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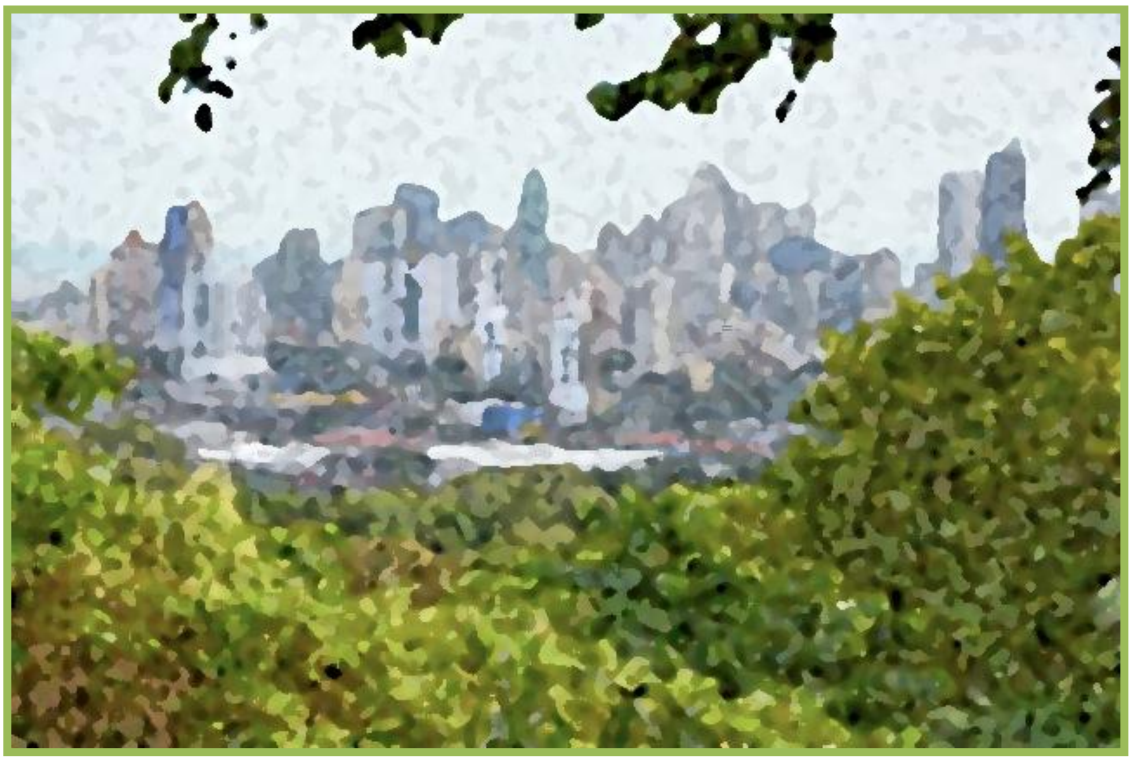
Conservation and Urban Development: Exploring the Impacts of Road Development on Parque Natural Metropolitano



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Panama City has been experiencing incredible levels of economic growth over the past ten years. Economic prosperity in the area has resulted in high levels of immigration from other areas in Panama, leading to high population growth. The city's rapid growth has caused severe traffic congestion problems, which the city has decided to address by improving road infrastructure. Parque Natural Metropolitano (PNM) is a privately owned protected area within city limits that encompasses 232 hectares of tropical dry forest. Their objectives are to protect the biological integrity of the Curundú watershed, conserve the flora and fauna of the park, and facilitate environmental education, recreation and research. The city's growth has posed numerous challenges to PNM, particularly from the improvement of city infrastructure around its limits. For example, Avenida de la Amistad was widened from two lanes to four several years ago, resulting in the loss of some PNM land.

Recently, a new construction project has started on Avenida Ascanio Villalaz that will result in the loss of 2,513.47 m2 of PNM land, plus additional ecological impacts. Three roundabouts, or *rotondas*, will be installed at the Juan Pablo II intersection, the Calle Curundú intersection, and at the PNM service road intersection in front of the University of Panama. Our internship goal was to evaluate the environmental impacts of the project on PNM, and assess how it would affect their ability to meet their stated objectives. Specifically we looked at how the construction would impact the fauna and flora communities living in or near the affected areas, and how the project would affect visitors' experience in PNM.

We used several approaches to assess the three components of our project: impacts to flora, impacts to fauna, and impacts to human visitors generated during and post-construction. To generate predictions on the impacts to flora, we reviewed available literature and accessed local knowledge through PNM employees. To generate predictions on the impacts to fauna, we also reviewed available literature and accessed local knowledge, in addition to taking field data on sound level through the forest. To generate predictions on the impacts to human visitors, we relied mostly on the local knowledge of the PNM staff gathered through semi-structured surveys.

Our research generated several predictions on how the construction project's impacts will affect PNM. The first major impact we predict is evidently the loss of 2,531.47 m2 of PNM land that contains a high level of flora and fauna biodiversity. We predict that there will not be significant long-term impacts to the flora community in PNM from the construction project, although there may be several short-term impacts from increased dust and the elimination of the dense forest edge. We also predict that the fauna community will in general will not be significantly impacted because of their mobility and resilience to noise disturbance, but will likely be

displaced from the local area. The motmot bird (*Momotus momota*), however, will be impacted significantly from the project, due to increased levels of traffic noise at their breeding location. It is likely that human visitors will experience significant impacts from this project. If fauna relocate due to the construction disturbances, the enjoyment humans experience from Sendero los Momotides will be diminished, inhibiting PNM's abilities to meet their educational and recreational objectives. The trail's quality itself will be decreased from increased noise, dust, and the newly visible road may flaw the landscape. Solutions to these problems, such as cutting a new trail to replace Sendero los Momotides, will also cause additional environmental impacts.

It is important that PNM continue monitoring the construction project in order to assess which predicted impacts are the most significant, and identify any new threats that emerge. This study provides PNM with baseline observations and data that can be used to determine the full extent of impacts and inform management decisions during and post-construction. We recommend that PNM continue monitoring the flora and fauna in and around the affected area in order to determine how the construction project affects the community as it progresses. Particularly, the motmot community should be monitored to assess if the construction is disturbing their breeding habitat, by using the sound meter to assess decibel increase and by assessing any changes in the frequency of observation in the area. The frequency of observation of other fauna near the affected area such as sloth, iguana, armadillo and coati should be assessed as well to help further understand which species are most sensitive or resilient to disturbance in their habitat. Additional efforts should be made to limit the establishment of *Saccharum spontaneum* in deforested areas, due to its invasiveness. Finally, PNM staff should evaluate post-construction to what degree the quality of Sendero de los Momotides has decreased, and evaluate if the loss of quality constitutes the creation of a new trail in the area away from the new road edge, despite the additional environmental impacts this would cause. This would allow PNM to continue to work towards their objectives of facilitating environmental education and recreation.

RESUMEN EJECUTIVO – Parque Natural Metropolitano

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La Ciudad de Panamá estaba experimentando crecimiento económico rápido durante los diez años pasados. La prosperidad de la ciudad causaba mucha inmigración en la región, entonces la población está creciendo mucho. Hay problemas de la congestión del tráfico y por eso la Ciudad de Panamá la resolvía por la mejora de las calles. El Parque Natural Metropolitano (PNM) es una área protegida privada al dentro de la Ciudad de Panamá, y tiene 232 hectáreas de bosque seco y tropical. Sus objetivos son proteger el régimen biológico de la cuenca del Curundú, conservar los recursos naturales como la flora y fauna del PNM, y facilitar la educación, recreación y las investigaciones ambientales. El crecimiento de la ciudad plantea desafíos al PNM a causa de proyectos de infraestructura cerca de los límites del PNM. Por ejemplo, la Avenida de la Amistad se ha ensanchado de dos carriles a cuatro carriles algunos años pasado y por esto PNM perdió tierra.

Un nuevo proyecto de construcción empezó en Avenida Ascanio Villalaz que va a requerir 2,513.47 m2 de la tierra de PNM, y va a causar impactos ambientales al parque. Tres rotondas se van a instalar en la intersección con la Avenida Juan Pablo II, en la intersección con la Calle Curundú, y en la intersección con un calle de servicio de PNM enfrente de la universidad de Panamá. Como objetivo de nuestra pasantía, evaluamos los impactos ambientales del proyecto de construcción en el parque, y evaluamos como los impactos van a afectar la capacidad del parque a realizar sus objetivos. Específicamente, estudiamos como la construcción va a afectar las comunidades de la flora y fauna que viven cerca o al dentro de las áreas afectadas, y como el proyecto va a impactar las experiencias de las visitas en PNM.

Utilizamos varios métodos para evaluar las tres partes de nuestro proyecto: los impactos a la flora, los impactos a la fauna, y los impactos a las visitas que van a ocurrir durante y después de la construcción de las rotondas. Para creer las predicciones de los impactos sobre la flora, revisamos la literatura académica y hablamos con los empleos del parque para ganar conocimiento local. Para creer las predicciones de los impactos sobre la fauna, así como antes revisamos la literatura académico y ganamos conocimiento local, y también tenemos datos sobre el nivel del ruido en el bosque. Para creer las predicciones de los impactos sobre las visitas al parque, dependimos sobre el conocimiento local de los empleos al PNM, colectandolos con encuestas escritas.

Creamos varias predicciones de cómo la construcción de las rotondas va a afectar el PNM. El primero impacto importante es la pérdida de 2,513.47 m2 de tierra que tiene un alto nivel de biodiversidad. Predecimos que no va a haber impactos permanentes sobre la comunidad de flora, pero va a haber algunos impactos temporales a causa del polvo y la eliminación del borde tupido del bosque. También predecimos que la construcción no va a causar impactos significativos a la comunidad de fauna, a causa de su movilidad y resiliencia al ruido pero es probable que la fauna va a estar desplazada a causa de la perturbación. Sin embargo, la construcción va a afectar a los momotos, una especie de ave, porque el nivel de ruido va a aumentar en su sitio de cría. Es probable que las visitas se van a afectar por la construcción significativamente. Si la fauna se traslada a causa de la molestia, la experiencia de las visitas va a ser más limitada, y la capacidad de PNM de lograr sus objetivos educacionales y recreativos va a disminuir. La calidad del Sendero de los Momotides va a reducir a causa del ruido, el polvo y el calle visible. Las soluciones por estos problemas, como crear un nuevo sendero para sustituir el Sendero de los Momotides, van a provocar nuevos impactos ambientales.

Es importante que PNM continua a observar la construcción para evaluar cuales predicciones son más significativas, y identificar nuevos problemas. Nuestro proyecto da a PNM algunas observaciones y datos iniciales que pueden utilizar para determinar todos los impactos, y crear planes de atenuación, durante y después la construcción de las rotondas. Recomendamos que PNM continua a vigilar las comunidades de flora y fauna al dentro y cerca de las áreas afectadas para determinar como el proyecto de construcción afecta la ecosistema durante su progresión. Específicamente, la población de momotos se debe observar para evaluar si la construcción interfiere con la cría del ave, para utilizar las medidas del ruido y evaluar si la frecuencia de las observaciones del ave cambia en este lugar. La frecuencia de las observaciones de algunas otras especies de fauna tales como perezosos, iguanas, armadillos y gatos solos se deben evaluar también para entender cuales especies son más sensibles a las perturbaciones ambientales. Necesitamos evitar el establecimiento de *Saccharum spontaneum* en las áreas deforestadas, porque puede invadir muy fácilmente y rápidamente. Finalmente, los empleos de PNM deben evaluar después la construcción como la calidad del Sendero de los Momotides cambia, y si PNM tiene que crear un nuevo sendero más lejos del calle a pesar de impactos ambientales adicionales. Un nuevo sendero puede ayudar PNM a trabajar hacia sus objetivos: facilitar la educación y recreación ambiental.

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MCGILL CODE OF ETHICS

A portion of this project's results relied on information gathered through written surveys and interviews of the employees of Parque Natural Metropolitano. An example of a survey is provided in Appendix 3. All surveys and interviews were performed with free prior informed consent, and were conducted according to the McGill Code of Ethics.

INTRODUCTION

Economic Growth in Panama City

Panama has been growing at an incredible rate in recent years, with the 2011 GDP growth rate estimated to be at 10.6% (CIA Fact Book, 2012). Panama was Latin America's fastest growing regional economy in 2007-2008 and a top regional performer in 2009 (Burn and Santos, 2010). Furthermore, the economy in the *Areas Revertidas*, regions that have been transferred from American to Panamanian control including parts of Panama City, have been projected to have economic growth rates of 8% annually from 2000 to 2020, with the metropolitan areas growing at a rate of 4% (MIVI, 2007). As a result, Panama City has seen an explosion of infrastructural spending, most notably in the construction of the Panama City metro system and the Panama Canal expansion project (Corazón del Latin Dollar, 2011). Additionally, road infrastructure has been the target of recent international investment, such as the recent $70 million secured by the government from the Inter-American Development Bank to finance road rehabilitation and maintenance (EPN Newswire, 2010). This growth is coupled with high levels of immigration to the city from both rural areas in Panama and other nations, resulting in a population boom (Latin Trade, 2011). The economic and human growth in the metropolitan regions in particular will have profound effects on the surrounding environment. Panama's *Ministerio de Vivienda* developed a *Plan del Desarrollo Urbano de las Áreas Metropolitanas del Pacifico y del Atlántico* to manage growth and development in the Panama City and

Colón areas. In this report, it indicates that Panama City has decided to address the growing traffic congestion problem by both increasing road capacity and by encouraging the use of public transport by its citizens (MIVI, 2007). Increasing road capacity has been done systematically through the expansion of the road network, and the widening of existing roads (MIVI, 2007).

Parque Natural Metropolitano

Parque Natural Metropolitano (PNM) is a privately-owned protected area located within the city limits. Founded in 1988, it contains 232 hectares of protected tropical dry forest, and is part of the Corredor Biológico Mesoamérica along with Parque Nacional Camino de Cruces and Parque Nacional Soberanía (PNM website, 2012). PNM is bordered by Avenida de la Amistad to the north, Avenida Ascanio Villalaz to the west and the Corredor Norte to the east, and is also segmented by Avenida Juan Pablo II. PNM a unique protected area both because it is an island ecosystem, and because it contains secondary stands of rare tropical dry forest (Muñoz Harris, interview). The stated objectives of the park as described on the PNM website include:

- Protecting the biological integrity of the Curundu River and the Panama Canal watershed
- Preserving a natural area within the city in order to facilitate outdoor recreation, environmental education and interpretation, and ecological research
- Conserving the natural resources, flora and fauna within PNM

Parque Natural Metropolitano works to meet these objectives by connecting local people to their environment by offering hikes, tours and educational programs, facilitating environmental research, and defending the park against encroachment. The park is privately owned, however, and is limited by available funding. In the past small areas of land have been consensually taken from PNM in order to make improvements to public infrastructure around the protected area (Muñoz Harris, interview). For example, several years ago Avenida de la Amistad was widened from two lanes to four lanes, taking up all land within 25m of the original road from PNM to the south, and Parque Nacional Camino de Cruces to the north (Muñoz Harris, interview). As remuneration for this loss of land, PNM received a financial compensation package and the construction project was refined to include the installation of subterranean and aerial wildlife corridors (Muñoz Harris, interview). PNM was able to use the funding to continue operating programs that help them achieve their objectives, and subterranean and aerial wildlife corridors were constructed to help mitigate some of the negative impacts of this construction project (Muñoz Harris, interview).

PNM is now facing encroachment from a new project, involving the installation of three roundabouts (see Figure 1), along Avenida Ascanio Villalaz at the Via Juan Pablo II/Calle Tomas Gabriel Duque intersection, the Avenida Bulevard Curundú intersection, and at the intersection with a PNM service road, in front of the University of Panama (EIA, 2012). The goal of this project is to reduce traffic congestion in the area by increasing the speed of flow by eliminating traffic lights, and reducing obstructions that occur when drivers perform U-turns in this area (EIA, 2012). PNM will be receiving an undisclosed compensation package for the consensual loss of 2,513.47 m^2 of park land (EIA, 2012). This land consists of four segments of forest edge that will be removed in order to accommodate the size of the roundabouts (correspondingly labeled as Affected Areas 2 through 5 in Figure 1, and discussed in more detail in the section entitled “Study Site”). Affected Area 1 will be lost as well, but is not included in the EIA or PNM’s consent form for unknown reasons. The total area that will be lost including Affected Area 1 is 3,760 m^2 of land. The loss of these areas of land may have significant impacts on the ecological function of the park, and hinder the park’s abilities to achieve its objectives.

Our Project

Our project at PNM is within the context of the construction project mentioned in the previous section. Since the construction of the roundabouts did not begin in earnest until we had finished our project, we decided to focus on making sound predictions about what these impacts would be, by performing a literature review, accessing local knowledge, and taking baseline measurements that the park would be able to repeat post-construction in order to evaluate any changes.

As previously mentioned, the construction of the roundabouts will present a loss to the park of 2,513.47 squared meters of land. It is important to consider other possible impacts that the construction will have on the park’s ecosystem, in addition to the terrain loss. There may be temporary impacts that occur during the course of construction which may last several months, and permanent impacts that persist after the construction is done. In order to approach this complex situation, we divided our study into three main components, evaluating different aspects of the park system.

Firstly, we evaluated the flora of the region. Our objective was to discover which major species inhabit the affected areas, and to discover how significant species and the plant community in general will be affected by the construction. Special emphasis is placed in this section on woody bamboo (genus *Bambusa*), which is said to be quite rare in and around the affected area, and *Saccharum spontaneum*, a highly invasive grass species (Muñoz Harris, interview).

Secondly, we evaluated the fauna species of the region. We accessed local knowledge to determine the species that are frequently observed in the affected areas, and then performed a literature review in order to obtain information about their sensitivities and their habitat requirements. In this way, we evaluated whether the construction will inhibit their ability to live in or near the affected area, either from noise or dust pollution generated during construction or from post-construction effects. Focus in this section was placed on the blue-crowned motmot (*Momotus momota*), a bird that is said to reproduce very close to Affected Area 3 (Figure 1) (Gómez, interview).

The third aspect we evaluated how the construction project would impact human visitors. As has been alluded to previously, PNM hosts a wide variety of visitors to the park on a regular basis. Our goal in this section was to evaluate how the construction process will detract from the visitors' experience in the park, and to evaluate how the park could address these challenges in order to continue meeting their objectives by delivering environmental programs.

The ultimate goal of this project is to predict the overall impact of the construction project on the park, so that we may present this information to PNM in the hopes it will help them to develop mitigation plans against current impacts and prepare for future similar projects. This is important in order to minimize the impacts of Panama City's development on PNM, so that they may continue achieving their goals of education and conservation in the future. Our project is limited to generating predictions and baseline data because the construction project has not yet begun as of the end of project. We therefore cannot generate hard data as to what the effects will be, or quantify the impact of the project. We focus instead on predicting possible impacts, and providing recommendations as to how PNM may begin to address or mitigate these effects.

Study Site

Our assessment covers the 5 areas of forest that will be affected and their surrounding areas, each directly adjacent to the existing Avenida Ascanio Villalaz that borders the west side of the park. In total, these areas account for approximately 3761 m2 of forest along approximately 500 m of Avenida Ascanio Villalaz. These areas were calculated from both measurements taken in the field and measurements described on the site map (Figure 1), and are represented using a map generated from QGIS and Google Earth software. It should be noted, however, that Affected Area 1 is not accounted for in the EIA. The total area being mentioned by the construction company, as stated by them in the EIA, measures 2513 m^2 (0.0025 km^2). The ownership status of Affected Area 1 is unknown, however because it is continuous with PNM, its loss will affect the ecosystem in question, and we are therefore including it in our report. Each area is currently bordered by a short (1-5m) transition zone of grass and a 1m-wide drainage ditch running parallel to the road. The distinction between the forest and transition zone is clearly defined – it occurs over less than 0.5 metres in all cases. Each affected area extends no more than 20m into the forest.

SECTION 1: IMPACTS TO FLORA

1.1: Methods

The plant communities of the affected areas were assessed through consultation with a park expert on Flora and Fauna, Sixto Chani, and through direct census of the affected areas. With the help of expert knowledge and review of appropriate literature, we identified significant species and generated predictions on how these species, as well as the plant community in general, will be impacted by the construction project.

1.2: Results and Discussion

1.2.1: General Impacts to Flora

The construction project's infringement on the forest could have many implications for the flora in the area. The purpose of this section is to outline the results of our literature review with respect to these impacts.

Forest edge effects have been studied extensively, establishing that the construction of a road has strong ecological impacts on the area it runs through. It is important to note, however, that negative impacts to the forest because of the nearby road are already being experienced in the area, and so we seek to establish what the new, additional impacts will be due to the expansion. It is clear that once the project is complete, current impacts on the flora from the road will continue to occur, albeit back several meters. Generally, projects that improve roads have significantly less impact on their surrounding environment than the original creation of said roads (Nelson et al., 2004). Evidence shows that Panamanian forests have very different microclimatic conditions between the forest edge and interior, with forest edges tending to be slightly warmer, windier and less humid (Williams-Linera, 1990). The construction project will result in the forest edge being pushed back several meters, up to 20m at the second roundabout. Likely this will not significantly impact species composition in the area, as species currently located in the edge will relocate to the new edge. However, the microclimate of the interior of the forest could be impacted for several years because it is the dense vegetation growing at the edge that insulates the interior and generates the cooler, less windy, more humid conditions (Williams-Linera, 1990). Within five years the vegetation at the new edge will develop to the density that existed at the old edge; until that point, the microclimate change in the forest near the edge could cause impacts to established vegetation, including increased mortality (Williams-Linera, 1990; Prasad, 2009). Tree mortality near roads can be 2.5 times greater than average dry tropical forest mortality due to microclimate changes and other impacts, showing how the vegetation outside the affected area may still be severely impacted (Prasad, 2009).

During the construction process, additional impacts to vegetation may be observed, with their severity dependent on what mitigation strategies are used and enforced by the construction company. For example, excessive or unnecessary removal of vegetation cover will increase erosion and construction equipment may leak contaminants such as oil or gasoline into the soil

(Southerland, 1994).

Dust generated during the construction process also poses a threat to vegetation near the affected area. Dust can smother leaves by blocking the stomata, however the degree of impact is highly dependent on the dust particle size and so is difficult to predict (Farmer, 1991). Paved roads, like Avenida Ascanio Villalaz, produce mean air dust concentrations of 463 µg/m3 for an average daily traffic of 18,000 vehicles. Unpaved roads produce dust at much higher levels, like 584 µg/m3 for an average daily traffic of only 250 vehicles. Deposition away from the road decreases logarithmically resulting in wide dispersal, and can affect forests by reducing plants' photosynthesis rates and increasing their susceptibility to drought (Farmer, 1991). All these impacts would be temporary, as it is unlikely that after the construction is finished the new road will generate higher levels of dust than the old road. In fact, the third *rotonda* will eliminate trucks and cars performing U-turns on the gravel road leading into the south end of PNM, reducing the level of road dust. However it is uncertain to what degree, and how long, higher levels of dust from construction will continue to impact the vegetation outside the affected area.

Post-construction, it is uncertain whether air pollution levels will increase or decrease, because more vehicles will pass through the area but there will be less idling due to increased fluidity. There is evidence, however, that the emissions emitted by vehicles, particularly gaseous nitrogen, can change vegetation composition over a significant area adjacent to the road (Forman & Alexander, 1998).

Our study of the area's flora relied heavily on local knowledge, provided by Sn. Sixto Chani, a head biologist of the park. He identified over 92 species of trees and plants growing in the affected areas, which shows the high level of biodiversity in the park. The affected areas are very well developed, with many large mature trees including *espave* (*Anacardium occidentalis*) and *inajero* (*Cordia panamensis*). The area supports a large variety of fauna in all areas of the forest, such as iguana and sloth in the canopy, armadillos and coatis in the understory, and birds in the edge areas (Chani, interview). The loss of this habitat is detrimental to the park in and of itself. The areas that will be eliminated, however, are composed of vegetation that is also found in the surrounding areas, indicating that their destruction likely will not eliminate any biological resources required for certain species' survival. Most likely, animals in this area will be displaced into surrounding areas in the park, and since the area lost is quite small compared to the size of the park this should not significantly overstress available resources.

1.2.2: Saccharum Spontaneum

One of our specific species of concern in near the affected areas is *Saccharum spontaneum*, a species of invasive grass that commonly invades deforested areas in Panama. It is highly competitive against native tree saplings, allowing it to dominate in deforested areas before trees have a chance to grow back and completely shifting the natural regime of an area from forest to grassland (Hooper et al 2005). The third affected area at the second roundabout site, at the Calle Curundú intersection, already has some patches of *S. spontaneum*, and since this species is more prone to fire, the area is now considered a 'fire risk' site at PNM (Gómez, interview). *S. spontaneum* is highly resistant to fire because it regenerates quickly, also helping it to out-compete neighboring forests that may be destroyed by a passing fire (Hooper et al., 2005). If the construction project results in the deforestation of land that is then not covered in pavement when the roundabout is built, this land will likely be prone to an *S. spontaneum* establishment, increasing the risk of fire in the area, facilitating the spread of an invasive species, and providing a source of *S. spontaneum* from which seeds could establish in gaps near the edge in PNM, increasing the spread into the park. The best way to combat *S. spontaneum* invasion is through shade, which inhibits the growth of the plant (Hooper et al 2005). It is therefore essential that only the land required for the project is deforested, and if excess cover is lost that it be re-established as quickly as possible after the construction is done to create shade in the area to prevent a grass invasion.

1.2.3: Bamboo

Another notable plant species that is present in PNM is bamboo. We noticed that a particular species of woody bamboo (genus *Bambusa*) seems particularly rare in and around the affected areas of the park. In fact, there seem to be only three individual clumps, one of which is located within the Affected Area near the second roundabout (Affected Area 3, see Figure 1), and the other two of which are located close to the entrance of Sendero Los

Momotides (Muñoz Harris, interview). As part of our investigation, we wanted to study the sensitivity of bamboo to disturbance, in order to assess what impact the construction will have on it and the ecological functions it fulfills. In this section we present a brief overview of the structure and ecological function of woody bamboos, as well as present predictions about the consequences of the construction on their ability to serve this role.

Bamboo is a forest grass that is highly diversified. The bamboos (Bambusoideae) can be divided into two classes: the Bambuseae (the woody bamboos) and the Olyreae (herbaceous bamboos) (Judziewicz, Clark, Londoño & Stern, 1999). For our purposes, we will focus on the former group.

The general structure of bamboos (more notably in the woody bamboos) consists of the roots, the rhizome and the culm (Judziewicz et al., 1999). The rhizomes are complete underground stems, or the basal portions of stems, and they support the aerial stems, store food reserves, and function in vegetative reproduction (Judziewicz). This is also where the branching of the plant occurs (Judziewicz). The culms are the segmented aerial vegetative axis of the plant (Judziewicz). A segment consists of a node, which contains a bud that will develop into a leaf, and an internode, the space between two nodes (Judziewicz). When the culm is thicker than the rhizome proper, the rhizome is said to be leptomorph; when the rhizome proper is thicker than the culm, it is said to be pachymorph (Judziewicz). This concept will be important later in this section.

It is important to note that the culms and rhizomes of a bamboo individual form a dense network of interconnected segments and axes (Judziewicz et al., 1999). Therefore, when one encounters a dense clump of bamboo stems (such as those that are seen in PNM), these most likely represent one individual. New culm shoot development is usually initiated in the rainy season, and any given culm is usually said to live approximately 10 years (Judziewicz). The above-ground growth rate of shoots is said to be quite high, however shoots have a high mortality rate in the first year of growth before the culms are hardened (Judziewicz).

Bamboos, as has been mentioned, have dense networks of underground rhizomes, facilitating horizontal spread and sometimes aggressive expansion (Judziewicz et al., 1999). Their high growth rate also means that they are able to grow quickly enough to block out light and prevent growth of other plant species (Judziewicz). This has been provided as an explanation to why they are prevalent at the edges of forests; they are often the first responders to forest disturbance. Furthermore, those plants with leptomorph rhizomes (i.e. those whose culms are thicker than the rhizome) are able to cover long distances underground (Judziewicz). In this way they are able to seek out suitable microhabitats for culm growth, such as gaps (Judziewicz). In addition, bamboos continue to grow new rhizomes throughout their lives (Judziewicz).

From the information mentioned above, it can be reasonably concluded that the bamboo plant is an extremely resilient organism that is able to adapt to its local environment with ease. From these findings it is possible to make predictions about the fate of the bamboos located in and near the affected areas of the park. In terms of disturbances to the bamboo habitat, there is only one bamboo clump that is going to be cut down entirely due to the construction (located within Affected Area 3). It is reasonable in this case to conclude that the individual that is being cut down may in fact survive. Because of the high ability to translocate rhizome growth, the individual may be able to translocate a short distance to what will be the new edge of the park, and regenerate culms in this area. How long it will take the plant to regrow to its former size is unclear.

Now that we have considered the adaptability of the bamboo plant itself, it is important to consider its place in an ecological context. In particular, we would like to consider interactions that bamboo may have with animal species.

There are many known cases of specialization in animals for living in or on bamboos. One of these specializations includes inhabiting bamboos for protection from predation, parasitism, and weather conditions (Judziewicz et al., 1999). For instance, in the Amazon there is exists an obligate bamboo specialist called the bamboo rat (*Dactylomys dactylinus*), which is entirely dependent on bamboo stands for protection from predation as well as rain and wind (Judziewicz). It is unknown whether this same species exists in PNM, but there exists the possibility that other animals exist that are at least partially dependent on bamboo stands for these purposes. Animals can also use them as a food source by eating the tender leaves, new shoots or seeds, or to build nests (Judziewicz). Examples have been given of animals that feed in such a manner, some of which are known to exist in PNM: The agouti (*Dasyprocta sp.*), and the nine-banded long-nosed armadillo (*Dasypus novemcinctus*), among others, have been known to feed on bamboo fruits on the forest floor after a flowering event (Judziewicz). It should be noted, however, that it is unlikely these fruits are necessary for the survival of these animals.

In addition to animals that are dependent on bamboo in this way, there are also species that actually live inside the water-filled internodes of the bamboo. These macrofauna mostly consist of mosquitoes, flies and other waterborne insects, however it has been found that some species of spider, beetle, ant, and even frog and snake are said to occupy the internodes of bamboo (Judziewicz). They are provided a constant source of water, as well as protection by the plant (Judziewicz). These aquatic habitats are called phytotelmata, and occur in many other plants as well. However, the phytotelmata in bamboo are distinct in that the microhabitat is provided year-round, as the water habitat is produced by secretions of the bamboo rather than precipitation, as seen in phytotelmata of tree holes or the like (Judziewicz). The advantage of this water to the plant is two-fold: it provides constant water to the bamboo plant (as the water is stored within the internodes for later use), and the detritus material generated from the insects inhabiting the plant provide it with a source of nutrients (Judziewicz). It is possible that his discrete water habitat has allowed for the development of fauna that are highly specialized to this environment. This may limit their ability to adapt to a new environment if the bamboo is destroyed. However, if these species are existent in the bamboo stands of PNM, then it is possible that they exist in the rhizomes as well. Whereas the culms will be destroyed as a result of the project, the rhizomes may still be intact, and the fauna species therein may survive within the park. Given the aforementioned resiliency of the bamboo, they may also be transported to a new, more suitable microenvironment, although it remains unclear to what extent this resiliency will apply in this particular construction project.

The results of our investigation may have left us with more questions about the status of bamboos in PNM than answers. Given the previous research, it is clear that there is some resiliency and flexibility within the bamboos, but it is unclear to what extent this resiliency will aid in the reestablishment of the bamboo stand that will be cut down in the affected area and the microfauna that inhabit it. It is also unclear to what extent this bamboo stand provides essential functions to the ecosystem. Further research is needed on the part of the park to determine which species are dependent on this stand, and whether these species will be negatively impacted by the ongoing construction.

SECTION 2: IMPACTS TO FAUNA

2.1: Methods

Information concerning fauna in the park was gained mainly by surveying the forest guards and Sixto Chani. Rather than attempt to census fauna seen within the limited affected areas, we tried to understand the general composition and location of animals within the park. We looked at how the impacts generated by the actual construction process itself, such as noise and dust, would impact local species through a literature review. Impacts to fauna were also assessed by qualifying the ecosystem services that the affected areas provide to animal species and searching for unique habitat features that may not be easily found elsewhere in the park. Specifically, we examined the literature concerning the reproductive needs of the blue-crowned motmot. The employees of the park identified an embankment near Affected Area 3 that provides a unique location for motmot reproduction (See Figure 1); we addressed this concern by evaluating the affected area with reference to the information provided by the literature. We investigated ambient noise level trends in the area in order to generate predictions on how noise levels will change around the motmot breeding area post-construction, and how this will affect the population.

2.1.1: Baseline Noise Level Measurements

We recorded measurements of the noise level up to 80m back into the forest from Calle Curundú. These measurements are considered baseline as they were taken before construction had begun and represent data from an average day of use. Measurements were taken with Digital Sound Level Metre, using a built-in function that takes a running average over 200 seconds; maximum and minimum readings were also taken over each 200 second sample. Two transects were made in the central affected area (Affected Area 3) running into the forest at right angles to the road, and samples were taken every 10 metres from 0m up to and including 80m. Post-collection, data from both transects was averaged and compiled to form one trend line for average noise level, maximum noise level and minimum noise level. The averaged data was also used to construct a noise-absorption value for each 10m interval. This data was compiled and graphed using Microsoft Excel.

2.2: Results and Discussion

2.2.1: General Fauna Impacts

Parque Natural Metropolitano is host to an immense variety of fauna species. Included in these are 45 species of mammal, and 254 species of birds, amphibians and reptiles (PNM website, 2012). It has been estimated that approximately 13 species of mammal, 17 species of bird, 8 species of reptile and 5 species of amphibians are likely to spend part of their time in the impacted area of the park itself (EIA, 2012). In this section, we explore the possible impacts of the construction of the roundabouts on these species, with particular emphasis on the blue-crowned motmot.

The impacts of road construction on fauna have been well documented, though the data that exists often refers to new roads that cut through existing forest, creating fragments. The situation created from the construction project in question is different from this in the sense that the already-existing edge of the forest is simply going to be extended farther into PNM, as opposed any additional fragmentation of the forest.

One consequence to consider of the construction of the roundabouts is habitat destruction. Within the affected areas of the park there exist numerous trees and other large woody plants like bamboos that are going to be cut down. As noted in the impact assessment completed by the construction company, there are species such as sloths, bats, and other mammals that are found in or around the affected area (EIA, 2011). These species are reliant on mature trees as part of their habitat, and so may be negatively affected by the cutting of large trees in the affected area. It is also important to consider the effect of the destruction of the bamboo stand mentioned previously. As bamboo is considered to be rare in and around the affected area (Muñoz Harris, interview), any animals that are dependent on this stand for their habitat may be significantly affected.

Despite future habitat degradation in and around the affected area, there exists variability in species' sensitivity to habitat disturbance. Sloths, for instance, live primarily in the canopy levels of a forest (Barrios, interview). Therefore, a reduction in the amount of trees in the forest may negatively impact it. However, animals like the armadillo (Gammons et al., 2009) and the coati (Beisiegel et al., 2006) do not seem to exhibit much habitat selection at all, and therefore may be more flexible in their ability to adapt to disturbance. According to Suárez-Domínguez et al. (2011), the iguana is another animal that does not appear to be very sensitive to disturbance. They found that resting, feeding, locomotion, aggression, and other behaviours were not significantly different between human-disturbed forest habitats and conserved areas, and they also found no significant differences in stress hormone levels (Suárez-Domínguez et al., 2011).

It is difficult to form predictions with regards to the effects of this habitat destruction on the populations of these animals and on the ecosystems in general. On the one hand, one can consider that the area being destroyed is relatively small. Given that the trees that are located in the affected areas are not the only ones of their species, it is quite likely that the animals located therein will be able to relocate to other adjacent areas in the park. However, it is important to consider the fact that construction of Avenida Juan Pablo 2 has created an ecological island to the south of it. The ecology of areas such as these tends to be highly chaotic and unstable. Effective “nibbling away” at such an ecosystem, as described by the US Environmental Protection Agency, can produce a result in which the overall effect is greater than the sum of its parts (Southerland, 1994). However unlikely it is that this project will push the ecosystem over the edge into collapse, one must take into consideration the incremental changes caused by multiple encroachments to the ecosystem over time.

One other important danger to consider for animals living in the area is road-related mortality. Since 1970, roadkill has overtaken hunting as the leading cause of human-related vertebrate death on land, and an estimated 1 million vertebrates are killed each year in this way in the United States (Forman et al., 1998). The reasons for which animals might venture into a road include attraction to spilled grain, small mammals, or dead animals, among others (Foreman et al.).

We predict in this report that the amount of roadkill occurrences in this area of PNM will increase as a result of the construction of the roundabouts. As previously mentioned, the main reason for the construction project is to reduce traffic congestion in the area. As a result of the elimination of traffic lights, we believe that the overall speed of vehicles moving through the area will be increased. It has been shown that even slight increases in the average speed of vehicles can have dramatic effects on roadkill rates (McGhee, 2006). During a study of the population of quolls in Tasmania, after sharp turns were eliminated in a road, the vehicle speed rose from 40-60 km/h to 60-80 km/h (McGhee). This all but eliminated the population of quolls in the area, but after measures were taken to reduce the speed of vehicles on the road, the population immediately began to recover (McGhee). One can see from this example the dramatic impact that increasing vehicle speed can have on animal populations close to roads, due to the inability of drivers to respond to wildlife quickly. If measures can be taken to reduce car speed in the area following the construction of the roundabouts, this increase in roadkill rates may be avoided.

*2.2.2: The Blue-Crowned Motmot (*Momotus momota*)*

Particular emphasis in this section must be placed on one particular species that we believe will be negatively impacted by the construction of the roundabouts: the blue-crowned motmot (*Momotus momota*). A member of the order coraciiformes, the genus *Momotus* is primarily located in Central and South America, as well as eastern Mexico (Skutch, 1963). It is 16 inches in length, and is characterized by a black crown bordered all the way around by blue plumage, and has two spatulate tips on the end of its elongated tail feathers. The bird characteristically swings its tail from side to side like a metronome, and the behaviour possibly involved in mating (Canaday & Jost, 1997).

One of the most important and relevant characteristics of the blue-crowned motmot to our study is its nesting behaviour. It tends to build its nests by burrowing into steep soil embankments, and generally lays approximately three eggs at a time (Skutch, 1963). The burrow is dug in the rainy season because the soil is soft and easier to remove, it takes approximately two months to completely dig, and the incubation of the eggs lasts approximately three weeks (Skutch).

The reason for our interest in the motmot is that such a vertical embankment is present at a very close distance to the road. It is currently located approximately 80 m from the road, running almost parallel to it. When the construction has ended, the embankment will be located around 60 m from the road, which is significantly closer. This is currently the only known location in the park where the motmot is said to reproduce (Chani, interview; Gomez, interview). The main concern for the motmot's ability to continue reproducing in this area is the increased amount of noise that will likely be present after the construction of the roundabouts.

The effect of road noise on the behavior of birds has been previously investigated. Those animals that are dependent on sound for communication, like the motmot, are particularly affected by ambient noise (Arevalo et al., 2011). Birds generally use their calls and songs to attract mates, defend their territory from rivals, maintain contact with their flock, and warn of danger from approaching predators (Parris et al., 2009). Naturally occurring noise is common in forests, and there are a variety of strategies that exist among birds to increase the active space of their call in response to this. However in addition to this naturally occurring noise, birds whose habitat is located next to a road have the additional obstacle of noise from passing traffic to contend with. If the frequency of the road noise is in the same spectral region as the frequency of the bird's call, a phenomenon called masking can occur wherein the call of the bird is interfered with by the road noise (Arévalo et al., 2011). This can reduce the reproductive success of the bird, as their call is not able to reach far enough to attract a mate (Parris et al., 2009). It has been demonstrated in previous studies on the *Momotus* genus that their calls generally lie within the range of approximately 300-550 Hz (Stiles, 2009), and that road noise generally lies below 2,000 Hz, in a similar enough spectral region to the motmot's call to potentially cause interference (Parris et al., 2009).

Bird species richness and abundance has also been found to decrease with increasing road noise, and this effect can be seen at remarkably low noise levels, the most noise-sensitive species decreasing in abundance at only 35 dB (Arévalo et al., 2011; Forman et al., 1998). The reasons proposed to cause this decrease in abundance include hearing loss, increase in stress hormones, deleterious effects on food supply (vibrational effects have been noted on the abundance of earthworms close to roads, for instance), and the above mentioned inhibition of reproduction (Forman et al).

2.2.2.1: Baseline Noise Level Measurements

To address the issue of the motmot and the increased proximity of its breeding site to what will be the new forest edge, we conducted a survey of noise levels within the affected area close to the breeding embankment. In gathering this information, we hope to provide baseline and referential measurements that PNM will be able to use and repeat after the construction period. In evaluating the change in noise levels pre- and post-construction, the park will be able to make accurate predictions concerning the effect on the bird's population.

The results of our noise level observations are summarized in Figure 2 and Figure 3 (See Appendix 1). Figure 2 displays the capacity of the forest cover to absorb noise at each 10 m interval away from the road; the values are percentages of noise reduction for each interval based on the 74 dB average reading at the road (0 m). Figure 3 displays the straight sound level data, with a trend line for maximum recorded, average recorded and minimum recorded. Generally, we saw almost a 20% reduction in average noise level at 80m into the forest, falling from 74.5 dB to 61.5 dB. Importantly, this is accompanied by an even greater reduction in maximum noise level, falling from 90 dB to 70 dB. The trends observed are linear; average noise experiences an arithmetic decline of approximately 1.9 dB per 10m, while maximum and minimum nose levels declined at a rate of approximately 2.5 dB per 10m. We also observed that thicker undergrowth, bamboo stands and other dense vegetation features dissipated noise more effectively. From measurements deeper into the forest and on the trails, we estimate the natural ambient noise level of the park to be between 55-60 dB.

This data is extremely important in assessing the impact of the construction project. Most tropical forests are populated with fauna that can be roughly distributed within three categories: those that are highly sensitive to noise levels such as the motmot, those that are indifferent to noise levels, and those that have an affinity for higher noise levels like the squirrel monkey, or *mono titi* (Trombluak et al, 2000). Within 50 m of the road, the noise levels (taking into account the maximum values) are above what many sources have described as disturbing for noise-sensitive species (Trombulak et al, 2000; Skutch, 1964; Malcolm, 1994; Coffin, 2007). At 80m, noise levels are approximately within the range of natural ambient noise, barring occasional spikes, and would likely not be overly disruptive even to sound-sensitive species.

Currently, the breeding grounds for the local motmot population is located on an embankment starting at 80m from the road, so the sound levels observed there are evidently not high enough to disturb their activities to a noticeable degree. However, as the embankment is located near one of the affected areas (Affected Area 3), the road will be up to 20m closer once the roundabout has been built. During construction all noise levels will likely be higher, which may displace or halt motmot breeding activity in the area. Once construction is completed, noise may or may not return to its current level, but it will penetrate deeper into the motmot breeding grounds as they will be around 60 m from the road. Based on our observations, we would expect the maximum noise level to be well above 70 dB and the average noise level to be above 65 dB. At this point it would be extremely valuable for PNM or other stakeholders to conduct another round of observations to determine the exact magnitude of the noise increase. Since it is believed that this embankment is the primary breeding ground used by the motmots in PNM, it is unclear whether an alternative could be easily found in PNM if the motmots abandon the breeding location.

It should be noted that the Digital Sound Level Metre used to record the measurements is only able to record within a 20 dB range at any given moment. For this reason, maximum and minimum values may not adequately represent the real full range of noise levels. For example, we expect that the maximum noise level at 0 metres is closer to 100 dB than 90 and the minimum is lower than 70. However, as distance into the forest increases, the variability declines. At 80 metres, there are rarely values above 70 dB. Therefore, we believe that our observations accurately represent the general trend, if not the exact range of values.

SECTION 3: IMPACTS TO HUMAN VISITORS

3.1: Methods

Research into the possible human-oriented impacts of the construction was accomplished by surveying PNM employees concerning visitor experiences and the importance of the regions near the affected areas for environmental education programs. We used a written survey with a variety of close- or open-ended questions related to the visitor experience in the park, fauna commonly seen in the regions near the affected areas and the employees own opinions on the construction project impacts (See Appendix 3). We interviewed three employees who are familiar with the education programs and the trails in order to gain insight into how the employees feel the construction will impact the park. This is a small sample size, but the intention was not to perform any technical analysis of the responses but rather develop a better idea of what future problems the employees are anticipating. The results of the distributed survey were the main informing factor of our assessment of human impacts.

3.2: Results and Discussion

Sendero Los Momotides is the walking trail that runs closest to the affected area, and is frequently used for environmental education programs (Muñoz Harris, interview) (See Figures 1 & 4). The trail is the most accessible to young children because it is the shortest full circuit at 0.9 kilometres, and the terrain is very flat (See Figure 1). The trail runs through the woods several metres back from the embankment. After construction is completed on the second roundabout (Affected Area 3), the buffer zone between the trail and the edge of the park will be reduced from approximately 90 metres to 70 metres. This could have significant impacts on how human visitors to the park experience the trail.

To understand further the potential impacts of reducing the distance between the road edge and Sendero los Momotides, we conducted a semi-structured survey of several of the employees of the park. We interviewed three employees who are familiar with the education programs and the trails in order to gain insight into how the employees feel the construction will impact the park. This is a small sample size, but the intention was not to perform any technical analysis of the responses but rather develop a better idea of what future problems the employees are anticipating. Sixteen questions of a variety of formats were asked to participants, to which they provided written responses (See Appendix 3).

The current state of Sendero los Momotides was described as already being affected due to its close proximity to the road, but still provides a positive experience to park visitors. A moderate level of noise and dust is already present along this trail that decreases visitors' enjoyment, however they also observe many birds such as motmots in this part of the park. Respondents also reported that several species of animals were commonly seen in this area, including ñeques, sloths, coatis, and armadillos.

It is anticipated by the park employees that the noise levels will continue to increase, decreasing the quality of the trail. Employees predict that with the road expanding into an area commonly thought to be bird habitat, the quantity of birds such as the motmot will decrease, reducing visitors' contact with the park's species. The park employees also are concerned that the roundabouts will increase traffic in the area because of the decreased congestion, increasing the level of particulate pollution. They indicated as well that increased traffic velocity might increase the frequency of cars hitting and killing animals.
Tracking how the road's expansion impacts local animal communities is essential to understanding how the construction will impact the human visitors' experiences in the park. Employees feel that the effectiveness of the education programs and conservation promotion in general are dependent on visitors seeing or hearing wildlife; this creates an emotional connection between the individual and the area or species the park is trying to protect.

Our research suggests that many of the employees' fears may be well founded, whereas other may not materialize. The air is dustier near roads, but unpaved roads produce more dust than paved roads (Coffin, 2007). The construction of the third roundabout will reduce the number of cars turning around on the unpaved road cutting into the park, potentially reducing dust. Additionally, increasing traffic fluidity may increase the amount of cars passing by the park, but by eliminating traffic lights cars will no longer be idling for significant periods of time in the area, reducing the total emissions in the area. There is some research, however, that suggests that even moderate increases in car velocity may result in significantly higher frequencies of animal deaths from car collisions (McGhee, 2006). Additionally, birds are the most affected by increases in noise pollution as they incorporate sound into their communication behavior, and since the motmots and other bird species are commonly found in this part of the park, increases in sound generated by traffic may disproportionately affect these birds (Coffin, 2007).

Perhaps the most damaging impact to this trail will be aesthetic loss when the road becomes much more visible to human visitors from the trail. Although Sendero los Momotides is already experiencing noise and dust impacts from the road, after construction it is possible that the road will be visible from the path. If this turns out to be the case, the road will no longer be as valuable to the park for educational programs and tours because part of the appeal of taking a hike on a nature trail is the intangible feeling of ‘getting away from it all’. It was indicated to us that if this ends up being the case, there is a possibility that a new replacement trail would be cut through the area (Chani, interview). This would allow the park to continue taking advantage of this area’s close proximity to the offices and the accessible terrain for children’s programs and others who are less physically able. This will result in increased habitat disturbance and fragmentation by clearing another route through the forest. Reducing the size of the park’s area south of Avenida Juan Pablo II because of the roundabouts’ construction in addition to increased fragmentation of the area from the cutting of new trails, all could decrease the area’s capacity to support animal populations at their current sizes which would also impact the park experience.

CONCLUSIONS AND RECOMMENDATIONS

Summary

Likely the construction of the three roundabouts beside Parque Natural Metropolitano will have certain specific impacts on the ecosystem of the surrounding areas, and may challenge PNM's ability to achieve their objectives. We predict a number of short- and long-term impacts, related to the flora, fauna, overall ecosystem and human visitors to the area:

- *S. spontaneum*'s establishment in PNM may be facilitated by the deforestation of the affected areas, compromising the local ecosystem and elevating the fire risk.
- The loss of the dense forest edge may alter the microclimate of the forest near the affected areas, becoming warmer, windier and less humid, compromising the ability of the present vegetation to subsist until the new edge has redeveloped.
- Increased levels of dust generated during construction may inhibit the photosynthesis of plants near the affected areas, although the levels may again decrease post-construction.
- Loss of vegetation and increased dust and noise may result in an exodus of fauna from the forest near the affected areas into other areas of PNM.
- Increased levels of noise in the forest both during and post-construction may disturb the motmot community, provoking them to abandon their

breeding embankment. It is uncertain if the motmots will remain in the park at another breeding site or leave to a site outside of PNM.

- The combination of the displacement of the fauna, the loss of the motmots, and the increased levels of noise and dust will all diminish the quality of Sendero los Momotides for human visitors, inhibiting their ability to deliver outdoor education and recreational programs. If the quality loss is significant enough, a new trail may have to be cut in the same area despite additional environmental damage in order to make sure PNM still has a shorter, easier trail accessible to young and elderly people in order to continue delivering their programs.

Problems Faced and Limitations

As with any other project in the field, this study has had its limitations that needed to be overcome throughout the duration of the project.

The first limitation of our study was lack of time. The construction of the roundabouts in question has still not begun in earnest, and so for our project is was not feasible to take more extensive field data. At the beginning of the semester, we had set out in our plan to have courses of measurement of various variables both before and during the construction of the roundabouts, in order to measure the impacts to the forest during construction (e.g. Noise, dust and disturbance observations). However, during our time in Panama the only construction activity observed was the placement of fences and some preliminary manual digging along the edge. Because construction never actually started, it was impossible to measure the actual impacts that these roundabouts were having. It would have been much easier for us to make recommendations to the park as to possible mitigation measures that can be employed for future projects if we were able to measure the impacts ourselves. Instead, we were limited to a literature review to evaluate the possible effects that roads generally have on tropical forest ecology, which limited the amount to which we could specialize our research to PNM.

Another limitation that we faced in our study was with the information provided to us about the project itself. The construction company had provided the park with a blueprint outlining the area and dimensions of the affected areas, and had also placed a number of stakes in the affected areas. However, the stakes were often placed contradictorily to the blueprint, and indicated an area (Affected Area 1) that was not even represented in the blueprint. We still do not have a comprehensive estimate of the total affected area, nor do we know whether the construction plans have been modified. It was extremely difficult to consolidate the information that was available to us in a coherent manner; the measurements that are referred to in the report are those that were taken by our team in the field. We also had no GIS data for the area, which made it much more difficult to construct a reference map and estimate the total affected area.

A final limitation that we faced, one that is likely held in common between most of the internship projects, was lack of technical expertise. We did not have the expertise to take accurate field observations on flora and fauna because we could not reliably identify what we were observing. This prevented us from doing a true census of the flora and fauna of the area. Sixto Chani was extraordinarily helpful in this respect, but it was not reasonable for us to have him conduct a full census on our behalf.

Recommendations

The benefits of this research depend heavily on continuing observation and data collection. Our aim is to provide PNM with baseline and reference data that they may use to determine impacts and inform management decisions once construction has begun and once it is completed. We recommend that PNM continue monitoring the vegetation near the affected areas, the integrity of the motmot population and breeding embankment near Affected Area 3, noise levels around the affected area, and any degradation of the quality of Sendero de los Momotides.

Further investigations into the flora near the affected areas should focus on key species, such as bamboo and the invasive grass *Saccharum spontaneum*, and we recommend continued monitoring of the overall health of the vegetation with increased dust levels and an altered microclimate. After the elimination of at least one large bamboo stand within the affected areas, the reestablishment of bamboo could prove to be a very important factor in the ecology of the park, so efforts to evaluate the ability of bamboo to regenerate and translocate are encouraged. This could be coupled with careful observation of species that depend on the bamboo, to see whether their populations experience any decline or displacement. Mortality of major large tree species near the new forest edges could also contribute to displacement of populations of tree-dwelling animals like the sloth and iguana, so changes in their distribution in the park should be assessed For the areas that will be cleared of vegetation and allowed to re-grow (nearest the edge and on easements used by construction workers), *Saccharum spontaneum* may move in and out-compete any seedlings in the area, leading to a disruption of the forest succession. We recommend that efforts are made to re-establish vegetation in the area as soon as construction is done to create areas of shade to inhibit *S. spontaneum*, and keep the forest around the affected area as intact as possible.

Observations of the motmot population should be done consistently and carefully, not only near the affected areas but throughout the park. We recommend that an observation plan be established to detect any decline in motmot population in the area around Sendero los Momotides, and identify other potential sites in PNM where breeding and nesting may commence. This should be done as soon as possible, to create as accurate a baseline of motmot population as possible before construction begins to ramp up. There should be regular monitoring of the motmot breeding embankment to discover whether breeding patterns have been affected. Alternatively, the motmot population may move north into the Parque Nacional Camino de Cruces or another forested area if there are no available breeding areas within PNM grounds.

In conjunction with observations of the motmots, we recommend that sound measurements be taken at various points during and after construction to measure any sound level changes. Specifically, it would be helpful to compare future measurements with the measurements that we took around Affected Area 3 and the motmot breeding embankment in order to establish how much the noise pollution has increased in the area. For consistency, the methodology should be similar to ours, consisting of 2 or more transects reaching into the forest perpendicular to the road, being sure to take running averages, maximums and minimums. We will bequeath the Digital Sound Level metre to PNM so that the hardware used to make the observations will also be consistent and they will be able to continue sound monitoring for other projects in the future.

We recommend that PNM also use the sound data to continue monitoring the quality of Sendero los Momotides, in addition to observing increased dust and a reduction in animal sightings. This trail is critical for the delivery of environmental education programs in PNM because it is shorter and easier, making it accessible to young children and the elderly. If dust and noise levels increase, and the frequency of animal sightings decreases, the quality of this trail may diminish to the point where it is no longer effective for delivering quality education programs. PNM should begin creating a contingency plan, in the event that the trail needs to be replaced with one that is also short and accessible but less disturbed.

Finally, it is important that PNM continue to monitor the impacts and implement prudent research and mitigation measures. It is evident from our research that the impacts are uncertain and subject to change; indeed, entirely new impacts may develop during the process of construction. The evaluation of these impacts is extremely important as a point of reference for future projects and for general ecological knowledge relating to the park. There is no doubt that the Panama City will continue to push for infrastructure development around PNM, and having a growing knowledge base of evaluation and mitigation strategies will aid PNM in making the right decisions during negotiations with the city for compensation and mitigation. PNM's ability to achieve its objectives depends heavily on the accessibility, cohesiveness and persistence of this knowledge base, and we hope that research contribution will continue into the foreseeable future. PNM is an inspirational organization at the forefront of conservation and environmental education efforts throughout the country. Authorities in Panama City would be remiss not to consider the goals of PNM as a top priority for the distribution of funding and administrative support.

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REFERENCES

Arevalo, J. Edgardo; Newhard, Kimberly (2011). *Traffic noise affects forest bird species in a protected tropical forest*. Revista de biologia tropical 59 (2): 969-980

Barrios, Hector. Interview. 2012.

Beisiegel, B. M.; Mantovani, W. (2006). *Habitat use, home range and foraging preferences of the coati Nasua nasua in a pluvial tropical Atlantic forest area*. Journal of Zoology 269: 77-87

Bern, Herman & Santos, Ricardo (2010). *BRAVO Panama: Panama's Entrepot Economy in Evolution*. Latin Trade English 18 (4): 73

Canaday, Chris; Jost, Lou. (1997). *Common birds of Amazonian Ecuador: A guide for the wide-eyed ecotourist*. Quito: Ediciones Libri Mundi E. Grosse-Luemern.

Chani, Sixto. Interview. 2012.

Coffin, Alisa W. (2007). *From roadkill to road ecology: A review of the ecological effects of roads*. Journal of Transport Geography 15: 396-406.

El Corazon del Latin Dollar [no author listed] (2011). Latin Trade (Spanish) 19 (2): 76-78

Mark Southerland (1994). *Evaluation of Ecological Impacts from Highway Development*. Issued by: United States Environmental Protection Agency, Office of Federal Activities.

Farmer, Andrew M. (1993). *The Effects of Dust on Vegetation - A Review*. Environmental Pollution 79: 63-75.

Forman, Richard T.T.; Alexander, Lauren E. (1998). *Roads and Their Major Ecological Effects*. Annual Review of Ecology, Evolution and Systematics 29: 207-231.

Gammons, Daniel J.; Mengak, Michael T.; Conner, L. Mike. (2009). Armadillo Habitat Selection in Southwestern Georgia. Journal of Mammalogy 90(2): 356-362.

Gómez, Rafael. Interview. 2012.

Greeney, Harold F.; Jamieson, Lana H.; Dobbs, Robert C.; Martin, Paul R.; Gelis, Rudolphe A. (2006). *Observations on the Nest, Eggs, and Natural History of the*

*Highland Motmot (*Momotus Aequatorialis*) in Eastern Ecuador*. Ornitologia Neotropical 17: 151-154.

Hooper, Elaine; Legendre, Pierre; Condit, Richard (2005). *Barriers to forest regeneration of deforested and abandoned land in Panama*. Journal of Applied Ecology 42: 1165-1174.

Judziewicz, Emmet J.; Clark, Lynn G.; Londoño, Ximena; Stern, Margaret J. (1999). *American Bamboos*. Washington and London: Smithsonian Institution Press.

Karr, James R. (1987). *Biological Monitoring and Environmental Assessment: a Conceptual Framework*. Environmental Management 11(2): 249-256.

Laurance, William F. (1991). *Edge Effects in Tropical Forest Fragments: Application of a Model for the Design of Nature Reserves*. Biological Conservation 57: 205-219.

Laurance, William F.; Goosem, Miriam; Laurance, Susan G.W. (2012). *Impacts of roads and linear clearings on tropical forests*. Trends in Ecology and Evolution (Article in Press).

Malcolm, Jay R. (1994). *Edge Effects in Central American Forest Fragments*. Ecology 75(8): 2438-2445.

Morales-Mávil, Jorge E.; Vogt, Richard C.; Gadsden-Esparza, Héctor (2006). *Displacements of the green iguana* Iguana iguana *(Squamata: Iguanidae) during the dry season in La Palma, Veracruz, Mexico*. International Journal of Tropical Biology 55(2): 709-715.

Muñoz Harris, Amelia. Interview. 2012.

Nelson, Gerald; De Pinto, Alessandro; Harris, Virginia; Stone, Steven (2004). *Land Use and Road Improvements: A Spatial Perspective*. International Regional Science Review 27(3): 297-325.

Parris, K. M.; A. Schneider. (2008). *Impacts of traffic noise and traffic volume on birds of roadside habitats*. Ecology and Society 14(1): 29

Parque Natural Metropolitano: “Park Profile”. Retrieved from http://www.parquemetropolitano.org/english/P3/park-profile/ on 18/04/2012. © 2012 PNM.

Plan de Desarollo Urbano de las Áreas Metropolitanas del Pacífico y del Atlántico (1997). Retrieved from http://www.mivi.gob.pa/urbanismo/4urbanismo/urbanismo/plan.htm. Ministerio de

Vivienda de la República de Panamá.

Prasad, Ayesha E. (2009). *Tree community change in a tropical dry forest: the role of roads and exotic plant invasion*. Environmental Conservation 36(3): 201-207.

Reid, Sharon; Díaz, Iván A.; Armesto, Juan J.; Willson, Mary F. (2004). *The Importance of Native Bamboo for Understory Birds in Chilean Temperate Forests*. The Auk 121(2): 515-525.

Rodriguez, Elizabeth (Ing). *Modificación de estudio de impacto ambiental. Cat. II. Estudio diseño de construcción de puente vehicular en la intersección via Santos Jorge, vía de la Amistad y Ave. Ascanio Villalaz, extensión de la vía marginal este y ampliación de vía La Amistad; para mejoras viales en la Avenida Ascanio Villalaz, construcción de rotondas. Ministerio de Obras Publicas* (Gobierno de Panamá). 7 de diciembre, 2011 [not published]

Skutch, Alexander F. (1964). Blue-Diademed Motmot. Life History of the Blue-Diademed Motmot Momotus Momota.

Stiles, Gary F. (2009). *A Review of the Genus* Momotus *(Coraciformes: Momotidae) in Northern South America and Adjacent Areas*. Ornitología Colombiana 8: 29-75.

Suárez-Domínguez, Emilio Alfonso; Morales-Mávil, Jorge Eufrates; Chavira, Roberto; Boeck, Lourdes (2011). *Effects of habitat perturbation on the daily activity pattern and physiological stress of the spiny tailed iguana (*Ctenosaura acanthura*)*. Amphibia-Reptilia 32: 315-322.

Trombulak, Stephen C. and Frissell, Christoper A. (2000). *Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities*. Conservation Biology 14(1): 18-30.

Western, Lyndon; Juvik, J. O. (1983). *Roadside Plant Communities on Mauna Loa, Hawaii*. Journal of Biogeography 10(4): 307-316.

Williams-Linera, Guadalupe (1990). *Vegetation Structure and Environmental Conditions of Forest Edges in Panama*. Journal of Ecology 78(2): 356-373.

APPENDICES

APPENDIX 1: Figures and Graphs

Plan de Desarrollo de las Rotondas

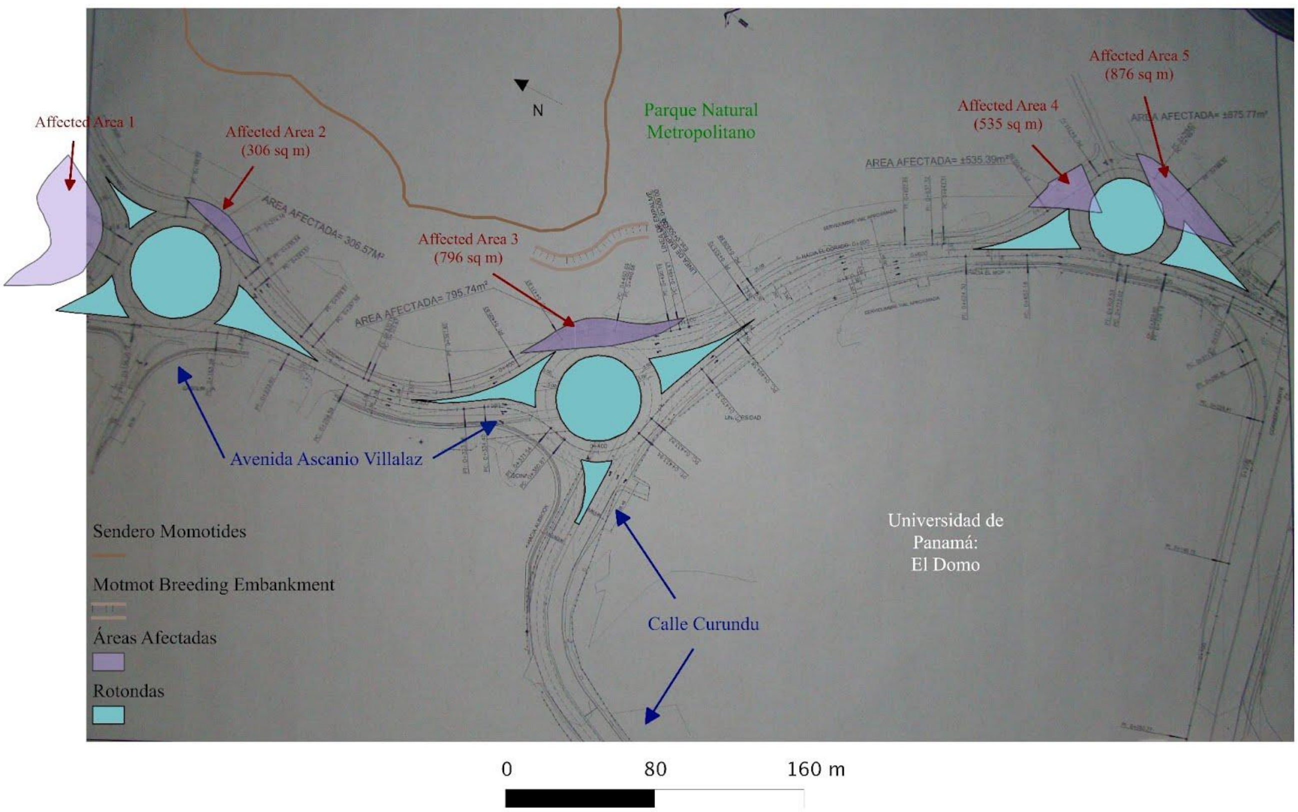


Figure 1: Site map

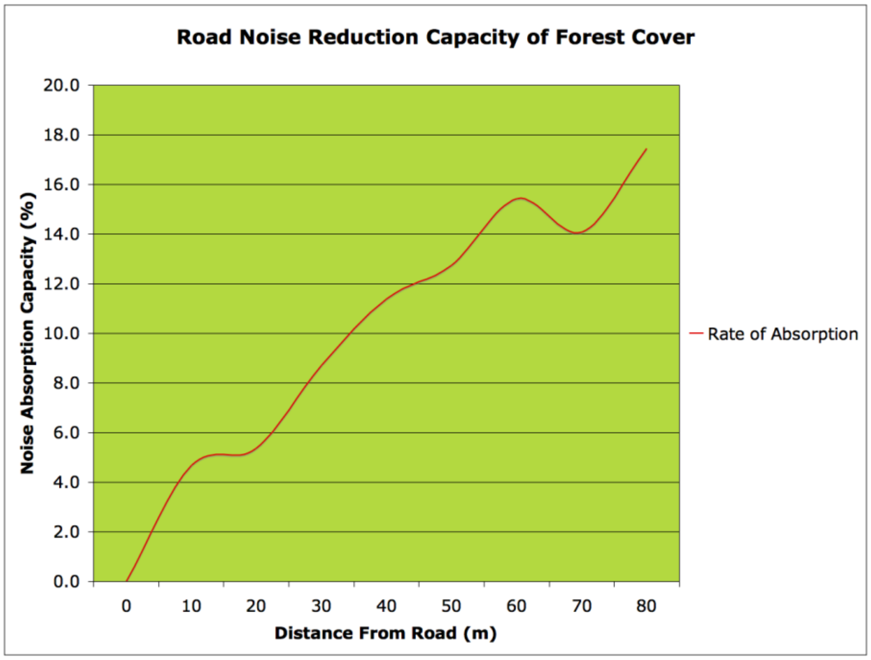
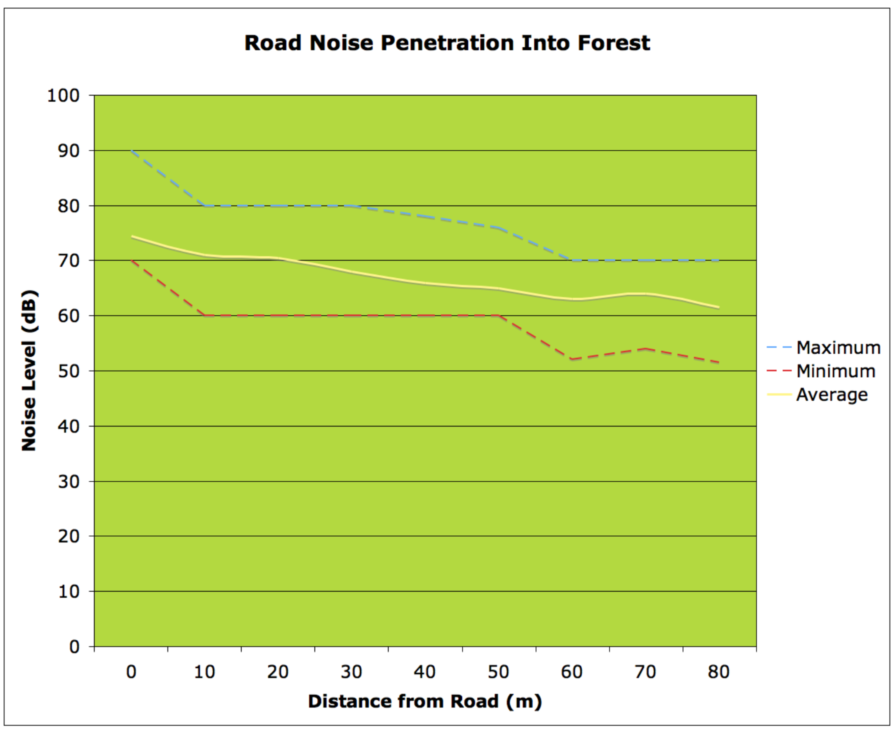


Figure 2: Represents the percentage of noise absorbed through each 10m interval away from the road, based on 74.5 dB average noise level at the road. Maximum and Minimum values are not represented; only average values were used to calculate absorption capacity. Trend line is smoothed.



<u>Figure 3</u>: Represents the noise levels recorded at each 10m interval away from the road. Trend line for average values is smoothed.

<u>Figure 4</u>: Trail map of Parque Natural Metropolitano

APPENDIX 2: Species Found in the Affected Areas

Flora

Anacardium excelsum
Annona spraguei
Annona purpurea
Annona hayesii
Acrocomia aculeata
Acacia collinsii
Albicia adinocephala
Andira inermis
Alibertia edulis
Allophyllus psilospermus
Apeaba tibourbou
Anemopaegna mapora
Aegiphila sp.
Aechmea carata
Bunchosia cornifolia
Bambusa balcooa
Cavanillesia platinofolia
Citrus limon
Cordia aleodora
Cochlospermun vitifolium
Costus villosisimus
Costus pulverulentus
Cojoba rufescens
Casearia commersoniana
Castilla elastica
Cedrela odorata
Coccoloba manzanillensis
Cupania latifolia
Cupania rufescens
Cupania scrobiculta
Cupania cinera
Cecropia peltata
Chrysophyllum cainito
Demdropanax arboreus
Dolio carpus dentatus
Desmodium sp.
Dioclea guianensis
Diphysa americana
Enterolobium cyclocarpum
Ficus insipida
Gurania makoyana
Guapira costaricana
Gouania lupuloides
Guazuma ulmifolia
Genipa americana
Hirtella racemosa
Hirtella americana
Heliconia hirsuta
Heliconia latyspatha
Heliconia platystachys
Ipomoea alba
Inga hayesii
Isertia haenkeana
Luehea seemannii
Mangifera indica
Matayba scrobiculta
Margaritaria lobilis
Mesechites trifida
Mostera deliciosa
Machaerium sp.
Miconia minutiflora
Miconia serulata
Miconia impetiolaris
Miconia borealis
Mimusops sp.
Niphidium crassifolium
Nectandra cuspidata
Oenocarpus mapora
Pseudobombax septenatum
Pseudosamanea guachapale
Pittoniotis trichanta
Pereskia bleo
Posoqueria latifolia
Phebe cinnamomifoia
Psichotria sp.
Piper reticulatum
Piper potomorphe peltata
Piper hispidium
Psichotria remota
Roystonia regia
Spondias Bombin
Scheflera morototoni
Scleria latifolia
Siparuna guianensis
Suzygium syzygioides
Serjania mexicana
Solanum sp.
Swietenia macrophylla
Tabebuia rosea
Trichilia hirta
Tectaria sp.
Urera baccifera
Vainilla planifolia
Walteria glomerata
Xilopia aromatica
Xilopia frutescens

Fauna Observed in the Affected Areas (Genus)

Bradypus
Callicebus
Dasyprocta
Dasypus
Iguana
Momotus
Nasua
Odocoileus

Trogon (genus not identified)
Toucan (genus not identified)
Snake (genus not identified)

Birds (of many varieties)

APPENDIX 3: Survey

Encuesta sobre el desarrollo vial en áreas cercanas al Parque Natural Metropolitano

Andrea Morden, Alex Aippersbach, Daniel Wilkenfeld

¡Atención!

Esta encuesta es realizada por los estudiantes de McGill University y Smithsonian Tropical Research Institute. Esta información será utilizada en nuestro trabajo sobre el Impacto de la Construcción de las Rotondas para el Parque Natural Metropolitano.

Si tiene preguntas, sugerencias y/o comentarios favor contactar a: andrea.morden@mail.mcgill.ca

Encierre en un círculo su respuesta

1) ¿Qué sendero le gusta caminar? y con qué frecuencia?

El Roble Los Caobos La Cieneguita Los Momotides

Camino del Mono Tití Los Guayacanes

2) ¿Con qué frecuencia camina este sendero?

1 vez x semana Más de una vez x semana

3) ¿Ha caminado el Sendero Los Momotides en el último mes?

Si No

4) Menciones los animales ve con frecuencia cuando camina el Sendero Los Momotides?

____

____

5) ¿Observa algunas diferencias en la frecuencia que ve los animales sobre el Sendero Los Momotides?

Si No

Explique____

____

6) Clasifique el nivel del ruido sobre el Sendero Los Momotides durante su última visita

(1 = muy silencioso, 10 = muy ruidoso)

1 2 3 4 5 6 7 8 9 10

7) Clasifique el nivel de polvo de la calle sobre el Sendero Momotides durante su última visita (1 = no hay polvo, 10 = muy denso)

1 2 3 4 5 6 7 8 9 10

8) ¿Qué piensa de la construcción de las rotondas en el Calle Curundu cerca del Parque?

____

____

9) En su opinión, ¿piensa que la construcción va a afectar los animales del Parque? ¿Cómo?

____

____

10) En su opinión, ¿cuáles son las amenazas principales para la salud del Parque?

____

____

11) ¿Realiza giras en el Sendero Los Momotides ? SI NO

12) Si realiza giras, en su opinión ¿cómo son los comentarios de los visitantes sobre este sendero?

(1 = muy malo, 10 = muy bueno)

1 2 3 4 5 6 7 8 9 10

13) ¿Puede mencionar algun comentario de los visitantes sobre el Sendero Los Momotides?

____

____

14) ¿Hay programas de educación que utilizan el Sendero Los Momotides?

____

____

15) En su opinión, ¿cómo la construcción de las rotondas va a afectar los programas de educación?

____

____

16) En su opinión, ¿por qué es el Sendero Los Momotides importante para el Parque?

____

____

APPENDIX 4: Days Spent on Project; Budget; Product for Host Institution

Days spent on the project: 30
Days spent in the field: 5

Budget:

Digital Sound Level Metre: $49.99
Transportation: $13.50
Total: $63.49

Product for the Host Institution

The product presented to our host institution is an abridged version of this report, in Spanish, a copy of which is provided in the attached CD.