CLOUDBRIDGE NATURE RESERVE

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Summary

Costa Rica is one of the most biologically diverse countries on earth, with 4 percent of the known terrestrial plant and animal species on only 0.04 percent of the world's land surface. Anthropogenic disturbances have transformed and deforested Costa Rica's rare and unique ecosystems, which have led to biodiversity loss and isolation of wildlife populations. Declining wildlife populations in Costa Rica are mainly the result of the large-scaled conversion of primary forest into pastureland. Recently, many reforestation projects have started, however, little is known about how reforestation projects affect wildlife populations, because population estimates of wildlife populations are lacking.

The objective of this study was to compare the precision of wildlife population density estimation methods, namely line transects and camera trap surveys. Density estimates focused on mammalian species in a Costa Rican cloud forest ecosystem. This study was conducted at the 300-ha large Cloudbridge Nature Reserve located at an elevation of 1550 m to 2600 m in the Talamanca Mountain Range, characterized by endangered cloud forests. The reserve aims to convert the old pastureland into forests through planting of trees and natural regeneration.

In this study, line transects and camera traps were used to estimate mammal densities and thereafter compare the precision of these estimates. During the line transect surveys, a 8.0 km trail system was walked regularly over a 4 month period, accumulating a total transect line of 127 km and 41 sightings of 77 individuals belonging to six different mammal species (White-faced Capuchin monkey, Geoffrey's Spider Monkey, Red-tailed Squirrel, White-nosed Coati, Collared Peccary, and Pocket Gopher). Perpendicular distances to all animals sighted were recorded and used for analysis. Camera traps yielded 575 images of 17 different mammal species. For every captured individual, the estimated distance to the camera was recorded and also used for analysis. Analysis of the data was done with Distance 7.3 to compare densities and precision for different mammal species. Density estimates and precision for comparison were obtained for Red-tailed Squirrel, White-nosed Coati, and Collared Peccary. The most precise method was the camera trap method for all these three species. We conclude that this method is the most precise for mammal inventory in all environmental conditions, allowing a rapid assessment of wildlife conservation status.

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1. Introduction

The ever-growing human population is making a huge demand on the world's ecosystems, resulting in a massive negative footprint (IFL Science, 2017). According to the Food Agricultural Organization, about half of the world's tropical forests have been cleared and we continue to lose 7.3 million hectares of forest on an annual basis (FAO, 2018). This loss has serious consequences for biodiversity conservation.

Costa Rica is one of the most biologically diverse countries on earth, with 4 percent of the known terrestrial plant and animal species in only 0.04 percent of the world's land surface (May, 1992) and is considered one of the 36 world biodiversity hotspots, as defined by Mittermeier and Cemex (2004). Costa Rica is home to more than 207 species of mammals in 10 orders and 31 families, with 9 species endemic to the country (Nadkarni, 2000).

Anthropogenic disturbances have transformed and deforested Costa Rica's rare and unique ecosystems which have led to biodiversity loss and isolation of wildlife populations (Mongabay, 2005). For example, the Giant Anteater (*Myrmecophaga tridactyla*) and the White-lipped Peccary (*Tayassu pecari*) have been locally extirpated in certain regions such as the Monteverde Cloud Forest area (Nadkarni, 2000).

Declining animal populations in Costa Rica are mainly the result of the large-scaled conversion of primary forest into pastureland, resulting in a 50 percent decrease in forest cover between 1940 and 1990 (Kaimowitz, 1996). Since then, 26.3 percent of the forests have been reclaimed by tree planting and forest conservation activities (Lopez, 2013).

Reforestation programs are important mechanisms to recover fragmented ecosystems and mitigate deforestation effects, yet little is known about how this affects wildlife populations. For example, a study by Oosterhoorn and Kappelle (2000) concludes that actively reforested areas tend to have less biodiversity and a different species composition compared to naturally regenerated forests.

Cloudbridge Nature Reserve (283 ha) is dedicated to restoration of primary forest through reforestation and the process of natural regeneration. This privately-owned reserve is located between Chirripó National Park and the Talamanca Reserve in the Talamanca Mountain range of Costa Rica (Cloudbridge, 2017). This high-altitude reserve (1550 m to 2600 m) is home to the fragile and rare cloud forest ecosystem, which only makes up 2.5 percent of worldwide tropical forests and harbors a disproportionately large number of the world's species (Bubb, 2011). For example, the Puma (*Puma concolor*), and Geoffrey's Spider Monkey (*Ateles geoffroyi*) (listed as Endangered by the IUCN (Cuarón et al., 2008)) can be found here. Unfortunately, little is known about the population densities of the present mammal species at Cloudbridge. The choosing precise but functional population estimation methods (e.g., line transects and camera trapping) depend on taking into account the environmental characteristics of the study area, such as the steepness or slopes, visibility due to dense vegetation, and weather conditions (Wilson, 2011).

Camera trapping has become increasingly popular (Noss, 2012), is a non-invasive method with low environmental disturbance, has potential for capturing cryptic species, and provides opportunities to estimate mammal population density in difficult terrain (Rowcliffe, 2008). For arboreal primates and highly mobile mammals, repeated sampling of strip transects is the most common method of estimating population density (Tomick, 2002). However, transect methodology is highly variable regarding number and placement of transects and degree of habitat stratification and species

behavior. The line transect methodology and camera trap sampling have proven to deliver precise estimates of population density.

Therefore, the aim of this study is to evaluate the precision of population estimation methods (e.g., line transects and camera trapping) to estimate mammal densities. The main research question is:

How does the precision of estimates of diurnal medium-sized mammal density depend on the method (i.e. line transects and camera trapping) being used?

It is expected that the camera trap method will yield the most precise density for terrestrial and semi-terrestrial mammalian species. As study by Silveiria (2003) comparing track census, camera trapping and faunal counts, concluded camera traps yielded densities with the highest precision.

2. Materials and methods

2.1 Study area

The study was conducted at Cloudbridge Nature Reserve (9°28’14.15” N, 83°34’31.22” W) (283 ha) located in the Cordillera Talamanca mountain range between the Chirippó National Park and the Talamanca Reserve in the southern part of the province of San Jose, Costa Rica (see Fig. 1). Cloudbridge is located in a tropical cloud forest ecosystem. The climate results in an average daily rainfall of 6.6 mm and an average daily temperature of 17.7°C, with a defined dry (Dec-April) and wet (May-Nov) season (AYA, 2018). The reserve ranges from 1500 to 2600 m altitude. The Chirripó river is the greatest transporter of water in the area originating from the higher elevated national park. An important source of moisture is the deposition from the daily fog. Soil types are characterized by high acidity, high water content, and low rates of decomposition and mineralization. The reserve is part of an important bio-region, that includes the most threatened ecosystems in Costa Rica (Obando, 2002), and are known for high species richness. Cloudbridge Nature Reserve includes patches of primary forest, and planted and natural regenerated secondary forest. With increasing elevation so do typical montane species occur more numerously, such as epiphytes, mosses, climbing ferns and lichens.

Figure 1: Cloudbridge Nature Reserve (Costa Rica – Central America).

2.2 Study species

The species of interest included all medium to large sized mammal (> 1 kg) previously encountered (Powell, 2018) in the reserve (see Appendix I). This is because smaller animals are more difficult to detect. Smaller animals therefore require different methodologies such as Sherman traps and pit fall traps in the case of, for example, rodents. Nocturnal, diurnal, and crepuscular mammals, as well as terrestrial and arboreal animals, were included in the study.

2.3 Data sampling

A total of three transects were established with a mean (± SD) length of 2.67 (± 0.35) km to cover the major parts of the reserve. I made use of existing trails that included all the habitat types (see Fig. 2). Rio loop begins at the start of main trail and travels up into the reserve where its elevation levels off, then, once the main trail meets the entrance of Rio, the transect follows along the river and then back down to the entrance along the Heliconia trail. This transect covers only naturally regenerated and planted forest with relatively high visitor intensity, which is likely to impact results. The Gavilán transect runs along the Gavilán trail until it meets the Jilguero trail, where it then descends and passes through all three forest types equally, and has the lowest visitor intensity. The Montaña transect begins at the entrance of the Montaña trail going up to the Chirripó trail where the transect travels down along the Chirripó trail to Jilguero where it ends at the intersection of the Gavilán trail. This transect includes all forest types with high visitor intensity.

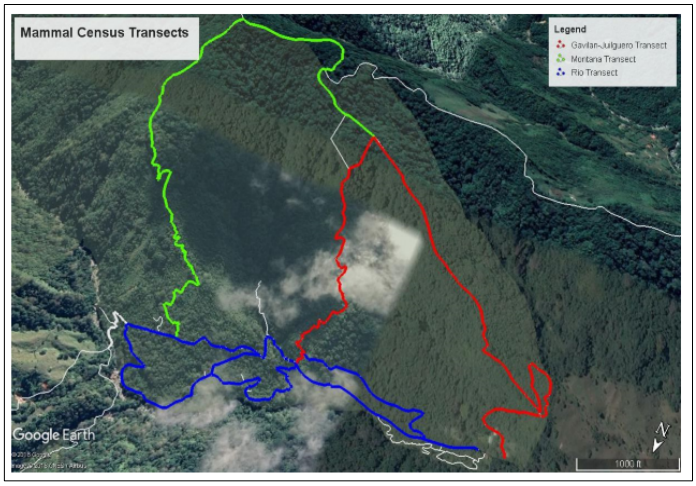

Figure 2: Locations and layout of the three mammal transect lines Rio (3.0 KM), Montaña (2.3 KM) and Gavilán (2.7 KM) in the Cloudbridge Reserve. Surveyed habitat types are Planted, Naturally Regenerated and Old Growth forests.

2.4 Line transect set-up

After selecting the transects, markers were installed along the transects every 50 m using a bamboo pole, 5 m string, and scrap wood. One end of the string was attached to the wood and the wood was placed on the trail, while the other end was walked forward along the trail until the string became tight. Then a bamboo pole was used to mark the location of the 5 meters and the piece of wood was dragged forward to repeat the process 10 times to reach 50 meters. This was repeated for all three transects.

2.5 Data collection

Data of mammal observations on transects was collected in the period between 17-08-2018 and 15-12-2018, three times per week, one transect per day with alternating survey and rest days. Transects were on a two-week rotation, the first week being conducted in the 'forward' direction and the second in the 'backward' direction to avoid temporal bias in the data collection. The first four weeks, the transects were walked (1 ± 0.2 km/h, mean ± SD, 3-4 hours per transect) two times per day, and thereafter once per day. Walking transects rotated between morning survey weeks and afternoon survey weeks for the rest of the period.

Surveys were conducted in the early mornings starting at 6:30 AM and in the afternoon at 12:00 PM, as previous studies have shown that general mammal activity is at peak during two periods of the day (Blake, 2012). The first peak occurs roughly between 6:00-9:00 AM, followed by a low period in the late morning, followed by increasing levels of mammal activity again in the afternoon, roughly between 13:00-16:00 PM. Due to the expectation of heavy afternoon rainfall, the afternoon survey started at 12:00 PM. A sighting was defined as an independent encounter with one or several animals of the same species if the time between encounters was less than five minutes. Upon a sighting, we recorded the species name (using a 8x42 Bushnell binocular to help identify them), number of individuals, and location along the transect (see APPENDIX II). Either the perpendicular or radial distance from the animal to the transect line (see Fig. 3) was measured by a Rangefinder (Opti Logic 120xLA Laser). When we encountered clusters, the distance to the first detected animal was recorded instead of the center of the group because the distance to the center was often difficult to measure due to dense growth. The direction of movement was recorded to prevent double counting.

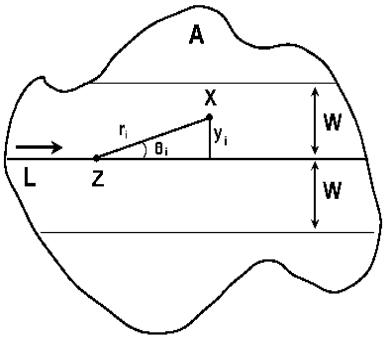

Figure 3: Line transect method. Z = Observer, X = Sighting, y= perpendicular distance, r= radial distance

To avoid bias, the searching method was consistent through the surveys (Buckland, 2015). The main focus was on the trail right in front of the observer, then scanning both left and right on different shapes and movement in the environment, followed by scanning the perpendicular sides. There was no distance beyond which vocal and visual clues were disregarded.

2.6 Distance 7.3 analysis

Data was analysed using Distance 7.3 (Thomas et al., 2010). The input for the four different data layers are global (300 ha), three different strata (planted -75 ha, naturally regenerated – 150ha and old growth – 75 ha), the line lengths in km and perpendicular distances (m) for each sighting per observation (see Appendix III). The default settings for importing and analyzing data were used. Density estimates were calculated in ha/km. All four different key detection functions (uniform, half normal, hazard and negative exponential) were applied to each dataset (different species) with one adjustment term (cosine series). Distance estimates were selected based on AIC values and goodness of fit (i.e., Q-Q plots, Kolmogorov – Smirnov and Cramer – von Mises).

2.7 Camera study set-up

A total of six camera traps (CT) were set up at six different locations along the selected transects (Fig. 2). Two CT's were placed in each of the different habitat types. Placement of CT's was determined by first identifying suitable stretches of transects which yielded 15 possible installation sites. After this we choose the most suited locations in terms of slope, (no dense) vegetation and reasonable angle of view. We used 2 Bushnell Trophy Cam HD (mo. Nr. 119875, se. no. B170111998 & B170111740), 2 Bushnell Trophy Camera Brown (mo. Nr. 119636, se. no. B140502334), 1 Bushnell Trophy Cam Aggressor Camo (mo. Nr. 119775, ser. No. B160102184), 1 Bushnell Trophy cam HD (mo. Nr. 119875, sr. no. B160102184) and 1 Browning Strike Force Model (mo. Nr. BTC-5HD, ser. No. 41110432091605). Settings were similar for all CT's: photo mode, high HD, 2 sec. delay between images, automatic sensor level, and 1 capture number. These settings are recommended by Howe et al. (2017). I replaced batteries and SD cards every week to minimize disturbance. Cameras were attached to trees in such a way that the angle of view was not obscured. Each trap was set between 30 – 50 centimeters from the ground to capture target species. Every camera was placed approximately three meters from a trail into the forest, directed towards the trail, and was placed such that slope, vegetation and sunlight would not result in images with unrecognizable species due to errors in the placement of the traps. The CT's were placed facing down parallel to the slope of the surface.

For every CT location we organized the site into 1 meter distance bands by previously taking pictures with signs displaying the distance to the camera. The noticeable features per meter distance away from the camera were written down. For every individual captured on a photo, we compared that image with our distance reference to estimate distances from camera to animal.

2.8 Formulation of the model

Densities from camera trap data was estimated by a model described by Howe et al. (2017). This model enables estimating density without the need for individual recognition.

Each location with a CT installed was determined as a point *k* for a period of time T_k which will record an image for as long as an animal is present to trigger it, which is based on activity pattern. A finite set of snapshot moments within T_k at which an image can be obtained are predetermined. A snapshot moment is 2 seconds apart (*t* units of time apart) was chosen for this study. The detection distance (r_i in the model) which is the distance between the midpoint of animal and camera trap was estimated at each snapshot moment. The overall sampling effort at point *k* is $\theta Tk/_{2\pi t}$. The θ radians describes the fraction of the circle covered by the camera or angle of view (AOV). The assumption that all animals that pass the camera are recorded is violated and we corrected for this by excluding values beyond a left boundary (close to the camera) of 1 meter and right boundary (far from the camera) of 5 meter from analysis .Truncation distance is *w* and P_k is the estimated probability of obtaining an image of an animal that is within θ and w in front of the camera at a snapshot moment.

The formula to estimate density is therefore:

$$D = \frac{2t \sum_{k=1}^{K} nk}{\theta w2 \sum_{k=1}^{K} TkPk}$$

The key assumptions for distance sampling according to Buckland 1993 apply. The time each species spent outside the AOV is corrected for as this causes negative bias in the estimates by defining T_k as the amount of time a population was available for detecting while cameras were running. For example, Red-tailed Squirrels (*Sciurus granatensis*) spent an average of 11 hours active of which they spent 25 % off of the ground and therefore outside the AOV.

3. Results

This chapter displays the outcome of the estimated densities of species encountered with the line transects and the estimated densities of the species captured with camera traps in two different sections. The precision and degrees of freedom are given for each density estimation.

3.1 Line transects

The surveyed area (283 ha) was comprised of old growth, naturally regenerated, and planted areas. A total of 127 km of transects yielded 41 sightings, of a total of 77 individuals, belonging to six different mammal species (Table 1). Sighting distances ranged from 1 to 53 m, and it was seen that the mean sighting distances varied considerably between species. Red-tailed Squirrels were sighted most frequently with 19 sightings, followed with 7 sightings each of Collared Peccaries (*Peccari tajacu*) and White-nosed Coatis (*Nasua narica*).

Table 1: Mean sighting distance by species, sample size and average group size

Species		Mean sighting ± SD	Sample size	Average group size ± SD
Geoffrey's Spider Monkey	*Ateles geoffroyi*	44.47 ± 8.63	3	6 ± 2.1
White-faced Capuchin	*Cebus capucinus*	4.2 ± 53.36	4	6 ± 1.4
White-nosed Coati	*Nasua narica*	7.7 ± 8.19	7	2 ± 1.1
Collared Peccary	*Peccari tajacu*	6.3 ± 12.18	7	5 ± 3.2
Pocket Gopher	*Orthogeomys sp.*	0.00 (1 obs.)	1	1
Red-tailed Squirrel	*Sciurus granatensis*	6.30 ± 2.84	19	1 ± 0.2

The Red tailed Squirrel density was calculated to be 0.004 ind./km^2 (Table 2). The White-nosed coati density was 0.0005 ind./km^2. The Collared Peccary was 0.000002 ind./km^2.

Table 2 : Species densities calculated with Distance 7.3 with 95 % CI and corresponding GOF, model with highest AIC and the Degrees of Freedom

Species	Density (ind./km^2)	95% CI	GOF	Model	Df
Peccari tajacu	0.0000002	0.0000001 - 10.00	P = 0.9431	Half normal cosine	23.93
Nasua narica	0.0005	0.0002 – 0.300	P = 0.1528	Hazard rate cosine	12.74
Sciurus granatensis	0.004	0.001 – 1.42	P = 0.3506	Uniform Cosine	25.32

3.2 Camera trap survey

In the period between 19-11-2018 and 19-12-2018 a total of 599 images contained 15 mammalian species of interest with a total of 702 individuals (Table 3). Most images were obtained from the species Collared Peccary, Red-tailed Squirrel and the White-nosed Coati.

Table 3 Species density with 95 % CI calculated with Distance 7.3

Species	Number of images	Density (ind./km2)	95 % CI	Df
Peccari tajacu	215	0.3	0.1 – 0.7	6.00
Nasua narica	158	0.6	0.3 – 1.2	11.04
Sciurus granatensis	133	0.5	0.2 – 1,5	7.34

3.3 Comparing methods

Table 4 below displays an overview of all the 17 mammalian species encountered during the study combining both methods, namely line transects and camera traps. Pocket Gopher (*Orthogeomys sp.*) and Geoffrey's Spider Monkey were only encountered during the line transect surveys. Density estimates and 95 % CI are only given when Distance 7.3 was able to run the analysis.

Table 4: Overview of species encountered with line transects and camera trap methodology.

Species		Encountered with:		Species density with camera traps (ind./km²)	95 % CI	DF
		Camera Traps	Line Transects			
Geoffrey's Spider Monkey	*Ateles geoffroyi*	No	Yes	No results		
Coyote	*Canis latrans*	Yes	No	0.04	0.005 – 0.37	33.29
White-faced Capuchin	*Cebus capucinus*	Yes	Yes	No results		
Striped Hog-nosed Skunk	*Conepatus semistriatus*	Yes	No	0.04	0.01 - 0.2	14.13
Central American Agouti	*Dasyprocta punctata*	Yes	No	No results		
Nine-banded Armadillo	*Dasypus novemcinctus*	Yes	No	0.05	0.01 – 0.2	9.52
Common Opossum	*Didelphis marsupialis*	Yes	No	0.02	0.009 – 0.05	6.00
Tayra	*Eira barbara*	Yes	No	No results		
Margay	*Leopardus wiedii*	Yes	No	No results		
Ocelot	*Leopardus pardalis*	Yes	No	No results		
White-nosed Coati	*Nasua narica*	Yes	Yes	0.6	0.3 – 1.2	11.04
Collared Peccary	*Peccari tajacu*	Yes	Yes	0.2	0.1 – 0.7	6.00
Kinkajou	*Potos flavus*	Yes	No			
Puma	*Puma concolor*	Yes	No	0.03	0.01 – 1.0	10.98
Pocket Gopher	*Orthogeomys sp.*	No	Yes			
Red-tailed Squireel	*Sciurus granantensis*	Yes	Yes	1.5 ind./ km²	0.001 – 19.2	7.44
Dice's Cottontail	*Sylvilagus dicei*	Yes	No	0.07 ind./ km²	0.017 – 0.36	7.56
Baird's Tapir	*Tapirus bairdii*	Yes	No	No results		

4. Discussion

Wildlife census techniques to estimate population parameters are still evolving and determining the appropriate methods for the species of interest are often the subject of study (Burnham, 1980). One of the major limitations associated with the use of population estimation methods for wildlife research is that some species may not be detected, such as with line transects (Fragaso et al., 2016) Nocturnal and illusive species (such as the Puma (*Puma concolor*), Margay (*Leopardus wiedii*), and Ocelot (*Leopardus pardalis*)) were only detected with camera traps. Also, Coyote (Canis latrans), Striped Hog-nosed Skunk (*Conepatus semistriatus*), Dice's Cottontail (*Sylvilagus dicei*), Common Opossum (*Didelphis marsupialis*), Tayra (*Eira barbara*), and the Nine-banded Armadillo (*Dasypus novemcinctus*) were only detected with camera traps. On the other hand, camera trap surveys excluded species such as e.g. the Geoffrey's Spider Monkey and White-faced Capuchin (*Cebus capucinus*) monkey, which are exclusively arboreal. The clear dissimilarity in detection between the two different sampling approaches for most species, suggests that the sampling methods used in the present study makes it difficult to compare the precision of density estimates of a wide range of species.

More diurnal and nocturnal species were sighted with the use of camera traps and, for species detected with both methods, encounter rate was higher using camera traps. Camera traps allow particularly for the study of rare and elusive species and are effective for monitoring a wide array of taxa (Burton, 2015), for example the endangered Baird's Tapir (*Tapirus bairdii*). When species density is expected to be relatively low or distributed non-randomly, chances to detect species and determine population densities are higher with camera traps. Also, animal surveys in non-homogenous habitats can lead to insufficient sampling of all habitats. Problems such as poor visibility and accessibility resulting from dense vegetation growth, often lead to only the partial sampling of habitats and will influence the precision of the estimates (Chapman, 1988).

The precision calculated with the line transect methodology for White-nosed Coati, Collared Peccary, and Red tailed Squirrel have a lower precision compared to the precision acquired with camera traps for the mean densities of these species. To improve precision of the estimates for line transects, a bigger sample size is probably needed (Byers, 2015). Other recommendations include increasing the number of transects, or doing stratified sampling. For the pocket gopher, capuchin monkey, and spider monkey, no reasonable results could be obtained with the line transect methodology due to too few sightings. The main issue is the lack of observations. When using line transects, estimated densities might become more reliable using the two observer method, which was not tested in this study. This method is mostly employed when detection of animals on the line is uncertain and thus will result in a higher detection probability. Also, camera traps recorded an additional 12 mammal species that were not found with line transects, of which we could estimate density and precision for 6 species.

Some problems were faced with the camera traps during the study as around 500 images were completely white. This is likely to affect the densities. The cause for this was a defective lens getting stuck open when the camera was triggered to capture an image. Also, sunlight shining into the lens affected the quality of images. As there were no replacement cameras, we decided to keep the defective cameras operational. A total of six cameras operated during the study period, but ideally more cameras should have been employed to increase sample size.

5. Conclusion

Based on the comparison of the acquired precision of the density estimates for the species Red-tailed Squirrel, Collared Peccary, and White-nosed Coati, it can be concluded that the camera trap method yielded a higher precision and is therefore more recommended for species that can be observed during the day and spent a relatively high amount of their time on the ground. The precision of the estimates are dependent on the number of sightings and these are more frequent with camera traps. To improve precision for the camera trap estimates it is recommended to conduct the study with more cameras for a longer period. For arboreal species, line transects are recommended, but to gain precise results, this also needs a longer study period.

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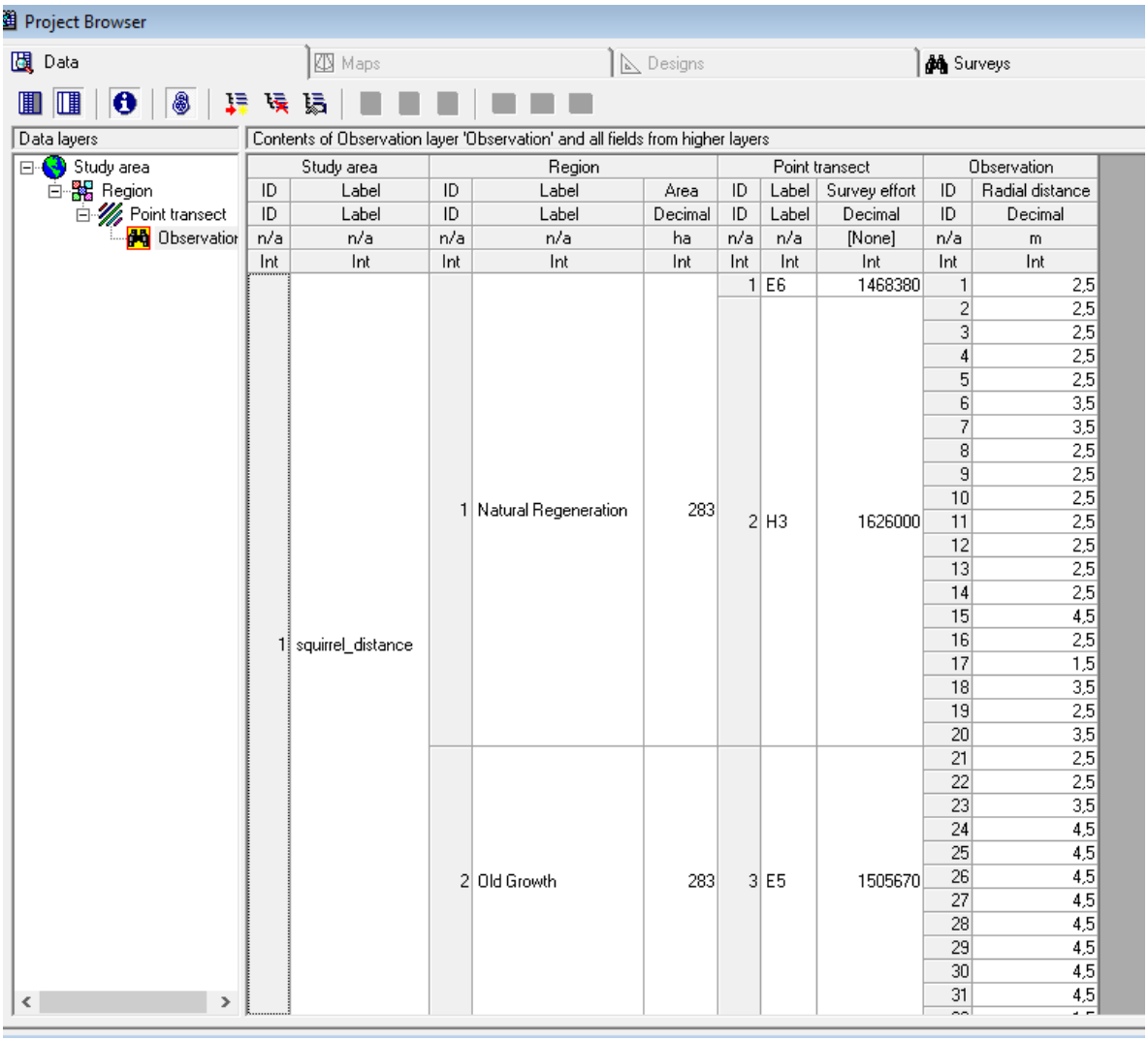
APPENDIX I

Species	Scientific name	IUCN status	Notable features
Red Brocket Deer	Mazama americana	Unknown (DD)	Reddish brown, rounded back, short tail, spotted young
Collared Peccary	Pecari tajacu	Least concern	Pale collar and dark jaw, pale brown young
Common Opossum	Didelphis marsupialis	Least concern	Naked tail with black base and long white tip, yellow/grey coat
Coyote	Canis latrans	Least concern	Yellow-grey, black tail tip
Striped Hog-nosed Skunk	Conepatus semistriatus	Least concern	Bare pink snout, two white strips on the back
Tayra	Eira barbara	Least concern	Longer legs then other weasels, blackish brown, head paler than body, white patch on throat
Greater Grison	Galictis vittata	Least concern	Grey body above, black below; white band across forehead and down neck
Long Tailed Weasel	Mustela frenata	Least concern	Reddish brown, white facial markings, black tipped tail
Cacomistle	Bassariscus sumichrash	Least concern	Erect, triangular ears; long, bushy, banded tail; face black with pale eye rings
White-nosed Coati	Nasua narica	Least concern	Long muzzle, and long, banded tail
Kinkajou	Potos flavus	Least concern	Golden or gray-brown color; long, tapered, tail with dark brown tip
Northern Raccoon	Procyon lotor	Least concern	Dark down; extensive black mask; short, banded tail; long, white hairs
Gray Four-eyed Opossum	Philander opossum	Least concern	White spots above the eyes; furred tail at base, black mid-section, and long white tip
Baird's Tapir	Tapirus bairdii	Endangered	Trunk-like nose; short tail; young are striped and spotted; tracks show three (sometimes four) triangular toe prints
Brown-throated Three-toed Sloth	Bradypus variegatus	Least concern	Coarse grey fur, limbs each bear three claws, male has patch of orange and black on back
Northern Tamandua	Tamandua mexicana	Least concern	Mostly golden with black vest (some individuals are entirely golden)
Central American Spider Monkey	Ateles geoffroyi	Endangered	Large and long limbed; reddish-brown back with dark head, tail, and limbs; female has penis-like clitoris while male's genitals are hidden from view
White-faced Capuchin	Cebus capucinus	Vulnerable	Medium size; mostly black with cream on head, chest, and shoulders; pink face
Central American Agouti	Dasyprocta punctata	Least concern	Orange/brown coat
Mexican Porcupine	Sphiggurus mexicanus	Least concern	Pale head with black body; yellowish spines; pink, bulbous nose
Red-tailed Squirrel	Sciurus granatensis	Least concern	Upper parts brown with orange belly, orange-frosted tail, ears project above crown of head
Variegated Squirrel	Sciurus variegatoides	Least concern	Color varies among species from white, black, or brown, but all color patterns have white frosted tail (tricolor pattern)

APPENDIX II

Time	Species	Numbers	Distance	Transect	Location	Direction of movement
7:02:12	Collared Peccary	4	7.5 Meter	Rio	700-750	34° NE
8:10:15	White-nosed Coati	1	24.5	Montana	1200-1250	328° NW

APPENDIX III



Study area		Region			Point transect			Observation	
ID	Label	ID	Label	Area	ID	Label	Survey effort	ID	Radial distance
ID	Label	ID	Label	Decimal	ID	Label	Decimal	ID	Decimal
n/a	n/a	n/a	n/a	ha	n/a	n/a	[None]	n/a	m
Int	Int	Int	Int	Int	Int	Int	Int	Int	Int
1	squirrel_distance	1	Natural Regeneration	283	1	E6	1468380	1	2,5
					2	H3	1626000	2	2,5
								3	2,5
								4	2,5
								5	2,5
								6	3,5
								7	3,5
								8	2,5
								9	2,5
								10	2,5
								11	2,5
								12	2,5
								13	2,5
								14	2,5
								15	4,5
								16	2,5
								17	1,5
								18	3,5
								19	2,5
								20	3,5
		2	Old Growth	283	3	E5	1505670	21	2,5
								22	2,5
								23	3,5
								24	4,5
								25	4,5
								26	4,5
								27	4,5
								28	4,5
								29	4,5
								30	4,5
								31	4,5