud trap waypoints were included on a visual representation of the study area.

Results

Visualization

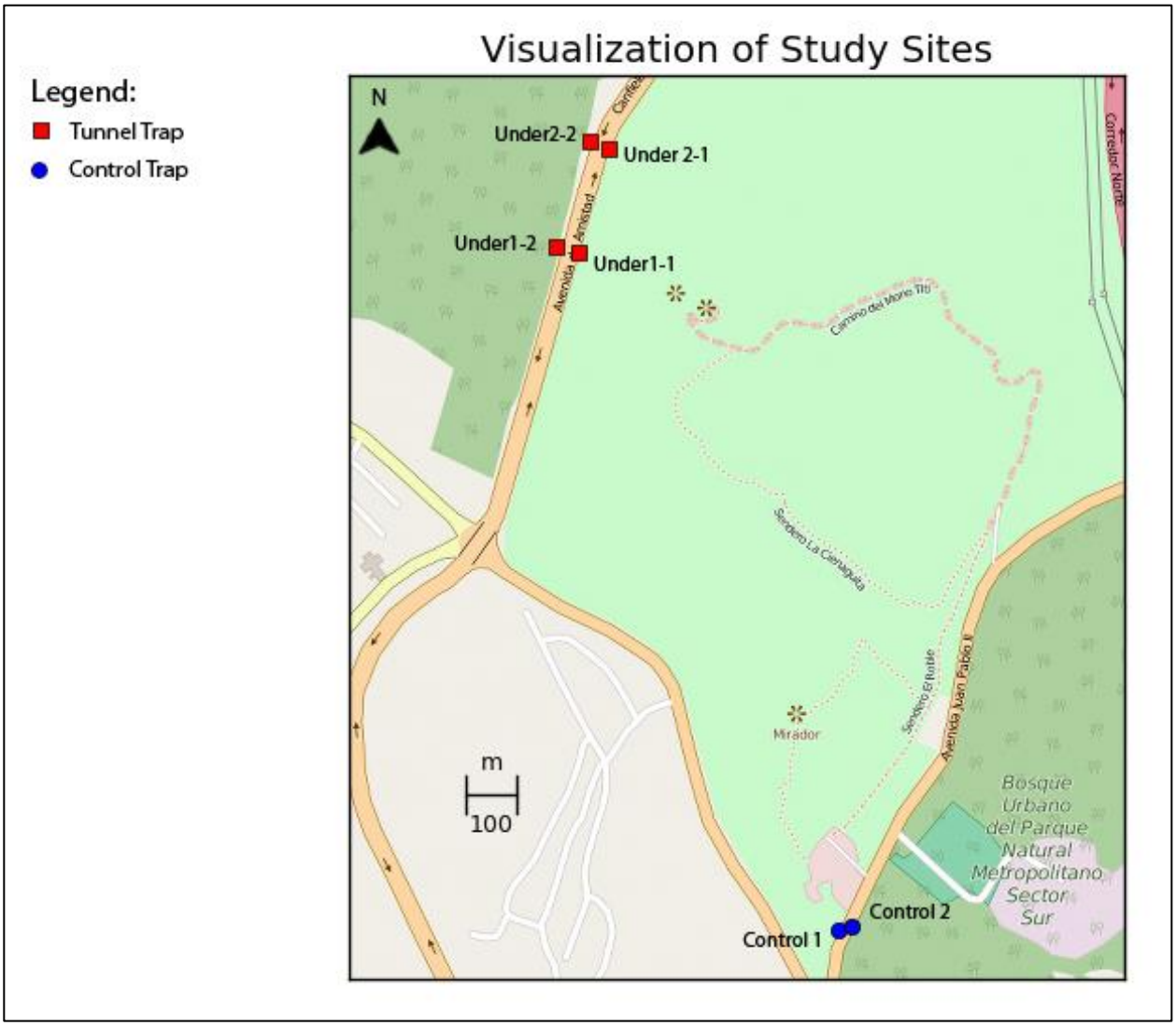


Figure 1. Visualization of the study sites around Parque Natural Metropolitano created in Python, with the help of Daniel Bye. Map image from openstreetmap.org.

Identified species composition

During the thirteen-day study period, seven mammal species were identified from their tracks (Table 1). The tunnel study sites were utilized by four of those species, whereas the control sites were used by three of those species. *D. novemcinctus* (Nine-banded Armadillo) and *D. marsupialis* (Common Opossum) were present at all sites. *P. semispinosus* (Tomes' Spiny Rat) was only detected at the control. *C. paca* (Paca), *D. punctata* (Central American Agouti), *H. yaguarondi* (Jaguarundi), and *M. Temama* (Red Brocket) were only found at the tunnel sites.

Site Type	Species	Common Name
Tunnels	*Cuniculus paca*	Paca
	Dasyprocta punctata	Central American Agouti
	Dasypus novemcinctus	Nine-banded Armadillo
	Herpailurus yaguarondi	Jaguarundi
	Didelphis marsupialis	Common Opossum
	Mazama temama	Red Brocket
Controls	*Proechimys semispinosus*	Tomes' Spiny Rat
	Didelphis marsupialis	Common Opossum
	Dasypus novemcinctus	Nine-banded Armadillo

Table 1. Species composition of mammals identified by their tracks at each site type.

Track counts and individuals

Across the study sites, a total of 55 individuals' tracks were collected in mud traps (Fig. 2). Of these 55 individuals, the species of 48 individuals were able to be identified. Identified individuals made up 87.3% of the total individuals found. Additionally, the tracks of seven unidentified individuals were observed. These were determined as separate individuals because each of the tracks were of different species, or were encountered on different days. Unidentified individuals made up 12.7% of the total individuals found. Furthermore, 83.3% of the trap plots that were constructed successfully showed signs of mammal use.

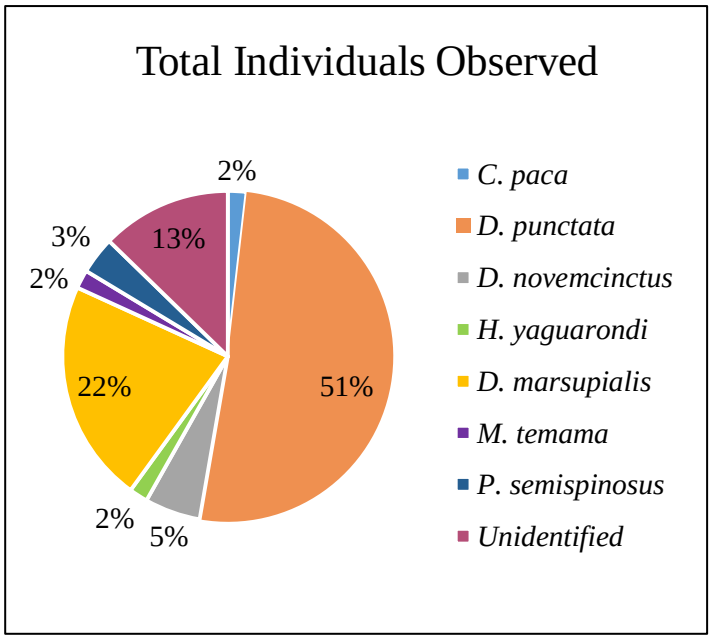


Figure 2. Percentages of total individuals observed across all study sites

Relative abundance indexes

Relative abundance indexes (RAI) were calculated at three different levels: observed species at each study site, overall observed species, and overall individuals observed at each study site.

The computed RAI values for species found at the different study sites (Fig. 3) showed that species abundance was disproportionately skewed between the sites. *D. punctata* (Central American Agouti) was the most abundant species at both tunnel sites, but *P. semispinosus* (Tomes' Spiny Rat) and *D. novemcinctus* (Nine-banded Armadillo) showed the highest abundance at the control sites. All individuals were identified at the control sites, but unidentified individuals yielded RAI values of 0.13 at Tunnel 1 and 0.17 at Tunnel 2.

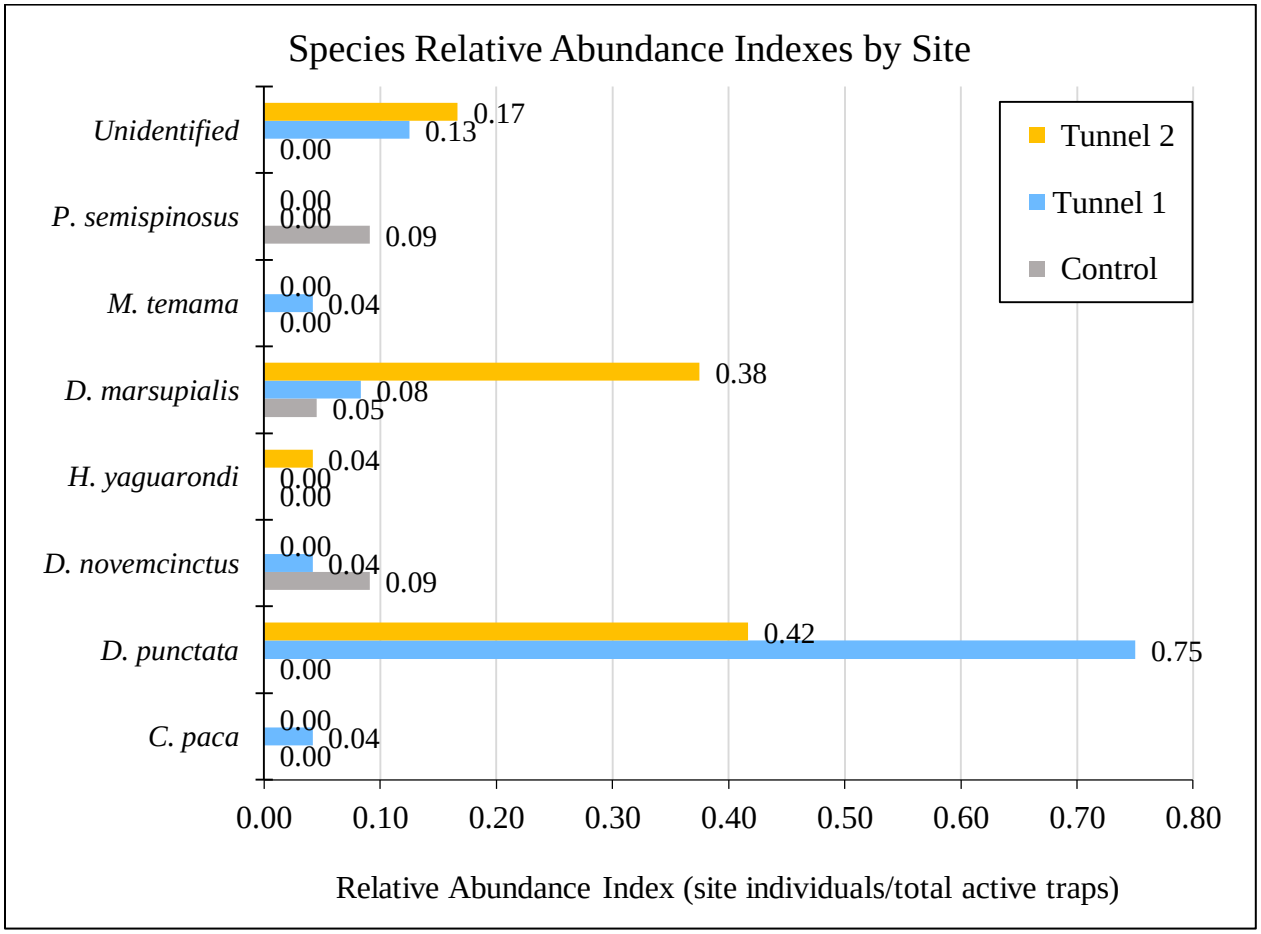


Figure 3. Relative abundance indexes calculated for observed species at each of the study sites

The calculated species RAI values (Fig. 4) revealed that *D. punctata* (Central American Agouti) was the most abundant species overall, with an RAI value of 0.44. *D. marsupialis* (Common Opossum) had a marginally higher RAI value, 0.19, than individuals in the unidentified category, which showed an RAI value of 0.11. *C. paca* (Paca), *H. yaguarondi* (Jaguarundi), and *M. temama* (Red Brocket) had the lowest RAI values, at 0.02.

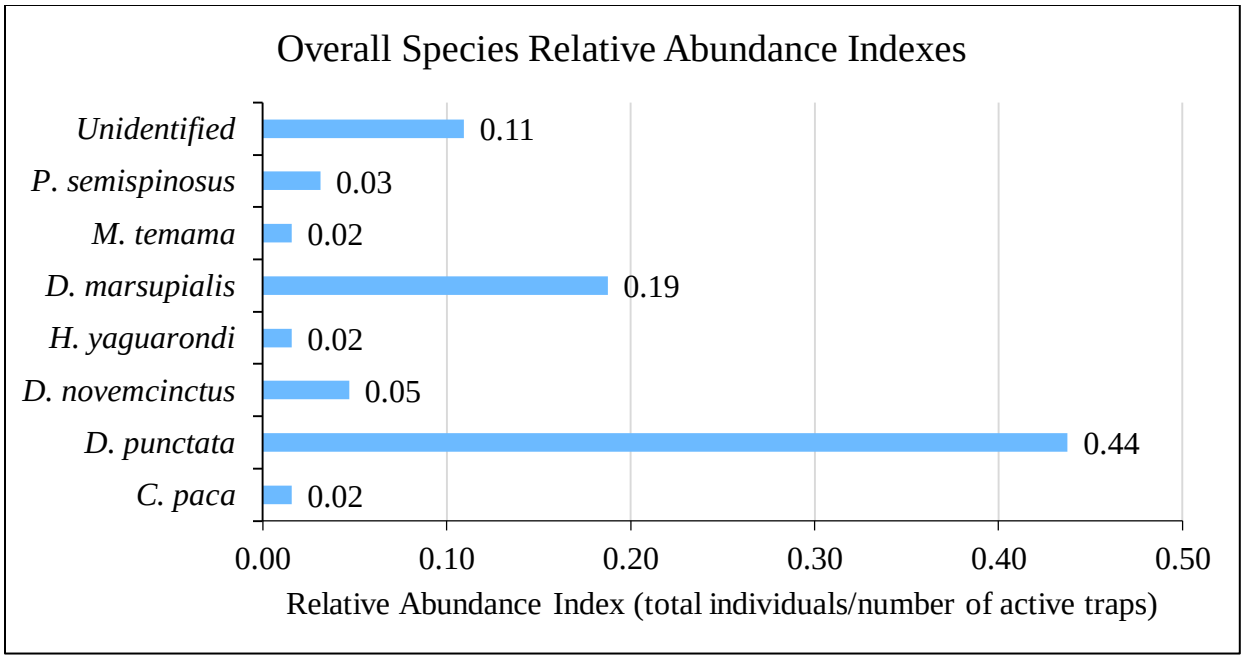


Figure 4. Relative abundance indexes calculated for the species observed overall.

Overall RAI (Fig. 5) at each site showed much higher RAIs at the Tunnel sites. Tunnel 1 had the highest overall RAI at 1.08, and Tunnel 2 followed at 1.00. The Control sites had the lowest overall RAI at only 0.23.

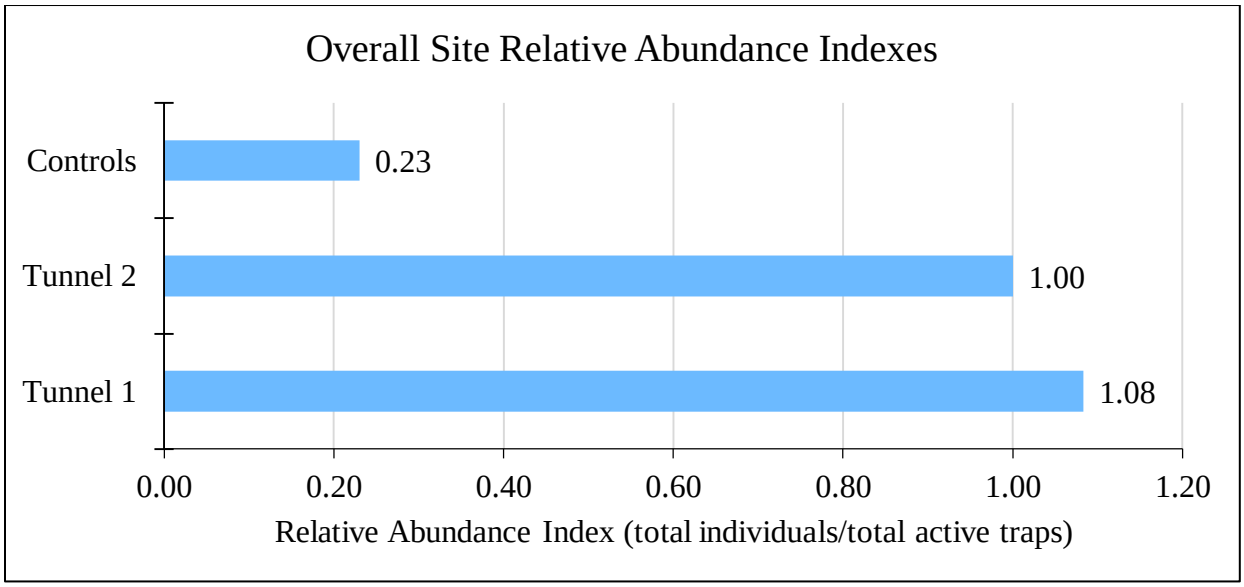


Figure 5. Overall relative abundance indexes calculated for each study site

Frequency

Frequency was analyzed at different levels: individuals per observation day at study sites, species frequency at each study site, overall species frequency, and overall frequency of individuals observed at each study site.

The Kruskal-Wallis test for individuals detected on each day of trap observation (Fig. 6) showed a very significant difference (df = 2, p-value <<0.001). The highest number of individuals detected were on observation day 12. No individuals were found on observation day 2.

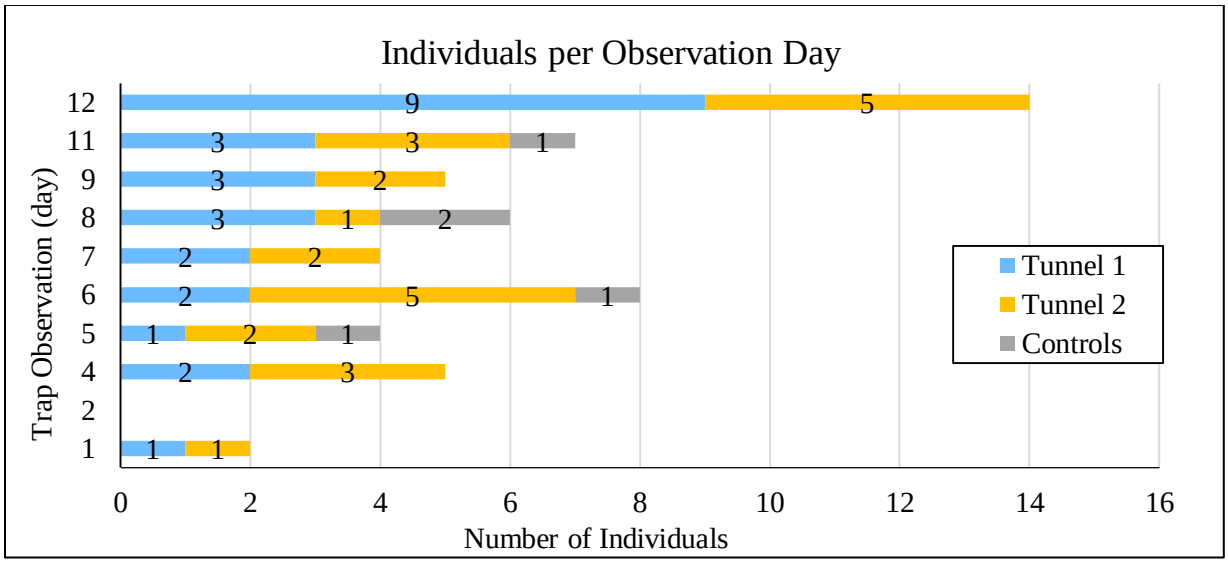


Figure 6. Number of identified individuals found per site on each day of trap observation

For the sites where *D. punctata* was present, it showed the highest frequency. *C. paca* (Paca), *H. yagurondi* (Jaguarundi), and *M. temama* (Red Brocket) showed the lowest frequency at the sites where they were present. Unidentified individuals were not present at the Controls, but showed frequencies of 0.33 individuals per day at Tunnel 2 and 0.25 individuals per day at Tunnel 1. However, the Kruskal-Wallis test conducted for species frequency by each study site (Fig. 7) revealed that species frequency did not differ significantly between the sites (df=2, p-value= 0.551).

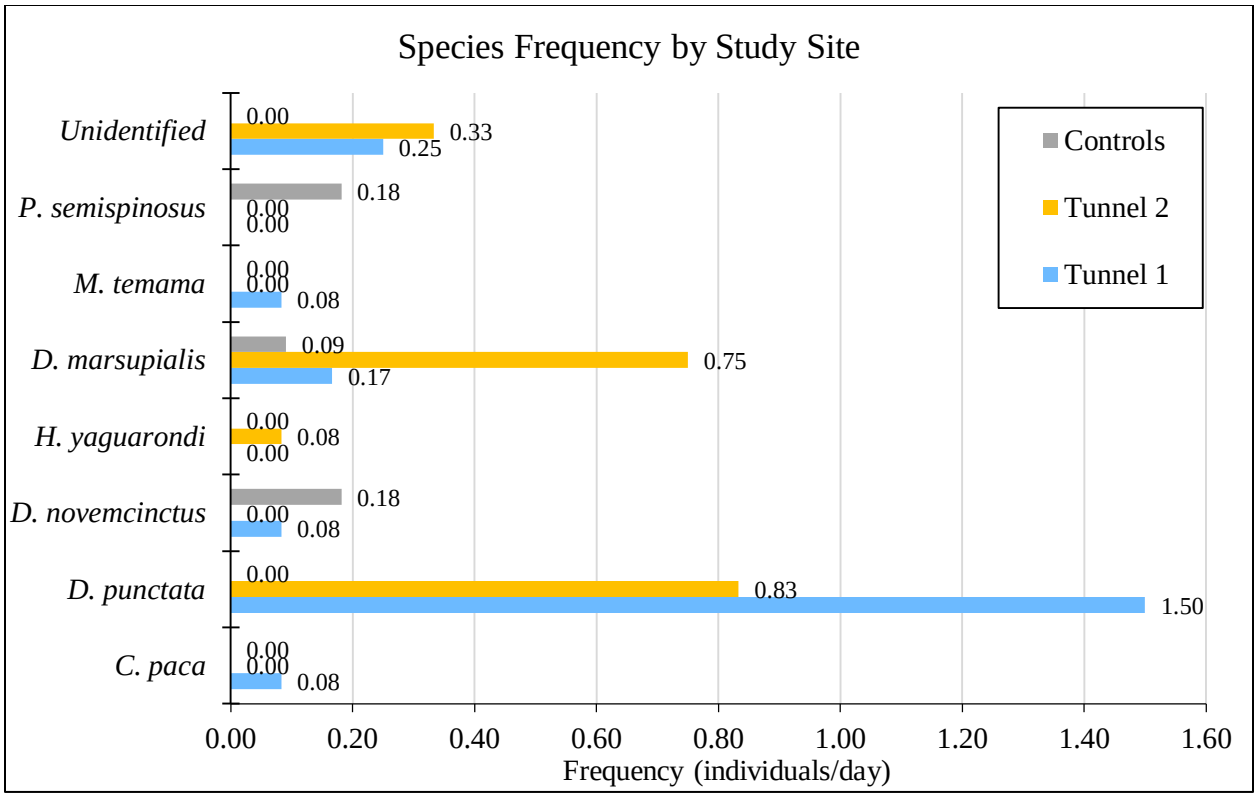


Figure 7. Frequency of each detected species calculated for each study site

Overall species frequency (Fig.8) calculations yielded 2.33 *D. punctata* (Central American Agouti) per day within the study sites. Only 0.08 individuals of *M. temama* (Red Brocket), *H. yaguarondi* (Jaguarundi), and *C. paca* (Paca) were detected per day within the study sites.

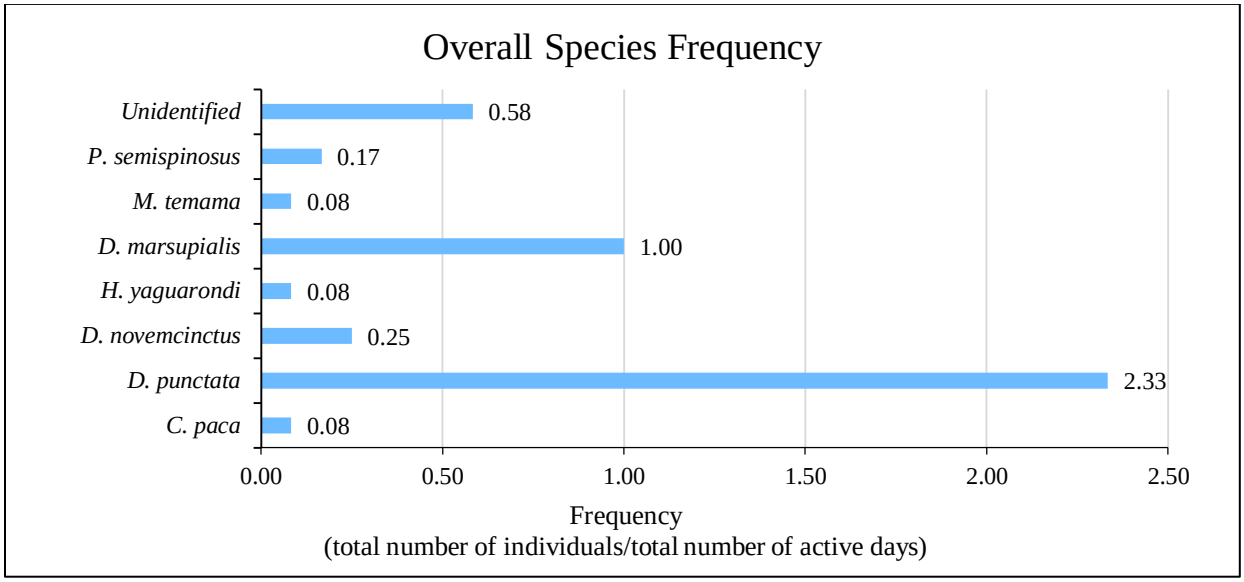


Figure 8. Overall frequencies calculated for observed species

Overall frequency at each site (Fig. 9) shows that the Tunnel sites are more frequently visited than the Control sites. Tunnel 1 had the highest overall frequency with 2.17 individuals visiting the sites per day. Tunnel 2 was utilized by 2.00 individuals per day. The Control sites had the lowest frequency with only 0.45 individuals visiting the sites per day.

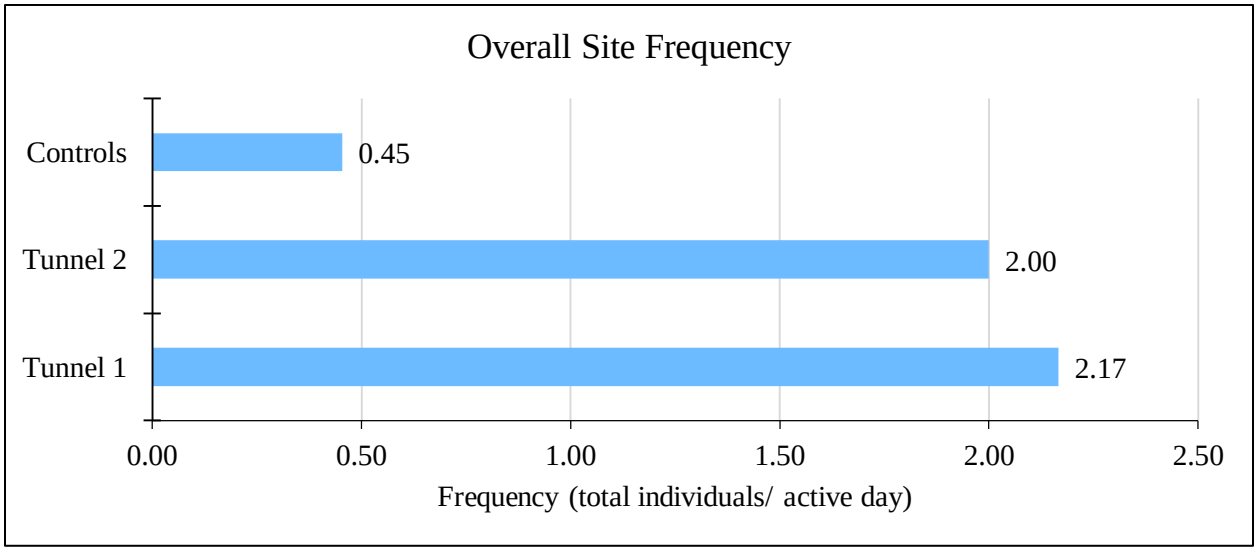


Figure 9. Frequency calculated for total observed individuals for each of the study sites

Discussion

The main objectives of this study were to determine which species of mammal utilized the two wildlife underpasses underneath Via La Amistad, and how frequently they did so. The results garnered baseline species composition, frequency, and abundance values that definitively show the utilization of the wildlife underpasses by mammals in Parque Natural Metropolitano.

Parque Natural Metropolitano supports a total of 45 mammal species (Carrión 2007). As such, only six, or 13.3%, of mammal species inhabiting the Park were found utilizing the wildlife underpasses underneath Via La Amistad. Despite this low percentage, the underpasses have the potential to be a source of connectivity for a wider range of mammals. The unidentified individuals that were detected could represent other species that utilize the tunnels if properly identified in later studies. Moreover, it is likely that more species are using the tunnels than the traps detected. Park guards mentioned the presence of additional species that use the tunnels than the species that were found in this study (personal communication 2016).

Of the species detected over the course of this study, the species RAI values, as well as species frequency values (Figs. 4 and 8) showed a disproportionate number of species visiting the study sites. The data gathered suggests that *D. punctata* (Central American Agouti) has the highest presence of the mammals detected in this study, followed by *D. marsupialis* (Common Opossum). Therefore, it is implied that *D. punctata* and *D. marsupialis* utilize the tunnels the most often to get across Via La Amistad. Other species utilize the tunnels, but they may not use them with the same frequency. This could be because of species' behavioral patterns and potential wariness of entering into an enclosed space (Bond and Jones 2008). Additional, long-term monitoring needs to be conducted in order to expand upon this study's results, as well as determine its significance.

The significant p-value of number of individuals detected per day at the three sites (Fig. 6) suggests a differing usage of the tunnels and roadside crossings over time. These findings could be a result of initial avoidance of the study sites due to human presence and altering of the floor of tunnels. Habituation to human scent and mud traps most likely occurred over time. The results garnered by this study may have recorded a glimpse into the seasonal usage of the tunnel. The study period took place during the transition between the wet and dry seasons in Panama, and the changing weather conditions may have affected the species composition, abundance, and frequency observed (Bond and Jones 2008).

The two control sites were not visited as frequently, nor by as many species, as the tunnel sites (Figs. 5, 6, 7, 9). This could be due in part to their location. They were randomly placed along Ave. Juan Pablo II, and there was no exclusionary fencing funneling animal movement. Fauna could have crossed at any point along this road, and the chances that they would have crossed through the two, meter by meter plots, were low. Despite this, the control sites demonstrated that there was animal presence and moment along the southwest side of Av. Juan Pablo II. Crossings could not be confirmed, even if track direction faced towards or away from the road.

The abundance and frequency differences observed between the tunnels—though their respective Kruskal-Wallis tests that yielded insignificant p-values—could be due in part to the microclimates that produced differing variations of tropical dry forest near the tunnel sites (personal observation). These variations could potentially attract particular species to one tunnel versus another or dissuade species from the area entirely. Additionally, the mouths of the tunnels were close to the road edge (personal observation). Consequently, species sensitive to roads and habitat edges may avoid using the tunnels to cross Via La Amistad (Goosem 2007).

Additional observations

During the thirteen-day study period, *Nasua nasua* (White-nosed Coati) were seen on the Park side (SW end) of Tunnel 1, and were also seen between the two tunnel locations on the same day. This suggests the potential for *N. nasua* to use both the tunnels and cross Via La Amistad. Also, large quantities of old and fresh *N. nasua* scat was present in Tunnel 1 (park guard personal communication 2016). No tracks of *N. nasua* were encountered, however, so usage cannot be confirmed within the framework of this study. Furthermore, an unidentified reptile, an unidentified amphibian, and an unidentified species of bat were visually confirmed in the tunnels. The reptile crossed Tunnel 1, while the amphibian remained near the first trap in Tunnel 1, undisturbed by researcher presence. The bats used the tunnel as a roost, and were spotted on all trap observation days. These observations suggest the potential for the wildlife underpasses to be utilized by a larger subset of mammals than were detected in this study, as well as their use by other taxa.

Limitations and sources of error

The study sites, length of the study period, and the methodology presented a number of challenges and limitations that may have affected the results.

The study period was only thirteen days and yielded only 64 active traps. Thus, a small study sample was collected. The substrates within the tunnels and at the control sites that were used to construct the traps were variable and may not have picked up tracks with the same accuracy. Track size is dependent on the softness and moisture content of the substrate (Lyra-Jorge et al. 2008). It was occasionally difficult to distinguish individuals from one another because moisture content of the traps could vary within the same tunnel. Double counting of individuals may have occurred as a result. The uncovered controls were more likely to be rendered inactive due to precipitation events. Though, the tunnels were also affected by large precipitation events, as they were located at the base of a sharp incline. The control traps were unable to be placed near the tunnels, which yields an inaccurate portrayal of species that crossed on Via La Amistad. Additionally, their locations were not ideal for determining if individuals attempted a road crossing.

Mud traps are a useful, time-efficient, and inexpensive method for determining species occupancy information, abundance values, and habitat-use (Conover and Linder, 2009; Simonetti and Huareco 1999). They are specifically designed to collect mammal tracks without influencing or limiting natural movements, unlike other methods of track-capture, such as track-plates and scent or bait stations (Conover and Linder 2009). As such, this methodology was appropriate for this study.

Despite these advantages, mud traps have their limitations as well. They are effective at capturing the tracks of medium and large-sized mammals, but not those of small mammals (Conover and Linder 2009; Lyra-Jorge et al. 2008). This limitation was observed in this study, as *P. semispinosus* (Tomes' Spiny Rat) was the only small mammal to be recorded. Furthermore, to an untrained eye, it was occasionally difficult to distinguish individuals from one another purely based on track length, width, and direction. Other studies mentioned environmental conditions as a limitation of this methodology (Conover and Linder 2009; Bond and Jones 2008; Lyra-Jorge et al. 2008). The high temperatures and variable occurrence of precipitation in tropical dry forests both over-dried and over-wet all traps during the course of this study. Over-drying caused the inability for traps to effectively record tracks. Over-wetting caused tracks to be messy, and made it harder to distinguish individuals of the same species from one another, as well as species from one another (Lyra-Jorge et al. 2008; personal observation).

Study recommendations

If this study were to be replicated, time of year should be taken into account. The methodology would be difficult to conduct in the rainy season, as even heavy precipitation in April caused the tunnels to be washed out and those mud traps to be destroyed. Though the controls remained active after these precipitation events, track presence may have been affected enough to render them unrecognizable.

The limitations of the study sites and the mud trap methodology could be remedied if camera traps were utilized in addition to or instead of mud traps (Cortés-Marcial and Briones-Salas 2014). Cameras could be placed at each end of the Tunnel sites to more accurately identify individuals and crossing events, and decrease the chance of environmental conditions affecting results. This change in methodology would also provide information about species crossings on Via La Amistad. Cameras could be placed at defined distance intervals between the traps, along

each side of Via La Amistad. Furthermore, the study period should be increased if possible. Indirect sampling methods generally are conducted for upwards of three months in order to gather enough data to report significant results (Olmos personal communication 2016; Cortés-Marcial and Briones-Salas 2014).

Conclusion

The baseline results of this study suggest that wildlife underpasses installed below Via La Amistad are utilized by a fraction of mammal species found in Parque Natural Metropolitano. Specific species usage data needs to be supplemented with additional data and should be conducted on a multiyear basis to understand seasonal species use. If a more extensive study was conducted, results could implicate effectiveness and demonstrate the ecological value of wildlife underpasses in a Neotropical, peri-urban setting.

To go further, road ecology studies should be conducted along all of the roads fragmenting Parque Natural Metropolitano from the Biological Corrior in order to better understand how to implement future mitigation methods. Lesbarreres and Fahrig (2012) suggested that integrating scientific research into road planning and development can potentially lead to the improved connectivity between habitats that are divided by roads. The lack of available literature investigating and discussing the impacts of roads on Neotropic wildlife needs to be remedied, especially as the the Neotropics continue to be developed (González-Gallina et al. 2013; Ramp and Ben-Ami 2006). Outside of the study area, there are more than three roads dividing the protected areas of Parque Natural Metropolitano, Camino de Cruces, and Soberania National Park. As these areas are a critical part of the Biological Corridor on the east side of the Panama Canal, it is important to understand the effect that roads have on wildlife, connectivity, and the surrounding habitats.

Works Cited

ANAM. (2006). *Informe El Sistema Nacional de Areas Protegidas*. Autoridad Nacional del Ambiente (ANAM).

Aippersbach, A., Morden, A., and Wilkenfeld, D. (2012) Conservation and Urban Development: Exploring the Impacts of Road Development on Parque Natural Metropolitano. McGill University.

Aranda, M. (2012). Manual para el rastreo de mamíferos silvestres de México. *Comisión nacional para el conocimiento y uso de la biodiversidad (CONABIO). Ciudad de México, México*.

Beben, D. (2012). Crossings for Animals–an Effective Method of Wild Fauna Conservation. *Journal of environmental engineering and landscape management*, *20*(1), 86-96.

Bond, A. R., and Jones, D. N. (2008). Temporal trends in use of fauna-friendly underpasses and overpasses. *Wildlife Research*, *35*(2), 103-112.

Carrión, A. L. (2007). *Propuesta para El Desarrollo del Ecotourismo Cientifico en El Parque Natural Metropolitano* (Unpublished master's thesis). Universidad de Panama. Retrieved April 13, 2016, from http://www.sibiup.up.ac.pa/bd/captura/upload/917287c23.pdf

Conover, R. R., and Linder, E. T. (2009). Mud track plots: an economical, noninvasive mammal survey technique. *Southeastern Naturalist*, *8*(3), 437-444.

Corlatti, L., Hacklaender, K., and Frey-Roos, F. (2009). Ability of wildlife overpasses to provide connectivity and prevent genetic isolation. *Conservation Biology*, *23*(3), 548-556.

Cortés-Marcial, M., & Briones-Salas, M. (2014). Diversidad, abundancia relativa y patrones de actividad de mamíferos medianos y grandes en una selva seca del Istmo de Tehuantepec, Oaxaca, México. *Revista de Biología Tropical*, *62*(4), 1433-1448.

Cray, H., & D'Avignon, G. A. (2009) Contribution to the Ecological Understanding of Bats in the Natural Metropolitan Park, Panama. McGill University.

Glista, D. J., DeVault, T. L., and DeWoody, J. A. (2009). A review of mitigation measures for reducing wildlife mortality on roadways. *Landscape and Urban Planning*, *91*(1), 1-7.

González-Gallina, A., Benítez-Badillo, G., Rojas-Soto, O. R., & Hidalgo-Mihart, M. G. (2013). The small, the forgotten and the dead: highway impact on vertebrates and its implications for mitigation strategies. *Biodiversity and conservation*, *22*(2), 325-342.

Goosem, M. (2007). Fragmentation impacts caused by roads through rainforests. *Current Science*, *93*(11), 1587-1595.

Lesbarreres, D., & Fahrig, L. (2012). Measures to reduce population fragmentation by roads: what has worked and how do we know?. *Trends in ecology & evolution*, *27*(7), 374-380.

Lyra-Jorge, M. C., Ciocheti, G., Pivello, V. R., & Meirelles, S. T. (2008). Comparing methods for sampling large-and medium-sized mammals: camera traps and track plots. *European Journal of Wildlife Research*, *54*(4), 739-744.

McNaughton, C. (2015). Characteristics of Geoffroy's tamarin (Saguinus geoffroyi) population, demographics, and territory sizes in urban park habitat (Parque Natural Metropolitano, Panama City, Panama). *Independent Study Project (ISP) Collection*, Paper 2276.

Olmos, M. (2016, April 5). *Mud Trap Preparation*. Lecture presented in Panama, El Valle.

Orjuela, O. J., & Jiménez, G. (2004). Estudio de la abundancia relativa para mamíferos en diferentes tipos de coberturas y carretera, finca hacienda cristales, área cerritos-La Virginia, Municipio de Pereira, departamento de Risaralda-Colombia. *Universitas Scientiarum*, *9*, 87-96.

ANAM. (2014). *Quinto informe nacional de biodiversidad de panamá ante el convenio sobre diversidad biológica*. Autoridad Nacional del Ambiente (ANAM).

Ramp, D., & Ben-Ami, D. (2006). The effect of road-based fatalities on the viability of a peri-urban swamp wallaby population. *Journal of Wildlife Management*, *70*(6), 1615-1624.

Ramp, D., Wilson, V. K., and Croft, D. B. (2006). Assessing the impacts of roads in peri-urban reserves: Road-based fatalities and road usage by wildlife in the Royal National Park, New South Wales, Australia. *Biological Conservation*, *129*(3), 348-359.

Rompré, G., Robinson, W. D., and Desrochers, A. (2008). Causes of habitat loss in a Neotropical landscape: The Panama Canal corridor. *Landscape and Urban Planning*, *87*(2), 129-139.

Simonetti, J. A., & Huareco, I. (1999). Uso de huellas para estimar diversidad y abundancia relativa de los mamíferos de la Reserva de la Biosfera-Estación Biológica del Beni, Bolivia. *Mastozoología Neotropical*, *6*(1), 139-144.

Stoner, K. E., & Timm, R. M. (2011). Seasonally dry tropical forest mammals: Adaptations and seasonal patterns. In *Seasonally Dry Tropical Forests* (pp. 85-106). Island Press/Center for Resource Economics.