A long term monitoring study to evaluate the primate conservation status in Panama using species distribution modelling and complementary information

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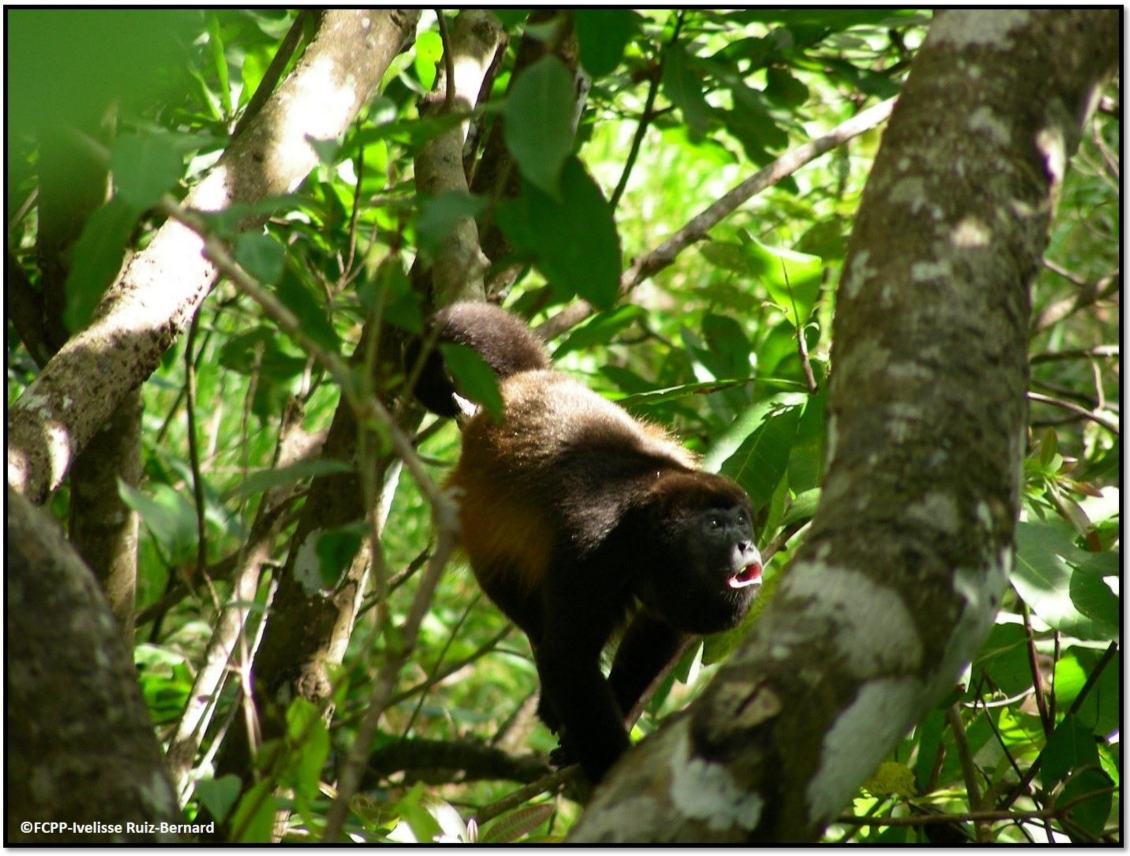

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Pedro G. Méndez-Carvajal

Abstract

This thesis presents an account of research into the presence, absence and actual distribution of primate species in the Central American country of Panama, including research on local human perceptions of primates and their implications for the survival of primate populations. I mixed qualitative research methodsand a variety of quantitative methods to examine primate population presence/absence, distribution and size. This thesis gives an account of a range of techniques to easily evaluate primates' presence, their densities and habitats, revealing factors limiting primate survival, including the key factors that influence human communities' attitudes to wildlife (analysis of the perceptions of primates held by a sample of Panamanian adults and children was employed in the latter case). From April 21 of 2001 to March 20 of 2016 I collected 1,144 presence points in a non-systematic order, including literature review of previous presence points cited in old references. MaxEnt Species Distribution Modelling was then applied to this data. This was complemented with information I obtained about population densities in continuous forest and fragmented habitats. I concluded that annual mean temperature (0.45-0.75 AUC), annual precipitation (0.60-0.75 AUC), human population presence and density are very important factors determining likelihood primate presence (0.92 AUC). These environmental parameters are affecting the presence of primates in Panama, and their migration within the country, as is the growing human population. Methodologically, I show that for small size primate species it is reasonable to run the MaxEnt programme with only environmental variables, and still have good accuracy for habitat suitability; however, for medium size primates such as spider and howler monkeys, it is recommended that remote sensing and indigenous people's local knowledge be included to complement the accuracy of the distribution models. An innovative 'camera trap' system, or OCS, was used to gather visual data relevant to the estimation of primate group size. Formal and informal interviews with adults resident in Azuero peninsula, and data from school-age in the form of drawings and compositions on the theme of primates I obtained a Shannon Index of 3.8 in terms of diversity of 77 words used by local people in relation to primates, being categorized as negative, neutral, and positive. Analysis of this data provided an overview of how local people think about primates, and

of their base of biological knowledge, and allowed the researcher to identify areas where improvements are needed to assist primate conservation.

The conservation status of Panamanian primates was last reviewed by the International Union for Conservation of Nature (IUCN) in 1996 and 2008. This thesis presents a new conservation status evaluation, one that permits a useful assessment of the actual threats and habitat requirements of primate survivorship in Panama. This thesis proposes certain updates to the IUCN Criteria, via a new perspective on the situation facing Panamanian primates. The case study of primate evaluation and research presented in this thesis is not only relevant to Panama: it will also be useful to other countries in the Neotropics, especially those where conservation education is needed. Environmental education is an important part of conservation activities: in this thesis I show how it can be enhanced by an understanding of local people's knowledge base as it relates to their local environments in general and to local primate species in particular. I recommend to other researchers, and those active in conservation work, the methods I have been using to survey primates in diverse habitats, and to understand the links between cultural values and primates in Azuero, one of the more fragmented areas in Panama. The research presented here will also be relevant to management support, in the case of Panamanian or other authorities needing to assess translocation options or release primates after rehabilitation.

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Fifteen years have elapsed since I started my initiatives in the study and conservation of the non-human primates of Panama. The following are institutions or organizations that made this long term data collection possible over those years:

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List of Abbreviations

ANCON Asociación Nacional para la Conservación de la Naturaleza/National Association for the Conservation of Nature

AUC Area Under the Curve

CCT Cultural Consensus Theory

CIAT International Center for Tropical Agriculture

CoZEM Colección Zoológica Dr. Eustorgio Méndez

DNA Deoxyribonucleic acid

EVI Enhanced Vegetation Index

FCPP Fundación Pro-Conservación de los Primates Panameños (FCPP)/ For Conservation Foundation of Panamanian Primates

FCP Community Forestry Program

GHCN Global Historical Climatology Network

GPS Global Position System

ICGES Instituto Conmemorativo Gorgas de Estudios de la Salud/ Gorgas Commemorative Institute for Health Studies

INEC Instituto Nacional de Estadística y Censo/ National Institute of Survey and Statistics

IUCN International Union for Conservation of Nature

LGM Linear Generalized Model

LEK Local Ecological Knowledge

MaxEnt Maximum Entropy

MIDA Ministerio de Desarrollo Agropecuario/ Agriculture Development Ministry

MNHN Museum of National History of Nature

NDVI Normalized Difference of Vegetation Index

NGO Non-Governmental Organization

NHP Non-Human Primates

OCS Orion Camera System

PSG Primate Specialist Group

PO Presence only data

PVC Policloruro de Vinilo/ polyvinyl chloride

SDM Species Distribution Model

SOMASPA Sociedad Mastozoológica de Panamá/ Panama Mammal Society

SR Species Richness

SSC Species Survival Commission

STRI Smithsonian Tropical Research Institute

USD United States Dollar

USNM United States Natural Museum

Dedication

As a child, I was exposed to literature, music and people that are difficult to forget, and some of them influenced my desires to study zoology, and, eventually, to work in conservation. This thesis is considered to be the final grade and most important achievement in my academic life, and I think it is important to recognize who influenced me.

For my mother Marta Carvajal Vda. de Méndez and my father Rodolfo A. Méndez Vargas (R.I.P.), who inspired me to learn from the animals and plants, and to always protect them. Also in memories of my favourite television shows *Animal Kingdom* directed by Marlin Perkins, *The Submarine World* by Jacques Yves Cousteau, and El Mundo Marino-in Sabados con Martínez Blanco by Carlos Arellano Lennox.

I dedicate this thesis, also, to the scoutmasters that took care of me when child, and taught me well how to observe and respect wild animals when I was a boy scout: Alexis Madrid (R.I.P.), Manuel Quintero, and Eduardo Soto from the Scout Group 55, Rev. Francisco Javier Saenz, San Felipe, Old Town, Panama.

For the flora and fauna of Panama, especially the non-human primates.

Keywords per Chapter

CHAPTER 1	CHAPTER 2	CHAPTER 3
Neotropical primates Panama Diversity Limitations Evaluations Species survivorship	Fragmentation Literature Habitat suitability Presence/absence Species	Forest cover Presence Distribution Endemism Modelling

CHAPTER 4	CHAPTER 5	CHAPTER 6
Human Perception Culture Education Ideas	Survivorship Limitations Knowledge Status Species	Orion Camera System Species evalution Popular perception of primates Conservation planning Endangered species

1 Introduction: the Conservation Status of Panamanian Primates

The conservation status of a species is based on an evaluation and an estimation: an evaluation of the threats to the survival and biology of that species, and an estimation of the probability that the species will survive under natural conditions (Rylands et al., 1997). The study of the biology of the target animal is important to understand their needs and which factors affects them. The next step is to evaluate their presence, as species are present where they can survive (Rodríguez-Luna et al., 1996). Food availability and climate drive distribution patterns (Elith et al., 2006; Vidal-García and Serio Silva, 2011). We also need to understand birth rates and mortality, group structure, and densities, including total population size, when possible (Peck et al., 2010). In addition to these three aspects, it is important to include a human aspect to understand and contribute to conservation efforts and evaluation of threats to primates (Setchell et al., 2016). Accurate information is important, as it allows us to prioritise investment appropriately. In this thesis, I seek to understand threats to non-human primates in Panama. I use 15 years of primate surveys and conservation in Panama to improve our understanding of the strategies necessary to conserve those primate species. I use updated information to monitor and evaluate the potential distribution of primate in Panama, report population densities and examine human perceptions of non-human primates in one of the most fragmented areas of the country. I use my results to complement the IUCN Criteria for the Conservation Status of the species.

1.1 Primates: an Overview

Primates are an order of mammals that includes human beings (Wich and Marshall, 2016; Figure 1.1). In general, primates are found in tropical regions, with a smaller distribution at high and low latitudes (Mittermeier et al., 1989). Primates vary in size, with a mass range of 30-200 kg (Dammhahn and Kappeler, 2005; Wich and Marshall, 2016). The main point of differentiation separating primates from other mammals is their physical characteristics. These include nails instead of claws, opposable thumbs, stereoscopic vision, five fingers on their hands and feet, brains that are relatively large for their body size, complex social organisations, long lives, and a slow life history (Cowlishaw and Dunbar, 2000; Fleagle, 2013). Primates can be solitary, or they can live in uni-male multi-female systems, multi-male uni-female systems or multi-male multi-female systems (Sussman 2000). In each of these systems, survival depends on satisfying nutritional requirements, and avoiding competition, predation and infanticide (Wrangham, 1980; Wich and Marshall, 2016).

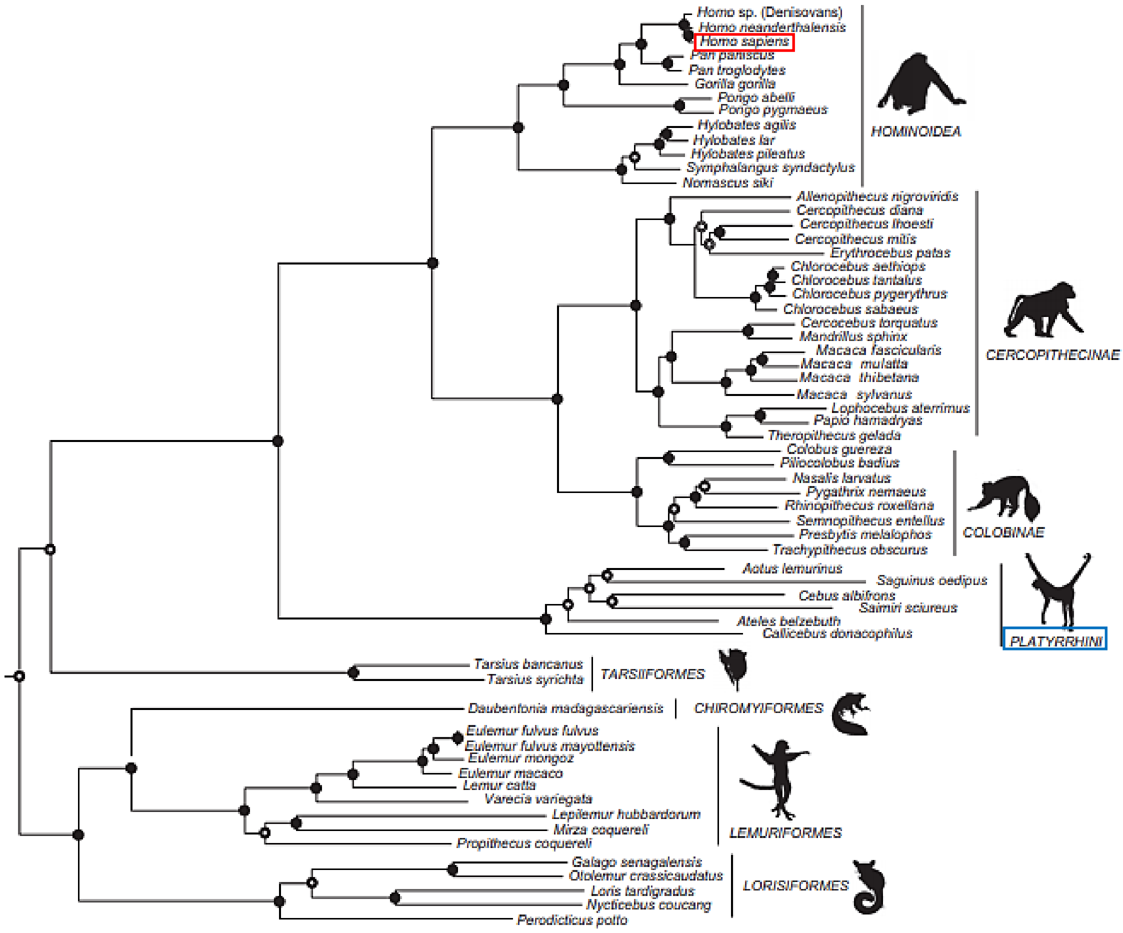

Figure 1.1 A composite phylogeny of primates, taken from Pozzi et al., (2014) with some modifications. The red square marks our own position, so we can understand our relationship to the Platyrrhini (in blue), the topic of this thesis.

Most primates are frugivores, but they can also be insectivores, faunivores, omnivores, and folivores (Rowe, 2016). Due to this variation in food requirements, primates have few dental specialisations (Lucas, 2004; Which and Marshall, 2016). Primates live in numerous habitats, from extended arid savannahs to tropical evergreen forests. They can be terrestrial, like some of the African primates, or strictly arboreal, like the Neotropical primates.

The primates comprise 77 genera, 504 species, and 634 subspecies (Mittermeier et al., 2013, Estrada et al., 2017) (Figure 1.1.). They are divided into two groups, the strepsirrhines and haplorrhines. Strepsirrhines contain the lorises and lemurs, among others. Haplorrhines are divided into tarsiiformes and simiiformes, and this last group is divided into the catarrhines (Old World monkeys and apes) and the platyrrhines (New

World monkeys). Old World primates include cercopithecines, such as baboons and mandrills, which are distributed in South and East Asia, the Middle East, Africa, and Gibraltar (Cowlishaw and Dunbar, 2000). The New World (or Neotropical) primates, on which this thesis focusses, are distributed in the Neotropics, the American continents and the Caribbean, and evolved from ancestral African primates 40 million years ago (Mittermeier et al., 2013).

Neotropical primates are mainly medium size mammals, from 107 g (e.g., pygmy marmosets *Cebuella pygmaea*) to 12 kg (e.g., muriquis *Brachyteles hypoxanthus*) (Rylands et al., 2006). Medium-sized primates in the families Cebidae and Atelidae have evolved a prehensile tail which helps them to both balance and to grab larger branches as they move upwards into forest canopies (Mittermeier, 1977). Neotropical primates are naturally present only in Mesoamerica (Southern Mexico to Panama) (Figure 1.2) and South America (Colombia to northern of Argentina). The latter continent is the most diverse ecoregion in terms of primate species, accounting for 215 of the world's 504 species of primate (Olson and Dinerstain, 1998; Estrada et al., 2017). Panama has the highest primate biodiversity in Mesoamerica, supporting almost 50% of the Mesoamerican region's subspecies. This thesis deals with Panama, and most of my examples and comparisons involve or are informed by studies of Mesoamerican primates.

Non-human primates are part of the trophic chain, serving mostly as primary consumers, protein resources for top predators, and controllers or modifiers of their surrounding flora. This makes them important contributors to the efficient functioning of their local ecosystems (Oppenheimer, 1992) and the presence of primates in their natural habitat can be considered as a sign of a healthy environment (Cowlishaw and Dunbar, 2000). They disperse seeds, trim branches, pollinate flowers, and if arboreal, drop fruits while eating, indirectly feeding other animals in the understory (Jones et al., 1994; Boogert et al., 2006). For example, in the Neotropics, whitefaced capuchin monkeys (*Cebus imitator*) consume around 95 of the 240 tree species available and spit out and excrete seeds as far as 800 m from the original tree (Janzen, 1970; Wehncke et al., 2003). The Colombian night monkey (*Aotus lemurinus*) is another example of seed disperser; they can eat 10 *Inga edulis* fruits in 20 minutes (Marín-Gómez, 2008). Rainforest structure is also influenced by mammal diversity and primates' role as seed predators (Oppenheimer, 1992). The presence of primates in a forest is important, as it helps to preserve the structural integrity of forests and could be a potential focus of conservation activities.

1.2 Threats to Non-Human Primates

Despite being important contributors to the forests and their environmental diversity, primates are under pressure. Most of the world's biodiverse regions are threatened by increasing human population densities (Cowlishaw and Dunbar 2000; Luck et al., 2004). The demand for increased crop production is turning tropical forests into over-exploited and deforested lands (Kindall and Pimentel, 1994). The overuse of soil tends to cause a loss of nutrients, while deforestation is reducing the rate of rainfall and causing other climatic disorders (Swinton et al., 2003; FAO, 2011). Non-human primates are one of the most threatened groups of mammals, and conservation efforts are needed to save them from extinction. In addition to habitat destruction, local people may hunt primates for cultural and commercial purposes, such as for food, traditional medicine and the pet trade (Bowen-Jones and Pendry, 1999; Mercado and Wallace, 2010). Indirect factors, including regional beliefs, taboos, and inappropriate practices, can also have adverse effects on primate populations. Examples of inappropriate practices include releasing captive primates without no management plan or knowledge of their distribution, the removal of animals from protected areas to introduce animals to un-protected areas, and the perception that human feeding of non-human primates is a positive action (Adams, 2007). Other pressures, such as habitat encroachment, can affect primate behaviour. Fragmentation of habitats forces arboreal primates to walk long distances on the ground to reach other trees, leaving them at risk of being killed by dogs, or other predators (Méndez-Carvajal, 2005; Méndez-Carvajal and Moreno, 2014). A diversity of threats arising from anthropogenic activities could lead a primate group or species to extinction. For this reason, there is a need for periodic and realistic evaluations of the conservation status of each taxon. The accurate evaluation of each taxon around the world is difficult if there is a lack of researchers who can provide relevant and reliable data. My goal in this thesis is to enhance the evaluation of Panamanian primate taxa.

1.3 Assessing Primate Conservation Status

The International Union for Conservation of Nature (IUCN) is a global authority on the conservation status of species. The IUCN Red List of Threatened Species is based on a system designed to determine the chance of extinction or vulnerability of all species. It is a global source of data that evaluates the conservation status of animal, plant and fungi taxa, in which each species is individually assessed (Cotton et al., 2016). The evaluation of primates is the responsibility of the Primate Specialist Group, which brings together more than 100 specialists from all over the world to act for the Species Survival Commission of the IUCN. This system analyses risk factors including: life history and distribution of the organism; conservation actions; data quality and population assessment; and habitat range conditions and their implications (Rylands et al., 1997). Understanding species' ecology and the potential threats they face are important aspects of conservation (Cowlishaw and Dunbar, 2000; Nadler et al., 2007) and for understanding how anthropogenic pressures may affect survival (Butynski and Koster, 1994). The IUCN categorises threatened species according to habitat availability and anthropogenic threats, species distribution, and overall population viability (Crocket, 1998).

The IUCN Red List of Threatened Species categories and criteria were first described in 1994 and have developed over time into a list of criteria to guide conservation activities and avoid extirpation (IUCN, 2012). There are nine categories: Not Evaluated, Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild, and Extinct (see Chapter 2) (IUCN Standards and Petition Subcommittee, 2016). The evaluation of a species requires knowledge of distributions and populations to be as accurate as possible. Ideally, a long-term monitoring program should measure the population growth, reproductive rate, fluctuations and food availability (Cowlishaw and Dunbar, 2000). IUCN allows the incorporation of inference and projections in the evaluations to assess taxa in the absence of information (IUCN Standards and Petitions Subcommittee, 2016).

According to IUCN, in the world, there are 64 subspecies of primate taxa considered Critically Endangered (CR), 141 are Endangered (EN), 98 are Vulnerable (VU), 37 are Near Threatened (NT), 195 are Least Concern (LC), 83 are Deficient Data (DD), and 16 are Not Evaluated (Cotton et al., 2016). In the Neotropics, 21 species are listed as CR, 28 as EN, 30 as VU, 9 as NT, 95 as LC, 16 as with DD, with none listed as NE (Cotton et al., 2016).

1.4 Human Dimensions of Conservation

To conserve primates, it is important to understand the threats to primate habitats which are caused by human activities. Conservation efforts must be tailored to address different causes of habitat and primate species losses (Rabinowitz, 2003). For example, we need to understand local people's perceptions of primates, and use this understanding to promote conservation. Promotional activities may include talks, dissemination of informative material, and informal conversations between researchers and the local people (Barrett and Arcese, 1995; Campbell et al., 2016). Involving local volunteers as field assistants in monitoring projects helps local people learn about, and become more conscious of, the importance of their local natural resources. It can help them to realise that species are vulnerable to extinction and inspire them to act against potential threats (O'Grady et al., 2004). Local people may not cooperate with conservation activities if the community lacks an adequate educational framework and the institutional guidance necessary to mitigate conflicts for resources (Isager et al., 2002). However, community participation programs can succeed if they are well structured and consistent (Wily and Dewees, 2001; Horwich et al., 2013). Local people hunt primates for cultural and commercial reasons, such as the need to obtain protein sources, procure ingredients for traditional medicine, supply the illegal pet trade, and lethal control of crop foraging animals (Mercado and Wallace, 2010). Other pressures related to agricultural activities in overlapping habitats may attract primates to take advantage of nearby crops, creating an economic problem (Lokschin et al., 2007; Isabirye-Basuta and Lwagna, 2008).

Ethnoprimatology, the study of the relationship between humans and the non-human primates living in a common habitat, can help evaluate peoples' perceptions of, attitudes and knowledge of wildlife (Hill and Webber, 2010). Ethnoprimatology is especially useful in agricultural zones where non-human primates interact with human-made farming lands, which can lead to conflict due to overlapping resource use (Sprague, 2002; Riley and Ellwanger, 2013; Nekaris et al., 2013).

1.5 Mesoamerican Primates

In Mesoamerica, nine countries are home to 23 primate taxa. In those nine countries, IUCN has reported eight CR species, 17 EN species, four VU, eight NT, no LC species, and two DD (IUCN NPSG 2015, unpublished data). Neotropical primates cannot survive without access to forest habitats. In consequence, they are affected by climate variables, increasing local human population levels, human hunting and agricultural activities, and the number of human dwellings (Kindall and Pimentel, 1994; Cowlishaw and Dunbar 2000; Swinton et al., 2003; Luck et al., 2004; FAO, 2011). Conservation activities are urgently needed to protect their biodiversity. The richness of primate diversity in Mesoamerica (Figure 1.2) is related to the number of plant species and ecological niches this region possesses, in which primates serve as disseminators and pollinators, and the region's proximity to the Colombian Chocó (Oppenheimer, 1992). This proximity is crucial as primates tend to migrate from the Colombian Chocó to Panama's Darien province and to the Panamanian Chocó.

Figure 1.2. Map of Mesoamerica

Mesoamerica's primates include tamarins (*Saguinus* spp.), owl monkeys (*Aotus* spp.), squirrel monkeys (*Saimiri* spp.), capuchin monkeys (*Cebus* spp.), howler monkeys (*Alouatta* spp.), and spider monkeys (*Ateles* spp.) (Rylands et al., 2006) (Table 1.1). However, the taxonomy of the Mesoamerican primates is not yet clear, due to difficulties involved in obtaining genetic information for some species (Estrada et al., 2006), and confusing historical information collected by naturalists (Rylands et al., 1995). Improving the knowledge of local primate diversity is important for conservation (Rodríguez-Luna et al., 1996). Some of the species that are not well identified in Mesoamerica are from the genus *Ateles*, as the first identifications used phenotypic characteristics, but these subspecies differ in coloration patterns, causing controversy. Some examples of subspecies not well defined yet are *Ateles geoffroyi geoffroyi*, *Ateles geoffroyi panamensis*, *Ateles* *geoffroyi azuerensis*, *Ateles geoffroyi yucatanensis*, *Ateles geoffroyi grisescens*, *Ateles geoffroyi pan*, and *Ateles fusciceps rufiventris* (Kellogg and Goldman, 1944). The genus *Alouatta* is also causing taxonomic controversy, particularly around the two species described as endemic in Panama, *Alouatta coibensis* and *Alouatta palliata* (Cortes-Ortiz et al., 2003).

Table 1.1. Primates of Mesoamerica. Subspecies present in Panama are highlighted in green.

Family	Subspecies	Distribution	Spanish name	English name
Callithricidae	*Saguinus geoffroyi*	Costa Rica*, Panama, Colombia	Tamarino	Geoffroyi's tamarin
Aotidae **Cebidae**	*Aotus zonalis* *Saimiri oerstedii oerstedii* *Saimiri oerstedii citrinellus*	Costa Rica*, Panama, Colombia Costa Rica, Panama Costa Rica	Mono nocturno Mono titi chiricano	Panamanian night monkey Black crowned CA squirrel monkey
Cebidae	*Cebus capucinus limitaneus* *Cebus imitator* *Cebus capucinus*	Belize, Honduras, Nicaragua Costa Rica, Panama Panama, Colombia	Mono capuchino	Panamanian white fronted capuchin monkey
Atelidae	*Alouatta palliata mexicana*	Mexico, Guatemala	Mono aullador, pardo, saraguato	Mexican howler monkey
Atelidae	*Alouatta palliata palliata*	Honduras, Nicaragua, Costa Rica, Panama	Mono aullador de manto	Golden mantled howler monkey
Atelidae	*Alouatta palliata aequatorialis*	Panama, Colombia, Ecuador, Peru	Mono aullador de ecuador	Howler monkey
Atelidae	*Alouatta coibensis coibensis*	Panama	Mono aullador de Coiba	Coiba howler monkey
Atelidae	*Alouatta coibensis trabeata*	Panama	Mono aullador de Azuero	Azuero howler monkey
Atelidae	*Alouatta pigra*	Mexico, Belize, Guatemala	Mono aullador negro	Black howler monkey

Atelidae	*Ateles geoffroyi geoffroyi*	Nicaragua	Mono araña	Geoffroy's spider monkey
Atelidae	*Ateles geoffroyi azuerensis*	Panama	Mono araña	Azuero spider monkey
Atelidae	*Ateles geoffroyi frontatus*	Costa Rica, Nicaragua	Mono araña	Black-browed spider monkey
Atelidae	*Ateles geoffroyi grisescens*	Panama, Colombia	Mono araña	Hooded spider monkey
Atelidae	*Ateles geoffroyi pan*	Guatemala	Mono araña	Guatemalan spider monkey
Atelidae	*Ateles geoffroyi panamensis*	Costa Rica, Panama	Mono araña	Panamanian Red spider monkey
Atelidae	*Ateles geoffroyi ornatus*	Costa Rica	Mono araña	Ornate spider monkey
Atelidae	*Ateles geoffroyi vellerosus*	Mexico, Guatemala, El Salvador, Honduras	Mono araña	Mexican spider monkey
Atelidae	*Ateles geoffroyi yucatanensis*	Mexico, Belize, Guatemala	Mono araña	Yucatan spider monkey
Atelidae	*Ateles fusciceps robustus*	Panama, Colombia	Mono araña	Colombian black spider monkey

*Reported as rare for some authors

Mesoamerica is composed of different terrestrial habitats, the most common being tropical rainforest, and the others being mangroves, and other tropical and subtropical habitats including perennifolia forest, caducifolium forest, pine forest, palms, mesofilium forest, and areas that are populated by humans or turned into agroecosystems (Campbell and Hammond, 1991) (Figure 1.3.). The lack of development, influence and demand of high-income countries for natural resources, along with local corruption, has increased the difficulty of protecting the forest such that each country is fighting to protect its biodiversity. Most recently, the main driver of habitat loss in the Mesoamerican region was illegal deforestation related to smuggling (McGrath, 2014).

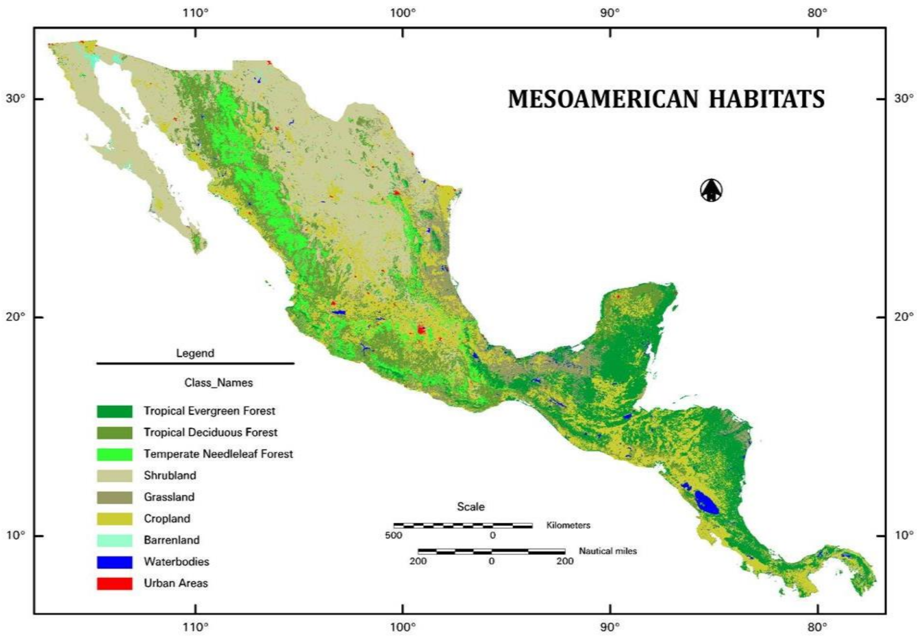

Figure 1.3. Mesoamerican vegetation. Map taken from US Geographical Survey, U.S. Department of the Interior.

1.5.1 Studies and Conservation Status of Mesoamerican Primates

Existing population densities of Mesoamerican primates are based on narrative descriptions of what naturalists saw while exploring natural habitats. Even in those cases where it is appropriate to use the presence data available in scientific collections, information about locality, elevation, body measurements, population densities, and habitat condition is poorly described. My experience working at natural science museums alerted me to the number of specimens that were inaccurately identified and incorrectly attributed to locations. Ecological niche models using mathematical algorithms can provide improved potential species distribution maps (Zaniewski et al., 2002; Phillips et al., 2006) but only if locations are supported with quality distribution data.

Local scientists and their knowledge are very valuable for conservation in Mesoamerica, since this knowledge is a key tool for the mitigation of threats to primates (Table 1.2) (Rylands et al., 2006). Two evaluations of Mesoamerican primatology, by primatologists and veterinarians from Mesoamerica (Table 1.3) (Matamoros et al., 1995; Rodríguez-Luna et al. 2006), concluded that to evaluate the conservation status of Mesoamerican primate species, it is important to consider how threats (e.g. hunting and logging) are changing primate distribution (Chapter 3), and how to assess the effects of fragmentation on the distribution, population structure, presence, genetic diversity, physiological stress, and health of primates.

Table 1.2. Basic information about Mesoamerican primates.

Taxon	Mating system	Gestation (days)	Diet	Activity	Threats
Family Callitrichidae					
Saguinus geoffroyi	Monogamous	130	Insects/ fruits	diurnal	Habitat loss, pet trade
Family Aotidae					
Aotus zonalis	Monogamous	117	Insects/ fruits	nocturnal	Habitat loss, capture for laboratory use
Family Cebidae					
Saimiri oerstedii	Polygamous	167	Insects/ fruits	diurnal	Habitat loss, pet trade
Cebus imitator	Polygamous	160	Insects/ fruits	diurnal	Habitat loss, pet trade, hunting
Cebus capucinus	Polygamous	160	Insects/ fruits	diurnal	Habitat loss, pet trade, hunting
Family Atelidae					
Alouatta coibensis coibensis	Polygamous	186	Leaves/ fruits	diurnal	Habitat loss
Alouatta coibensis trabeata	Polygamous	186	Leaves/ fruits	diurnal	Habitat loss, herbicides
Alouatta palliata palliata	Polygamous	186	Leaves/ fruits	diurnal	Habitat loss
Alouatta palliata aequatorialis	Polygamous	186	Leaves/ fruits	diurnal	Habitat loss
Ateles geoffroyi panamensis	Polygamous	226	fruits	diurnal	Habitat loss, hunting
Ateles geoffroyi azuerensis	Polygamous	226	fruits	diurnal	Habitat loss, pet trade, hunting
Ateles geoffroyi grisescens	Polygamous	226	fruits	diurnal	Habitat loss, pet trade, hunting
A. fusciceps rufiventris	Polygamous	226	fruits	diurnal	Habitat loss, pet trade, hunting

Table 1.3. Research topics relevant to primate conservation in Mesoamerica

Research topic	Advantages	Disadvantages	Country	Reference
Landscape studies, Fragmentation	Allow interaction with human communities	Fragments are difficult to measure, require long term data	Mexico	Rodríguez-Luna et al., 2006

Population surveys	Enables understanding of population densities, mortality and nativity	Difficult to achieve full coverage of country, high probability of bias, requires adequate funding	Mexico	Rodríguez-Luna et al., 2006
Biological studies	Allows understanding of behaviour and requirements for survival	Needs sufficient sample size to draw conclusions	Mexico	Rodríguez-Luna et al., 2006
Distribution by modelling program	Produces accurate understanding of species' location	Needs data to cover whole country	Mexico	Rodríguez-Luna et al., 2006
Genetic studies	Some of them produces accurate taxonomies	Needs appropriate sample size and expensive logistical support	Mexico	Rodríguez-Luna et al., 2006
Assessing species status by literature	Helps prioritise conservation efforts	Needs good, long-term data, including on threats	Mexico	Rodríguez-Luna et al., 2006
Population Survey, Monitoring	Allows us to understand population densities, mortality and natality rates	Difficult to cover entire country, high probability of bias, requires adequate funding	Costa Rica	Rodríguez-Matamoros et al., 1997
Taxonomy	Helps us to recognise taxa accurately	Needs appropriate sample size and expensive logistical support	Costa Rica	Rodríguez-Matamoros et al., 1997

The IUCN has recommended an improvement in the studies of primate distribution and population status, and the participation of more primatologists from each country (Rodríguez-Luna et al., 1996). The IUCN primate conservation status is based on biological information (e.g., a few reports of densities, sights, and local references), reported distributions, and available records or publications, and on knowledge of the extent of forest cover in National Parks and Reserves from each country. However, the first evaluations of primate species in Mesoamerica made by the IUCN assume that all protected areas contain non-human primates, expecting that local scientists will improve this information. A recent study of Mexican primates improved on this by using the Maximum Entropy algorithm to understand habitat suitability for *Ateles geoffroyi*, *Alouatta* *palliata* and *Alouatta pigra* (Vidal-García and Serio-Silva, 2011). This survey used the WorldClim database as a source for 19 environmental variables, all of which are available on the internet (https://www.worldclim.org/bioclim). In this thesis, using MaxEnt software, I analyse Panama's 13 subspecies using the same bioclimatic parameters as in Mexico.

1.6 Assessing the Conservation Status of Panamanian Primates

The conservation status of Panamanian primates has been poorly assessed in the past, as little information relevant to the subject was available. In Panama, the first such evaluations were done by Felix Nuñez, Jacobo Araúz and Ariel Rodríguez of the University of Panama, using available information about forest cover and population surveys. Their work was based on information from surveys focused on mammals in general and relied heavily on anecdotal reports from local people and historical data about locations mentioned in the literature (See section 1.7). This information was useful in creating a basic map of the vegetation distribution in Panama, but less useful for conservation. Precision in distribution maps is important if we wish to use those maps to examine patterns of threats to primates, and to relate them to human behaviour. Some of the species whose presence has been reported in Panama are absent in other Mesoamerican countries, so we cannot infer the anthropogenic pressure these species experience in Panama from accounts of anthropogenic pressures in other Mesoamerican countries. In Costa Rica, for example, there is no reported presence of the Darien black spider monkey, the night monkey, or tamarins, so, for those species, the anthropogenic pressure these species experience in Panama cannot be inferred from that in other Mesoamerican countries. This also implies that conservation strategies which focus on these species that are unique to Panama will also be unique.

The conservation status evaluation described in section 1.3 is augmented in Panama; IUCN parameters are used as the main guidelines, but law enforcement is also empowered to confiscate or arrest people for illegal traffic. This is important for the government, as it allows them quantify the threat of illegal trade – and it also helps to regulate scientific permission or not to control scientific collection (Svensson et al., 2016). For primate species the conservation status is evaluated via an assessment of the conditions in which the animal still survives, including the enforcement of laws which may impact upon those conditions, and through a consideration of the possibility of that species becoming extinct (Rylands et al., 1997). Data about local people and the political nature of the area are also important (Hill and Webber, 2010). Protected areas can serve as species "banks" to ensure the survival of Endemic and Critically Endangered species (Butchard et al., 1996). Once protected areas are created, it is necessary to monitor local biodiversity through regular surveys to evaluate conservation status. Depending on land use and target species, protected areas may not always work effectively for conservation if there good links between communities and conservationists are absent (Setchell et al., 2017). Therefore, communities should always be involved with conservation activities (Boyd et al., 2008), and the promotion of this involvement is a principal objective of the community-based conservation movement that started in the early 1980s (Waylen et al., 2010). One of the most important recommendations for conservation projects is that they should outline the protection of forest, education, local interest, and communication as early as possible (Kortlandt et al., 1995). Conservation practices tend to be deployed in areas situated between agro-ecosystems remaining populations of wildlife (Setchell et al., 2017). In such cases, predation rates, vegetation cover and poaching incidence all need to be monitored (Estrada et al., 2017). "Conflict" between humans and wildlife can be addressed by integrating local practices into conservation work, and by attending to the needs of village communities (Hill, 2015). For conservation, we need a clear idea of species distribution patterns, involving both geographical and anthropological variables (Kay et al., 1997; Horwich et al., 2013).

1.6.1 Description of the Republic of Panama

Here, to put my work in context, I describe some generalities of Panama, including its history, geographic and political organisation, and cultural influences. I carried out fieldwork in the entire Republic of Panama, in Central America, located at 7°12' - 9°37' North latitude, between Costa Rica (western limit) and Colombia (eastern limit). The north is bordered by the Caribbean Sea and south by the Pacific Ocean. Panama has a total area of 75,517 km^2; the country's main exports are bananas, fish, shrimp, coffee, watermelon, pineapple, sugar, beef, iron residuals, copper residuals, gold, wood, and petroleum. Principal countries receiving exports from Panama in order of importance are: United States of America, Germany, China, Costa Rica, Netherlands, Vietnam, Spain and Italy (Instituto Nacional de Estadística y Censo (INEC, 2014). The human population is about 3 800 000 with life expectancy of 74 years for men and 79 years for women and a gross national income per capita of USD 7,910 (World Bank, 2011). Population densities vary (Figure 1.4). The dominant wealthy population is of European descent, and 33% of Panamanians are below the poverty line (Githens et al., 2014). The main religion is Christianity.

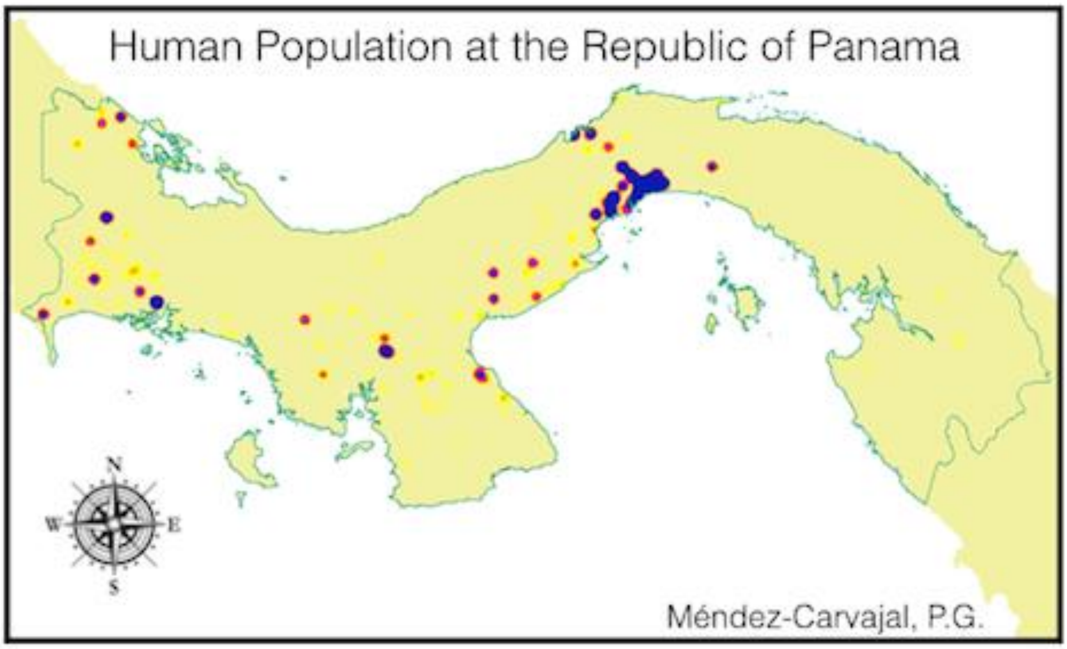

Figure 1.4. Human population density map of Panama based on data from 2010. Darker colours indicate higher human population density. Map created using data from the National Institute for Survey and Statistics in Panama (INEC in Spanish).

1.6.2 Panama: Ecological Extension Zones

Panama has a fragile ecosystem. It is narrow and long, with 12 life zones (Holdridge 1957, 1967; Tosi, 1971), and five vegetation categories (Figure 1.5). Panama has nine provinces as follows (from west to east): Bocas del Toro, Chiriqui, Veraguas, Cocle, Los Santos, Herrera, Colon, Panama, and Darien (Figure 1.6). Each province has a governor, and some have a special territory selected for indigenous people, termed as a "Comarca" or Indigenous territory. Life zones extensions in Panama comprise:

1) Wet Tropical Forest covers 32% of the national territory**.** Found in the Caribbean and Pacific sides of Panama, transitioning into Low Mountain Forest at 400 m above sea level (m.a.s.l.).

2) Very Wet Pre-mountain Forest covers 18% of the national territory of Panama's territory. It extends from the north and south of the continental division, with more presence in the Pacific side, mostly in Darien province, Panama east and some parts of Veraguas.

3) Very Wet Tropical Forest covers 13.4% of the national territory**.** Present on the Caribbean coast, the Azuero peninsula and the Panamanian gulf up to Darien.

4) Pre-Mountain Pluvial Forest covers 12.6% of the national territory. Found in the Chiriqui central mountain chain up to the Panama Central area and Darien.

5) Dry Tropical Forest constitutes 7% of the national territory**.** Found only in a small area of the Pacific side of Panama.

6) Pre-Mountain Wet Forest constitutes 3.5% of the national territory**.** Found in a small area in Darien province.

7) Low-Mountain Pluvial Forest constitutes 3.2% of the national territory**.** Found above 300 m.a.s.l., in the highlands of Chiriqui province only.

8) Pre-Mountain Dry Forest constitutes 3% of the national territory. Found on the Panama Gulf between Cocle, Herrera and Los Santos provinces.

9) Very Wet Low-Mountain Forest: Little is known about the forest coverage that can be included in this category.

10) Low-Mountain and Very Humid Forest constitutes 2% of the national territory. Found in Panama over 2,400 m.a.s.l.

11) Very Humid Mountain Forest: High land areas with 3,000 mm precipitation.

12) Pluvial Mountain Forest: Covering a medium size mountain chain and extending into lowland areas in the central west of Panama.

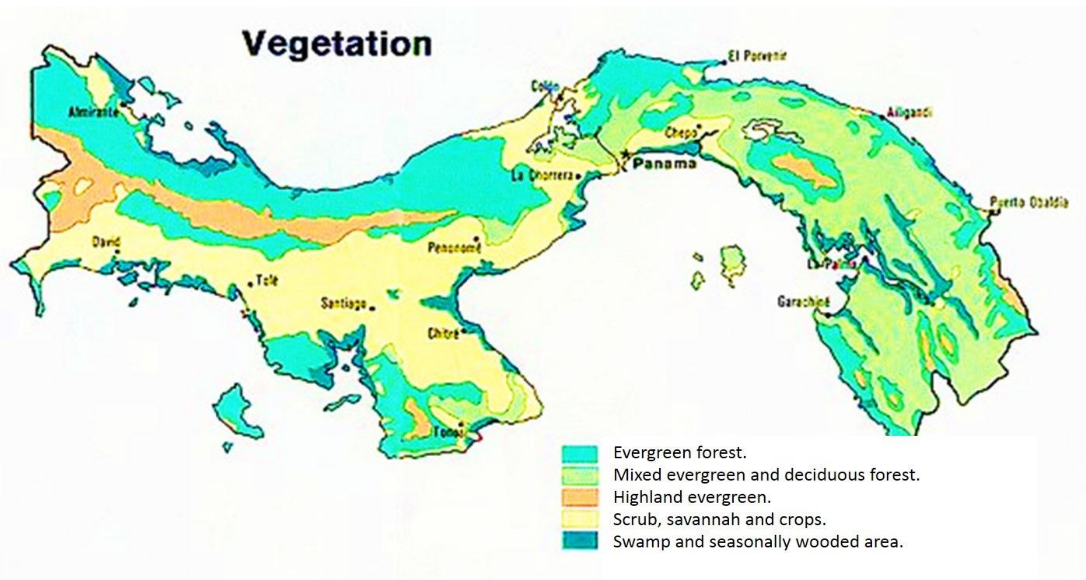

Figure 1.5 The five predominant vegetation zones in Panama.

Figure 1.6. The nine provinces and indigenous "comarcas" or territories in Panama.

1.6.3 Panama: a Brief Ethnographic History

The Panamanian Isthmus originated around three million years ago as a land bridge joining Central America with South America (Montes et al., 2015; Cook et al., 2017). Archaeological data indicate that at least three different indigenous groups lived in Panama during the period 500-900 AD: the Chibchan, Chocoan and Cuevas groups. The members of these groups mostly lived by hunting, fishing, and growing root crops, ultimately attaining a population of around two million (Calvo, 1995; Martínez-Mauri, 2011). From these indigenous cultures, 60 different groups emerged and spread across the isthmus, and were living there when the Spanish Captain Rodrigo De Bastidas arrived in Panama in 1501 (Heckadon-Moreno, 2001). The Spaniards, seeking to establish themselves in the country, fought against the indigenous people, who were eventually restricted to the forested mountains of the Chiriqui and the central mountain chain in the west of Panama, to the northern or Caribbean coasts, and to the Northeast mountain forests of the Darien and San Blas indigenous reserve. Once under the control of the Spaniards, the landscape was transformed by the introduction of farming and cattle ranches, and new culture that mixed Spanish culture with that of the indigenous peoples emerged (Torres de Araúz, 1980).

Panamanian culture was also influenced by the introduction of slaves from Africa and the Caribbean by the Spanish and French, which ultimately resulted in a unique mix of customs and diversity of religions in the isthmus, as well as a unique, village-level use of wildlife and a diversity of food preparation methods. After the interoceanic Panama Canal began to operate in 1914 (an earlier attempt to build such a canal across the isthmus, begun by Ferdinand de Lesseps in 1876, collapsed through fraud, maladministration and the effects of malaria and yellow fever on the construction workers) new Chinese, Jewish, Arabic and Indian communities entered Panama, further adding to the country's cultural and social diversity. Panama is composed of 65% mestizo, 9.2% black, 6.7% white and 12% tribal ethnic Indian (United Nations Department of Economic and Social Affairs, Population Division, 2017). An early map of ethnic distribution is printed here to understand cultural influence in Panama from INAC (2014) (Figure 1.7). Seven different indigenous populations exist and maintain their own languages and territories established and recognized by the Panamanian Government. These include the Ngäbe-Bugle, Guna, Emberá, Wounaan, Naso-Tjerdi, Bokota, and Bri-Bri, constituting a total population of 417,000 (Martínez-Mauri, 2011; INAC, 2014; Fortis, 2014) (Figure 1.8).

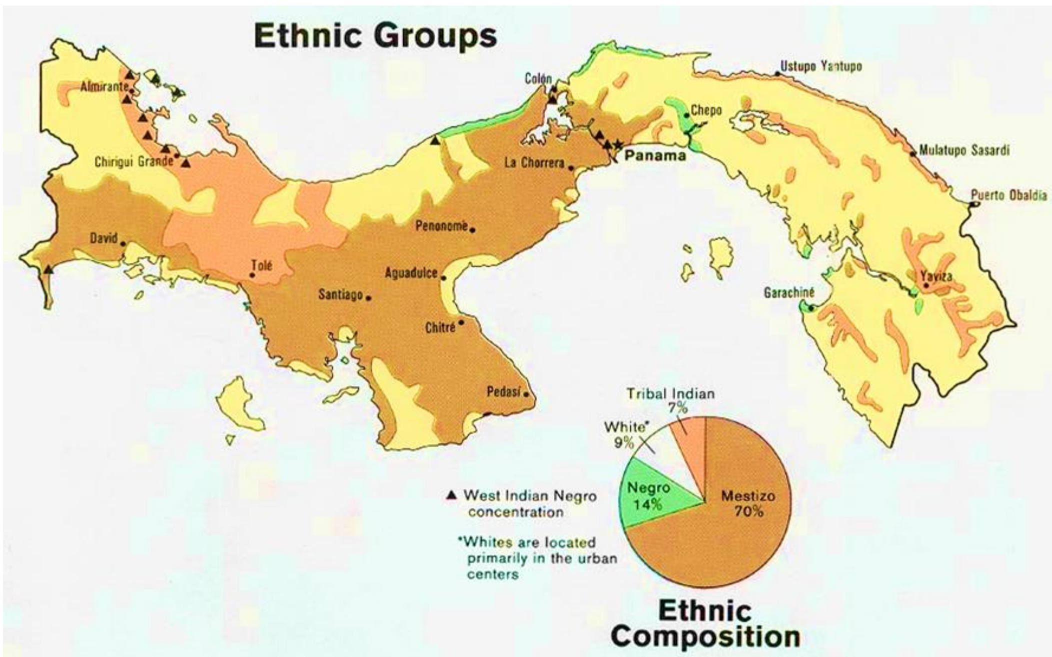

Figure 1.7. Ethnic composition of Panama (INAC, 2014).

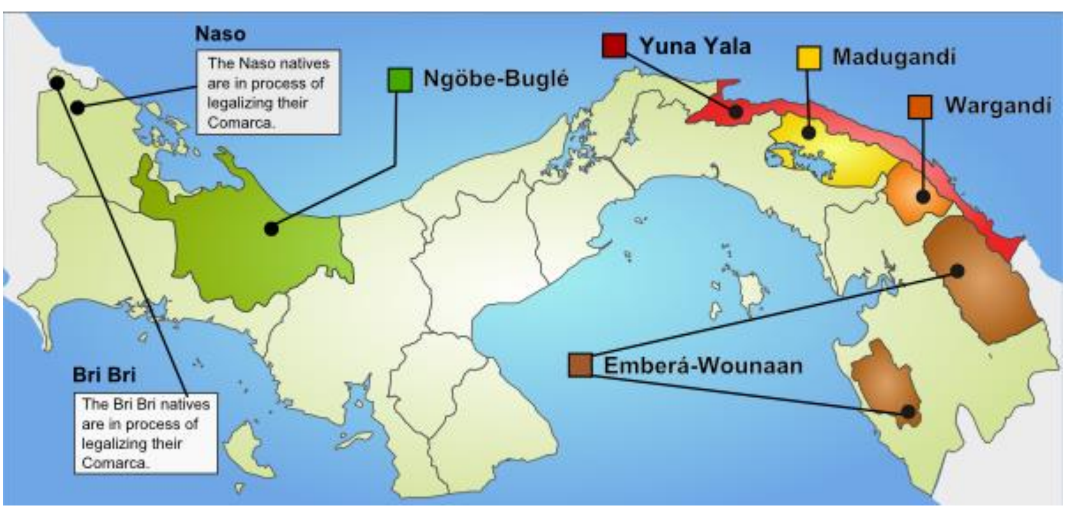

Figure 1.8. Indigenous territories in Panama (INAC, 2014).

1.6.4 Panama: Biodiversity

Panama is rich in biodiversity, with 264 mammal species, 354 reptiles and amphibians, and 954 species of birds, with at least 125 of these species being endemic to the country (Méndez, 1970; Ridgely and Gwynne, 1989). Panama has around 10,000 species of plants, with 687 species of ferns, 1,200 orchids and 1,500 species of trees. A recent Carbon Map has been created using a LiDAR by Smithsonian Tropical Research Institute (STRI), shows the vegetation (Figure 1.9).

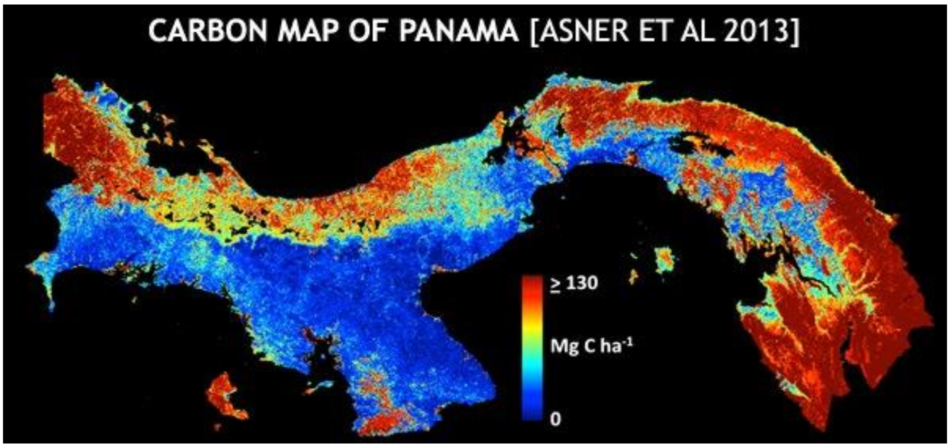

Figure 1.9. Forest cover in Panama based on LiDAR-NASA Landsat data. Red represents forest and blue represents grassland, cattle or human settlements (Asner et al., 2013).

Panama has 16 National Parks (Figure 1.10), and 10 different categories of natural reserves including Private Reserves, Protected Forest, Forest Reserves, and Natural Parks. Each province has a record of forest cover, which could be used to extrapolate primate population levels sizes of primates if we knew the population density.

Figure 1.10. Protected areas and reserves in Panama (INAC, 2014).

1.7 The History of Primatology in Panama

The study of Neotropical ecology in the early twentieth century, focused on the taxonomic and ethological study of non-human primates, especially for scientists from the United States of America, who made some of the first studies in countries such as Brazil, Panama, and Peru (Platas-Neri, 2007). Brief reports related to non-human primates have been published since the 1500s (Table 1.4). Panama was an interesting habitat for the naturalists who worked in the Panama Canal Biological Zone, who established a scientific base on Barro Colorado Island, in the centre of the Panama Canal, from 1923 to the present, producing a huge literature (Strum and Fedigan, 2000). However, unlike the scientific development that occurred gradually in Brazil and Peru, Panamanian primatology was left behind (Méndez-Carvajal, 2008). Despite the number of publications on Panamanian primates, Panamanian science did not focus on primatology (Méndez-Carvajal, 2014). Apart from biomedical studies that involve the use of nocturnal monkeys *Aotus zonalis* to test anti-malarial drugs (Obaldia III, 2015), primatology remained dormant in Panama.

The first Panamanian primatologists to achieve their bachelor thesis in primate behaviour did so between 1980 and 2001. The first Panamanian interested in studying primates in Panama was the late Carlos Brandaris. Brandaris completed his degree with the first thesis dedicated to Azuero howler monkeys *Alouatta coibensis trabeata* (Brandaris, 1983). In 1993, Jacobo Araúz completed his Master of Science in the Regional Wildlife Management Program (PRMVS) at the National University of Costa Rica (UNA) with a study conducted in Bajo Capulín, Herradura, Jacó, El Valle de Parrita, Quepos, and Río Grande de Térraba, with the title "Conservation status of the marmoset (*Saimiri oerstedii citrinellus*) in its original distribution area, Manuel Antonio, Costa Rica" (Araúz, 1993). Another professor who stands out in efforts to develop primatology in Panama was Ariel Rodríguez-Vargas, a graduate of the PRMVS of the UNA, who carried out the first Panamanian research on *S. o. oerstedi*i, with the title: "Analysis of the hypothetical population structure of the squirrel monkey (*Saimiri oerstedii*) in Panama". Ultimately published in English (Rodríguez-Vargas 2003) this was the greatest contribution to primatology made, to that date, by a Panamanian researcher.

The period from 2001 to the present started with the creation of the For-Conservation Foundation of Panamanian Primates (FCPP). The foundation's activities include surveying non-human primates all around Panama, developing long term research and conservation projects, supported by international funding (for the first time), publishing at national and international level, participating in primatological conferences for the first time, being referenced as national primatologists to the Environmental Ministry of Panama and at IUCN PSG, organising Primate symposia in Mesoamerica, and extending collaboration in primate conservation at the international level.

Table 1.4. Primatological contributions in Panama from the 1500s to 2019.

Author/Researcher	Year	Published books, references and reports
Pedro Mártir de Anglería	1516	"Décadas de Orbo Novo": reported non-human primates in Panama
José de Acosta	1580	Reported the presence of *Ateles* spp., in Capira, near Nombre de Dios, in his book "Historia Natural y Moral de las Indias"
Hugh Cumming	1791-1865	He published some references about primates
Berthold Seemann	1825-1871	He published some references about primates
Godman & Salvin	1879-1888	Published a book "Biologia Centrali-Americana
Lucien Napoleon Bonaparte Wyse	1845-1909	Reported fauna at the Panama Canal
Andreas Sandøe Öersted	1816-1872	Central American squirrel monkey *Saimiri oerstedii* discovered
Oldfield Thomas	1858-1929	Published and reviewed mammals taxonomy
Lionel W. Rothschild	1868-1937	Published and reviewed mammals taxonomy
Thomas Barbour	1884-1946	Published and reviewed mammals taxonomy
Harold Anthony	1890-1970	Published and reviewed mammals taxonomy
Joseph Batty	1902	Published and reviewed mammals taxonomy

Edward Goldman	1873-1946	Published and reviewed mammals taxonomy
Remington Kellogg	1873-1946	Published and reviewed mammals taxonomy
R.K. Enders	1930-1935	Published and reviewed mammals taxonomy
Charles R. Carpenter	1933-1935	Did the first study of ethology in Neotropical Primates
Patterson Bole	1937	Described *Ateles azuerensis*
Martin Moynihan	1964	Studied the ethology of *Saguinus geoffroyi* and *Aotus zonalis*
I.S. Bernstein	1964	Studied the activity patterns and behaviour for the howler monkey *A.p.aequatorialis*
David Chivers	1969	Studied behaviour of *Alouatta*
W. Richards	1970	Studied the genetics*, A.p.aequatorialis*
A. **Hladik & C.M. Hladik**	1969	Studied the diet and plant-primate relationship
K. Milton/C. Campbell, Dawson/Nagy/Wong/ K. Glander/J. Giacalone	1977-2018	Studied diet and plant-primate relationship
J.D. Baldwin & J.I. Baldwin	1971-1977	Studied populations in *S. oerstedii*, *A.p. aequatorialis* and *Cebus imitator*
Russell Mittermeier	1973-1977	Studied densities of *A. coibensis* and *C. imitator* in Coiba Island
S.G.C. Gaulin et al.	1980	Studied *Alouatta*/population dynamic
Leighton & Leighton	1982	Studied *Alouatta*/population dynamic
Carlos Brandaris	1983	Studied *Alouatta coibensis trabeata*/behaviour
Colin Chapman	1998	Studied *Alouatta*/population dynamic
Carolyn Crockett	1997	Studied *Alouatta*/conservation
Christina Campbell	1991-2015	Studied *Ateles*/behaviour/conservation

J.W. Froehlich & J.S. Froehlich	1987	Studied *Alouatta*/ phylogeny
Liliana Cortés-Ortiz	1999-2003	Studied *Alouatta*/phylogeny
R. Gil Da Costa	2003	Studied *Alouatta*/predation/vocalisations
Ariel Rodríguez-Vargas/Jacobo Araúz	2006	Studied *Saimiri*/modelling/conservation
FCPP	1998-2019	Study population density, distribution, and conservation

1.8 Primates of Panama

In 1996, the IUCN Action Plan for Mesoamerican Primates included the most recent review of Panamanian primates (Table 1.5) (Ruiz-García et al., 2007; Boubli et al., 2012). The 13 Panamanian primate species were evaluated as two Critically Endangered (CR), four Endangered (EN), two Vulnerable (VU), four Least Concern (LC), and one as Data Deficient (DD) (Rodríguez-Luna et al., 1996) (Table 1.5). The distribution map obtained in this evaluation suggested extensive vegetation cover in Panama, implying the potential presence of primates, and was based on direct observations by naturalists from the beginning of the 1900s, which had inaccuracies in locations due to the lack of technology such as GPS (Anderson et al., 2003).

Table 1.5. List of Panamanian primates according to Rodríguez-Luna et al (1996).

Common name	Scientific name	IUCN category
Geoffroy's tamarin	*Saguinus geoffroyi*	Least Concern (LC)
Panamanian Night monkey	*Aotus zonalis*	Data Deficient (DD)
Central American squirrel monkey	*Saimiri oerstedii*	Vulnerable (VU)
Capuchin monkey	*Cebus capucinus* *Cebus imitator*	Least Concern (LC)
Gold mantled Howler monkey **Ecuadorian howler monkey**	*Alouatta palliata palliata* *Alouatta palliata aequatorialis*	Least Concern (LC)
Coiba howler monkey	*Alouatta coibensis coibensis* *Alouatta coibensis trabeata*	Vulnerable (VU)

Red spider monkey	*Ateles geoffroyi azuerensis* *Ateles geoffroyi panamensis* *Ateles geoffroyi grisescens*	Endangered (EN)
Colombian Black spider monkey	*Ateles fusciceps rufiventris*	Critically Endangered (CR)

Panamanian primates are the most diverse and most threatened in Central America, but no conservation plan was implemented after the evaluation carried out by Rodríguez-Luna et al. (1996). In 2008, the IUCN attempted a second evaluation, with results that were almost the same due to the lack of scientific research on the distribution and population of Panamanian primates in the interim (Cuarón et al., 2008). There were, subsequently, no attempts at research by relevant authorities and non-governmental organizations (NGOs) in Panama, and no efforts to develop conservation plans for Panamanian primates (Table 1.2).

In 2001, I decided to address this problem by using the information presented in Rodríguez-Luna et al. (1996) to develop a primate conservation plan in Panama, with three aims. These were to develop research, educational activities, and a new cadre of Panamanian primatologists. From the point of view of research, we assessed: 1) the natural history of the animals we sought to protect, 2), their demographic characteristics, and 3), their distribution. Here, I briefly introduce each of the genera in Panama, then identify activities which threaten them.

1.8.1 *Saguinus*

Geoffroy's tamarin (*Saguinus geoffroyi*) is found only in Panama and Colombia (Rylands et al., 1993). It is a very adaptable primate that can live anywhere from mature forests to near riparian vegetation to secondary forest, and in open areas with living fences near to urban areas (Teldford et al., 1972; Dawson, 1976). Its diet is largely fruit-based, complemented with insects and nectar from plants (Rowe, 1996). Average group sizes for this primate are 20-40 individuals, while their home range is estimated as 0.26-0.32 km^2 (Dawson, 1976). The distribution of *S. geoffroyi* in Panama is shown in Figure 1.11.

Figure 1.11. Distribution and phenotype of *Saguinus geoffroyii* in Panama. Distribution based on forest presence and anecdotal reports, assessed by Prof. Felix Nuñez and Prof. Jacobo Araúz, University of Panama. Animals have not been observed in Chiriqui province. Map copied from Rodríguez-Luna et al., (1996).

1.8.2 *Aotus*

The Panamanian night monkey (*Aotus zonalis*) (Figure 1.12.) is endemic to Colombia and Panama. It lives in primary and secondary forest (Wolfheim, 1983), and feeds on fruits, leaves and insects (Rowe, 1996). The average number of individuals per group is 5. Members of this species are normally monogamous, and their density has been calculated as 14 - 19 ind/km^2 (Svensson et al., 2009). It was previously considered to be *Aotus lemurinus lemurinus*, a species that remains very poorly known due to its nocturnal activity pattern. *A. zonalis* is proposed to be dispersed in several parts of Panama (Figure 1.12.).

Figure 1.12. Distribution and phenotype of *Aotus zonalis* in Panama. Distribution based on forest presence and anecdotal reports, assessed by Prof. Felix Nuñez and Prof. Jacobo Araúz, University of Panama. Map copied from Rodríguez-Luna et al., (1996).

1.8.3 *Saimiri*

The Central American squirrel monkey (*Saimiri oerstedii oerstedii*), has a range that stretches from Panama's Chiriqui Province into Burica, Costa Rica (Rylands et al., 1995). It is considered one of the most adaptable of the region's primates, able to survive in different habitat types, including remnant forest areas close to sites of human habitation (Rodríguez-Luna *et al.*, 1996). *Saimiri* feeds on fruits and insects (Rowe, 1996). The average number of individuals per group is reported to be 30 (range 15-68 per group) (Wong, 1990) with densities of 130 ind/km^2 (Thorington, 1968). The reproduction of *Saimiri* is suggested to be sensitive to environmental changes (Rodríguez-Luna et al., 1996) (Figure 1.13).

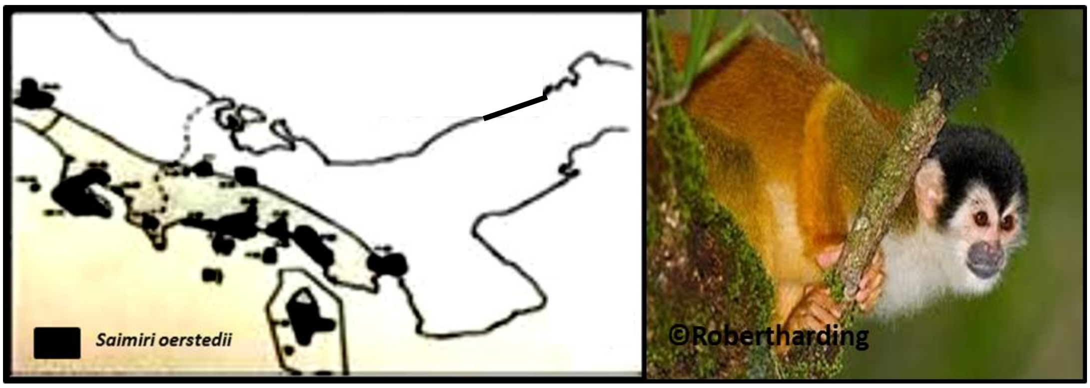

Figure 1.13. Distribution and phenotype of *Saimiri oerstedii oerstedii* in Panama. Distribution based from data on forest presence and anecdotal reports, assessed by Prof. Felix Nuñez and Prof. Jacobo Araúz, University of Panama. Map copied from Rodríguez-Luna et al., (1996).

1.8.4 *Cebus*

Capuchin monkeys (*Cebus* spp.), are present in Nicaragua, Costa Rica, and western Panama. They are very well adapted to life in a variety of habitats, from mangrove swamps to mature forests (Rowe, 1996; Sponsel, 1997). They are mostly omnivorous, with a high percentage of their food being fruits and insects, which are complemented with leaves and flowers (Napier and Napier, 1994). Capuchins have groups of 10-30 members, whose size varies in density depending on food availability. Densities are 4-6 ind/km^2 (Fishkind and Sussman, 1987). Figure 1.14 shows the suggested distribution of *C. imitator* and *C. capucinus* in Panama.

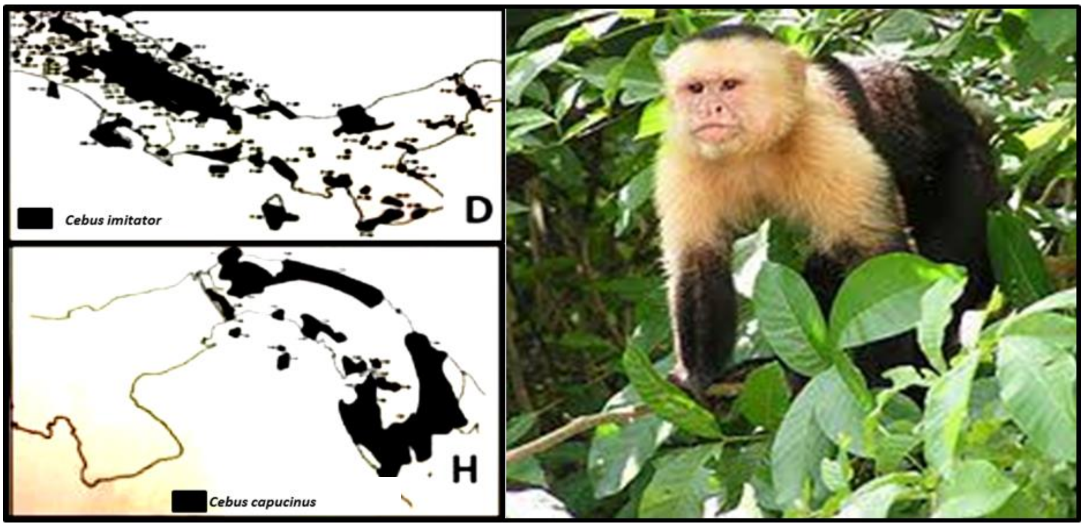

Figure 1.14. Distribution and phenotype of *Cebus imitator* and *Cebus capucinus* in Panama. The two species differ in DNA but have a similar phenotype (Boubli et al., 2014). Distribution based on forest presence and anecdotal reports, assessed by Prof. Felix Nuñez and Prof. Jacobo Araúz, University of Panama. Map copied from Rodríguez-Luna et al., (1996).

1.8.5 *Alouatta*

Panama has four subspecies of howler monkey (*Alouatta* spp). (Table 1.4). Howler monkeys are herbivorous, eating fruits and leaves (Milton, 1979; 1982; et al., 1980). They are diurnal, and spend 64-80% of their time resting, 11-24% eating and 10-12% of their time engaged in locomotion (Chivers, 1969; Milton, 1992). There is minimal pressure on these animals related to bushmeat, with natural botfly parasitism possibly representing a natural population control (Horwich et al., 1993). Howler monkeys have a uni-male–multifemale or multi-male–multifemale social organisation (Whitehead, 1995). *Alouatta palliata* appears to be more tolerant of anthropogenic effects such as habitat degradation than other Neotropical primate species and can be found in different types of habitats from riparian forest to cloud forest (Eisenberg, 1989). Their average group size is 14 individuals, with a maximum of 44 individuals (Crocket and Eisenberg, 1986). See Figure 1.15 for the suggested distribution of *A. palliata* and *A. coibensis* in Panama.

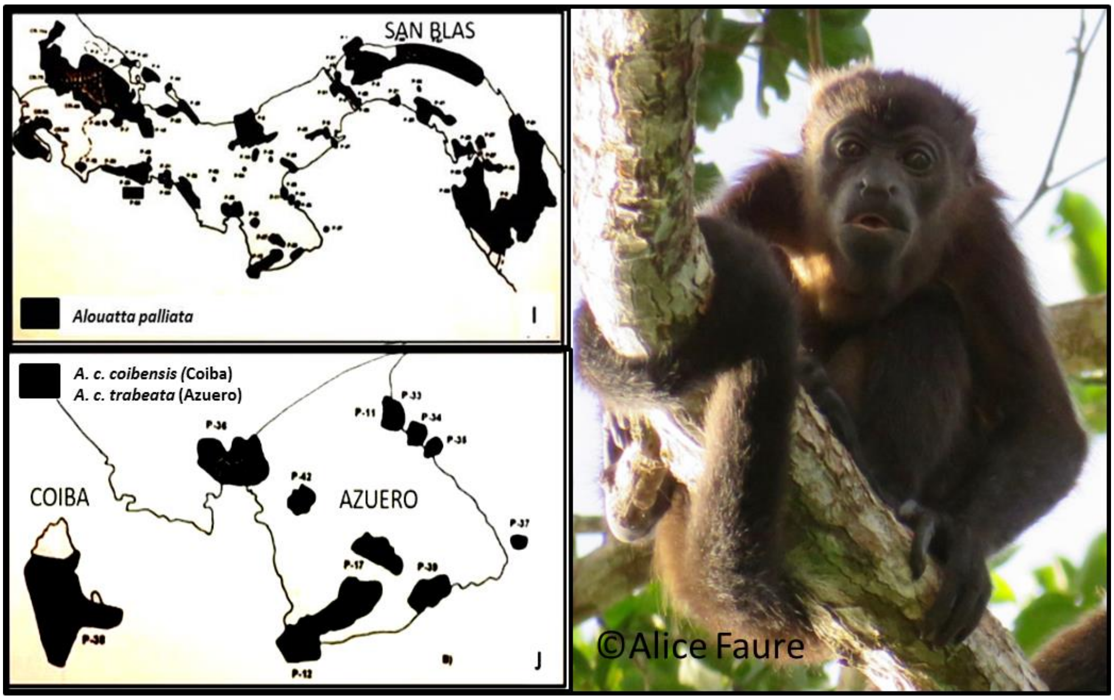

Figure 1.15. Distribution of *Alouatta palliata* and *Alouatta coibensis* in Panama, with the phenotype of *Alouatta palliata*. Distribution based on forest presence and anecdotal reports, assessed by Prof. Felix Nuñez and Prof. Jacobo Araúz, University of Panama. Map copied from Rodríguez-Luna et al., (1996).

1.8.6 *Ateles*

Spider monkeys are represented by two species in Mesoamerica: the Panamanian red spider monkey, *Ateles geoffroyi* and the Darien black spider monkey, *Ateles fusciceps* (Rylands *et al*., 1995). Spider monkeys are 90% frugivorous, but also eat soft parts of plants, flowers, leaves and barks (Chapman and Chapman, 1991). They live in group sizes averaging 17-20 individuals, and containing subgroups numbering 8-11 individuals (Carpenter, 1935; van Roosmalen and Klen, 1988). The distribution of *A. geoffroyi* and *A. fusciceps* in Panama is shown in Figure 1.16.

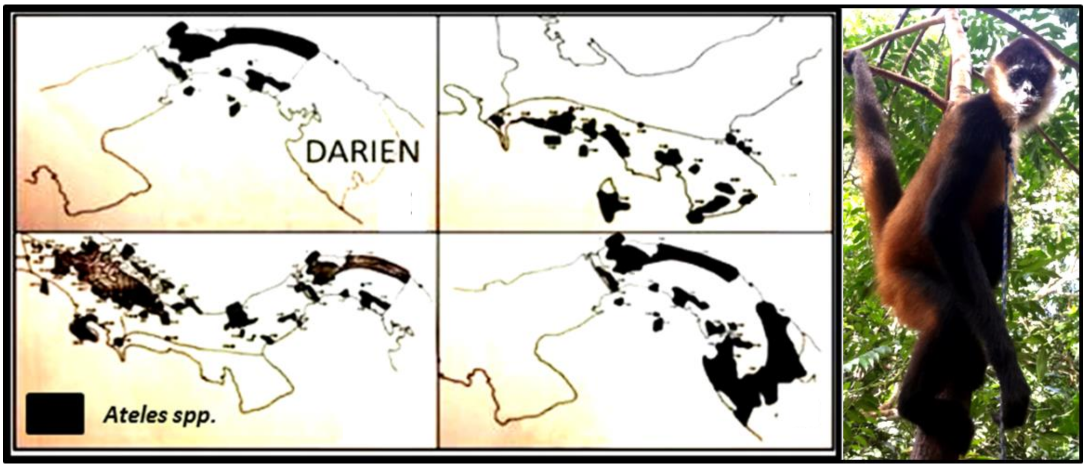

Figure 1.16. Distribution of four subspecies of *Ateles* in Panama: *Ateles geoffroyi panamensis*, *Ateles geoffroyi azuerensis*, *Ateles geoffroyi grisescens*, *Ateles fussiceps*, with the phenotype of *Ateles geoffroyi panamensis.* Distribution based on forest cover and anecdotal reports, assessed by Prof. Felix Nuñez and Prof. Jacobo Araúz, University of Panama. Map copied from Rodríguez-Luna et al., (1996).

1.9 Thesis Aim and Structure

This thesis is based on long-term data on the presence/absence of non-human primates of Panama, collected as a part of a project that I have conducted from 2001 to the present. I aimed to evaluate the conservation status of Panamanian primates by assessing: (i) species richness, potential distributions of primates, and habitat suitability; (ii) human perceptions of non-human primates, (iii) primate populations. I use a combination of methods to detect Neotropical primates in continuous forest and in fragments, and explore a new evaluation system for the conservation status of Neotropical primates in Panama, to complement the IUCN categories. This thesis will serve as reference to study and protect the Panamanian primates.

In this first, introductory, chapter, I have briefly introduced the Order Primates, described the primate species present in the Mesoamerican region and those which are present in Panama, and showed the lack of accurate baseline information for Panamanian primates – something that is badly needed if their conservation status is to be properly assessed. In Chapter 2, I explain the methods I used to carry out primate surveys, and how I obtained information on the presence of species and accurate global positioning data to evaluate the distribution and population density for each primate taxon in Panama. I describe how I used Maximum Entropy (MaxEnt) species distribution modelling to obtain approximations of species richness and habitat suitability. Chapter 3 describes the results of the species distribution modelling, obtaining potential distribution maps and relating them to environmental and anthropogenic factors. It also shows areas in Panama were conservation is most needed, based on endemism and threatened species. In Chapter 4, I evaluate local peoples' perception of primates in the most fragmented primate habitat in Panama, based on general information obtained from surveys, and essays in which people relate their knowledge of the primates living in their town. Chapter 5 provides a full evaluation of the conservation status of the 13 primate subspecies with which this thesis is concerned, including all the information related to distribution contained in the previous three chapters, the total population, and a description of relevant human behaviour. This allows me to update the IUCN conservation status for the threatened taxa and their priorities. I incorporate a new proposed list of threats to Panamanian primates. I recommend new activities for conservation and, in some cases, new categories that I propose should be considered in future evaluations of Panamanian. Chapter 6 provides the main discussion and conclusions of my thesis: I discuss the results obtained from my ecological modelling analyses and suggest locations in Panama that should be classed as untouchable for logging activities or industrial exploitation. I argue that these zones should be dedicated to environmental education, and as potential sites for the translocation or reintroduction of rescued primates based on habitat suitability. The brief study of human perceptions of wild primates will guide us in our future educational activities to drive conservation in the villages. The proposed conservation statuses will help the Panamanian government (and my NGO) to take action to protect primate species, and channel more available funding to address problems such as hunting and deforestation through wildlife perception-education.

2 Methods

2.1 General Methods

I use data from my long-term primate monitoring project, which I have collected since founding FCPP in 2001: I lead the organisation under scientific permit No.SE/A-7014. I obtained primate location points and applied MaxEnt Species Distribution Modelling to understand potential distribution and species richness (Phillips et al., 2006). My analysis of relative population densities is based on Wilson et al., (1995), Ross and Reeve (2011), and Plumptre et al., (2013), with slight modifications that synthesise several techniques to make them more appropriate for conservation. To study human perceptions of non-human primates in Panama, I selected one of the most fragmented provinces in Panama. I used questionnaires with adult informants, to gain appropriate data to analyse via cultural consensus theory (Nekaris et al., 2017). I used elementary and secondary student drawings and compositions (Franquesa-Soler and Serio-Silva, 2017) to understand their knowledge of primates (Jhones-Angel et al., 2011 and Riley et al., 2013).

2.1.1 Long-term Data on Primate Densities

During an exploratory survey in Azuero province in 2001, in which I sought to confirm the presence of two endemic and Critically Endangered primates, the howler and spider monkeys, I found several howler monkeys living in fragmented vegetation around villages. Some of them were under serious threat from farming and other human related activities (Méndez-Carvajal, 2001; 2005). I decided to start a monitoring project in the Azuero peninsula to obtain data on the distribution of these two primates, as this type of data could provide information of crucial relevance to conservation activities (Rode et al. 2013). My main goal with this monitoring project was to obtain information about primate presence, group size, group structure, and GPS location, and data on landscape management practices that might affect primate groups around the villages. My aim was to increase villagers' awareness of the protection of the natural reserve, and of its vulnerability to anthropogenic activities.

I began by conducting surveys twice a year for 5 to 10 days each, depending on the budget available. I first focused on obtaining primate census data from three provinces in the Azuero peninsula: Herrera, Los Santos, and southeast Veraguas. I chose these provinces because their primates are among the most endangered in the country. I started by visiting patches of forest between farming areas, and testing methods; later on I also included natural parks and reserves. The landscape of Azuero province is highly heterogeneous, including forest reserves, human dwelling, cattle ranches, farming areas, gallery forest, patches of forest, and living fences in villages and secondary roads. I decided to vary my methods according to the landscape types I encountered, including species presence/absence recording, listening posts, strip transects, road counts, and camera trapping (details below). I sometimes used two or more methods simultaneously to thoroughly survey a given area. Some of my first research trips were conducted under constraints caused by the lack of key equipment, which in turn constrained the methods that could be employed. For example, I did not have access to vehicular transport, cameras, GPS, or rangefinders. It was difficult to buy or rent this equipment in Panama when this project began and I decided to invest the limited funds available in transportation and food, leaving other expenses for later. Therefore, survey data were obtained with the equipment available.

After my first visit to a study area, I tried to confirm the continued presence of the groups during my annual return visits, and I complemented my surveys with additional methods if needed. The trips also included conservation activities such as interviewing farmers, giving talks about the biology and role of the primates, and later on distributing informative bookmarks, posters, and t-shirts to local people, and organising community talks for elementary schools. I also visited the national parks and reserves and talked with personnel from the Environmental Ministry of Panama to help raise their awareness of the situation of primates living in protected areas (I have published an account of my conservation activities and some research outputs in Méndez-Carvajal et al. 2013). I also published the first description of the distribution and population surveys of the Critically Endangered primates of Azuero after obtaining my Primate Conservation MSc degree at Oxford Brookes University, UK (Méndez-Carvajal, 2008; 2013). However, the data I use here to evaluate primate distribution in this thesis are based on more accurate data acquired using newly available technology.

After I completed the distribution surveys of the Azuero primates (2008), I conducted additional surveys in other parts of Panama, focusing on other Critically Endangered species like the Darien black spider monkey, or on endemic primates such as the Coiba howler monkey. I have published preliminary information from these surveys (Méndez-Carvajal 2012ab). Most of the areas previously surveyed were re-visited by me, and new areas were added to the annual research trips, where the available budget made this feasible. I carried out observations alone or in conjunction with the FCPP team. The number of assistants involved varied from 1 to 10, depending on the availability of funding and of assistants (Table 2.1).

Table 2.1. FCPP's team 2001-2016. See Appendix 1 for more information.

Year	FCPP team	Local assistants	People and related Institutions	Funding
2001	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard	Nidia Aguirre Didio González Emigdio Mitres Wedlis Gonzalez Donald Osorio	Rafael Quintero Villarreal secondary school	Private funds and University of Panama
2002	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard	Didio González	Jorge García [j] Eduardo Santamaría[1] Cristina Garibaldi[1] Agustín Noriega [j] Johnny Pérez [j] Miguel Cotes [j]	Private funds University of Panama
2003	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard	Didio González	Ricardo Moreno [h] Alonso Santos[1]	Private funds
2004	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard	Didio González	Publio González[2] Eustiquio Broce[2] Omar Vargas[2] Francisco Crespo[2] Nelson Ríos[2]	Private funds
2005	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard	Rafael Samudio [a] Julieta C. de Samudio [a]	Private funds
2006	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard	Didio González		Idea Wild Private funds
2007	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard Valeria Franco Somaly Silva Kennia Sánchez Yarelis González Glenis De León	Didio González Tacho González Agustín Domínguez	Félix González[b] Ignacio Vega[b] Ángel Luis Alain[b]	Idea Wild Primate Conservation Inc. Oxford Brookes University Private funds
2008	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard Yarelis González Glenis De León Alejandro Garrido	Tacho González		Idea Wild Primate Conservation Inc. Private funds

2009	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard Yarelis González Glenis De León Isis Ochoa Alejandro Garrido	Tacho González	Daniel González[2]	Ford Motor Company Award Idea Wild Mohamed bin Zayed Species Conservation Fund Private funds
2010	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard Marta Carvajal de Mendez Elena Mendez-Carvajal Jorge Garzón	Ceverino De León Jr.	Guido Berguido [ñ] Ricardo Moreno [h]	Idea Wild Rufford Small Grant 1 Wild future Private funds
2011	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard	Ceverino De León Jr.		Private funds
2012	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard Marta Carvajal de Méndez Glenis De León Elena Méndez-Carvajal Luz Loria Amores	Ceverino De León Jr.		Private funds
2013	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard Elvia Miranda Jorge Garzón Luz Loria Amores Elvia Miranda José Aparicio José Atencio Glenis De León Jonathan González Marlen Aguirre	Ceverino De León Jr.	José Polanco[3] Mario Urriola[3] Ovidio Jaramillo[3] Guido Berguido [ñ] Ricardo Moreno [h] Samuel Valdes [p]	Mohamed bin Zayed Species Conservation Fund Rufford Small Grants 2 Private funds
2014	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard Elvia Miranda Jorge Garzón Luz Loria Amores Elvia Miranda Glenis De León Jonathan González Marlen Aguirre	Ceverino De León Jr.	Hilario Espinosa [j] Daniel Medina [j] Laura Martínez [j]	Mohamed bin Zayed Species Conservation Fund Rufford Booster Grant 1 Private funds

2015	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard Elvia Miranda Jorge Garzón Luz Loria Amores Elvia Miranda Glenis De León	Ceverino De León Jr.		Mohamed bin Zayed Species Conservation Fund Private funds
2016	Pedro Méndez-Carvajal Ivelisse Ruiz-Bernard Elvia Miranda Jorge Garzón Luz Loria Amores Elvia Miranda Glenis De León Bonarge Rodríguez Ovidio Jaramillo Pedro González	Ceverino De León Jr.	Guido Berguido [ñ] Ricardo Moreno [h] Samuel Valdés[p] Abel Batista[p]	Second Rufford Booster Grant Mohamed bin Zayed Species Conservation Fund Private funds

Note: Institutions: [1]University of Panama; [2]Gorgas Commemorative Institute for Studies of Health ICGES; [3]National Association for Conservation of Nature ANCON; [h]es of H Panama; [ñ]Advantage Tour Panama; [j]Environmental Ministry of Panama MiAmbiente; [a]Mammal Society of Panama SOMASPA; [b]Ministry of Development and Agriculture in Panama MIDA; [p](Panamanian Society of Biology).

To standardize the information collected, I trained all the participants, who were normally bachelor students in biology at the University of Panama, who had enlisted as volunteers in my trips, or local people whom I had recruited (Figure 2.1).

Figure 2.1. Biology students undergoing project training with the FCPP volunteer program to survey primates. From left to right: Valeria Franco, Glenis De León, Somaly Silva and Kennia Sánchez.

I adapted my methods according to variations in the landscape and taking into account the speed of movement of the target species, as suggested by Wilson et al., (1995). I adopted several methods to cover different landscapes, as I had found that primates were living in fragmented areas, and sometimes even near people (Appendix 1.1

to 1.7). In 2010 I added one more method to ensure continuity of surveillance in those areas where I could not stay long, to understand circadian activity, and to monitor primates' presence in fragmented areas: I placed camera traps in the understory of the forest, between the forest floor and canopy. To do this, I invented a method to set up camera traps up to 12 m from the ground, without climbing trees. I named this method the Orion Camera System, drawing on the symbolism of the Orion constellation. The Orion Camera System 'hunts' animals with its camera lens, unlike the Orion of Greek mythology, who was represented as a giant hunter who hunted animals with a bow, and from whom the name of the constellation derives.

These methods generated a huge amount of location data per year (Appendix 2.1 to 2.12 for detailed dates of surveys and location description). In 2012, I added additional surveys around the country, complementing this with data provided by several informants whom I recruited as "citizen scientists". In this thesis, I use the results of these efforts to locate primates to generate distribution maps, describe species richness and calculate population densities. In the following sections of this chapter I explain each method and its scientific principles.

2.1.2 Species Presence/Absence Records

My main objective in using this method was to obtain presence location points. When I arrived at a new site, I recorded the local fauna, descriptions of surrounding flora, small sketches of the landscape, data on patterns of land use, and other relevant information. In this thesis, I report only location points of primates. On the first day at a new site I collected data on the presence of primates in the area by surveying the habitat looking for signs of occupancy. This method requires biological knowledge of the animal target (Ross and Reeve, 2011), such as the ability to recognise the presence of the animal by characteristic smell, faeces, vocalization, tracks, chewed leaves, carcasses, and other signs (Wilson et al., 1995). I used my observational skills to detect any presence of primates while visiting the survey areas; these data was eventually confirmed by direct observation at most of the sites. I recorded the GPS location points of each species target observed or detected (Ross and Reeve, 2011). I included information about presence based on reports from local people, always being sure to check the accuracy of their recognition of species using the illustrations in Reid (1987). I applied this method in both areas and sites that later become long term points in my monitoring project, and where

I could only stay a single day but which had vegetation that could, potentially, hold primates (Figure 2.2; Appendix 2.1 to 2.12).

Figure 2.2. Example of fragmented landscape, often with living fences and gallery forest, or forested mountains surrounded by a matrix of cattle ranches (e.g., Landscape of Llano Grande of Ocu, first place surveyed in my project, April 2001).

2.1.3 Listening Posts

I used this method to obtain presence location points and to estimate primate densities. I set up 13 listening posts and manned them for fixed periods, usually from 0400 to 1200 hours, and from 1700 to 1800 hours. I selected areas with patches of forest and living fences or connective forest at random. To record primate presence and density, I camped overnight in an area surrounded by vegetation, and began recording vocalisations at 0400 hours, recording the time, distance, and compass bearing of the groups from the listening post (my camping area). In using this method I followed the examples of Brockelman and Ali (1987); and Aldrich et al. (2006) (Figure 2.3). Once the primates ceased vocalising (usually around 0600 hours), I halted my listening activity and waited until sunrise (usually around 0700 hours) to walk, using compass bearings, directly to the groups to verify the presence of primates by direct observation (Renner et al., 2007 for similar procedures). I recorded group composition and noted the GPS location so as to accurately calculate the distance between my listening post and the location of the observed group. I counted group size at least twice each day while I stayed in the area, to obtain an accurate group size and composition, following the examples of

Milton (1992) and Ferrari (2002). This method could be considered a variation of triangulation, or "using group calls to survey primates" (Plumptre et al., 2013), which is not applicable in the fragmented zones of Panama, because the landscape matrix limits the home range of groups to lines of vegetation or small patches. This habitat structure made it easy for me to detect each group from a single listening post at the camping location, without needing three listening posts. I then used a variation of the "cue counting" method (Buckland et al., 2006), in which all vocalisations are annotated and all distances from the group to the listening post are recorded, with the consideration that the observer does not affect the animals' movement. This method is effective with species such as howler monkeys, which often vocalise three times per day, and in connective forest it can also be applied to spider monkeys. An important factor that affects the ability to detect the animals is the speed of movement of the species (Rabinowitz, 2003). Howler monkeys are active early but in fragmented habitats they tend not to move away from a pivotal tree if it has a good amount of leaves or fruits (personal observation). Howler monkeys also avoid vocalising or avoid midday choruses if the group is relatively small (only three individuals, personal observation). Spider monkeys however, avoid vocalising if they have been exposed to hunting activity or severe deforestation (Carpenter, 1935).

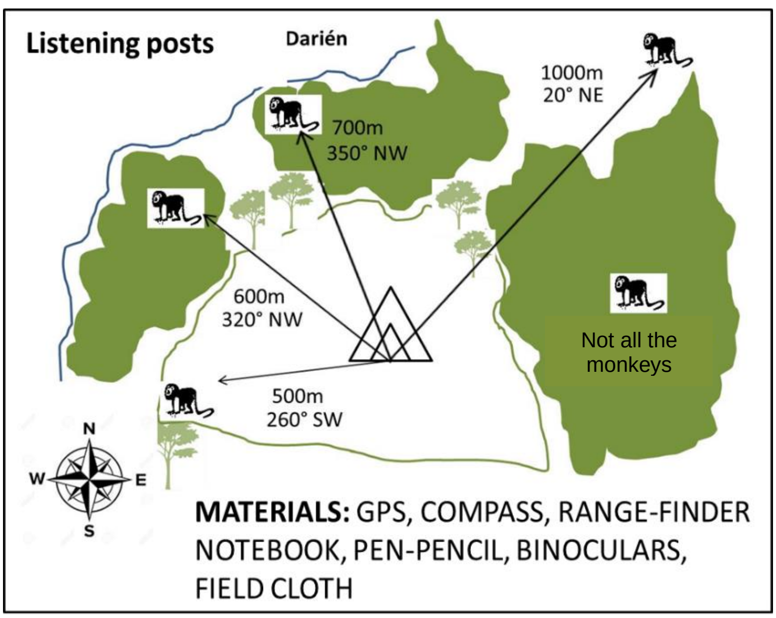

Figure 2.3. Listening Post: a landscape of fragmented habitat, common in the Pacific side of Panama, mostly a flat land matrix with cattle ranches (white), surrounded by small forested elevations (green), patches of forest and living fences (green lines), creating several scenarios like this. Camping areas are indicated by triangles, with each primate icon representing a primate group.

When using listening posts to estimate occupancy, it is necessary to incorporate the probability of detection, to know if we are listening to all the groups or a proportion of the population which happens to be vocalising in a study area. I calculated the mean call rate of animals as 1/pm, where p=proportion of groups expected to vocalise in a period of (m) days, suggested by Aldrich et al., (2006). Calculations of the number of groups using this method should be repeated several times by the observer. I calculated densities were using (n) number of individuals counted (or groups detected), divided by the total area, the sum of the total area of each patch of vegetation. To calculate areas, I used Google Earth and its tools to estimate polygons and area (see Appendices 2.1 to 2.12).

2.1.4 Strip Transects

The main objective using this method was to collect presence location points and densities. Strip transect is a type of plot sampling, with a rectangular sampling area (Ross and Reeve, 2011). I used 38 strip transects to survey gallery forest, living fences and forest fragments, when the extent of forest cover allowed. I calculated the width of the transect by first testing my visual detectability, marking the relevant points with measuring tape and fluorescent flagging. It is recommended that the width of the strip should be determined by measuring different parts of the section to be surveyed, then obtaining the minimum and maximum width (Ferrari, 2002; Carvalho-Oliveira et al. 2003). It is also recommended to use the "reliable perpendicular distance" method (Chapman et al., 1988), or standardise strip width to the lowest visibility (Ross and Reeve, 2011). I selected this width to standardise on the best distance where my team agreed they could detect an animal from the centre line. I strove to apply, as much as possible the key rules for applying this method: that target animal does not move before detection, that an individual specimen is not counted twice, and that sightings must be independent.

This method allowed me to calculate population density by dividing the mean number of individuals per group over the total area sampled. I made observations by walking strips 1-5 km in length and 20 m in width, using my minimum visibility (Figure 2.4). I visited the same transects twice every day, between 0800 hours and 1200 hours, or between 1400 and 1800 hours. I located my transect, and then walked along the centre line, recording every primate observed as I walked. When I found a group I counted it, identified group composition (males, females, juveniles and infants), and recorded the

GPS location within a 10-minute period. My speed of travel along the strip transects was 1 km per hour, as recommended by Wilson et al. (1995).

One disadvantage of this method is the difficulty involved in finding the correct width within the survey area. However, due to the high level of fragmentation, most of the strip transects were convenient for the observer to detect animals ranging in size from that of a tamarin to medium size primate species such as howler monkeys. Most of the surrounding vegetation was less than 40 m from each side of the transect. Given these habitat characteristics, I felt comfortable that we could accurately detect any movement of an arboreal animal, and for this reason opted not to use an alternative line transect method, which detects mammals using a rangefinder and angle measurements (Wilson et al., 1995).

This method (strip transect) has several advantages in a previously unvisited areas, required less logistics, and was easier to explain to the assistants than the methods involved in line transects. When working with several volunteers, it allowed for the acquisition of an enhanced number of samples with a higher possibility of observation and, potentially, decreased bias (see locations Appendix 2.13). I also applied this method to connective forests, with a similar protocol was applied. If I detected a group outside the strip width, I recorded this event in my comments and used the location point but did not include it in my density calculations.

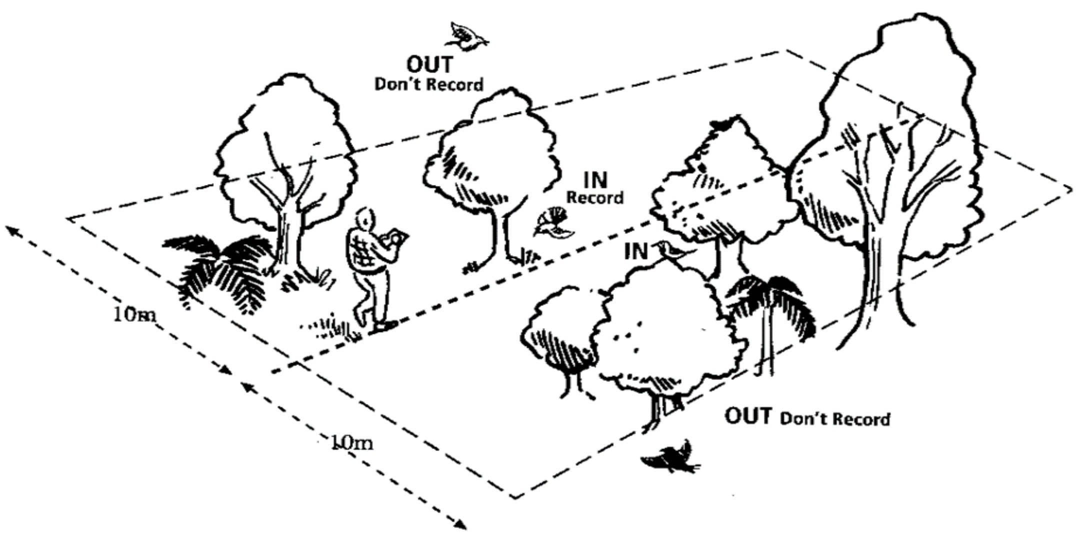

Figure 2.4. The strip transect method. The figure shows a person walking along an imaginary line between vegetation.

In Figure 2.4, the rectangle indicates the area of detection selected by width and longitude. Everything inside the area is counted, but anything outside will be ignored for calculations. This method is recommended for animals with low rates of movement who are easy to detect (Ross and Reeve, 2011). Intended for use in flat areas, it avoids 'zigzag' paths and irregular topography (Wilson et al., 1995). I calculated densities using the standard equation Dw=n/2Lw (Krebs 1998, Glanz 1992, Nijman and Menken 2005) where n is the total number of individuals of a species counted inside the strip area, L is the longitude of the transect, normally no less than 1 km long (transects were different in longitude depending on forest cover available), w is the width of the transect (normally 20 m left and right, totalling 40). Mean canopy height was normally 15 m. By using this equation to calculate densities I was able to compare my density data with other densities obtained for mammal projects on Barro Colorado Island and other parts of Panama (e.g. Glanz, 1992).

2.1.5 Road Counts (Traversing the Area and Detecting Animals)

The main reason for using this method was to obtain location presence data and densities. This method requires researchers to be well trained and skilful: their sampling efforts should (as far as possible) be carried out at the right speed to detect animals, they should take into account the weather, and also take care to consider habitat conditions that could alter visibility in the area they are researching (Ross and Reeve, 2011). I follow the requirements and I took advantage of some of Panama's principal and secondary roads that are forested on both sides. I first selected, in a topographic map, the GPS location of the straighter sections of the roads, which I had previously observed to have vegetation on both sides. I then selected a starting point and drove slowly for some distance, observing the line of trees on both sides of the road. I surveyed the 12 roads by car twice a year (Appendix 2.2.1.4), at a mean speed of 15 km/h. Whenever I saw a primate group, I stopped and noted the location point using a GPS, identified the species, and then recorded the number of individuals in the group. If possible, I took note of tree species in the area, and also noted the primates' behaviour. I calculated densities using the equation described in Section 2.1.4 (above). Most of the data I collected with this method related to the Azuero peninsula, a section of eastern Panama, Chepo and Darien, along the Pan-American highway, and in western Panama at Punta Burica. These areas all have roads that are straight, forested on both sides, and allow the slow speed required (Figure 2.5, Appendix. 2.14).

Figure 2.5. Road counts using living fences, i.e. roadside lines of trees. I often used these to detect primates. Living fences provide primates with food to eat, places to rest, and crossing points between patches of forest. Local villagers often use them for fruit, shade, and firewood.

2.1.6 Orion Camera System

The main reason for using the Orion Camera System was to collect location presence points. Camera trapping has proven very useful as non-invasive tool in ecological studies, mainly for tropical birds and terrestrial mammals (Rabinowitz, 1993; Williams et al., 2002; Bowkett et al., 2007; Schipper, 2007; O'Connell et al., 2011; O'Shea et al., 2011). My main objectives in using this method were to monitor primate activities, confirm the presence or absence of arboreal fauna in Panama, improve the information of primate actual distribution, and to update data on their conservation status (Méndez-Carvajal, 2014). I set up cameras for one complete year of detection, setting cameras at medium strata level without climbing a tree (Méndez-Carvajal, 2014). To set up a trap, I first selected an appropriate branch (one shaped like a fork), then passed a rope over the branch. To do this, I (a) tied a weight to an arrow, (b) tied one end of a rope to the rear end of the arrow with fishing line, (c) shot the arrow over a selected tree branch using a bow, (d) removed the arrow, then tied the filament to a rope 5 mm in diameter, (e) pulled the rope until the filament was again in my hand, and (f) tied one end of the 5 mm rope to another rope 11 mm in diameter, and pulled the rope, (g) set the camera and tied it to a PVC pipe, put a T shape in the top of the PVC pipe, and placed the camera at one end of the PVC pipe, then (h) passed the 11 mm diameter rope inside the PVC pipe with the camera first, then added a connector, and did this several times, pushing upwards until the camera gets to the branch, (i) tied the end of the 11 mm rope to a tree and moved the camera from the ground by grabbing the PVC pipe with my hand (Figure 2.6).

Figure 2.6. The Orion Camera System: a method used to set up camera traps at medium strata of forest, without climbing trees (Méndez-Carvajal, 2014).

I set traps up at 19 places in Panama with Bushnell Trophy Cam cameras. These camera traps are powered by eight AA batteries, have highly sensitive passive-infrared motion sensors, and can detect presence/absence and wildlife diversity, with information stored on 4 GB digital memory cards (Kent and Hill, 2012). I placed 21 cameras in the canopy: 5 at Limones (Chiriqui), 4 at Boquete (Chiriqui), 5 at La Miel (Los Santos), and 7 at Chucanti (Darien), with a mean height of 12 m. I operated canopy cameras continuously for one year (Figure 2.6). I also placed another two cameras for three months at Montijo Gulf (Veraguas), Canajaguas Forest (Los Santos), and Bajo Chiquito (Darien). I set the capture setting to three images per trigger, and the interval between triggers to

1 second. I programmed the cameras to record date and time according to Panama Standard Time. I used the location points for the distribution analysis presented in Chapter 3. The full results are presented in Appendix IV.

2.1.7 Citizen Scientist Reports

To obtain extra location points, and to confirm previously recorded data, I also added primate sightings made by volunteers in the project 'watch the monkey'. These participants included biologists, tourist guides, and followers of FCPP's Facebook page. Citizen scientists are defined as "members of the general public, doing scientific work undertaken and often in collaboration with or under the direction of professional scientists and scientific institutions" (Dickinson et al., 2010; Crain et al., 2014). One form of citizen science is that in which cooperative volunteers engage in collecting scientific data in a reduced habitat or in expanded geographical regions (Cooper et al., 2007). The idea, in the case of this project, was to locate primate species and record cases of captive primates, road killed animals, or any matters of concern for primates the volunteers observed. I initially hoped to create more concern for primates amongst the local people in the country, but later realised that this could also be a very good source of presence data. This method proved to be more effective than I first expected, as people became interested in knowing more about the species they were reporting on, and came to feel that they were contributing important information to the cause.

Large data sets are becoming crucial in conservation biogeography and conservation planning (Devictor et al., 2010). Panamanian citizens and foraging people, who wished to assist in our cause of primate conservation, offered their help by sending pictures, GPS location, and other information that I requested in public media postings on the webpage and Facebook page of the FCPP. The statement on the FCPP webpage informed interested parties that they could help 'inform about groups of monkeys while visiting any region of Panama', and directed them to the web address, http://fcprimatespanama.org/ayuda.html. Later, people wrote to FCPP's email address (fcprimatespanama@gmail.com), and I collected their information.

I used this announcement to encourage people to help with information about primates:

> *You can inform us about any monkey group you have seen while you were visiting Panama. To do this, please write down the following details and send it to us by this page (fcprimatespanama.org): a) Place (e.g. Ancon Hill, Panama province)" b) Common name of the animal observed (e.g. Howler monkey, spider monkey), c)*

number of individuals observed (e.g. they were at least five animals), d) location using Global Position System (GPS) (if you have it is better), e) photo, f) date, g) hour, h) activity (e.g. they were resting on a ficus tree), i) send to us your electronic or postal address, with your complete name, and we will add you to FCPP's volunteer list, and send you our newsletters and new publications.

There are some problems associated with this method of obtaining location points, because people that are not familiar with a particular species make mistakes in identifying a species (Schmeller et al., 2009). However, I selected data carefully and confirmed it personally before adding to the primate location data used in species distribution modelling, I confirmed this by contacting the people and revisiting the places they reported.

This strategy helped me to cover remote areas that I could not visit for logistical reasons, and as this was not the only method I used for species distribution analysis, I felt comfortable using it as a complementary information source to confirm data from 2001 or before. I obtained, in total, 122 point locations, 86 of which I had already obtained, and 36 of which were new locations.

2.2 Maximum Entropy Software for SDM

Ecological niche modelling uses ecological variables to generate maps, identify habitats suitable for the presence of a species, and to identify their geographic distribution (Holzman et al., 2015). MaxEnt is one of the most widely used programs for calculating potential species distribution by the detection of environmental niches (Booth et al., 2014). This program is normally used to answer complex questions derived from a scientific hypothesis, based on assumptions about densities, total population and habitat suitability. MaxEnt requires: a) presence only data (PO); b) continuous or categorical data for the study area; c) an algorithm developed to build the maximum entropy (i.e., probability of distribution), and, d), a Linear Generalized Model (LGM) to reduce the bias and recognize accurate probability. The LGM is equivalent to a Poisson Punctual process for estimating the distribution of a species based on its background (Fithian and Hastie, 2012).

When using a geographical perspective, the mathematical principle used in MaxEnt is the Bernoulli rules: where π is proportional to the probability of occurrence, and $p(y=1/x) = 0.1$, meaning a 10% probability of detection per x pixel. Then, $p(Y=1/x)$

=1-p(Y=0/x), because it is difficult to obtain the total area of presence for a species. This provides an estimate of the probability of presence: data on the absolute absence of animals remains uncertain, which is a weaknesses of the MaxEnt system (Baldwin, 2009). However, to reduce the bias, it is important to use simplifiers. Since it is difficult to obtain precise absence data, the model requires the use of a "background", built using the Bayes rule, the probability of being similar to presence in a x pixel, which defines p(x)=1/IGI. This suggests three probabilities: a) the probability of presence of the species because cell x is observable, b) the probability of the observer visiting the x pixel is similar to the presence of the species and depends on the size of the region (this is an environmental index, which means that its value will be higher if the habitat in x is likely to the suitable habitat reported for the particular species), and, c), the probability of being present in x pixel, if as random, p(x)=1/n, and the value π prevalence, or the unconditional probability of observing the species target. The percentage of pixels or cells occupied is estimated with respect to all the cells in the grid. For other parts, if using the environmental perspective, then the relation π will be as π'=index of environmental suitability. Other will be that p(Y=1/z), where z is the probability of distribution for a species being found in a place that presents specific environmental characteristics. To work with this alternative, we define π'as the proportion of the area G, where we can find the species. Then p (z) will be the density of environment in the area G; p (z/Y=1) (Elith et al., 2011). But MaxEnt could also calculate the logistic output by p(Y=1/z) (Table 2.2). The fact that MaxEnt works with PO data is a point of concern: it means that the analysis may be weak if the researcher does not consider the following:

1. MaxEnt has spatial autocorrelation by collecting data in places near each other.
2. Sampling methods to collect presence-only data are not standardized.
3. Criteria of ID of species could be a problem.
4. Number of observed instances may be too low to estimate parameters of the model.
5. Environmental variables may be not enough to describe all the parameters of a fundamental niche for a species.

Table 2.2. Mathematical expression of the calculations of MaxEnt.

X	Z	p(x)	p(Y=1/x) Logistic output	p(x/Y=1) Raw output
1	1	1/9	0	0
2	1	1/9	0	0
3	2	1/9	½	(1/2x1/9)/(5/18)=1/5
4	1	1/9	0	0
5	1	1/9	0	0

MaxEnt attempts to recognise the probability of each pixel x, based on environmental combination z, but without any presence information about the species. These probabilities between logistic output and raw output are related using an equation. Although the equation mentioned will need the information of p(x) and π, which is difficult to obtain, the raw output is the probability of a species' presence while visiting each cell, and the Logistic output is the probability of the presence of the species in that cell. To summarise, the raw output is represented as p (z/Y=1), which is the probability of being present in the pixel x (or environment z), based on our knowledge that the species target is present.

The logistic output is a transformation of the raw output, made under the condition that we know the p(Y=1/x) value in the common environment. MaxEnt software relies on the use of GIS location points and requires the observer to generate at least 13 location points per species, creating a useful and accurate database for the identification of the species and their geographic locations. This information forms the basis of my species distribution modelling. Using the ArcGIS map I stored bioclimatic variables in layers and set them together in an excel table with a csv document. I extracted layers from (http://www.worldclim.org/current. I obtained data on the following variables:

Bio 1: Annual Mean Temperature
Bio 2: Mean Diurnal Range
Bio 3: Isothermally
Bio 4: Temperature Seasonality
Bio 5: Max Temperature of Warmest Month
Bio 6: Min Temperature of Coldest Month
Bio 7: Temperature Annual Range
Bio 8: Mean Temperature of Wettest Quarter
Bio 9: Mean Temperature of Driest Quarter
Bio 10: Mean Temperature of Warmest Quarter
Bio 11: Mean Temperature of Coldest Quarter

Bio 12: Annual Precipitation

Bio 13: Precipitation of Wettest Month

Bio 14: Precipitation of Driest Month

Bio 15: Precipitation of Seasonality

Bio 16: Precipitation of Wettest Quarter

Bio 17: Precipitation of Driest Quarter

Bio 18: Precipitation of the Warmest Quarter

Bio 19: Precipitation of the Coldest Quarter

The climate databases used in my research were compiled by the Global Historical Climatology Network (GHCN), the FAO, the WMO, the International Center for Tropical Agriculture (CIAT), R-Hydronet, and other organisations from Australia, New Zealand, the Nordic European countries, Ecuador, Peru, and Bolivia, among others. In this system they use the SRTM elevation database to 30 arc-seconds per kilometre. They also used the ANUSPLIN software, combining latitude, longitude, and elevation as independent variables. They have data available for 1960-90, and 10 years of data for 1950-2000. Many of these additional databases had mean monthly values, without a specified time period.

2.3 Remote Sensing Variables

Forest cover is an important limiting factor for Neotropical primates, which are 90% arboreal, and have chances of survival that will only be reduced if their access to forest cover is diminished. I obtained climate data for the years 1950 to 2000 using DIVA-GIS (www.worldclim.org), with a resolution of 30 arc seconds (1 km^2) (Hijmans et al., 2005). Altitude information was derived from a digital elevation model recorded by a NASA Shuttle Radar Topography Mission. Spatial resolution was 0.000833333 decimal degrees (100m at the equator) and the projection was in World Geodetic System 84 (WGS84). The remote sensing layers used were the Normalized Difference of Vegetation Index (NDVI), which is a remote sensing measure of vegetation greenness that identifies the relative density and health of vegetation at a specific location. Other parameters included the Enhanced Vegetation Index (EVI) for primary productivity (photosynthesis). NDVI is calculated by satellite system monitoring far red waves produced by photosynthesis processes, which indirectly shows were it is a vegetation cover. Data was extracted from Modified Resolution Imagine Expectroradiometer (MODIS-NASA) MODIS

Vegetation Index Products (NDVI and EVI). I obtained NDVI and EVI with satellite information taken from the Republic of Panama at 1 km at 0.05 degree from earth, with grid projection. I downloaded productivity layers for April (minimum productivity), July (transition productivity), and September (maximum productivity). One factor which could introduce bias into the use of this tool, is the fact that vegetation index measures photosynthesis. This measure will, therefore, include areas that could be characterised by C4 plants (e.g. Graminea) or crops, causing problems when analysing the distribution of a species. For this reason, I added other variables to obtain a better evaluation of the habitat suitability of a species.

2.3.1 Anthropogenic Variables

Some of the major problems we face when trying to estimate the presence of primates are those related to deforestation, which is directly linked with human development. Although Panama still possesses an amount of vegetation, the vulnerability of the national forests is exacerbated by the fact that the country is long but narrow, with a mountain chain in its central part. This means that any site where vegetation cover is interrupted will quickly become a human settlement, and from that point onwards human occupancy will increase, as will deforestation. It is then important for this research that human presence be included as a limiting factor for non-human primates. An additional reason for adding this variable is the fact that Panamanian primates face heavy hunting pressure by indigenous people, who see primates as a valuable protein resource. It is, therefore, important that I analyse these two anthropogenic variables, one causing problems with habitat loss, other limiting the potential distribution of a species target.

I used data from the Geographic Information System (GIS) Laboratory of the Smithsonian Tropical Research Institute (STRI) in Panama to add two layers to Arcmap 10.3. One layer was information about political regions inside Panama marking the Guna, Embera-Wounaan, Ngäbe-Buglé indigenous areas (Ind. Areas) as an anthropogenic factor to identify areas where the local population may consume primates (Smith, 2005), Méndez-Carvajal (2005; 2013) (Chapter 1). I assigned each indigenous area a value of 1, and all other regions 0. I obtained the other layer - as human population density across Panama - from the website World Population (http://www.worldpop.org.uk), which estimates number of people per pixel ('ppp'), with spatial resolution of 0.000833333 decimal degrees (approx. 100 m at the equator) with national totals adjusted to match population division estimates (http://esa.un.org/wpp/). The creation of these layers allowed me to test different versions of species distribution modelling for each subspecies of primates, and to see which version is more accurate according of the outputs, in particular the graphics relating the area under the curve and thresholds.

2.3.2 Evaluating Primate Conservation Status

As mentioned in the introduction to this thesis, the IUCN is the world authority that classifies species in different conservation categories, basing its classificatory decisions on different factors. Primate conservation status is evaluated by the Primate Specialist Group (PSG) and the Species Survival Commission (SSC) of the IUCN (Cotton et al., 2016). To better understand the conservation status of the Panamanian primates I used factors listed in IUCN literature. Due to the difficulty inherent in compiling and collecting information for the whole process, I focus this evaluation on the three most important criteria proposed for the assessment of the conservation status of a species. There are, however, constraints involved in the IUCN evaluation, related to the feasibility of data collection in a long-term monitoring system, the lack of consistency in evaluating different species under the same methods, and the lack of accuracy by inference. Some authors claim that the IUCN easily approves the negative status of a species but requires several more forms of proof to release those species from a negative classification (Webb, 2008). Based on this, I considered the most realistic variables to assess conservation status to be those that match at least three references: population, distribution and local people's perceptions of non-human primates.

2.3.3 Population Size Reduction

IUCN has three ranked criteria for the assignment of threatened status: Vulnerable, Endangered and Critically Endangered (see Figure 2.7), and complements this trio with a numerical data denoted as Population Size Reduction (A). This category is based on observation, statistically estimated, inferred, or suspected in the past, and suggests possible causes for decline in a population that can be A1 (reversible, understood, and ceased already), A2 (may not be reversible, understood and may not have ceased), A3 (population projected for a future up to 100 years but not from 0), A4 (estimated for more than 100 years, not ceased, not understood, and possibly not reversible).

2.3.4 Distribution and Species Richness

Distribution and species richness are correlated with habitat heterogeneity (Cowlishaw and Dunbar, 2000). Heterogeneity is important because knowledge of the species richness of a forest allows the identification of habitats with more ecological niches, and, therefore, greater probabilities of survivorship (Schwarzkopf and Rylands, 1989). This information is crucial if conservation efforts are to be directed appropriately, and IUCN evaluations include it in the evaluation of geographic range (B). In this category the distribution can be based on the extent of occurrence (B1) or area of occupancy (B2). For both of these the categorisation is based on two conditions: (a) severely fragmented or number of locations, (b) continuing decline observed, estimated, inferred or projected in any of the following: (I) extent of occurrence, (II) area of occupancy, (III) area, extent and/or quality of habitat, (IV) number of locations or subpopulations, (V) number of mature individuals.

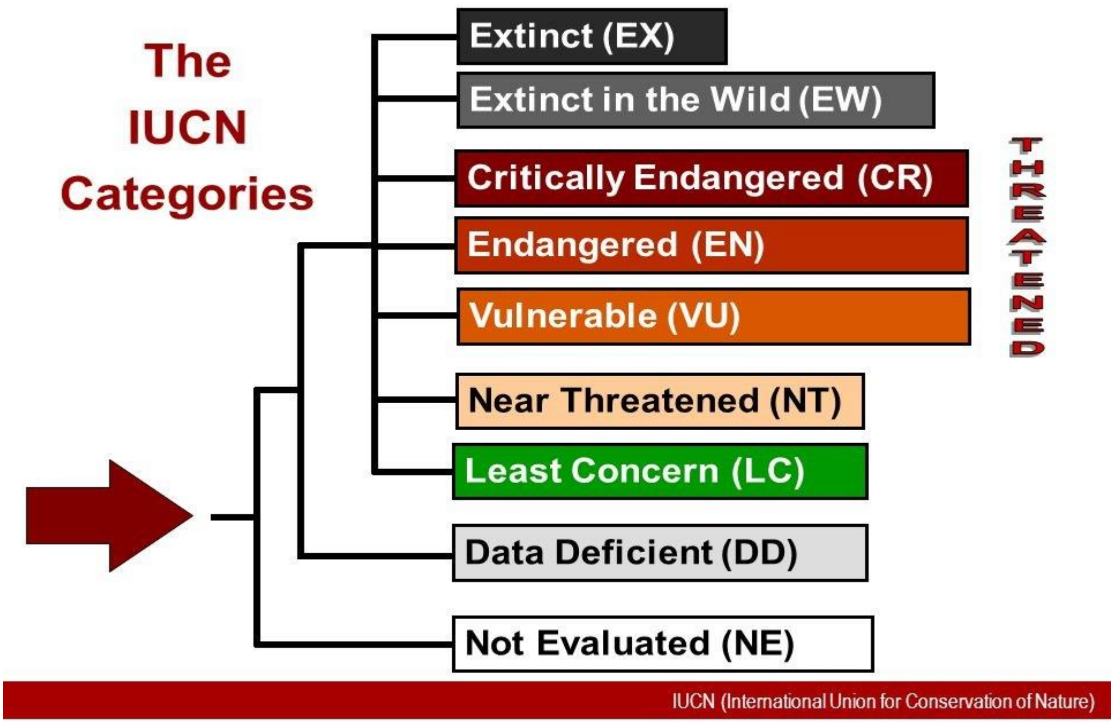

Figure 2.7. Categories used by IUCN to evaluate the Conservation Status of species.

These categories are evaluated based on: a) direct observation, b) index of abundance, c) decline in area previously present (AOO), or extent of occurrence (EOO) on habitat quality, d) actual or potential level of exploitation, and e) effects of introduced taxa, hybridisation, pathogens, pollutants, competitors, or parasites. In this thesis I measure population reduction using distribution maps obtained using MaxEnt Species Distribution Modelling, and population densities obtained from strip transects, listening posts, and road counts, and describe the situation of each subspecies in forested areas in Panama, including national reserves and fragmented landscape. I then consider three categories of population density: urban density, fragment density, and forested density. I use these densities in my consideration of each case, and extrapolate to calculate a total population based on density averages and on total forest cover for each species distribution. This serves as a convenient method to quickly make inferences about populations that can be later be evaluated more effectively. For good vegetation I use the strip transect method (Section 2.1.4). I estimate the percentage of population in each density category (Appendix 2.4). The information is, however, not used in addressing the objectives of this thesis, but is included as supporting information in Appendix 2.4. The evaluation of a species requires knowledge of the distribution and population to be as accurate as possible, and long-term monitoring should measure population growth, reproductive rate, and food availability (Cowlishaw and Dunbar, 2000).

2.4 Methods to Evaluate Human Perceptions of Primates

I evaluated how Azuero people interact with and perceive non-human primates. I collected these data in the east of the Azuero Peninsula. I began surveys in Los Santos province at Tonosí, Tonosí District, including Aguas Buenas, La Zahina, Venao, Flores, and La Miel, which has 500 inhabitants in total. My aims in this section were to understand people's perceptions of non-human primates in adults and children, and the value of primates for the Azuero community. This approach is important as it involves people living in the area with the highest agriculture production in Panama, and this fragmented zone could serve as an example to avoid similar problems in other parts of Panama.

2.4.1 Previous Attempt to Understand Azuero's People

At first, I did informal surveys and formal or structured interviews to understand the aspects needed to develop an educational project that would be relevant to primate conservation. This information generated information that I later used to evaluate adults' knowledge and perceptions of primates, using Cultural Consensus Theory (Kim et al. 2008). For children's perception and knowledge of endangered primates I used drawings and composition writing as a source material, as recommended by Franquesa-Soler and Serio-Silva (2017). In interviews during 2001 – 2010, I selected sampling areas based on: a) the presence of living fences, gallery forest, patches of forest and houses; b) communities located no more than 1 km from patches of forest); c) a high likelihood of wild monkeys in the vicinity. To introduce myself, I contacted community leaders to introduce my project and main goals. I visited houses, approached pedestrians and visited small supermarket stores, interviewing individuals or groups of people. In all cases

I introduced myself as a Panamanian biologist from FCPP and asked them if they would be happy to answer some questions. I conducted four tests to understand local people perceptions of non-human primates, depending on the person's availability (Appendix 4 for ethics permission).

When approaching people, I generally began with an informal conversation, in which I asked five neutral questions about the regional situation (e.g., weather, crops, water, and politics). This was to help the person understand that I was interested in their day to day life and helped avoid bias and improve the validity of the survey (Riley and Ellwanger, 2013). I then asked the following four questions:

1) Do you know whether monkeys live in this area? If you do, where do they live?
2) What kinds of monkeys live in this area? I used images of different monkey species based on the illustrations in Read (1987), and included species that are not found in Panama, to test reliability.
3) How long have you been living here?
4) Are there any problems related to monkeys here?

In general, people were willing to collaborate in helping to conserve primates and did not report using primates as a protein resource. However, their answers also revealed a lack of basic knowledge about the life history of the monkeys, the presence of the authorities, and low levels of information about the topic generally (Méndez-Carvajal, 2013). Based on this first approach I selected La Miel to evaluate the perceptions of non-human primates (Chapter 4). The following Chapter 3 will show the first aspect to be evaluated in this thesis, which is: the potential distribution of the non-human primates in Panama. Chapter 3 is based on MaxEnt software and a completed data base of presence points.

3 Distribution of Panamanian Primates: an Ecological Niche Modelling Approach

3.1 Introduction

In this chapter, I calculate the potential distribution, species richness, and endemism of primates in Panama using species distribution modelling. Understanding the geographical distribution of wildlife species is an important component of effective conservation programs (Boubli and De Lima, 2009; Vidal-García and Serio-Silva, 2011; Marcer et al., 2013). The study of species distribution is challenging, however, mostly due to the lack of information on the presence or absence of species, the costs of developing systematic surveys, and the fact that many places of interest are remote and difficult to reach (Vidal-García and Serio-Silva, 2011). These challenges can be overcome by combining available observational data with mathematical algorithms and global information systems (GIS), which can help us to identify key habitat requirements, species richness, and species densities. This can help conservationists identify appropriate areas for protection and lead efforts for effective conservation management (Willems and Hill, 2009; Carvalho et al., 2010; Chetan et al., 2014; Holzman et al., 2015). Aspects to evaluate when using species distribution models include species diversity and areas that form unique habitats for individual species. Species richness is an important correlate of behavioural patterns and diversity of plants, plants productivity and seasonality (Kay et al., 1997). This information is important to an understanding of the population dynamics of primary consumers, including primate species (Therborgh, 1986). Endemism, meanwhile, describes the ecological status of any species that is considered unique to a specific geographic location. The concept of endemism is related to the capacity of a species for resilient responses to stress in its particular habitat, including those species that may face less competition but remain sensitive to changes in vegetation (Walck et al., 2001). By identifying “hotspots” where certain species are especially prevalent, this strategy allows us to focus conservation efforts and reduce costs, both important factors in conservation activity (Myers et al., 2000).

Changes are occurring in forested landscapes, particularly in the tropics (Whitmore, 1995; Wright, 2005). These changing land use practices are especially concerning, given that these forests provide habitat for a high proportion of animal species. Among these taxa are non-human primates, many of which are threatened according to the IUCN (Cotton et al., 2016). Recent studies have used species distribution data to detect the environmental conditions that limit primate presence and protect these species or habitats (Fourcade et al 2014). For example, species distribution models have been used to assist conservation action for the vulnerable *Hoolock leuconedys*, whose population has declined by 30% in recent years (Brockelman and Geissmann, 2008). In India, species distribution models were used to identify potential areas for primate population surveys and improve conservation management plans based on potential habitats (Sarma et al., 2015). Distribution data can also help to identify features of a species' habitat, such as topographic variation, that potentially isolate organisms. Another case study in India provided evidence for the ecological variables and topographical features affecting the distribution of the species *Semnopithecus* (Chetan et al., 2014). On a broader scale, the distribution of *Chlorocebus pygerythrus* across sub-Saharan Africa was shown to align with predictions of time-budget models, with both driven by variation in the NDVI (Willems and Hill, 2009).

The use of SDM in conservation assessment has been questioned because it is perceived as entailing difficulties in both presence evaluation (detectability and accuracy) and in obtaining updated presence data (Campbell et al., 2016). Inadequate sampling can, for example, lead to problems of interpretation (Carneiro et al., 2016). An additional problem is that the databases available for some countries are 5 to 10 years old, making conclusions out-of-date. Some authors suggest corrections for sampling bias to evaluate regional and global models (El-Gabbas and Dormann, 2017). However, long-term monitoring projects can decrease this problem by conducting frequent surveys.

Despite these concerns, distribution modelling has been applied to several primate species in the Neotropics, with studies related to the description of fundamental niches or combining ecological factors to focus conservation efforts in priority areas. For example, MaxEnt (Phillips et al., 2006) was used to link population densities of *Callithrix aurita* and its habitat suitability in Brazil, generating information suitable for conservation management (Norris et al., 2011). This suggests that it is possible to assess population by extrapolating densities from habitat suitability models (Norris et al., 2011).

In Ecuador, NDVI has enhanced such approaches, using vocalisations and hunting records to map areas outside Ecuador's protected zones that are still potential habitats for *Ateles fusciceps* (Peck et al., 2011). Similarly, after *Oreonax flavicauda* was rediscovered in the tropical forests of the Peruvian Andes, the combination of anthropogenic variables in a Gap Analysis and GIS Risk Assessment allowed conservationists to propose new limits for protected areas based on habitat composition (Leo-Luna, 1987; Buckingham and Shanee, 2009). In south-eastern Mexico, researchers used MaxEnt and species presence data points to identify potential locations to conduct further primate surveys, allowing them to generate more accurate distribution maps of the local primate species, which they could use as the focus of future conservation activities (Vidal-García and Serio-Silva, 2011). In Argentina, MaxEnt was used to model and update the potential distribution map of primates and identify important zones of potential convergence in the species ranges of *Alouatta caraya* and *A. guariba* (Holzman et al., 2015).

More recently, species distribution models have been used to test whether anthropological factors improve the interpretation of the models in combination with selected environmental variables. To avoid biodiversity loss and prevent abrupt changes to primate habitats, Kamilar and Tecot (2015) showed that anthropogenic factors may change the distribution of *Eulemur* species in Madagascar, where lemurs have declined by 94%, leading to their classification as the most Critically Endangered group of mammals in the world (Schwitzer et al. 2014).

There is limited information on the distribution of Panamanian primates, although 75% of the primate species in Panama are listed as threatened (IUCN, 2016). This chapter tests 23 variables in three sets of factors (climatic variables, forest cover and human densities) that may influence Panamanian primate species to determine how they influence the species distribution model. I used 15 years of presence data (Appendix 2) to evaluate the current distribution of Panamanian primates and identify high priority habitats. The data are up-to-date, because I have visited most sites every year and employed citizen scientists to check those I could not re-visit. I aimed to model species distribution to evaluate the effect of climate and anthropogenic variables and define habitat suitability for each Panamanian primate subspecies, as well to obtain maps of species richness and endemism. To understand the role of climate variables in the distribution of Panamanian primates, I developed three types of models. The first model involved climatic variables only (19 Worldclim variables). The second model added remote sensing variables (2 forest cover; NDVI and EVI). The third model added anthropogenic effects to the other variables (2 human population; indigenous people and local people). This three-stage modelling approach was sensitive to the relative importance of the different types of variables for the different primate species studied in this thesis.

3.2 Methods

3.2.1 Study Sites

I used the methods described in Chapter 2 to sample each province in Panama. I sampled some provinces more than others, and only used some of the sampling methods in some provinces. My main objective was to detect the presence of each species, while some methods also allow density calculations. While this inconsistency in sampling is a potential bias, the data represent the most comprehensive presence data available at the moment. The following maps of the Panamanian provinces studied for this thesis all show the study areas, and the points where I applied different research methods.

3.2.1.1. Bocas del Toro Province

Bocas del Toro Province is mainly tropical rainforest: its territory includes the international park "La Amistad". There are hydroelectric projects in the indigenous areas of the province, which made visiting unsafe. To sample Bocas del Toro Province, I set up two listening posts, one strip transect and conducted surveys to complement primate presence data collected by trained citizen scientists (Figure 3.1).

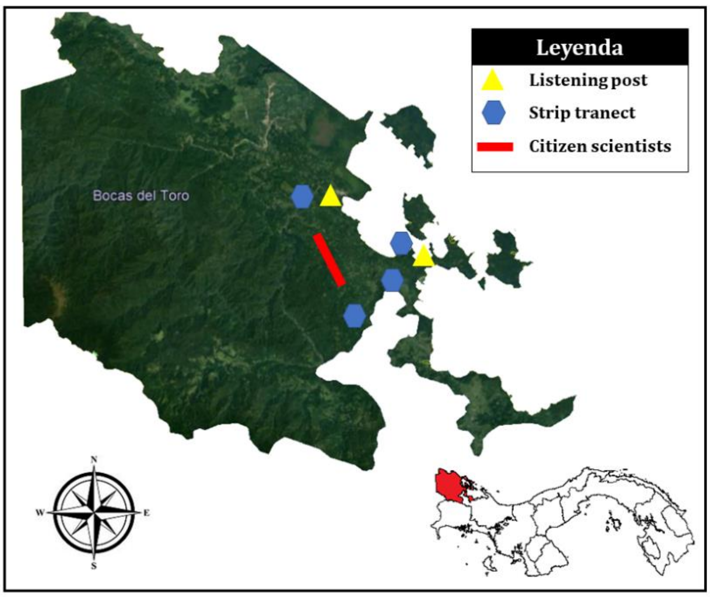

Figure 3.1. Study areas in Bocas del Toro province, and the points where I applied different sampling methods.

3.2.1.2. Chiriquí Province

Chiriqui has the highest peak in Panama, the Baru Volcano (3,475 mosl). It has highlands connecting the Tabasara Mountain Chain (Central Mountain Chain of Panama) and a fragmented landscape due to agriculture. I set up four listening posts, five strip transects, one road counts, three OCS and conducted surveys to update primate presence data collected by trained citizen scientists (Figure 3.2).

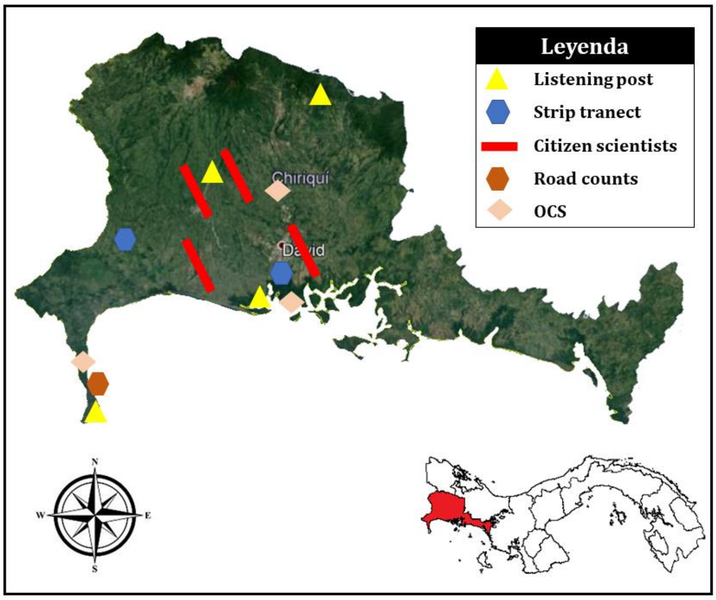

Figure 3.2. Study areas in Chiriquí province, and the points where I applied different sampling methods.

3.2.1.3. Veraguas Province

Veraguas province is the only province in Panama that stretches from the Caribbean Sea to the Pacific Ocean. It has forested landscape in the north but has recently been a conflict zone due to gold and copper extraction. I set up two listening posts, one strip transect, one OCS, one road count and conducted surveys to update primate presence date collected by citizen scientists (Figure 3.3).

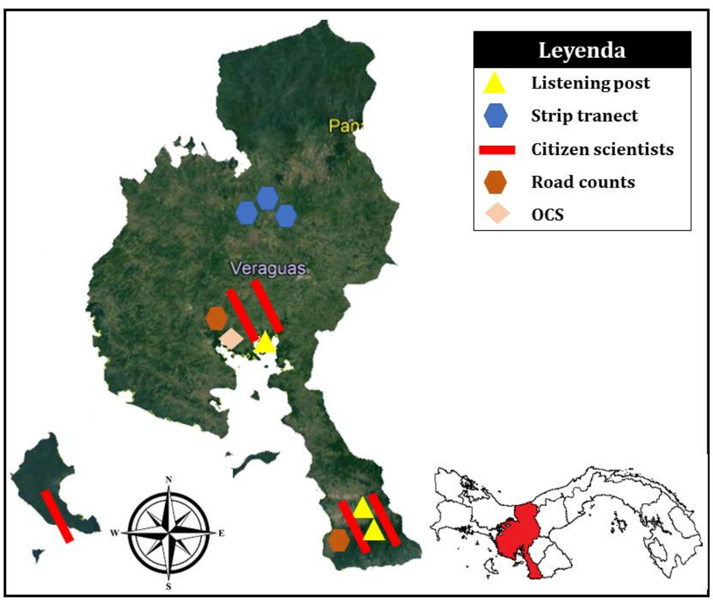

Figure 3.3. Study areas in Veraguas province, and the points where I applied different sampling methods.

3.2.1.4. Herrera Province

Herrera province is one of the three provinces forming the Azuero peninsula. El Montuoso Forest Reserve (RFEM) is the most forested area. It has elevations <1000 m and fragmentation due to agriculture. I set up three listening posts, three strip transects, three road counts, and conducted surveys to update primate presence data collected by trained citizen scientists (Figure 3.4).

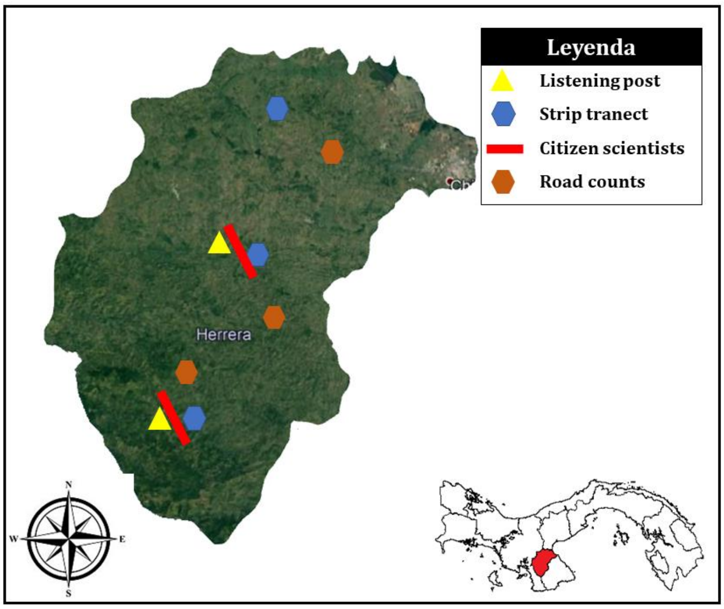

Figure 3.4. Study areas in Herrera province, and the points where I applied different sampling methods.

3.2.1.5. Los Santos Province

Los Santos province is one of the three provinces forming the Azuero peninsula. La Tronosa Forest Reserve (RFLT) is the most forested area. It has elevations less than 1000 m and fragmentation due to agriculture. I set up three listening posts, three strip transects, five road counts, one OCS, and conducted four surveys to update primate presence data collected by trained citizen scientists (Figure 3.5).

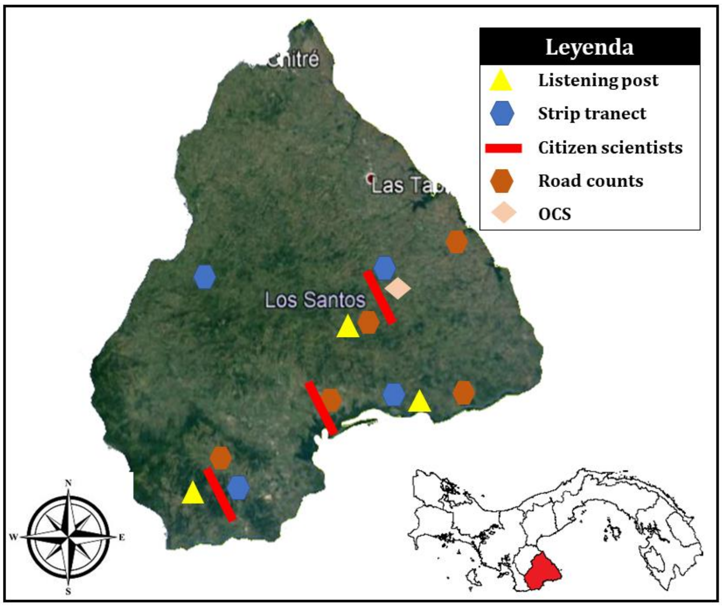

Figure 3.5. Study areas in Los Santos province, and the points where I applied different sampling methods.

3.2.1.6. Cocle Province

Cocle province has forest cover in the north but mining activity has recently hugely increased. Other areas are populated by indigenous people and the lowlands are fragmented by cattle ranches and agriculture. I set up one listening post, one strip transect, one road count, one OCS, and conducted three surveys to update primate presence data collected by trained citizen scientists (Figure 3.6).

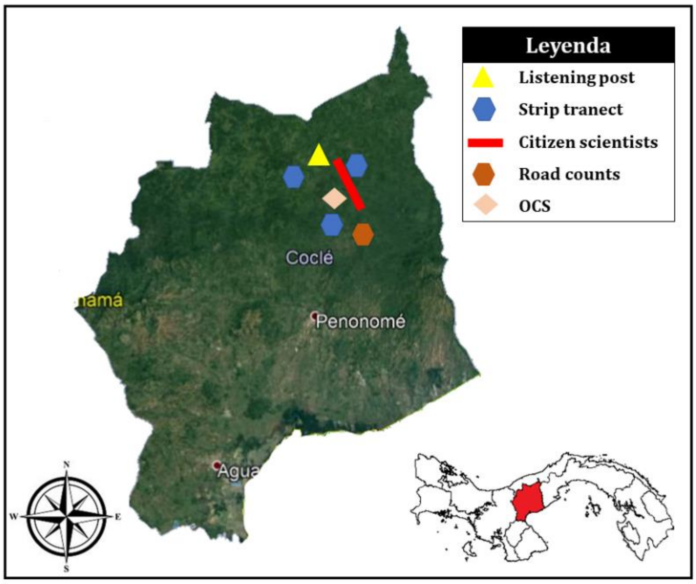

Figure 3.6. areas in Cocle province, and the points where I applied different sampling methods.

3.2.1.7. Colon Province

The north of Colon province has the most forest, with elevations less than 1000 m and fragmentation due to agriculture. It has two national parks: Portobelo National Park and San Lorenzo National Park. I set up four listening posts, performed two strip transects, three road counts, and three surveys to update primate presence data collected by trained citizen scientists (Figure 3.7).

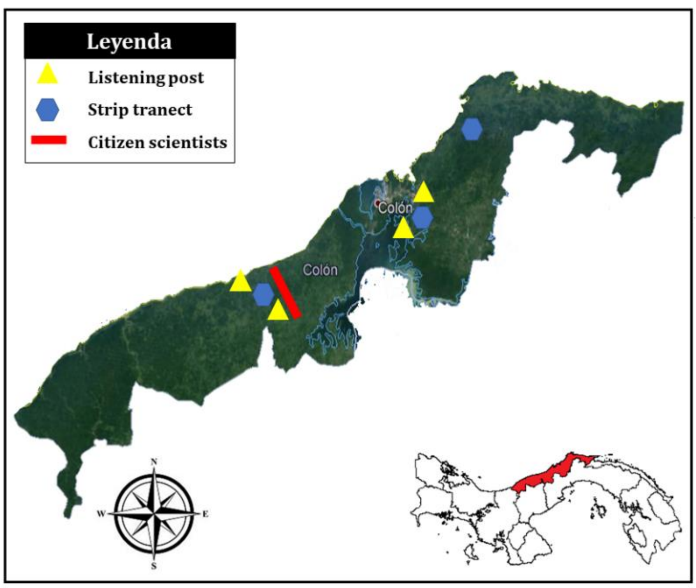

Figure 3.7. Study areas in Colon province, and the points where I applied different sampling methods.

3.2.1.8. Panama Province

Panama province has three national parks: Camino de Cruces National Park, Soberania National Park, and Metropolitan Natural Park. The forested areas are protected by to the Panama Canal Zone, with elevations less than 1000 m and fragmentation due to urbanisation. I set up four listening posts, six strip transects, two road counts, and conducted five surveys to update primate presence data collected by trained citizen scientists (Figure 3.8).

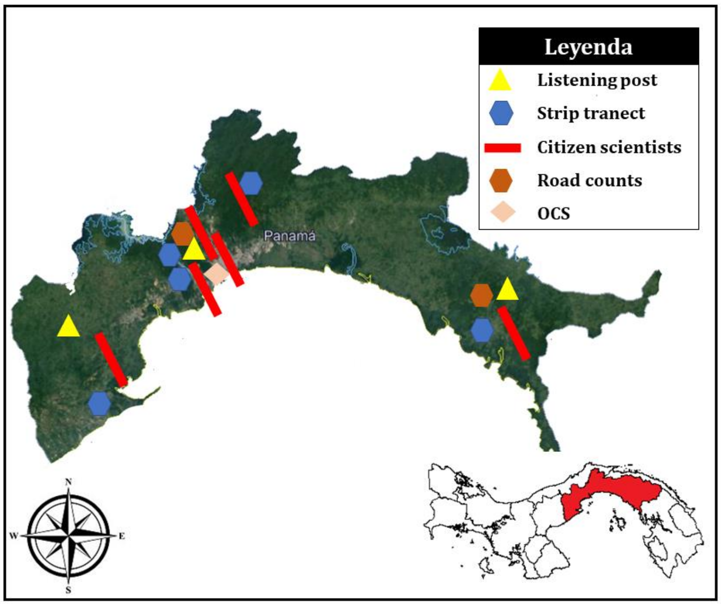

Figure 3.8. Study areas in Panama province, and the points where I applied different sampling methods.

3.2.1.9. Darien Province

Vegetation in Darien province includes tropical rainforest, cloud forest, and mountain forest. The province also has several National Parks: Bagre Nature Reserve, Maje Mountain Chain, Chucanti Nature Reserve, and the Pacific Mountain Chain. I set up four listening posts, performed eight strip transects, three OCS, one road count, and collected six new reports from citizen scientists (Figure 3.9).

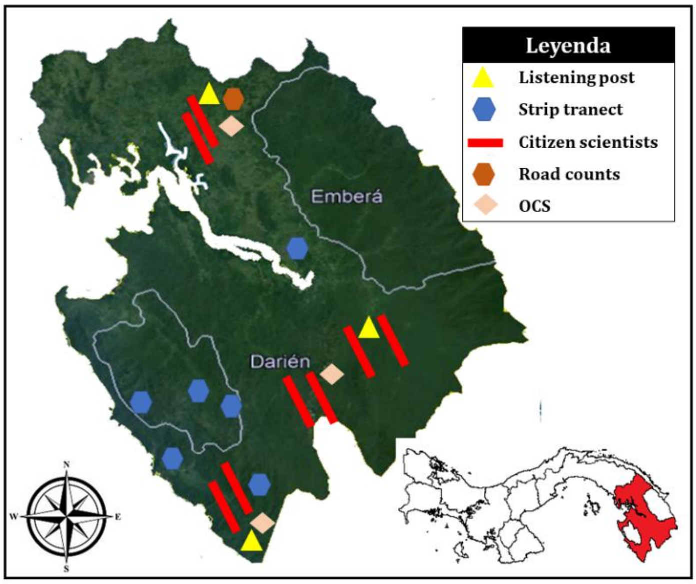

Figure 3.9. Study areas in Darien province, and the points where I applied different sampling methods.

3.2.2 Climate Variables

I obtained climate data for 1950 to 2000 from DIVA-GIS (www.worldclim.org), with a resolution of 30 arc seconds (1 km^2) (Hijmans et al., 2005). I derived altitude information from a digital elevation model recorded by a Shuttle Radar Topography Mission-NASA at the USGS (https://lta.cr.usgs.gov/SRTM1Arc). Spatial resolution was 0.000833333 decimal degrees (100 m at the equator), and the projection used was the World Geodetic System 84 (WGS84). I used the remote sensing layers NDVI and Enhanced Vegetation Index (EVI) for primary productivity (photosynthesis). I downloaded productivity layers for April (minimum productivity), July (transition productivity), and September (maximum productivity).

3.2.3 Anthropogenic Data

I defined anthropogenic data as data relating to human populations in general and indigenous areas in particular. I obtained data on anthropogenic variables using GIS from the Smithsonian Tropical Research Institute (STRI), in Panama. I added two layers to Arcmap 10.3. The first layer coded the presence of the indigenous areas of the Guna, Embera-Wounaan and Ngäbe-Buglé (Ind. Areas) as an anthropogenic factor to identify areas where the local population may consume primates (Smith, 2005; Méndez-Carvajal, 2005; 2013). I assigned indigenous areas a value of 1, and all other regions 0. I obtained a layer for human population density across Panama from World Population (http://www.worldpop.org.uk), which estimates the number of people per pixel ('ppp'), with spatial resolution of 0.000833333 decimal degrees (approx. 100m at the equator), with national totals adjusted to match population division estimates (http://esa.un.org/wpp/).

3.2.4 Data Analysis

I used a Geographical Information System (GIS, ArcGIS Desktop 10.3; ESRI, 2015) to store the location points obtained from surveys as decimal coordinates, and organised these location points in csv files in Excel 2016. I used MaxEnt 3.3.3 k (Phillips et al., 2006) to evaluate the potential distributions of the non-human primate taxa in Panama. MaxEnt takes as its input a set of layers or environmental variables (such as elevation, precipitation) and a set of georeferenced occurrence locations, and uses these inputs to produce a model of the range of the given species (Phillips et al., 2006). It uses an algorithm to calculate the probability of presence of a species based on environmental variables, and the geographic space. The results are based on the relative probability that a subspecies will occur in a cell given the corresponding environmental variables (Figure 3.10 and 3.11).

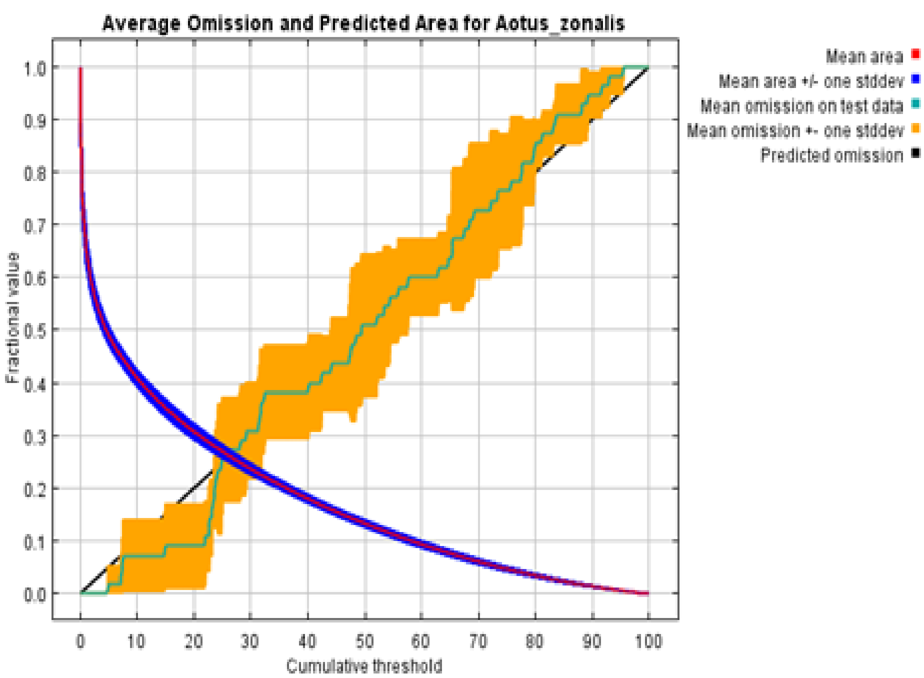

Figure 3.10. Example of a plot of Average Omission (turquoise line) and Predicted Omission (black line) in MaxEnt. Omission is the proportion of sites incorrectly predicted to be unsuitable for a species. The cumulative threshold is the proportion of pixels or sample points that have a probability of occurrence less than or equal to that for the focal

location. In this case the mean omission line and predicted omission coincide with the cumulative threshold.

For Model 1, I selected 19 environmental variables from the Worldclim Global Climatic Data (Hijman et al., 2005). I then used Pearson correlations in the SDM toolbox (Brown, 2014) (http://sdmtoolbox.org/) to examine relationships between the variables, and selected only those variables where $R<0.50$, to remove highly correlated variables from the data set (Appendix 3). The variables retained were: Annual Mean Temperature, Annual Precipitation, Precipitation Seasonality, Isothermality, Mean Diurnal Range, and Temperature Seasonality.

For Model 2, I repeated the process of assessing the correlations between climate variables from Model 1 and adding remote sensing variables (Appendix 3). Since some NDVI and EVI variables were highly correlated, and since EVI was more strongly correlated ($r > 0.50$) with some climatic variables, I excluded it from analysis.

For Model 3, I evaluated correlations with the anthropogenic variables (Appendix 3). Neither was strongly correlated with the existing variables and I retained both for analysis.

MaxEnt evaluates a model in two ways, using: a) "training data" to explain how the data fit the model, and b) "test data" to explain how the model predicts the data. For each model, I used 75% of the species' known localities as training data and the remaining 25% of localities as test data, contrasting these with 10,000 background points. MaxEnt uses background points as pseudo absence to evaluate the models since true absence data were not available. I ran three replicates per subsample. I used subsamples to reduce the effect of similar presence points collected for some subspecies in the same location following Elith et al (2011; Fourcade et al., 2014), and three replications to generate three outputs, a very conservative setting (Fielding and Bell, 1997; Young et al., 2011). In Figure 3.11 we see how variables are expressed as output, using *Aotus zonalis* as an example.

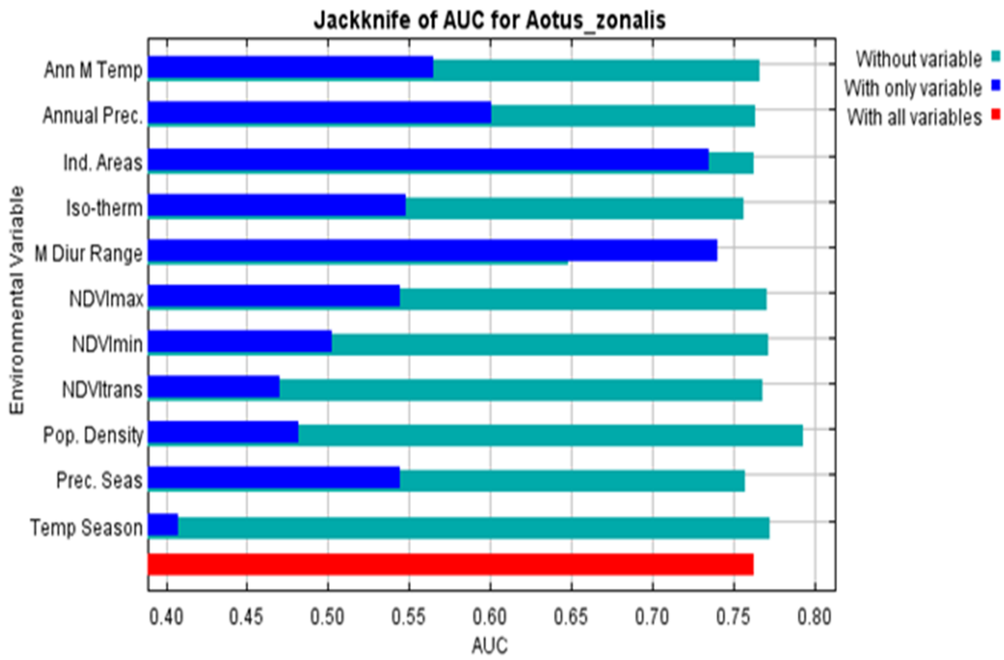

Figure 3.11. Example of a plot showing the Area Under the Curve (AUC) with variables (in blue) and without variables present (in red). The output shows that Indigenous areas and Mean Diurnal Range are both important factors limiting the range of *Aotus zonalis* in Panama.

In the MaxEnt Advance setting panel, I selected 3,000 points with a maximum interaction of 0.00001 (the convergence threshold), and 10 as the sample ratio, with a 0.5 default to test accuracy. The experimental settings included 1 thread, with 10 linear thresholds and hinge threshold at 15. I tested the relevance of each variable using jack-knife (Figure 3.11) and Pearson's correlations to determine how the test variables influence each subspecies' distribution model (Brown, 2014). I evaluated the performance of the model using the AUC values: the resulting scale was 0.5-1. Values <0.5 indicate that the performance of species presence was poor, values similar to 0.5 indicate the model had a uniform probability of presence, and values >0.5 to 1 indicate a model that performs well (Elith et al., 2011; Young et al., 2011). I assessed 0.7-0.8 as an acceptable prediction, 0.8-0.9 as excellent, and >0.9 as outstanding (Hosmer and Lemeshow, 2000). I expressed results as the mean test AUC, estimating the precision of sample statistics using standard deviation and p values for each subspecies (Fielding and Bell, 1997). I also obtained a test of training omission to test predictions on training and testing data sets predicted by the MaxEnt Model (Phillips et al., 2006). The models can be linear, quadratic, product, threshold, hinged and discrete functions of all environmental predictors from which the researcher must select the best option for the project (Phillips and Dudik, 2008). Maps showing the potential distribution of target species will represent in red the higher possibility of presence of a species based on the climatic conditions where you originally marked the presence of an animal. See Fig 3.12 to understand scales of colours used to mark zones on the maps where primate presence is likely to be detected.

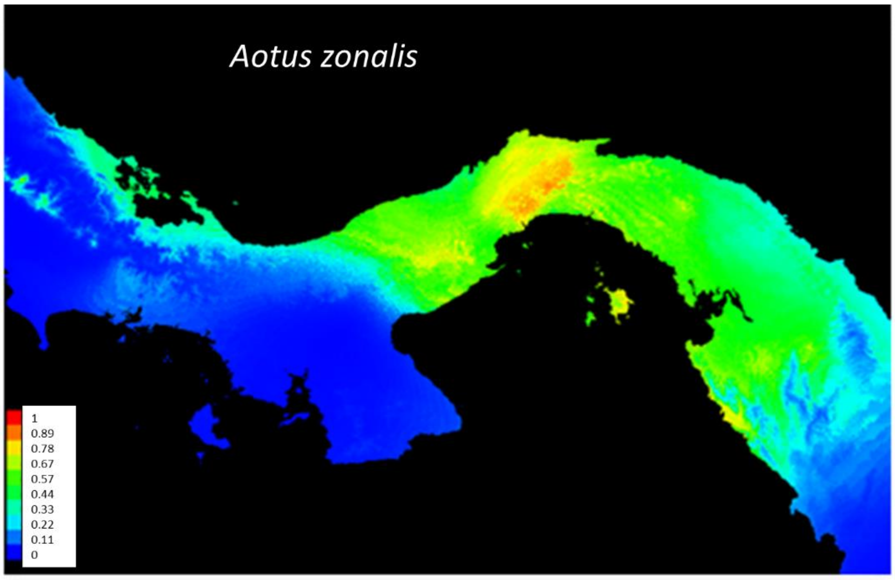

Figure 3.12. Example of MaxEnt Habitat Suitability results for *Aotus zonalis.* The colour scale ranges from 0 (blue, no probability of presence) to 1 (red, high probability of presence).

For species richness and endemism analysis I used the SDM toolbox (Brown et al., 2014) and the binary SDM analysis proposed by Crisp et al. (2001). The analysis calculated species richness per quadrant (SR) as:

a) SR = K (complete number of species in a grid cell),

b) Weighted Endemism (WE). The number of cells where each species is present, where WE = Σ 1/C (C is # grid cells each endemic occurs in), and

c) Corrected Weighted Endemism (CWE). I used 1 square kilometre as the grid cell area, with 30 km as the buffer area (Crisp et al., 2001).

3.3 Results

3.3.1 Primate Detections

I surveyed almost all provinces, using at least three methods to estimate primate presence. Some species were only detected with one of the methods, showing the importance of using several methods to detect primates. Listening posts were effective mostly for *Alouatta* spp., and in non-fragmented habitats. *Ateles* spp. and *Aotus zonalis* were both detected via their vocalizations. I used the strip transect method for all species, including diurnal and nocturnal surveys. Road counts were effective for primate detection in fragmented landscapes, and living fences helped with road counts between villages: this method mostly detected *Alouatta* spp. The OCS method was useful as a complementary method, due to the high probability of detection it enabled, and its automatic system of surveillance (Table 3.1).

Table 3.1. Number of *Aotus zonalis* detected per province and methods of detection used.

Province	Listening Posts	Strip transects	Road counts	OCS	Citizen Scientists	Total
Bocas del Toro	0	0	0	0	0	Undetected
Chiriqui	0	0	0	0	0	Undetected
Veraguas	0	0	0	0	1	1
Herrera	0	0	0	0	0	Undetected
Los Santos	0	0	0	0	0	Undetected
Cocle	2	3	0	6	12	23
Colon-SB	0	0	0	0	11	11
Panama	54	4	0	2	2	62
Darien	0	5	0	0	5	10
Total	56	12	0	8	30	107

In the case of the species *Saguinus geoffroyi,* this species appears to be undetected for five provinces in Panama, well represented in Panama province and Darien, diminishing detection as more I move to the west (Table 3.2). It is very well detected by strip transect, if compared to other methods.

Table 3.2. Number of *Saguinus geoffroyi* detected per province and methods of detection used.

Province	Listening Posts	Strip transects	Road counts	OCS	Citizen Scientists	Total
Bocas del Toro	0	0	0	0	0	Undetected
Chiriqui	0	0	0	0	0	Undetected
Veraguas	0	0	0	0	0	Undetected
Herrera	0	0	0	0	0	Undetected
Los Santos	0	0	0	0	0	Undetected
Cocle	0	10	2	0	0	12
Colon-SB	0	29	0	0	0	29
Panama	0	173	0	0	0	173
Darien	0	150	0	0	0	150
Total	0	362	2	0	0	364

The species *Saimiri oerstedii oerstedii* was only detected in Chiriqui province, which shares a frontier with Costa Rica-Panama (Table 3.3). Detection, in this case, was successful thanks to the use of strip transects.

Table 3.3. Number of *Saimiri oerstedii oerstedii* detected per province and methods of detection used.

Province	Listening Posts	Strip transects	Road counts	OCS	Citizen Scientists	Total
Bocas del Toro	0	0	0	0	0	Undetected
Chiriqui	0	35	2	7	7	51
Veraguas	0	0	0	0	0	Undetected
Herrera	0	0	0	0	0	Undetected
Los Santos	0	0	0	0	0	Undetected
Cocle	0	0	0	0	0	Undetected
Colon-SB	0	0	0	0	0	Undetected
Panama	0	0	0	0	0	Undetected
Darien	0	0	0	0	0	Undetected
Total	0	35	0	0	0	51

The species *Cebus imitator* and *Cebus capucinus* are both represented in this table, showing their presence in the entire Republic, with *C. capucinus* being more frequently detected and having representatives from Panama and Colon. *C. imitator* showed more detectability at Cocle but was detected in all provinces (Table 3.4).

Table 3.4. Number of *Cebus capucinus** /*Cebus imitator* detected per province and methods of detection used.

Province	Listening Posts	Strip transects	Road counts	OCS	Citizen scientists	Total
Bocas del Toro	0	0	1	0	0	1
Chiriqui	0	1	1	0	0	2
Veraguas	0	6	0	0	1	7
Herrera	0	0	0	0	2	2
Los Santos	0	0	13	0	0	13
Cocle	0	20	0	0	5	25
Colon*	0	58	0	7	0	65
Panama*	0	25	3	5	0	33
Darien*	0	4	0	5	0	9
Total	0	114	18	17	8	**157**

The species *Alouatta palliata* species was divided into the subspecies *Alouatta palliata palliata* and *Alouatta palliata aequatorialis,* andshowed good detectability in almost all provinces: they showed higher detectability in Panama, Darien, Colon and Chiriqui provinces (Table 3.5). The strip transects and OCS methods proved to be good choices for these surveys.

Table 3.5. Number of *Alouatta palliata palliata* */*Alouatta palliata. aequatorialis* detected per province and methods of detection used.

Province	Listening Posts	Strip transects	Road counts	OCS	Citizen scientists	Total
Bocas del Toro	0	1	1	1	0	3
Chiriqui*	0	20	0	5	0	25
Veraguas*	0	0	1	0	0	1
Herrera	0	0	0	0	0	Undetected
Los Santos	0	0	0	0	0	Undetected
Cocle*	0	8	4	0	0	12

Colon	0	35	0	0	0	35
Panama*	0	30	0	7	0	37
Panama	10	5	5	5	8	33
Darien	9	11	1	5	1	27
Colon-SB	0	2	2	1	6	11
Total	19	112	14	24	15	**184**

Two subspecies make up the species *Alouatta coibensis*: these are *Alouatta coibensis coibensis* and *Alouatta coibensis trabeata,* which are found on Coiba Island / Jicaron, and on the Azuero peninsula. I found that Herrerra province was the location where this primate was most detectable (Table 3.6).

Table 3.6. Number of *Alouatta coibensis coibensis* / Alouatta coibensis trabeata* detected per province and methods of detection used.

Province	Listening Posts	Strip transects	Road counts	OCS	Citizen scientists.	Total
Bocas del Toro	0	0	0	0	0	Undetected
Chiriqui	0	0	0	0	0	Undetected
Isla Coiba*	20	25	0	10	5	60
Veraguas	12	18	1	0	0	31
Herrera	45	34	100	19	4	200
Los Santos	10	9	6	0	0	25
Cocle	0	0	0	0	0	Undetected
Colon-SB	0	0	0	0	0	Undetected
Panama	0	0	0	0	0	Undetected
Darien	0	0	0	0	0	Undetected
Total	87	86	107	29	9	318

The species *Ateles geoffroyi azuerensis* was only detected in two provinces, Los Santos and Veraguas east (Table 3.7). Detectable by using strip transect.

Table 3.7. Number of *Ateles geoffroyi azuerensis* detected per province and methods of detection used.

Province	Listening Posts	Strip transects	Road counts	OCS	Citizen scientists	Total
Bocas del Toro	0	0	0	0	0	Undetected
Chiriqui	0	0	0	0	0	Undetected

Veraguas	3	0	1	0	2	6
Herrera	0	0	0	0	0	0
Los Santos	0	17	7	6	2	32
Cocle	0	0	0	0	0	Undetected
Colon-SB	0	0	0	0	0	Undetected
Panama	0	0	0	0	0	Undetected
Darien	0	0	0	0	0	Undetected
Total	3	17	8	6	4	38

The species *Ateles geoffroyi panamensis* exhibited an extended distribution, being found from Mexico to Panama. In the latter country, it was detected in Bocas del Toro and Chiriqui, Colon and Panama provinces (Table 3.8). Methods usable for detection of Ateles were strip transects.

Table 3.8. Number of *Ateles geoffroyi panamensis* detected per province and methods of detection used.

Province	Listening Posts	Strip transects	Road counts	OCS	Citizen Scientists	Total
Bocas del Toro	0	1	0	0	1	2
Chiriqui	0	9	0	0	0	9
Veraguas	0	0	0	0	0	Undetected
Herrera	0	0	0	0	0	Undetected
Los Santos	0	0	0	0	0	Undetected
Cocle	0	0	0	0	0	Undetected
Colon-SB	3	1	1	0	1	6
Panama	0	2	0	0	0	2
Darien	0	0	0	0	0	Undetected
Total	3	13	1	0	2	19

Across almost the entire country, the species *Ateles fusciceps rufiventris* was undetected. The only exception was in the cases of Darien and Panama provinces, the two provinces that lie next to the Colombia-Panama frontier (Table 3.9). In those provinces , the strip transect method allowed for the successful detection of this species (Table 3.9).

Table 3.9. Number of *Ateles fusciceps ruviventris* detected per province and methods of detection used.

Province	Listening Posts	Strip transects	Road counts	OCS	Citizen scientists	Total
Bocas del Toro	0	0	0	0	0	Undetected
Chiriqui	0	0	0	0	0	Undetected
Veraguas	0	0	0	0	0	Undetected
Herrera	0	0	0	0	0	Undetected
Los Santos	0	0	0	0	0	Undetected
Cocle	0	0	0	0	0	Undetected
Colon-SB	0	0	0	0	0	Undetected
Panama	0	7	0	0	3	10
Darien	2	76	0	12	3	93
Total	2	83	0	12	6	103

3.3.2 Species Distribution Modelling (MaxEnt)

3.3.2.1. Model 1: Climatic Variables Only

Of the 13 subspecies in Panama, I did not detect *Ateles geoffroyi grisescens*. For Model 1, AUC values for the climate variables ranged from 0.74 (*Aotus zonalis*) to 0.99 (*Alouatta coibensis coibensis*), with a mean of 0.90 (SD±0.07) (Appendix 3). Precipitation seasonality was the most important variable for members of Atelidae family: *A. c. coibensis*, *Alouatta coibensis trabeata*, and *Ateles geoffroyi azuerensis* (AUC values 44.9-55.2, Appendix 3) while mean diurnal temperature range was the best predictor for the presence of Atelidae, Cebidae and Callithirichidae: *Aotus zonalis*, *Ateles fusciceps rufiventris*, *Alouatta palliata aequatorialis*, *Cebus capucinus*, *Saguinus geoffroyi*, and *Saimiri oerstedii oerstedii* (AUC values 59.6-78.5, Appendix 3). Temperature seasonality was the best predictor variable for *Cebus imitator* and *Saguinus geoffroyi* (AUC values 41.9-61.4, Appendix 3). Assessment of the relationship between the testing presence points and the training points suggested that poor presence prediction for *Alouatta coibensis coibensis*, *A. palliata aequatorialis*, *Alouatta palliatapalliata*, *Ateles fusciceps rufiventris*, *Ateles geoffroyi panamensis*, *Cebus capucinus*, *Cebus imitator* (Appendix 3). Nevertheless, Model 1 predicted the other subspecies well. Excluding them from the model caused the biggest drop in performance (see Appendix 3). For the other subspecies, AUC values for the Jack-knife test had values <0.80 (Appendix 3), meaning that this variable is a key influence on their presence. However, precipitation seasonality was more important for some subspecies (e.g. *Saimiri oerstedii oerstedii* and *Cebus imitator,* Appendix 3, Model 1; AUC 0.965 (Appendix 3). The omission vs. predicted area showed a fraction of the area of 0.045, confirming a poor approach for the first model for *Ateles fusciceps rufiventris* (Figure 3.13). For each set of models I compared variables to recognize Pearson Correlation and eliminate the ones are correlated, see Table 3.10 for each model.

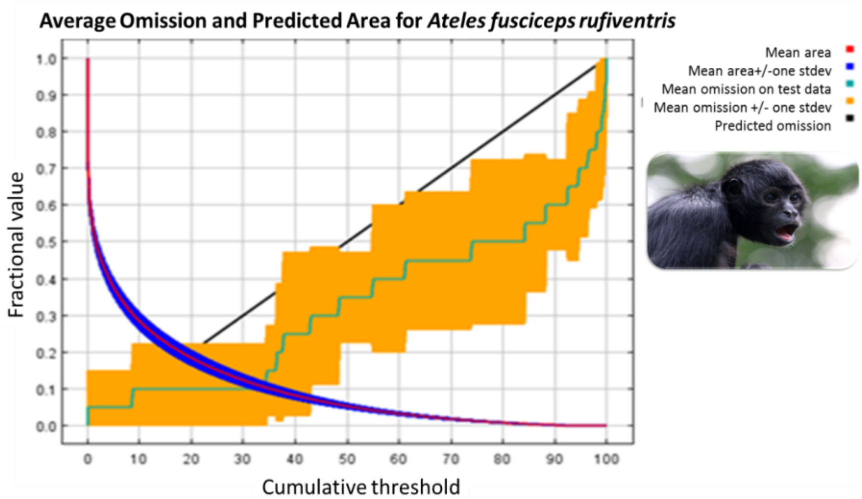

Figure 3.13. Example of Average omission and predicted area statistics from Model 1 for *Ateles fusciceps rufiventris*. The mean test omission lies below the predicted omission indicating relatively poor model performance. Model 2 (climatic variables and remote sensing).

3.3.2.2. Model 2: Climate and Remote Sensing Variables

Model 2, incorporating NDVI, did not improve the main test AUC values, which ranged from 0.66 (*Ateles geoffroyi panamensis*) to 0.99 (*Alouatta coibensis coibensis*) with a general mean of 0.88 SD±0.09 (Appendix 3). Annual Precipitation and Mean Diurnal Range became less important with inclusion of the remote sensing variables (Appendix 3). NDVI transition and NDVI maximum had some of the lowest percentage contributions, but NDVI minimum was important for *Alouatta coibensis coibensis* and *Ateles geoffroyi panamensis* (Appendix 3). Despite this, the relationship between the testing and training points generally improved Model 1 with Model 2, with AUC values of 0.891 ±0.029. Model 2 also improved slightly on Model 1 in terms of accuracy, with a higher mean omission overlaying the random value of absence (Appendix 3).

The model for the Atelidae family – in particular *Alouatta coibensis coibensis* – remained poor in predicting presence probability (Appendix 3, Model 2) although the fraction area was smaller than in Model 1. The Model 2 results for *A. palliata aequatorialis*, *A.p. palliata*, and *Ateles fusciceps rufiventris* were similar to those for Model 1, with training and testing points closer to the predicted omission but still under the line of no discrimination. However, Model 2 improved results for *Ateles geoffroyi panamensis*, *Cebus capucinus* and *Cebus imitator*, increasing the true positive rate of the area under the curve just to the point of the uniform line (Appendix 3; Model 2). Model 2 showed influence for most subspecies, except for *Ateles geoffroyi panamensis*, *Cebus imitator* and *Saguinus geoffroyi* (Appendix 3; Model 2).

Jackknife evaluation for each variable in Model 2 confirmed the importance of Annual Precipitation, Mean Diurnal Range, and Temperature Seasonality variables for all species except *Alouatta coibensis coibensis*, *A. c. trabeata*, *Ateles geoffroyi azuerensis*, *Cebus capucinus* and *Saimiri oerstedii oerstedii* where AUC values for Annual Mean Temperature was less than 0.45 (Appendix 3). Graphing omission vs. predicted area showed that the fraction of the predicted area was the same as for Model 1, but with a higher standard deviation, suggesting the need for a better model than one and 2, to clearly evaluate habitat suitability (Figure 3.14).

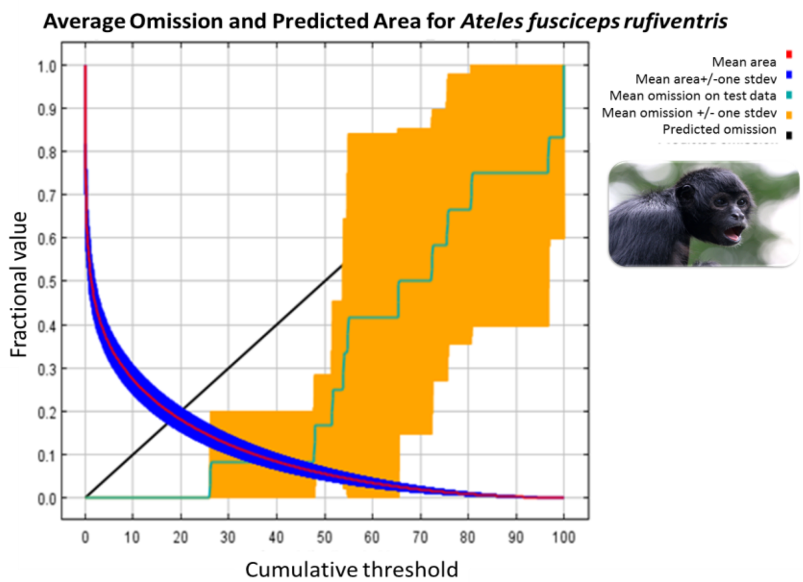

Figure 3.14. Example of results for *Ateles fusciceps rufiventris*, derived from Average Omission and Predicted Area statistics provided by Model 1. The mean test omission still lies below the predicted omission indicating relatively poor model performance. Moreover, the AUC is now further from zero, meaning that the model needs to be tested with other variables if it is to be improved.

3.3.2.3. Model 3: Climate, Remote Sensing and Anthropogenic Variables

Model 3 was improved by the inclusion of data on anthropogenic effects experienced by primates of the families Atelidae, Aotidae and Cebus, including species such as *Alouatta coibensis trabeata*, *Alouatta palliata palliata*, *Aotus zonalis* and *Saimiri oerstedii oerstedii* (Appendix 3). AUC either decreased or remained the same for the species *Alouatta coibensis coibensis*, *Cebus capucinus*, and *Cebus imitator*, with an overall mean of 0.88 (SD±0.10) (Appendix 3). Where environmental variables were concerned, values of AUC decreased when anthropogenic factors were added. Among the various species, the strongest change observed was in *Alouatta palliata palliata*, where Temperature Seasonality decreased from AUC value 52 to 29.1 (Appendix 3). The application of Model 3 to my data suggests that not all primate species are affected by human population density, with rates of AUC ranging from a low of 0.7 to as much as 10.4 (Appendix 3). In Indigenous areas, the presence of some subspecies is limited. The sum of contribution values for the two anthropogenic variables was 54.9% for *Ateles fusciceps rufiventris*, 46.6% for *Saimiri oerstedii oerstedii*, and 28.9% *for Alouatta palliata palliata.* In contrast, the combined contribution for *Alouatta coibensis coibensis*, *Ateles geoffroyi azuerensis*, and *Ateles geoffroyi panamensis* was less than 5%, with all other subspecies intermediate between these values. Inclusion of anthropogenic values, therefore, improved the performance of Model 3 with the mean omission test data exceeding the random value assigned to absence (Appendix 3, Model 3; Table 3.10).

Model 3 improved the presence probability for all subspecies, although *Alouatta coibensis trabeata* subspecies did not move from the uniform line (Appendix 3). AUC values for the Jackknife test were s >0.80 AUC (see Appendix 3). The plot of omission vs. predicted area was similar to those for Models 1 and 2 (see Figure 3.14 for an example). The results of the Jackknife test implied that anthropogenic variables, in particular in the presence of indigenous populations, were important for *Alouatta coibensis coibensis*, *Alouatta coibensis trabeata*, *Alouatta palliata aequatorialis*, *Alouatta palliata palliata, Ateles fusciceps rufiventris*, *Ateles geoffroyi azuerensis*, *Cebus capucinus* and *Cebus imitator*, with AUC values of 0.70 - 0.90 for Indigenous areas (Figure 3.15; Table 3.10).

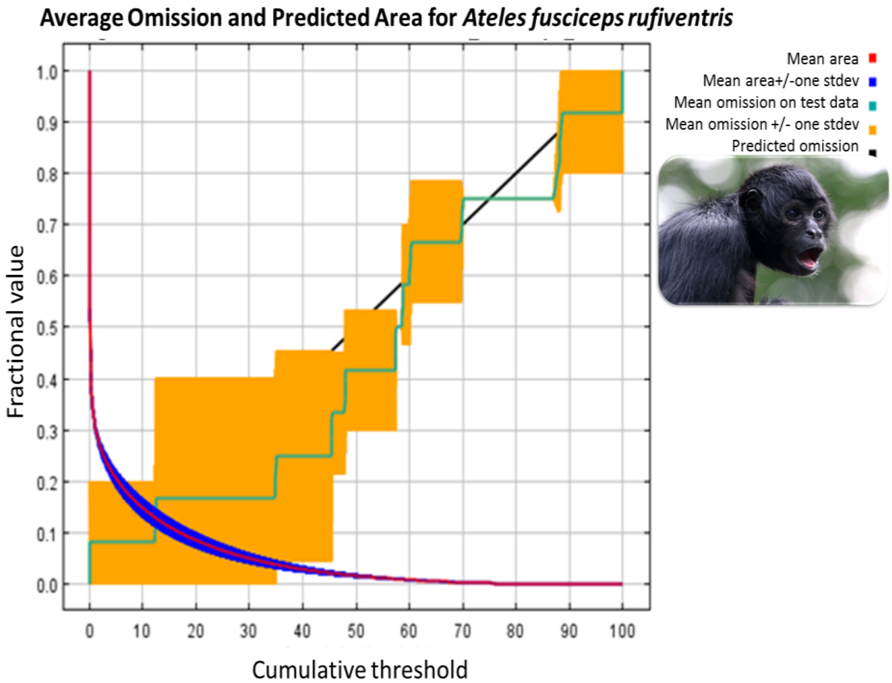

Figure 3.15. Using Model 3: an example of results concerning Average of Omission and Predicted Area of *Ateles fusciceps ruvfiventris*. The mean omission values are closer to the predicted omission line, indicating that the model has been improved by the addition of climatic variables, remote sensing and anthropogenic factors. The AUC of the mean area is closer to the 0.1-10, an improvement on the AUC produced by the previous model.

Table 3.10. Predictions of Panamanian primate distribution using the three different models in MaxEnt.

	Model 1 Environmental Variables						Model 2 Remote sensing			Model 3 Anthropogenic	
Subspecies	**Ann M Temp**	**Annual Prec**	**Prec. Seas**	**Isoth-erm**	**M Diur-Range**	**Temp Season**	**NDVI min**	**NDVI trans**	**NDVI max**	**Pop. Density**	**Ind. Areas**
Alouatta coibensis coibensis[1]	0.5	25.1	30.8	26.8	13.4	3.3					
Alouatta coibensis coibensis[2]	0.2	4.5	27	28.6	11.7	0.7	27.2	0	0		
Alouatta coibensis coibensis[3]	1	13.1	20.1	8	26	1.3	29.7	0.4	0.1	0	0.4
Alouatta coibensis trabeata[1]	1.7	4.3	55.2	1.9	14.2	22.8					
Alouatta coibensis trabeata[2]	2.3	2.2	51.2	2.7	10.6	25.8	0.3	4.1	0.9		

Alouatta coibensis trabeata[3]	2.3	2.7	43.5	2.4	15.4	24.2	0.1	2.3	1.5	2.8	2.8
Alouatta palliata aequatorialis[1]	1.2	2.8	13.2	2.3	74	6.4					
Alouatta palliata aequatorialis[2]	1	4.3	11.4	2.7	71	6.7	0.8	1.4	0.7		
Alouatta palliata aequatorialis[3]	0.6	4	6.2	0.5	59.6	4.3	0.9	0.2	0.6	10.4	12.7
Alouatta palliata palliata[1]	1	12.4	18.8	6	5.6	56.1					
Alouatta palliata palliata[2]	1.1	10.5	19	6.2	6.7	52	2.2	2.2	0.1		
Alouatta palliata palliata[3]	1.7	9.7	13.4	9.6	6.1	29.1	0.1	0.6	0.7	3.5	25.4
Aotus zonalis[1]	0.4	0.2	6.2	21.6	70	1.6					
Aotus zonalis[2]	0.4	1.2	4.7	14	71.5	2.1	2.3	0.9	2.8		
Aotus zonalis[3]	0.2	0.1	1.4	6.9	66.4	0.7	2.2	0.4	1.5	15	5.2
Ateles fusciceps rufiventris[1]	36.4	2.5	8.6	3.8	43.5	5.2					
Ateles fusciceps rufiventris[2]	33.1	1.1	6.3	1.6	35.4	7.9	4.3	7	3.4		
Ateles fusciceps rufiventris[3]	24.9	2.2	0	1.7	5.6	2	1.3	1.2	6.2	9.9	45
Ateles geoffroyi azuerensis[1]	1.5	2.5	44.9	1.3	7.9	41.9					
Ateles geoffroyi azuerensis[2]	2.2	1.9	39.8	1.2	9.1	43.1	0.1	0.9	1.7		
Ateles geoffroyi azuerensis[3]	3.2	2.4	24.2	1.5	14.7	46.1	0.1	0.5	5.1	0.7	1.5

***Ateles geoffroyi panamensis*[1]**	4.9	4	16.8	29.4	31.8	13.1					
***Ateles geoffroyi panamensis*[2]**	6.1	2.9	5.2	25.9	18.6	2.7	26.9	3.2	8.6		
***Ateles geoffroyi panamensis*[3]**	0.7	49.6	9.2	1.5	11.1	0	17.9	2	7.3	0.8	0
***Cebus capucinus*[1]**	3.4	2.6	9.6	3.6	73.9	6.9					
***Cebus capucinus*[2]**	4	3.3	9.4	3	70.8	7.1	0.5	0.8	1.1		
***Cebus capucinus*[3]**	3.5	5.5	1.8	1.3	62.3	7.8	0.6	0.2	0.9	12	4.1
***Cebus imitator*[1]**	2.3	4.3	23.2	5.5	4	60.8					
***Cebus imitator*[2]**	2.2	3.5	22.6	1.7	4	61.4	2.1	0.4	2		
***Cebus imitator*[3]**	4.3	7.3	5.5	2.7	2.7	49.6	8.4	0.5	2	5.6	11.3
***Saguinus geoffroyi*[1]**	1.2	2	6.3	0.8	78.5	11.3					
***Saguinus geoffroyi*[2]**	3.3	1.2	4.6	1.4	73.9	10.4	2.7	0.5	1.6		
***Saguinus geoffroyi*[3]**	3.2	1.1	4.6	0.5	66	8.2	1.6	0.7	1	11.3	1.7
***Saimiri oerstedii oerstedii*[1]**	0.9	3.4	22.5	2.9	31.5	38.8					
***Saimiri oerstedii oerstedii*[2]**	0.9	4.1	19.8	3.8	28	39.9	1	0.9	1.6		
***Saimiri oerstedii oerstedii*[3]**	0.9	3.7	2	3	21.3	19.2	1.1	1.8	0.5	23.1	23.5

Note: Model 1 refers to the Environmental variables only; Model 2 refers to Environmental Variables and Forest Cover; and Model 3 refers to the relevant variables from Model 1 and 2 plus additional variables as Anthropogenic Presence (indigenous and local people). Superscripts next to the scientific names refer to the modelling variable used in Maxent (1-Environmental variables(EV), 2-Vegetation index(VI)+EV, 3-Anthropogenic variables +EV+VI).

3.3.2.4. Habitat Suitability Map After Complementing Three Models Using MaxEnt.

The results obtained by using the most elaborated maps of habitat suitability could be used to infer the actual distribution of primate species in Panama, if present data is confirmed in the future. So far I can present the small primates from the isthmus: *Aotus zonalis* distribution (Figure 3.16), *Saguinus geoffroyi* (Figure 3.17) and *Saimiri oerstedii oerstedii* (Figure 3.18).

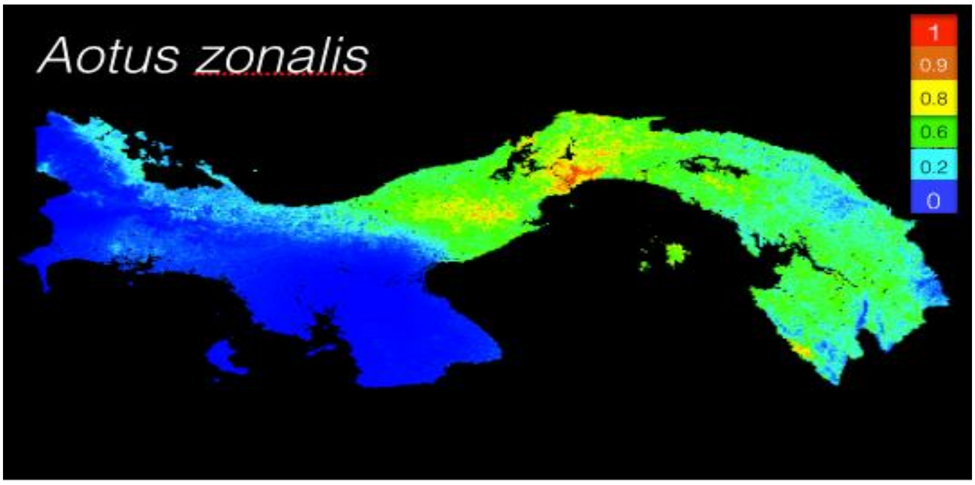

Figure 3.16. Distribution map of habitat suitability for *Aotus zonalis* in Panama.

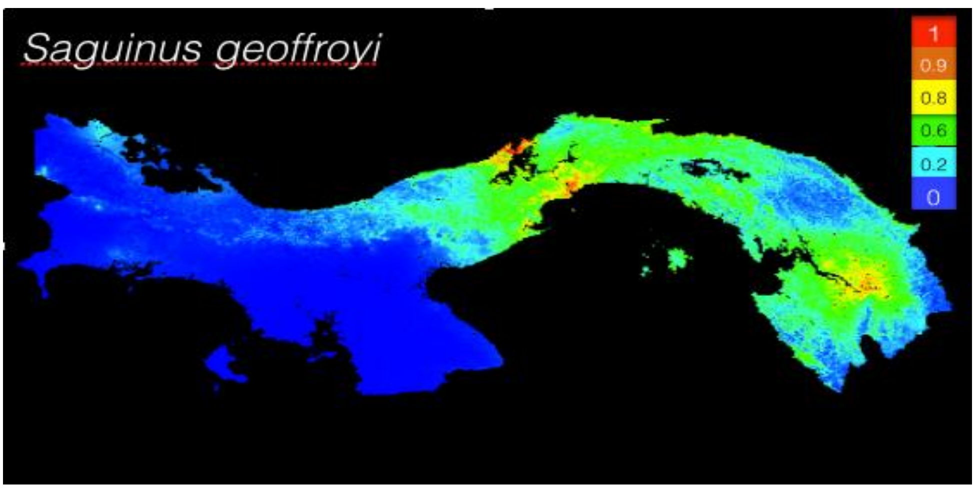

Figure 3.17. Distribution map of habitat suitability for *Saguinus geoffroyi* Panama.

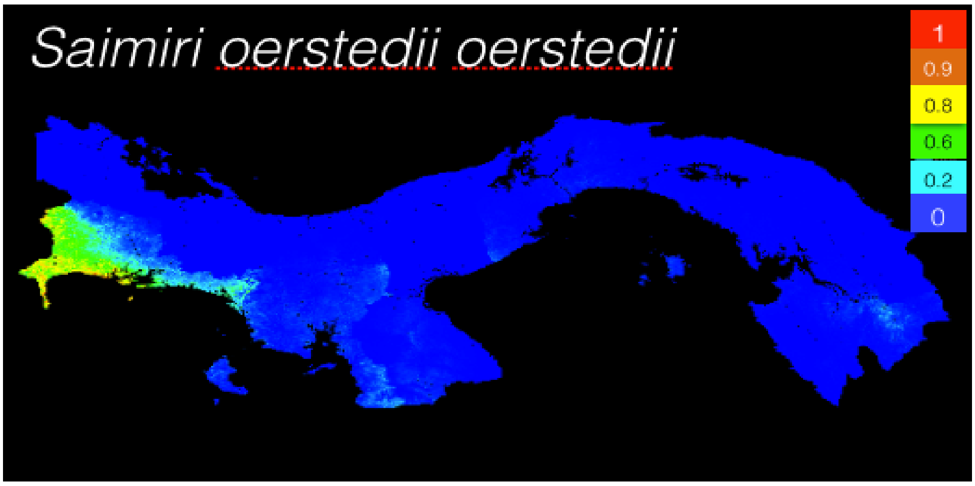

Figure 3.18. Distribution map of habitat suitability for *Saimiri oerstedii oerstedii* in Panama.

Variations in the distribution of medium sized non-human primates in Panama could be based on patterns of habitat suitability in different parts of the country. My results shown here are for the species *Cebus capucinus* (Figure 3.19) and *Cebus imitator* (3.20), as well for eight species from the Atelidae family, and four from the Alouatta genus, (these latter species are *Alouatta coibensis coibensis* (Figure 3.21)*, A. c. trabeata* (Figure 3.22) and *Alouatta palliata palliata* (Figure 3.23) and *A. p. aequatorialis* (Figure 3.24)).

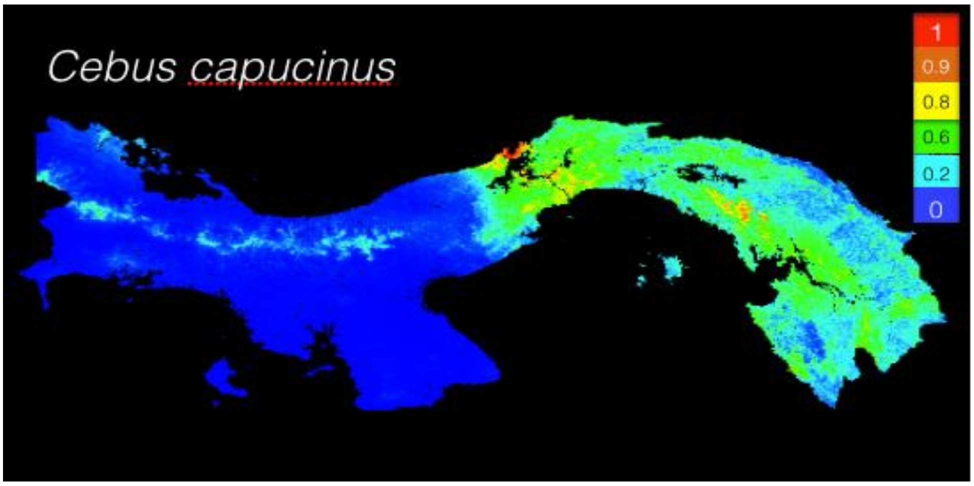

Figure 3.19. Distribution map of habitat suitability for *Cebus capucinus* in Panama.

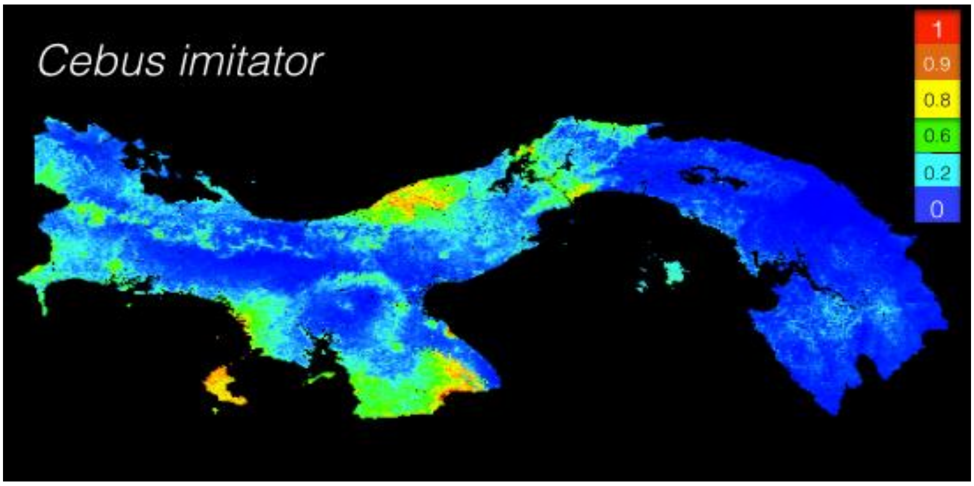

Figure 3.20. Distribution map of habitat suitability for *Cebus imitator* in Panama.

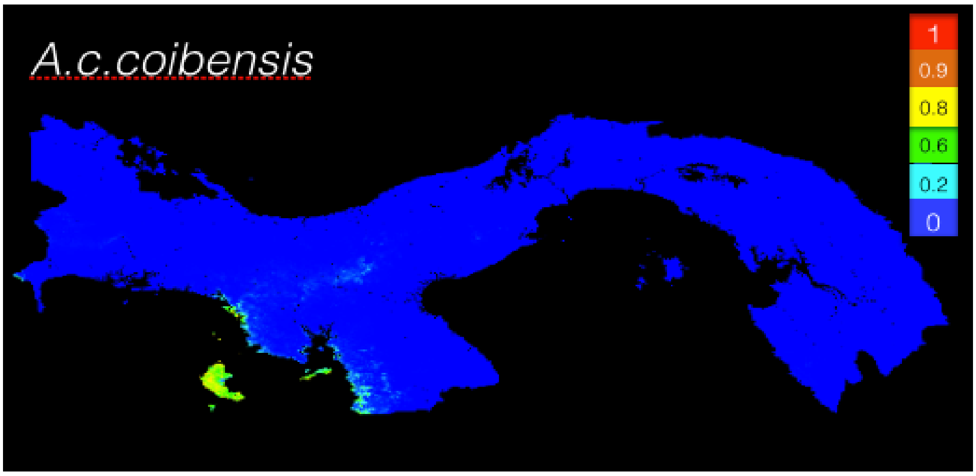

Figure 3.21. Distribution map of habitat suitability for *Alouatta coibensis coibensis* in Panama.

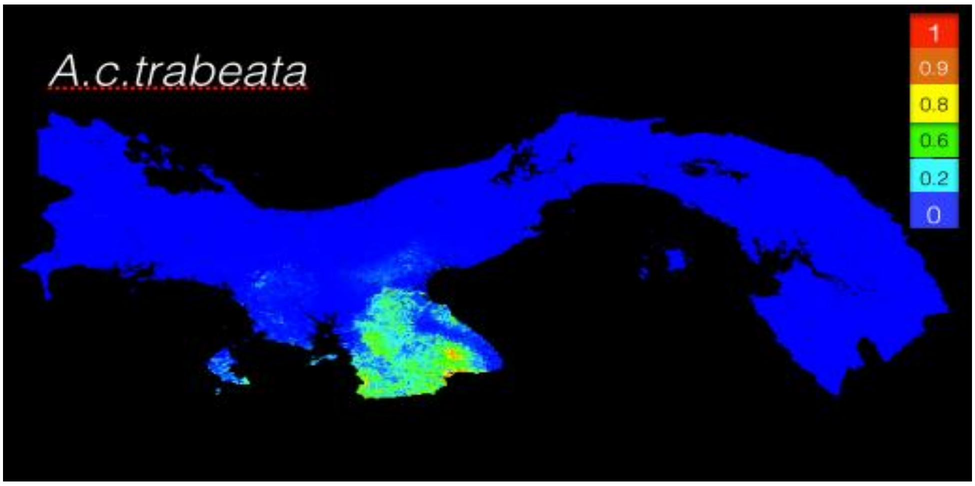

Figure 3.22. Distribution map of habitat suitability for *Alouatta coibensis trabeata* in Panama.

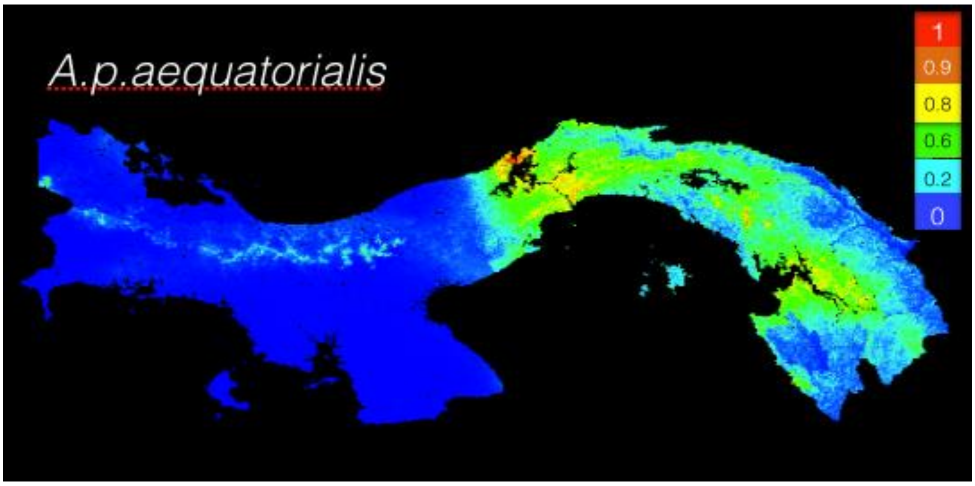

Figure 3.23. Distribution map of habitat suitability for *Alouatta palliata aequatorialis* in Panama.

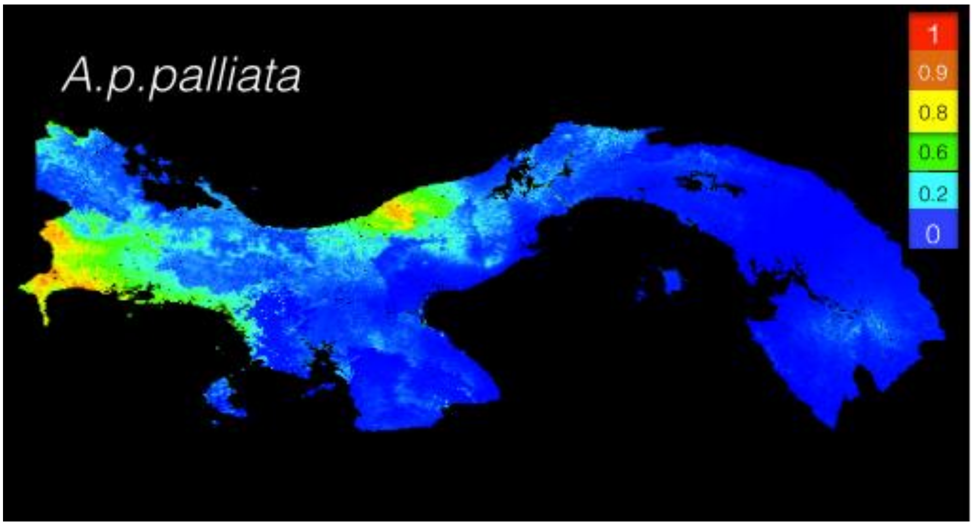

Figure 3.24. Distribution map of habitat suitability for *Alouatta palliata palliata* in Panama.

The last group of subspecies I tried to detect in Panama, and evaluate in terms of their habitat suitability, were the country's four reported subspecies of spider monkeys. Observations were done for three of them: the exception was Ateles *geoffroyi grisescens,* which appears to be either absent or difficult to detect. Although I failed to locate this primate, I here present my results for habitat suitability of three of the Ateles subspecies: *Ateles geoffroyi azuerensis* (Figure 3.25), *Ateles geoffroyi panamensis* (Figure 3.26) and *Ateles fusciceps rufiventris* (Figure 3.27).

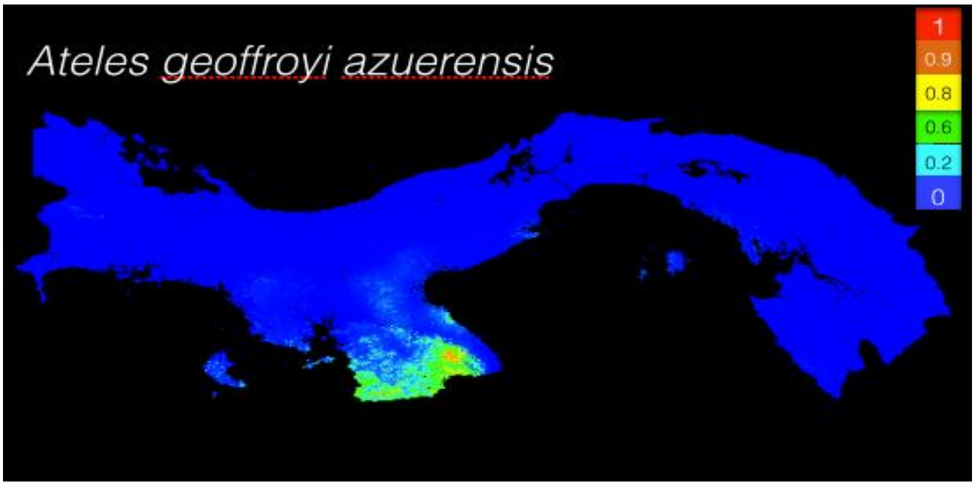

Figure 3.25. Distribution map of habitat suitability for *Ateles geoffroyi azuerensis* in Panama.

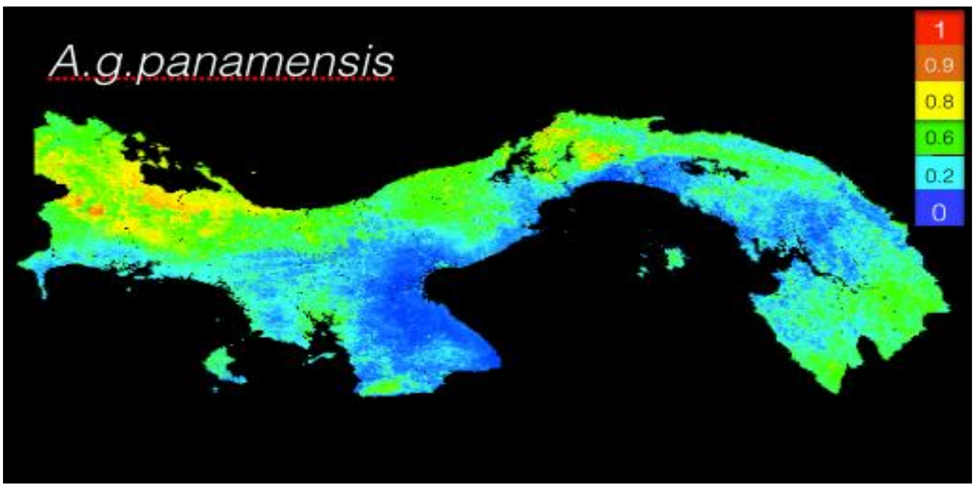

Figure 3.26. Distribution map of habitat suitability for *Ateles geoffroyi panamensis* in Panama.

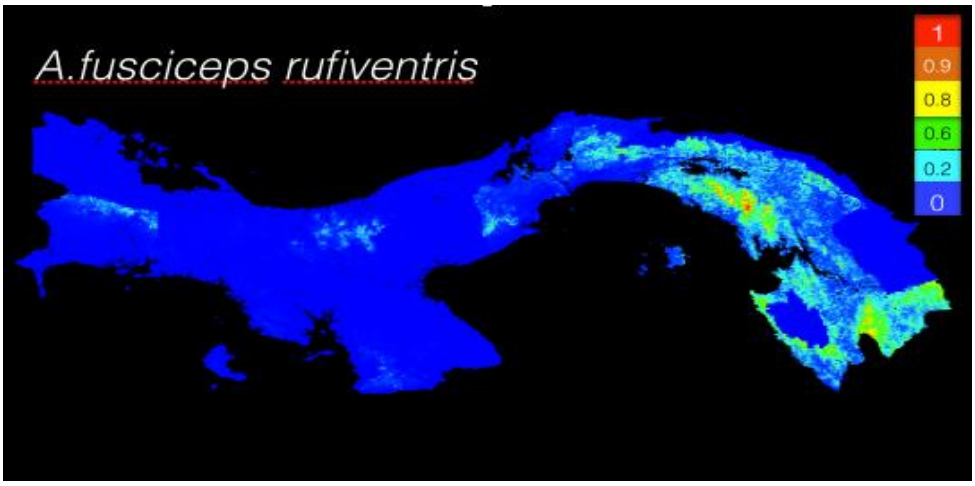

Figure 3.27. Distribution map of habitat suitability for *Ateles fusciceps rufiventris* in Panama.

3.3.2.5. Species Richness and Endemism

In Panama, in terms of primate species endemism, I found that the province of Panama (located at the central part of the isthmus) was the most diverse where primate species was concerned, with a score of seven subspecies overlapping distribution (Figure 3.28).

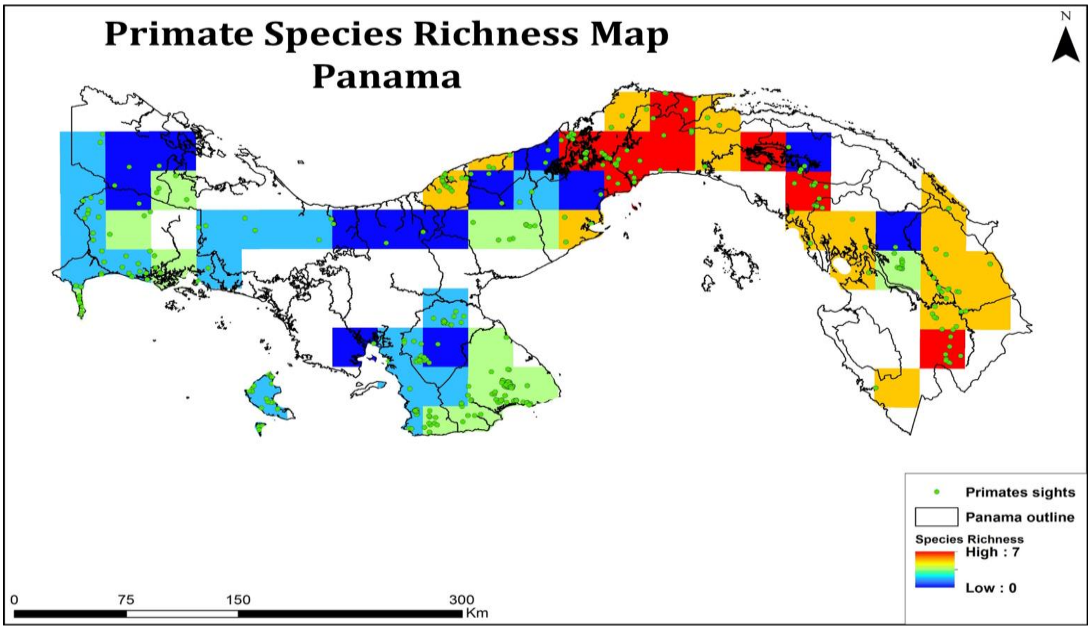

Figure 3.28. Primate species richness in Panama.

Other parts of Panama also showed tendencies towards endemism, with a score of 0.26 score in the case of Coiba Island, and with another similar, isolated spot in Bocas del Toro, near Costa Rica (Figure 3.29).

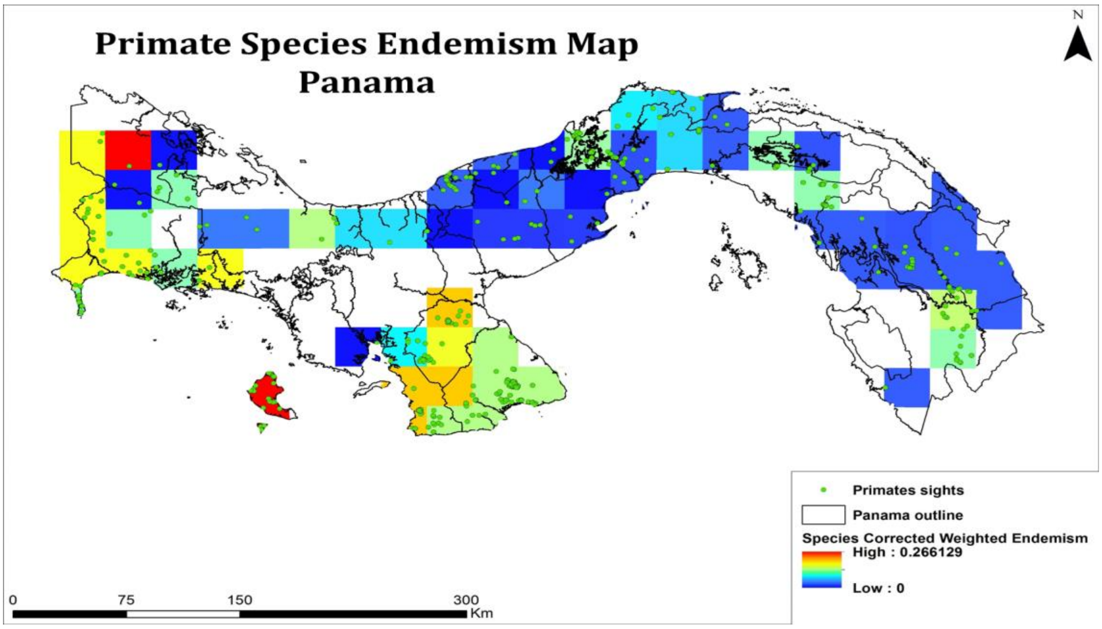

Figure 3.29. Endemism for primates in Panama.

3.4 Discussion

3.4.1 Species Distribution Modeling

Species distribution models that use biogeographical and ecological data are important for assessing the conservation status of primate species (Wilson et al., 2005; Hermoso et al., 2015; Wittmann et al., 2016). Model 1 identified six variables related to the presence of primates, of which three were particularly important: Mean Diurnal Range, Temperature Seasonality, and Precipitation Seasonality. These variables may have direct impacts on food availability, dispersal patterns, group structure changes (van Schaik, 1983), and marginal population changes (Sexton et al., 2009). These findings differ slightly from other studies of primate species with similar body mass in the Neotropics. In Mexico, for example, the presence of *Alouatta palliata, A. pigra* and *Ateles geoffroyi* groups were found to be limited by Mean Temperature of the Warmest Quarter and Precipitation during the Coldest Quarter (Vidal-García and Serio-Silva, 2011). These variables were excluded from my analysis due to their correlation with other variables, although neither correlated strongly with the seasonality variables identified as important in Model 1 (Appendix 3). In contrast, my results for *Cebus imitator* were similar to those for *Cebus albifrons* in Ecuador (Campos and Jack, 2013).

In Panama, rainfall was related with a negative implications on primate populations, if rain extends its season, it could affect changes in fruits or insects, as primates are sensitive to this variable (Milton and Giacalone, 2014). My observations finding rainfall extensions correlate with howler monkey's mortality when the rainy season is prolonged, as happens in Azuero peninsula in the case of *Alouatta coibensis trabeata* (Méndez-Carvajal, 2013). In Coiba Island I found low densities and low female: infant ratios for *Alouatta coibensis coibensis* in Coiba Island (Méndez-Carvajal, 2012), which suggests that the population is decreasing (Clark and Glander, 1964). Other primate deaths in BCI, Panama Canal Zone, have been empirically linked with the amount of rainfall over long periods. Rainfall affects the abundance of insects and thus indirectly affects *Cebus imitator* in more than 70% of their population, and for hypothermia to the howler monkeys (Milton and Giacalone, 2014). Although environmental variables contributed to more than the 0.85 of the training gain AUC values, the performance for average omission suggested more analysis is needed to predict the presence of some Panamanian primates. The results revealed strongly limited distributions of *Alouatta* spp., *Ateles fusciceps rufiventris*, and *Cebus* spp. This may due to be human deforestation, since the program was not very strong in the use of NDVI or EVI, but did use negative anthropogenic influence in the modelling. I expected that Model 2 would improve performance for most of the Panamanian primates by including an estimate of vegetation cover using remote-sensed NDVI. However, Model 2 had similar performance to Model 1 for some subspecies (*Alouatta palliata* spp. and *A. f. rufiventris*) and only slightly improved the performance for others (*Ateles geoffroyi panamensis* and *Cebus* spp.). Among the three NDVI layers selected for our study, the most important in the models was NDVI at the point of minimum annual productivity, suggesting that this is a key constraint on primates.

Model 3 tested whether anthropogenic activities affect the non-human primate population. Increasing human population density changes the landscape from forest to farming lands, leads to the growth of villages, or turns land over to industrial use : these all reduce forest connectivity, with implications for primate survival (Kamilar and Tecot, 2016). Where primates form a part of the local indigenous diet, this is also detrimental to primate survival (Peck et al., 2011). Anthropogenic variables did improve the performance of the models, and were the most important variable for all subspecies, including *A. g. panamensis,* one of the four subspecies of spider monkeys that is considered Critically Endangered by IUCN. The inclusion of EVI and NDVI in Model 2, and of anthropogenic effects in Model 3, were all important in the distribution models of several subspecies where forest cover is affected by anthropogenic factors (Sahney et al., 2014).

3.4.2 Species Diversity and Endemism

Based on the results obtained for each genus, the program identified areas of greatest relevance to direct conservation based on habitat suitability. This coincided with those habitats which have more remaining vegetation suitable for *Alouatta* and *Ateles*. For *A. c. trabeata*, the main areas in need of protection lie outside Panama's nature reserves: Santa Maria, Paris, Parita, Ocu, El Montuoso Forest Reserve (Herrera province). These areas should be regenerated with native vegetation and people should pursue environmental education and promote the restoration of forest connection within, via the use of aerial bridges over roads. From the map, the program detected areas that I found to be of importance. Those areas are: Mariato, Arenas, and the more important region in Azuero is pointed to be Valle Rico, La Miel, Oria and the southern of Los Santos, at El Valle de Tonosi, Pedasi and La Zahina. Cerro Hoya National Park and La Tronosa Forest Reserve must stay untouchable, and both environmental education and reforestation with native trees must remain active in these areas.

Primates from the Atelidae and Cebidae families are distributed on both sides of the Gatun Lake in the Panama Canal Watershed, in Panama centre and in Cerro Azul, Bayano, the San Blas mountain chain, and also in the Maje mountain chain, Chucanti Nature Reserve. For Darien province, Gariche, Boca de Sabalo, Boca de Pavarando, Chucunaque River, Balso River and Sambu River should be well protected, as these habitats possess the most suitable factors for the survival of *Cebus capucinus, Alouatta palliata aequatorialis* and *Ateles fusciceps rufiventris*. Species from the Atelidae and Cebidae families also need to be protected, with attention focused on the north of Cocle, Miguel de la Borda, Reserva Chorogo, La Concepcion, Puerto Armuelles (Chiriqui province), and Puerto Viejo (Bocas del Toro). Islands such as the Bastimentos and others in the Mosquito Gulf need to be visited to confirm the presence of *Alouatta palliata palliata* and *Saimiri oerstedii oerstedii*, and to identify any local anthropogenic threats. The main areas of importance to the conservation of *Alouatta palliata, Cebus capucinus* and *Ateles fusciceps* in eastern Panama lie in Bayano, Piriati, Maje Mountain Chain, Pirre Mountain Chain, and in the Sapo Mountain Chain. All the ecosystems near these mountains are already under threat. In Darien, the areas detected as having the most suitable habitat conditions are being fragmented by human activities. It is vital that these areas be declared untouchable, so that Panama may not lose these primate species.

Areas suitable for endemic and Critically Endangered species from the *Ateles* genus are Valle Riquito, La Miel, Los Buhos, Oria Arriba, Los Pixvaes, Flores, the Tonosi Valley, Cambutal, Cerro Hoya, La Tronosa Forest Reserve, Achiotines, La Zahina, and

Aguas Buenas (Los Santos province). The villages of Quema, Arenas, Quebro and Peña Blanca in Veraguas are good places for conservation. *Ateles* species are not present in El Montuoso Forest Reserve, but the area could be a viable site for reintroduction efforts if further environmental education is conducted there, in conjunction with reforestation.

3.4.3 Effects of Variables on Primate Distribution in Panama

The effects of Temperature Seasonality depend on the season, and suggest that primates could be affected by global warming, and by human activities such as deforestation. The species whose distributions in Panama are best predicted by Temperature Seasonality are the nocturnal *Aotus zonalis* and the diurnal *Alouatta palliata aequatorialis*, which also has one of the largest predicted suitability areas. These cover the whole Panamanian Tabasara (the western Panama mountain chain), and the country's eastern Mountain Chain (Darien, San Blas, Panama, Colon, Cocle, Veraguas provinces), and also includes the protected areas of the Panama Canal Watershed and Darien National Park. Temperatures and rainfall have been changing in Panama (Milton and Giacalone, 2014). One example of the effects of this change in the local climate can be seen in the Azuero peninsula, where howler monkeys die every year when the rainy season is delayed and high temperatures persist for increasingly long periods (Méndez-Carvajal, 2005; personal observations). Primate deaths have been increasing in the region, and reports of more than 50 animals dying at around the same time raised alarm in Mexico, Honduras, Nicaragua and Panama in early 2016. These primate deaths were thought to be mostly due to loss of vegetation or yellow fever (García-Nisa, 2016).

Climate effects have been suggested as the main reason for the absence of *Aotus zonalis* in several places where it used to be abundant. In Panama, this primate was reported to be common in Darien forest in the earliest years of the twentieth century (Anthony, 1916). Over a century later, however, the species is now undetected or scarce in forested areas in the east of Panama (e.g., Chagres) the Maje Mountain Chain, Pirre, Cana, and Darien National Park (Svensson et al., 2010: Méndez-Carvajal, 2014). Deceased individuals of *A. zonalis* have recently been found in protected forests at Donoso-Colon and Soberania National Park (Méndez-Carvajal pers. obs. 2016). These primate deaths were probably a result of climate change. Temperature and precipitation can change circadian activity patterns in primates, as in *Aotus azarai*, the owl monkey of Argentina (Fernández-Duque, 2010). These two factors may also increase the incidence of infectious disease outbreaks (Harvell et al. 2002). In Panama, the environmental variables most predictive of the presence of *A. zonalis* were Temperature Annual Range and Mean Diurnal

Range (>0.75 AUC: see Appendix 3), meaning that they are vulnerable to reductions in forest cover. This contrasts with results for another species of the same genus, *A. miconax* in Peru, where the Precipitation of the Wettest Quarter was the most relevant variable (Shanee et al., 2015). The difference between these two species could be related to latitude, the influence of deforestation, and the high humidity usually observed in Panama, as the country is narrow and heavily influenced by the seas on both sides, unlike the range of *A. miconax* (Shanee et al., 2015).

The genus *Saimiri* is restricted to a small portion of the western part of Chiriqui province and the Costa Rican eastern Pacific coast in Panama (Wong et al., 2008). Its range observed in our models matches that calculated by Rodríguez-Vargas (2003), where Burica Peninsula holds the main population, with isolated peripheral metapopulations in the northern Chiriqui (Rodríguez-Vargas, 1999). If we evaluate this isolated and small distribution, the model clearly detects poor habitat suitability for this species (0.62%-0.92% AUC) (Appendix 3). This supports the idea that landscape modifications by human agriculture and climatic pressures alter species distribution (Dale et al., 2001). The model detected Temperature Annual Range as the most limiting variable for *Saimiri* which means that fragmentation in the distribution zones threatens the presence of this primate in agricultural zones (with >0.90 AUC) (Appendix 3).

For *Saguinus* and *Cebus* genera, the Mean Diurnal Range (0.75 and 0.90 AUC, respectively) was influential (Appendix 3). This variable is related to the diurnal temperature variations occurring when solar energy warms the earth's surface (Qu et al., 2014). In the forest this variable could affect the acidic components of fruits, directly changing the chemical properties of the fruits as well the activity patterns of foraging primates (Janmaat and Byrne, 2006). These temperatures may change depending on local winds, soil type, body water, cloud, and vapour. In Panama, *Saguinus* and *Cebus* species should not have the same distribution range according to the habitat suitability models. Distributions for both include Darien National Park, San Blas, Colon east side, and Panama province, but *Saguinus* extends to Cocle, and the western part of north Veraguas (Figure 3.17). The main areas that are geographically convenient for conservation of these species are the Panama Canal Zone and the central part of Darien province.

Cebus showed the highest probability of presence (0.92), particularly in the northern area of the Colon province (including San Lorenzo Natural Park), Los Santos province (El Valle de Tonosi), Veraguas province (Montijo Gulf), and the mangrove swamp areas and the protected forest of Coiba Island National Park. There was a moderate probability of presence in 0.62 for areas near towns, agricultural fields, and riparian vegetation for the provinces of Bocas del Toro, Chiriqui. All these areas differ in temperature and experience the strongest anthropogenic effects due to urbanisation, crop production, and primary and secondary roads. The principal environmental variable related to the presence of *Cebus imitator* was Temperature Seasonality (0.75 AUC) (Appendix 3), which influences the trophic chain in the ecosystems (i.e., plant-pollinator relationships; Takemoto et al., 2014). I found an influence of the human population and indigenous communities on *C. capucinus* and *C. imitator*, with >70 AUC, similar to Ecuador and Peru, were similar variables were affecting *C. albifrons* (Campos and Jack, 2013). People are reducing their local primate populations by shooting them for consumption, and also because they consider monkeys to be pests who forage on their crops. In terms of climate, Panama reported the population reduction of more than 70% of *C. imitator* in Barro Colorado Island, in the Panama Canal Watershed, due to pick of arthropods were decreasing due to high pick rainfall (Milton and Giacalone, 2014).

Atelelidae are predicted to occur within the dry tropical forest in the Azuero peninsula in the south-western Panama, inside Herrera, Los Santos and southeast Veraguas provinces (Figures 3.3, 3.4 and 3.5). Azuero is a highly fragmented area, and climatic variables are related to the rainfall changes. Precipitation of Warmest Quarter, which is the average of the three warmest months in the year, was the most important variable in these models, affecting their stability. This variable has a marked effect: individuals with high levels of dehydration are found dead every year, especially in the dry season between February and May (Méndez-Carvajal, 2001; 2013). Other studies relate the distribution of Atelidae to Annual Temperature Range, including *Alouatta caraya* in Argentina (Holzmann et al., 2015). For *A. g. panamensis*, the predicted range extends to the entire Caribbean side and Central Mountain Chain, with AUC of 0.62-1 (Figure 3.26), including all the San Blas Mountain Chain, some areas near the northern border of Darien, Panama province (Chagres National Park), Colon province (Portobelo National Park, San Lorenzo National Park), Cocle province (Omar Torrijos National Park), northern Veraguas province (Santa Fe National Park), Chiriqui and Bocas del Toro provinces (Palo Seco Protected Forest, La Paz International Park). Factors limiting the habitat suitability of this subspecies are forest cover, particularly in the dry season, expressed by EVI from April 2015, which is also correlated with precipitation seasonality (both with AUC > 0.75). The most important areas to conserve, based on the highest AUC are, from west to east: Palo Seco and La Amistad International Park, Cauchero, Rambala, Buri in Bocas del Toro, and Chagres National Park in Colon and Panama provinces. Observations in Mexico found Precipitation Coldest Quarter as the main variable related with habitat suitability for *A. geoffroyi* (Vidal-García and Serio-Silva, 2011). The *A. g. panamensis* subspecies has experienced anthropogenic pressures but in the model these effects are still small. It suffers from hunting pressure in the western part near Bocas del Toro, as this area has three different indigenous groups: the Bri-Bri people near Costa Rica (Sixaola River), the Naso people (El Empalme), and the Ngäbe-Buglé people in parts of Palo Seco, Piedra Roja, Jadeberi, Cerro Tolica, and Chichica. These peoples use *A. g. panamensis* as a protein resource and keep infants of the species as pets (Smith, 2005). In the central part of the Talamanca mountain chain and near the extended forest of Cocle and Colon, mining activity is breaking up the Mesoamerican Corridor in a very sensitive area that still connects primary vegetation between North and South America. The only places where this species is less affected by anthropogenic effects are Chagres National Park, San Blas Mountain Chain, and Mamoni River (eastern part of Panama) (Figure 3.26).

Ateles are distributed in different parts of Panama, the model detected two types of environmental variables influencing their population: Isothermality (mean diurnal range/temperature annual range) with 0.80 AUC, and Temperature Seasonality (AUC = 0.82), but also including human population, in particular indigenous Embera-Wounaan people (0.92 AUC) (Appendix 3), limit their distribution due to habitat loss and hunting (Méndez-Carvajal, 2012a). The *Alouatta* genus includes species which distribution is restricted to two islands, 24 km off the coast in the Pacific western of Panama. Both islands have protected primary tropical rain forest, and the model identified Precipitation of Coldest Quarter (0.95-0.98 AUC) (Appendix 3) as the most important variable for this subspecies, meaning that an abrupt change in the coldest month will be the most important variable determining unexpected mortality. This influence was expected as the biggest island has a low density of howler monkeys compared with howler population in Barro Colorado island, Panama Canal Zone (Milton, 1992), and climatic limitations were suggested as one of the natural causes that constrict the population rate (Méndez-Carvajal, 2012).

According to our models, there are two priority areas in which to concentrate conservation strategies. One option for conservationists is to concentrate on saving endemic species with a demonstrably higher degree of vulnerability, in which case focus should be on efforts in Peninsula Burica (*Saimiri oerstedii*), Azuero Peninsula (*Alouatta coibensis trabeata* and *Ateles geoffroyi azuerensis*), and Maje Mountain Chain, Boca de Cupe, Darien National Park (*Ateles fusciceps rufiventris*) (see Figure 3.27) The four species associated with those areas are endemic to Panama or share endemic status with only one other country. The second alternative is to focus conservation in areas of marked sympatrywhere it may be possible to protect five to seven taxa. The most diverse province in the Republic of Panama is Panama province, which possesses seven subspecies (*Alouatta palliata aequatorialis*, *Alouatta palliata palliata*, *Ateles geoffroyi panamensis*, *Ateles fusciceps rufiventris*, *Cebus imitator*, *Cebus capucinus*, and *Saguinus geoffroyi*) (see Figure 3.28); Darien province is second, with five subspecies (see Figure 3.28).

3.5 Conclusion

I tested species detection models in order to predict habitat suitability for primates in Panama. The results suggest that users of species detection models should consider other factors in addition to environmental variables. NDVI and anthropogenic data helped to identify places in Panama where we need urgent conservation efforts. For example, this suggests conservation activities to protect the forest of Darien and the Panama province, as they have the highest diversity of primates. Potential areas for protection also include northwest Colon, Donoso, the Panama Canal Watershed, the Portobelo National Park at the Colon province eastern, Bayano, the entire Maje Mountain Chain and the southern Darien forest. Areas near the frontier with Colombia, such as the Tuira River and Tacarcuna, also appear to be important areas. My results helped determine where primates are located in these areas, and the habitats conditions they require. These results indicate that protection of Lowland Tropical Rainforest areas should be our priority in Panama. In terms of conservation, my results showed the highest rates of endemism to be in Coiba Island, Darien, Panama, Chiriqui and Bocas del Toro provinces, and the Azuero peninsula. The results also show that variables tracking human environmental effects were relevant for almost all the subspecies, and contributed significantly to changes in the final potential distribution map.

4 People's Perceptions of Primates in Azuero, after 15 years of Environmental Education

4.1 Introduction

Human agricultural use of land in primate habitats leads those primate groups who depend on forest resources to be gradually restricted to patches of forest, reserves, or gallery forest, a development which seriously threatens the continued existence of those groups (Cormier, 2003; Estrada et al., 2017). Activities affecting native forest are particularly threatening to Neotropical primates, because of their arboreal character. For example, the fragmentation of habitats can force arboreal primates to walk long distances on the ground to reach another tree, placing them at risk of being killed by dogs, coyotes, or other predators (Méndez-Carvajal, 2005; Méndez-Carvajal and Moreno, 2014). Among Mesoamerican countries, Panama has a high diversity of primates, and any fragmentation of Panamanian forests will affect primates severely, not only in terms of exposing them to greater predation by other animal species, but the human factor will also be important. Effective conservation plans are therefore urgently needed, and these plans require adequate information, including that derived from the study of local human perceptions of primate groups. In addition to habitat destruction, local people may hunt primates for cultural and commercial purposes (to acquire protein resources or substances required for traditional medicine, to participate in the pet trade, or to eliminate perceived threats to crops) (Mercado and Wallace, 2010). In this chapter, I present findings of research I conducted on the attitudes and perceptions of people in the Azuero peninsula towards the primates that live around and with them, and discuss the ways in which those attitudes and perceptions can be used to inform successful education on environmental issues relating to primates.

An understanding of people's perceptions of their local natural resources, and of how they manage those resources, allows conservationists to identify negative, neutral, or positive attitudes towards a particular wildlife species or the natural environment as a whole (Ruddle and Chesterfield, 1977; Morauta et al., 1982; Spellberg, 1994; Dunbar and Cowlishaw, 2000; Hill, 2002; Berkes, 2004; Ferraro and Pattanayak, 2006; Pusey et al., 2007; Jacobson, 2010; Setchell et al., 2016). This information can be used to inform educational activities that are intended to improve local attitudes to wildlife and to mitigate threats that wildlife might face (Patton, 2002; Chatty, 2003; Power, 2004; Reyes-Garcia et al., 2013; Waters, 2014). This involves the study of human-animal interaction: the particular study of interactions between human and non-human primates is, in turn, termed ethnoprimatology (Papworth et al., 2013: Sponsel, 1997), and draws on the qualitative methods of social science and the quantitative methods of the natural sciences (Riley, 2006). Ethnoprimatologists advocate the study of specific problems at a local level (Jones-Engel et al., 2011), arguing that if the goal is to create conservation strategies and programs then local people and their local knowledge should be the focus of educational efforts.

The people of the Azuero peninsula have a particular history of farming and hunting, and a particular type of conservative rural and agricultural culture. Their dialect of Spanish contains many archaic words: in religion, they profess Catholicism, but also nurture superstitions around witches, and perceive nocturnal animals as evil. They regularly use traditional medicine, which can involve plant or animal species that are believed to provide power, health, and protection against evil spirits or good luck in hunting. Cooperation and solidarity are prevalent within their social groups, and they display a welcoming and inclusive attitude towards outsiders. They are not afraid of outsiders, or of saying what they think. They are afraid of, and will kill, any animal such as jaguars or capuchin monkeys which they perceive as threatening their crops. Among them, a culture of caring for wildlife is absent, at least if it conflicts with crop protection and economic survival. Local people's skills in hunting and agriculture involve techniques that have also been identified in other parts of the world, and others that have developed in response to local needs and local resources. Today, the Azuerenses (as people from the peninsula are called) are changing those traditional activities in ways that are relevant to my interests in this chapter. They also have lengthy experience in dealing with researchers from bodies such as the Peace Corps, or the Panamanian ministry of health, something which facilitated the use of questionnaire based research, a research method which requires care and attention if it is to be used correctly (Herberlein 2012).

In the Azuero region, the farming areas and cattle ranches are demarcated by living fences formed by native trees of *Spondias mombin*, *Enterolobium cyclocarpum*, *Anacardium excelsum*, *Ficus* spp. Trees of these species form lines of vegetation that are tied together with barbed wire. This allows local people to save medicinal, fuel, and food resources for themselves and their cattle: they also benefit from the shade provided by the enhanced tree cover. Another local practice is to preserve areas of forest less than 0.5 km^2 in area as zones where they can practice hunting. In this way, local people in Azuero not only take care of their food production, but also of their leisure needs. While hunting may have originally been used as a survival practice, it now has the role of providing both protein resources and recreational activities. The Azuero people have a credible knowledge of their local flora and fauna, and have been surviving in a close relationship with that local flora and fauna for a long time. Today, after more than 100 years, the local population has begun to rapidly increase in number, and to move into new areas. In those new areas, they are implementing deforestation practices for farming, something that is putting more pressure on the remaining groups of primates in the area and elsewhere in Panama. If we understand their perceptions of wild primates we can help other areas before fragmentation reaches the levels now being seen in the Azuero peninsula.

In the Neotropics, indigenous people perceive non-human primates as an important protein source, a symbol of ancestral ceremonies, and, in some cases, as spiritual protection for a body of water (Lee and Priston, 2005; Cormier, 2006; Parathian and Maldonado, 2010). Some local people in some Central American countries (e.g., El Salvador and Panama) report that other local people hang primates in trees near crops to deter crop-foraging primates (Méndez-Carvajal, 2005). People's perceptions of primates have been used to inform conservation in the Community Baboon Sanctuary (CBS) in Belize to mitigate a population decrease of *Alouatta pigra* and loss of forest habitat (Horwich, 1986). A similar project monitored the effectiveness of studying local people's perceptions of *Alouatta ululata* in the State of Piaui, Brazil. Using a community perceptions study, researchers in this case analysed the main threats to the local howler monkey population, and found that while most people regarded primates as important and deserving of protection, there was also a regional lack of knowledge about the monkeys and the protected areas. This study helped the promotion of environmental education and habitat protection for the *Alouatta ululata* species in Brazil (Pinto and Roberto, 2011). As another example, the study of community perceptions of primates has been important for improving environmental education on Margarita Island, Venezuela, protecting *Cebus apella* from the pet trade (Ceballos-Mago and Chivers, 2010).

In this chapter, therefore, I evaluate the perceptions that the local people in Azuero have of native non-human primates, seeking to understand people's association with the area's flora and fauna, how they think these contribute to their lives, and to decipher the cultural and political frame in which we may be able to influence people and promote primate conservation. This study will contribute to the knowledge of primate conservation in Panama through an improved understanding of local people's perceptions of primates and other wildlife in fragmented habitats used for agriculture.

I evaluate people's perceptions of primates and wildlife using information gathered from 2001 to 2017. Focusing on negative, neutral and positive attitudes towards primates held by the population living in Azuero (both adults and children), so as to better focus educational material and identify any points where my educational programe may lack effectiveness. To analyse the data I obtained, I employed Cultural Consensus Theory (CCT). CCT is a social science method used to recognize patterns of shared cultural knowledge and beliefs in a given social environment (Oravecz et al., 2014). In environmental education this could be applicable when evaluating answers from surveys of local people. In this method it is important to have people built a free list to be evaluated (Sample). The free list is built by asking people in a composition or informal interview how they refer to the word primates, in which case we will select 10 words that are repeated most often by each person interviewed. Using a free list of this type, I was able to create an evaluation of a domain that allowed me to understand if the responses are coming from previous influence (e.g. Educational guide) (Nekaris et al., 2017). The cultural consensus approach matches with my objectives to recognize the influence of previous information collected when first visited the villages, and then the effect of the educational guide I provided to the Azuero peninsula's people (particularly to Los Santos province, Tonosi District in South Azuero).

4.2 Methods

In 2001, I started the "Conservation Project for Azuero Endemic Primates" (Méndez-Carvajal, 2001) in the Azuero Peninsula, a region considered the most deforested area in Panama (González, 2002). Most of the territory is farming land where primates live in close proximity to local human settlements. This project included a population and distribution study, and also educational talks related to primate's biology and their role in the ecosystem, because education is important in increasing human responsibility for natural resources (Jacobson, 2010). I also used preliminary ethnoprimatological data to inform the educational program (Méndez-Carvajal, 2001; 2005; 2014; et al., 2006; 2013ab). As noted above, primates endemic to this region include the Critically Endangered *Alouatta coibensis trabeata* and *Ateles geoffroyi azuerensis* (Chapter 1) as well as *Cebus imitator*, which is present in some areas of the peninsula and considered to be locally endangered. This latter species is viewed negatively by local people because it forages on crops (Méndez-Carvajal et al., 2013ab).

Environmental education, in this case, included the basic concepts of nature and the importance of biodiversity, and information on vegetation, primates and other animals in the area. I also taught people about primates and their needs. During the course of my teaching, I would ask people to volunteer for my monitoring project so that they could help me to detect the presence of primate groups in the area, and obtain demographic data. These activities allowed me to measure local primate population sizes, and estimate their long-term viability. One local biologist offered support in the form of periodic observations and provided advice *in situ*. Similar projects elsewhere have developed the same strategies of community involvement, creating among local people a sense of responsibility for their resources (Melkani, 2001; Chen et al., 2006; Supriatna and Ario, 2015). Meanwhile, problems related to politics and population growth have continued, leading to increased habitat fragmentation.

4.2.1 Azuero Primates Education Program

I developed a forty page illustrated pamphlet entitled *Environmental Guide to the Protection of Azuero Primates,* for use by teachers and children (aged 12 – 18) in elementary and secondary schools. This guide included a glossary of 33 technical words that would be recognizable if people subsequently used them in answers to survey questions. They would, therefore, serve as signs of influence of my guide (Wells and Zeece 2007, Nekaris et al 2017). The contents also included descriptions of the three kinds of primate prevalent in the Azuero peninsula, with information on their taxonomy, natural history and food requirements. I also designed t-shirts, bookmarks and posters which carried information on the importance of primates to their ecosystems. I listed several reasons for this importance, including their actions as natural trimmers, in seed dispersal, pollination, insect control, and the fact that they indirectly assist in the feeding of other animals that cannot climb trees. I remarked at one point on the importance of primate mothers in teaching their young to recognize fruit. This was directly intended to raise the consciousness of local school students, to make them understand that if they took a young monkey for a pet, this would mean destroying the learning process that would have made it possible for that monkey to survive in the wild – and that they would need to kill the mother as well, if they were to take her child. A crucial component of this guide was the inclusion of illustrations taking the form of black and white line drawings, which could then be coloured by the children using them: the ways in which they completed this task would prove to be important to my overall analysis. I began this project in 2001, and it continued until 2017 (here, however, I only use information gathered in the period 2011 to 2017).

4.2.2 Study Area and Subjects

This study was conducted in the east and southeast of the Azuero Peninsula, on the Pacific, western, coast of Panama. I carried out surveys in the areas of Aguas Buenas, La Zahina, Venao, Flores, and La Miel, which have 500 inhabitants in total, and which lie in the Tonosí District of Los Santos province. The main economic activities in these areas are raising livestock for protein and milk, and growing sugar cane, watermelon, rice, maize or pineapples (Garibaldi, 2004). Some villages in the area have particular primate-human interactions, and I had previously selected them as sites where I would concentrate my educational efforts. My informants were local people from the peninsula, living near forested areas or gallery forest zones where non-human primates are seen or heard around twice a day (pers. obs.). In addition to the children mentioned above, the adults in the sample in that case included people from a broad range of local occupations including farming, cattle ranching, housekeeping, teaching, mechanic, etc. (Table 4.1)

4.2.3 Data Collection

I used four different methods to assess local people's perceptions of primates, particularly those that are Critically Endangered: formal questionnaires, informal questionnaires, drawing and compositions. Formal questionnaires were administered to 26 residents of La Miel, aged between 18 and 100 years old. I told them that I sought to understand the perceptions local people had of wildlife. In this case used a survey with 10 questions. Informants were recruited at a communal meeting where I asked the community for their permission to acquire their personal information, and also asked for people who would like to answer a questionnaire related to wildlife. 26 people agreed to complete the questionnaire (Figure 4.1). When administering the questionnaires, I used pictures of particular animals in order to confirm that the informant and I were both talking about the same animal.

To produce data suitable for analysis using cultural consensus theory, I employed the 'free list' method, described above, in which informants are invited to list all items in a category. From adult men and women I obtained my free list data from informal interview questionnaires, but in the case of children I evaluated short essays and drawings as recommended by other scholars engaged in environmental education evaluation (Rule and Lord, 2003; Nekaris et al., 2017). I used a pictorial guide to Mesoamerican mammals (Reid, 1987) and a draft of my pamphlet "Environmental Guide to Protect Azuero Primates" to inform my interviewees of the environmental context in which I was seeking answers a technique recommended by Myers and Saunders (2002). In CCT, different kinds of answers can be acceptable (open ended, multiples choice, etc.) (Nekaris et al., 2017). I used here different free list sources to generate a word cloud, which I then analysed using NVivo.

Figure 4.1. Azuerenses from La Miel, Los Santos province, responding to the questionnaire. May 2016.

Informal interviews were conducted in several randomly chosen areas in the Azuero peninsula (Herrera, Los Santos and Veraguas provinces), where I asked people from those areas if they would agree to answer some questions. To obtain insights into Azuerense ideas concerning primates, I asked people questions related to Azuero primates. The questions concerned recognition of the physical traits of monkeys prevalent in the Azuero peninsula, the species they believe exist in Azuero and what they are called, and any primate-related stories they could tell me from their daily life, from their childhood to the present day. I listed their responses in my results, and divided them into the three attitudinal categories of negative, neutral or positive. Negative answers were those comments that depicted primates as bad, or that showed incorrect understandings of primates' actual biology or ecology. Neutral answers were those where the interviewee expressed no opinion, or gave no idea about the primates. Positive answers, finally, were those where the opinion of the person was similar to a correct biological or ecological view of the primate.

School students' drawings and compositions: I coordinated this activity with Glenis De León, a teacher at the Professional and Technical Institute of Agriculture of Tonosí (IPTA-Tonosí) and a member of the FCPP. Data gathering, in this case, took place in the south of the Azuero peninsula, during August 2016 and involved 165 school students from the 4th, 6th, 7th, 8th, and 10th grades. The students we visited had not previously been taught about the topic, and we asked them to write, in 30 minutes, one A4 page on the topic of "what do you think a primate is?" and to draw a primate on the other side of the page. We did not specify which primate they should write about or draw, nor did we insist on any specific situation, to avoid influencing the students' work. We distributed A4 paper and coloured pens and pencils for these activities. I evaluated the results in terms of the word used and interpreted the drawings.

I conducted this project under scientific permits no. SE/A-70-14 and No. SE/A-12-16 from the Environmental Ministry of Panama, and it was approved by the Anthropology Ethics Committee, Durham University, United Kingdom (Appendix 4). This research followed the legal requirements for Associated Free Consent from the Environmental Ministry of the Republic of Panama.

4.2.4 Data Analysis

Interpretations using drawing and essays: To understand the students' perceptions of primates, I made a list of words in excel and counted the number of times they appeared in the essays. I used NVivo 10.2.2 to obtain a word cloud in which the most frequent words used in the students' compositions were displayed at a larger size. To analyse the drawings I sought the external, professional opinions of a biologist Solach Jaramillo and a psychologist Larissa Dutari, both of whom were familiar with the primates of the Azuero peninsula and the cultural background of the Azuerense. I asked them to award the drawings points according to whether they were realistic. For example, a drawing that depicts a monkey in a tree will receive more points than a depiction of a monkey lying in a house. I took the mean of the scores, and concluded that the perception was positive if the mean was >90%, as suggested in Lehener (1998) and Franquesa-Soler and Serio-Silva (2017).

Cultural Consensus Analysis: Here, descriptive data was obtained from a free list of topics, assuming that words classified in different groups represented bounded domains of knowledge (Schraruf and Sanchez, 2008; Nekaris et al., 2017). I used results from questionnaires, informal interviews and essays and drawings to evaluate the words by use of a frequency generator (NVIVO), and I removed from the analysis all irrelevant words as typos or synonyms. Employing the first ten usable words, I converted a free-list data from each essay (or answers from questionnaires) into an Excel file of the 'cvs' type, as suggested by Nekaris et al (2017). I transformed all essays into free list data by entering each first ten words into a cvs file in the same order they were used (Schrauf, 2010). This allowed me to detect which factors composed the domain for primates in Azuero. I recognized by presence or absence of factors the cultural consensus in the school and surrounding villages, and had this as a for cultural competence tests in future studies (Comrey and Lee, 2013; Miard et al., 2017 and Franquesa-Soler and Serio Silva, 2017). I assembled a table listing the words frequently used by children regarding primates in the Azuero peninsula, and then used an Excel table to organize them and enumerate the frequencies of individual words. Once in the Excel table, I used "NVivo"[1] to create a word cloud, a visual representation of the main words people use in relation to primates (more frequently used words are displayed in a larger font size than less frequently used words). I also calculated a Shannon-Weanner Diversity Index to understand the heterogeneity of words used by students when referring to "monkeys".

4.3 Results

4.3.1 Demography of the Sample

When results from questionnaires, informal interviews, essays and drawings are combined together, I found that people used 1,185 words when referring to "monkeys in Azuero". The sample of 79 persons in total included 26 persons who completed questionnaires, while the rest 53 were children who had participated in the essay writing and drawing activities: Table 4.1 shows socio-demographic data for the 26 adults, while Table 4.2 shows the same data for the child participants.

Table 4.1. Socio-demographic data of adult local people interviewed in May 2016.

	Categories	**Participants**
Sampled by age	17-29	8
	30-39	1
	40-49	5
	50-59	5
	60-69	4
	70-79	3
Total		**26**

[1] http://www.qsrinternational.com/nvivo-spanish

Sampled by *sex*	Female	11
	Male	15
Total		**26**
Occupation	Farmer	6
	Housekeeper	7
	Educator	2
	Student	4
	Mechanic	1
	Freelancers	2
	Constructor	2
	Trader	1
	Pensioner	1
Total		**26**

Table 4.2. Socio-demographic data for children sampled in May 2016.

	Categories	**Participants**
Sampled by age	10	4
	11	14
	12	14
	13	29
	14	32
	15	17
	16	1
Total		
Sampled by sex	**Females**	58
	Males	53
Total		111

4.3.2 Formal Interviews

When I asked the people who made up my sample how they got information about primates, the sources they specified in their answers were talks (9 people), newspapers (6), t-shirts (3) and a documentary (1). For the question about people's perception of nature, 14 people answered that they felt good about nature (8 of the respondents in this case were men, from a male sample of 15, and 6 were women, from a female sample of 11). Two people (one man and one woman) answered that they felt bad when surrounded by nature, while four people answered they felt comfortable around it, and six that they felt uncomfortable. Regarding a persons' view of the forest's importance (i.e., important/not important), seven people marked forest as important aged 16-29, followed by five people from ages between 50 – 59, and 40 – 49. The rest of the answers were given, usually, by two or three people, with only four people answering that they really did not know the value of the importance of the forest. In responses to the question "are monkeys important", 14 men and 7 women answered positively (five people did not know what to say). Younger people (those aged 16 – 29) were more likely to answer affirmatively when asked if monkeys were important, while people in the age range 30 – 39 were less likely to respond to that question with an affirmative answer.

4.3.3 Informal Interviews

Neutral answers related to basic knowledge about primates, and included such statements as the assertion that monkeys do not like rain. Answers indicating that the respondents did not know anything about primates, or considered them to be mysterious, were also considered neutral. Some older people remembered occasions when they used to shoot *C. imitator,* and revealed that they had almost totally extirpated some groups from their properties. By the time these interviews took place, most of these interlocutors were taking a more reflective perspective on this episode in human-primate relations, and on the attitudes it implied. They commented that in those days it was difficult to get money and that monkeys caused a great deal of damage to their properties. Their actions in killing individuals from the species *C. imitator,* therefore, were produced by the absence of any alternative options for securing their property from the threat of raiding by monkeys, and the threat to their economic wellbeing that raiding represented. In other words, they just did what they believed was the correct and necessary thing to do to survive. This feeling of fear about monkeys stealing crops was accompanied, at the same time, by a state of feeling bad for behaving towards these primates in a cruel fashion. These contradictory emotions had mixed results: sometimes my informants would report trying to persecute primates, and at other times, trying to feed them. This latter response to primates throws up another problem: that of how to teach well-intentioned people that giving food to primates is not an appropriate practice.

Positive answers included the point that the animal is unique to Azuero and Coiba. I also listed as positive those answers which demonstrated knowledge of *A.c.trabeata* as an endangered primate species, or which indicated that the respondent associated primates with disease, as this meant that the respondent knew of the worsening situation these monkeys were experiencing due to deforestation. The same point arose when people related to me that they perceived primates as numerous in their area (they are commonly seen in Azuero but only because of the reduced vegetation cover). Other people reacted against the idea of having monkeys as pets, another positive sign, as were those cases where people recognised the role of the monkeys as dispersers of seed and as (indirectly) feeders of other animals. When particular species such as *Cebus imitator* were mentioned as eating crops, it was also mentioned that they do this because they see that food is available. Some people were aware that it is a bad practice to feed wildlife, and mentioned that the conventional idea of monkeys as aggressive was not true. All such answers were considered in this research as positive answers. Some people directly described monkeys as important, and cited their relationships with other animals to whom they supplied fruits; others just considered the presence of monkeys as being a good feature of their local area, one that should be protected. Other positive answers included those that supported living fences because they help animals, and the expression of general hopes that people might stop bad practices that damaged nature.

Negative answers included thinking that monkeys are lazy, overabundant or suitable as good pets, or that they are crop-raiders or hosts for bot-fly parasites that could be passed on to their cows. Some people said monkeys make too much fruit fall, and consider this as a loss of resources, although the fruits in question were manly mangoes and did not represent an income source for local people. I considered people's perceptions of monkeys to be negative when they referred to the monkeys as noisy, or as a potential source of damage to their properties (e.g. if monkeys drop things on their cars or roofs), or when they (for example) reported seeing monkeys eating all the leaves on, and therefore killing, a tree standing inside their property. Other negative answers included the idea that monkeys are stealing food from kitchens, or that they present a danger of harm to dogs when those dogs chase them. Some people fear monkeys because of their perceived connection to diseases such as malaria, yellow fever or botflies, and because they think that monkeys may provide a vector for these diseases, making them a threat to humans.

4.3.4 Compositions and Drawings

I selected 100 compositions and drawings by students, with a maximum score of 8 for the word cloud, representing the level of understanding or familiarity displayed by the students in their individual pieces of work (Figure 4.2). Within the entire sample, and when comparing children with adults, students from elementary and secondary schools used a greater diversity of words from the entire sample. A test of diversity of words applied with the Shannon-Weaner Index resulted in an overall score 3.8., on a scale where a mark of 0 represents a state of no diversity, and where 5 represents a state of maximum diversity (Figure 4.2).

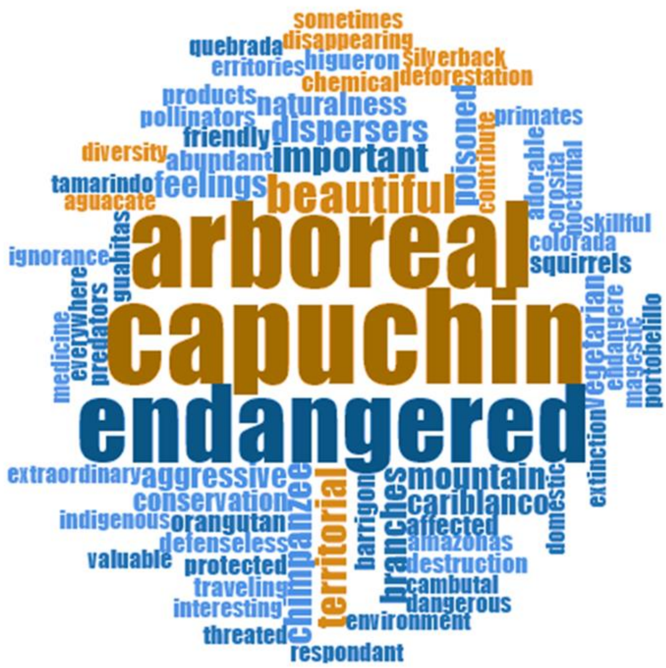

Figure 4.2. Word cloud generated from children's compositions.

Characteristics that meant that some drawings obtained higher scores than others were: presence of trees, depiction of monkeys with prehensile tails, the use of colours representative of native Panamanian species, and depictions of monkeys suspended from trees, which would indicate that the students know Panamanian monkeys are arboreal. Students' depiction of grass around trees showed that they know their local landscape very well, and can see that some groups are isolated from each other, as shown in other drawings (Figure 4.3 and 4.4).

Figure 4.3. Drawings showing primates related with vegetation from IPTA Tonosi, Los Santos province, 2017.

Drawings that depicted monkeys with characteristics that obtained lower scores by comparison with other drawings were: an absence of trees, monkeys depicted walking on the ground, an absence of prehensile tails, an absence of any tails, colouration that was not representative of the native species, the presence of bananas, depiction of monkey faces as similar to chimpanzees, and a lack of monkeys depicted as suspended from trees, indicating that they are not perceived as arboreal (Figure 4.4).

Figure 4.4. Drawings from IPTA Tonosi, Los Santos province, 2017.

4.3.5 Cultural Consensus Theory

For the purposes of Cultural Consensus Theory, all 79 answers were included in the set of answers to be analysed (with the exception of previous answers that I will not use in this chapter). I obtained a measurement of the frequency per word used to build the first free list of words in order of priority and repetition. 68 words used by respondents were found to be unique: the ten most frequent words used are listed in Table 4.4 (for adults), and Table 4.5 (for kids' essays).

Table 4.3. Cultural importance of words used to build the Cultural Domain of the Azuerense, when talking about primates (results from adults).

Words	Word count	Longitude	Frequency %
Capuchins	64	8	2.74
Arboreal	57	8	2.44
Endangered	50	10	2.14
Beautiful	18	9	0.77
Territorial	11	11	0.47
Important	10	9	0.43
Chimpanzee	10	9	0.39
Branches	8	8	0.34
Dispersers	8	10	0.34
Feelings	8	7	0.30

The most common words used in these surveys and drawings were related with the howler monkeys and in second place the capuchin monkeys. Secondly both groups surveyed provided information about the monkey's natural history and group organisation. The participants mentioned about what they think primates eat and the characteristics of primates as wild species. Finally they related the primates to the pressures and the risk of extinction they face (Table 4.5).

Table 4.4. Frequency of the 10 most commonly used words between student essays, drawings and adults written before any explanations about Azuero's primates. Question: What exactly do you know about Azuero's primates (results from children's essays)?

Word Frequency	Word	Total (%)
82	Howler	6
64	Capuchin	5
52	Live in groups	4
44	Human	3
39	Wild	3
39	Diverse	3
38	Bananas	3
32	Hunting	2
32	Folivorous	2
28	Extinction	2

To understand what the domain list means for Azuerenses, I separated the topics they build while answering my questions into categories of importance. For the first place they mentioned characteristics that refer to the biology of the animal as morphology, life history, and some behaviours related to what people see they do in the wild. People called out about the actual situation of the animals as endemic, diversity and level of risks. It was interested to see students mentioned some species are not regular from the region and may not exist in Azuero. Categories related with what monkeys are known they eat, or what they use to survive in Azuero, but also the role they have in the forest. After important aspects mentioned related to the biology of the animals, the other topics were related to how the people feel the primates are facing anthropogenic activities near to their habitats and how they consider affects human being (Table 4.6).

Table 4.5. Factors within the domain Azuero primates identified through minimum residual factor analysis.

Factor category (n)	Example word	Explanation
Biology of the primates in Azuero (139)	Prehensile tail, Migration, Diverse, Scent marks, Territorials	This word was found matching several activities primates do, so associated with the primates natural life
Diversity (199)	Unique species, capuchins, howlers, spider monkeys, tamarins	Different names were used here but I compiled the ones that are similar in these groups as different species present in Azuero. One species is not native from the area, the Tamarin, this is curious could be related with the precedence of the student.
Azuero landscape (106)	Lianas, Gallery forest, Forest, Trees	This word is good approach of the landscape of Azuero
Primate's role in the environment (51)	Seed dispersers, announce rain, Pollinator	Words match very well with the primate's role in the habitat
Feeding ecology (138)	Leaves, insects, Fruits, wild Fruits, Bananas, Mangoes, flowers, seeds, Inga, Terninalia, Spondias, Guazuma, Anacardium, Ficus, Pseudobombax, Enterolobium, Chrysophyllum,	Plants mentioned were wide informative about what is related or consumed by primates in Azuero

Humancentric (235)	Ecosystem, Hurt, Domestic, Hunt, Poisson, Road killed, Logging, Forest fire, Contamination, Conserve, To take care of them, People kill them, Monkeys are happiness, Crop-riders, Bad smell, Corral animals, Pet, Killers, Solitary, Humans, rights to be free	These words were related to anthropogenic influences and were mostly found in children's comments and recommendations that something that something should be done to save primates in Azuero.
Positive feelings (87)	skillful, climbers, friends, they have feelings, funny, speedy, smart, specials, important, curious, beautiful,	Adjectives that are considered positive about the Azuero primates
Negative feelings (49)	Aggressive, territorial, fights, annoying, noisy, damage, crop loss, destruction	Adjectives that are considered negative about the Azuero primates

I found 68 words for this preliminary free list: this represented 57% of the total amount of words used, and represent very well the Cultural Knowledge or Domain, showing some aspects that could be used to measure neutral, negative and positive perception about the primates of Azuero by the local people. Several examples stand out in this context. In many answers, the presence of the capuchin monkey is taken as a sign of general monkey presence, even though this monkey has been extirpated by farmers in most of the Azuero peninsula. In spite of this, however, Azuerenses farmers still perceive the capuchin monkey as a threat. Popular opinion in the area references the capuchin's capacity to steal crops, and this leads them to say 'these monkeys are bad, they make a lot of damage': this is one example of a negative perception. The words "arboreal" , "branches" or "seed dispersers" have been part of my educational guide glossary, and their presence in responses represent positive opinions of monkeys, and are evidence of the importance of education around these issues. Before my program, there were no reasons for the Azuerenses to recognize that primates may be terrestrial or arboreal, and in areas of fragmentation, it was normal to see monkeys on the ground. However, part of my educational material tried hard to clarify that these animals in Panama and in the American continent are not fully terrestrial, and are adapted to survive in the trees, which makes them particularly vulnerable when forest cover is eroded. I also added this clarification due to the image held by many respondents, that of bad behavior and aggression as a feature of monkey species. This is something that people have derived from viewing documentaries about African and Asian primates, in particular macaques. In some cases people remembered "branches" as a relevant word, I would ask why they think primates drop branches on them, and explain how this relates to movement in the canopy, during which they also drop seeds, thus indirectly helping the other animals that are not capable of climbing trees to get fruits.

4.4 Discussion

4.4.1 Perceptions of Non-Human Primates Held by Azuerense People

The results of the formal and informal interviews cited in this chapter indicate that the people of the Azuero peninsula easily recognise Azuero primates, and can accurately describe their physical features (colouration) and general behaviour. Informants also mentioned that the monkeys howl, are aggressive or steal crops in reference to *A. c. trabeata*, *C. imitator* and *A. g. azuerensis*. The Azuerense know very well those animals that are unique and exist in their area and showed positive attitudes and happiness in participating in interviews – which is a good sign for anyone seeking to conduct an environmental education campaign. People mainly obtained information related to primates in Azuero from educational talks, which make sense because this is FCPP's major educational activity (Méndez-Carvajal et al., 2013). The occupation of the person did not influence the way that person might access information about the environment. For questions about their perception of nature, people tended to report that they felt good and comfortable when surrounded by natural environments. This result is a good sign, since it indicates that new generations of Azuerenses are more aware about the impact of climate change and loss of vegetation on their crops. The study suggests that traders and housekeepers are the occupations whose members are most aware about the importance of monkeys, as well as the farmers. This may be related to the fact that they interact more with primates who howl early in the day, the same time when they are going out for their jobs. Students and teachers were less knowledgeable about the importance of the monkeys, so should be appropriated more visits to the schools for environmental education.

My results showed that farmers were more aware of what is happening in the surrounding environment and were more exposed to the educational strategies used by the FCPP. This result does not mean that Azuerense are not interested in nature, but may be related to the fact that some of them spend more of their time inside the home or taking care of family. Azuero people's lifestyle typically involves men working on the farms and cattle ranches while women work in the home and with children. Young men and women get equal opportunities for education and socialisation, where they learn outside doing activities in groups, and have duties related to the farm animals or other activities. In the early afternoon in the Azuero peninsula, all family members sit or rest in a hammock outside their home, talking about politics, school, family problems and other topics. This allows information exchange, including information about our media campaigns.

Informal interviews helped to identify ideas and myths that can lead the Azuerenses to behaviours that have strong impacts on wildlife, especially monkeys, and to recognize correct or wrong concepts of non-human primates that can have the same effect. Separating neutral answers from those that were either positive or negative, I found that Azuerenses know very well how special and unique howler monkeys are in their peninsula, but also have a contrasting aspect involving the ways in which they consider this or that animal is or is not important. While looking at animals in this way is a good sign for conservation of nature, many people in the peninsula still hold to the idea that they have the right to kill something that is interfering with their business. My goal is to try to change the old mentality of management for a friendlier way, one that can avoid the repetition of past errors by farmers while retaining their good practices, such as living fences. Answers such as “they are abundant” are, in relation to monkeys, just false positives: by this I mean that they express a false impression created by the reduction of vegetation in the area. After such reduction in vegetation cover, monkeys become more visible to Azuerenses people: this creates the incorrect perception that the population size of their local primate group is greater than it really is. By maintaining the long term monitoring system of primate groups this idea can be overcome and the people turned towards a more realistic assessment of the situation: that primates are losing their habitats, and that people’s action is the key to conserving them. Some people note that monkeys are important as seed dispersers, but did not appear to really know the meaning or impact of this. This is a point that should be more deeply explained in our educational talks. I consider that these ideas have to be presented with visual examples, so that people can better understand what will happen if we lose these primates.

The idea that primates are lazy is more related to the howler monkey, which is almost entirely folivorous and frugivorous (Glander et al., 2016). Sometimes the people humanize animals, or think botflies from howler monkeys can pass to cows, increasing the risk of death in their cattle (a vital economic asset for many people in the peninsula). Again the reality behind these opinions has to be explained to people, if we are to avoid people holding opinions that lead to behaviours with a destructive impact on primates.

When primates are being noisy, or dropping fruits on the forest floor, this can cause people to think monkeys destroy or waste resources. If I explained the reality of these situations in my talks, it could be helpful for future awareness of the need to protect primates in Azuero. Several times people related how howler monkeys and capuchins in their kitchens were offered food, and that they then learnt to come and taste bananas or other foodstuffs: once they had learned this, and had made good relations with humans, they would repeat their visits and, ultimately, steal food from people's kitchens. Food theft by monkeys is, therefore, a consequence of human action, but the people do not see this. This is another point in which I will use the data collected here to improve and focus my educational material.

The questions addressed to my informants inquired into how people perceived the ecological role of their local primates, and how they related directly to these primates and their environment. Almost all participants in my surveys agreed that primates are important, remarking on qualities such as their beauty, their singing, and their ability to detect when something is wrong in the forest. They referred to the primate marking of territories and the ways in which the howls of the monkeys make them happy. Further investigation of these qualities can identify factors that we can use to define how people appreciate the presence of primates in their surrounding area. This supports, in part, the idea of Community Conservation, where conservation should involve the participation of rural people and be a central part of their conservation activities (IUCN, 1980; Hill, 2002). There is evidence that people living in villages near to primates develop good feelings for and cooperate with conservation activities, if they are exposed to biological knowledge about primates (Alexander, 2000).

Of the seven techniques applied in environmental education, the most useful are engaging in educational talk in schools and community centres and outreach through publishing information in local newspapers. Further distribution of brochures and educational guides with information on Azuero's primates will be useful, while documentaries are likely to be less useful, as there is currently no television programming in Panama that is directly concerned with Panamanian wildlife (there are still villages in Panama where people do not have access to television, but this is becoming increasingly unusual).

4.4.2 Cultural Consensus Theory

Following the CCT, the idea of evaluating an educational program via its impact on a domain set of words or cultural importance seems to be positive and effective, as it provides a frame based on traditional knowledge, an exercise in the repetition of older ideas or way of thinking (Kuhar et al., 2010). Tracing the link between my respondents' essays and drawings and my prior educational material produced results supporting the idea that educational programs can change attitudes by increasing the knowledge of the target population (Borgatti, 1994). Efforts in the detection of predominance of words related to my educational material used by people produced positive results, supporting the idea of engaging more people with environmental education activities. I also propose to improve my educational guide by including new topics related to old world primates and new world primates, so people can understand their differences. After new period of educational programs, I will repeat the same analysis of Minimum Residual Factor to determine the presence of relevant concepts in people's cultural domain (Bloom, 1956; Patrick et al., 2007; Nekaris et al., 2017). There are still some gaps that need to be covered with more material, and evaluations should be done periodically with local communities, so as to provide baseline information and keep the program in a state of consistent and continuous improvement.

4.5 Conclusions

The data presented in this chapter helped me to understand the perceptions of the communities in the Azuero peninsula concerning primates. My first aim was to understand how Azuerense people feel about living near primates. To evaluate this, I assessed their perception of the value of primates and forest, and whether they think those elements of nature are important or represent a benefit for human beings. Azuero people confirmed that they feel happy when they see primates around their properties. For the Azuerenses, the forest is important as a source of wood, a provider of shade, and as a barrier between houses. The importance of the forest as a barrier matches with perceptions prevalent in European countries like Spain, where the erosion of rivers is associated with reduced vegetation along river banks, and a barrier of trees could be useful as a check on this sort of negative development (Piégay et al., 2005). However, some people consider that the forest offers good temperature, improves the climate and promotes rain and a generally healthy environment. In some ways this has a deeper meaning, although the data are for a small sample. Their reasons for considering the forest important were related to its implications for health, rather than to any use of forest resources. Azuero women show an appreciation of the forest, through their statements that women have an important role in conservation (Tikka et al., 2000). When I asked about their perception and knowledge of primates, they claimed to be happy with them and reported no damage in general, except for that caused by capuchin monkeys. Some Azuerenses felt that primates are funny, suggesting that the Azuero local people's basic knowledge and understanding has evolved to include a friendly attitude towards the surrounding environment and its primate fauna. More work is needed, however, to improve the local community's tolerance for wildlife.

Interview data suggests that the best method of increasing knowledge about primates was the educational talk, followed by newspaper publications: the other techniques were less useful. The actual situation of Azuero wildlife as a whole is deteriorating, due to increased deforestation. Changing crop types and the cultivation of native trees with preferred fruits for *C. imitator* and *Ateles* could be important if we wish to test whether having abundant natural food resources in and near farmers' crops will lead primates to avoid using maize. School students observed very well that primates are arboreal, but they think of their isolated state as something normal. It is part of our role to clarify that this is not suitable for primates. School students also think that Azuero primates are abundant, but this is likely to refer to the overcrowded population of primates in some areas, above all the howler monkey *Alouatta coibensis*. Children used a high diversity of relevant words and the evaluation of their compositions helped us understand that we still need to deal with wrong information generated by the media about what the Azuero primates eat (they mentioned bananas), and what our primates look like (if they draw them as chimpanzees). In summary, Azuerenses are well connected to their local natural environment, but their knowledge base lacks some valuable information where nature is concerned, and this inclines them to maintain the same practices observed in other parts of Panama – practices that are not conducive to the long-term security of the local primate groups.

5 An Evaluation of the Actual Conservation Status of the 13 Non-Human Primates from Panama

5.1 Introduction

Understandings of species' ecology and the potential threats to wildlife it may contain are important aspects of conservation (Cowlishaw and Dunbar, 2000; Nadler et al., 2007), as is knowledge of how anthropogenic pressures may affect survival (Butynski and Koster, 1994). The IUCN separates categories of threatened species according to 1) habitat availability, 2) anthropogenic threats, 3) species distribution, and 4) population viability (Crocket, 1998). Several studies have evaluated the status of primate conservation in a region or country based on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Rowe, 2000). As most countries lack information about the species they harbour, IUCN typically requests assistance from researchers studying closely-related species, so as to identify potential threats and status recommendations for each subspecies. The IUCN Red List categories and their criteria were first described in 1994, and have developed over time into a list of criteria for the guidance of conservation activities that can avert extirpation (IUCN, 2012). There are nine IUCN categories: Not Evaluated, Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild, and Extinct (see Chapter 2) (IUCN Standards and Petition Subcommittee 2016). An extra set of classifications is applied in the cases of species that are threatened (Critically Endangered, Endangered and Vulnerable). These are A (Population size reduction), B (Geographic range), C (Small population size and decline), D (Very small or restricted population), E (Quantitative analysis) (Chapter 2). The evaluation of a species requires that distribution and population data are as accurate as possible, implying the need for a long-term monitoring program for measuring population rates of growth and reproduction, as well as fluctuations in population numbers and food availability (Cowlishaw and Dunbar, 2000). For categories A, C and E, the main information required is the number of individuals. The IUCN allows for the incorporation of inference, and projections in evaluation activities, so as to allow taxa to be assessed in the absence of information (IUCN Standards and Petitions Subcommittee, 2016)

Knowledge of non-human primates in Panama has received little attention (Rodríguez-Luna et al. 1996), despite the fact that some of the country's primates have been studied (for biomedical and ecological purposes) since the beginning of the 20th century (Goldman, 1920). During this early period, scientists were interested in primate diversity, and in collecting specimens for museum collections, mostly those in the United States, United Kingdom, and France. Scientists also collected biomedical and ecological data on primates, but this research was mostly restricted to areas near the Panama Canal Zone and in Darien province (Goldman, 1920; Kellogg and Goldman, 1944; Milton, 1996). Primatology developed by Panamanians is a relatively new departure in the science, with little information published, at least so far, on primate densities, group structure, and population distributions. The major exceptions to this are the preliminary conservation studies carried out on Coiba Island, Azuero peninsula, and in Darien (Méndez-Carvajal, 2001; et al., 2004; 2005; 2008ab, 2012ab, 2013). This chapter engages with the available literature concerning non-human primates and their taxonomy, with the goal of developing unified criteria for diverse taxonomic names. I will develop here 1) an updated review of literature related to primate taxonomy in Panama and 2) a new plan to evaluate the conservation status of Panamanian primates, an evaluation to be carried out with a proposed dichotomous key. This will contribute to our understanding of the past, present and future of the 13 subspecies of Panamanian primates, and will do so using direct data collected from my long-term project for over 15 years in Panama. This study will then serve as reference material for conservationists to help evaluate the conservation status of the Panamanian primates, and minimize the risk of local primates' extinction in this country (Méndez-Carvajal et al., 2013a). This chapter is presented in a format different from that of the other chapters in this thesis. This is in order to facilitate the reader's understanding of the information I have been collecting for each of the primate species discussed here: the reader should take into account the fact that this is the first time something like this has been written, at least in the case of Panama and its primates.

5.2 Methods

5.2.1 Reviewing Published Literature and Visiting Museums

To contrast between original data of distribution per species, and take in consideration older descriptions from Panamanian primates, I was in need of reviewing material held in mammalogy departments to verify physical characteristics or ranges of measurements that have been used to previously define the species. Using the search terms:

Mammals of Panama, I searched Google scholar and the Smithsonian Library (http://library.si.edu/libraries/tropical-research-institute) for articles published between 1800 and 2016: these terms were accompanied, in my searches, by the common English and Latin names of each of the 13 subspecies reported in Panama. These literature searches were conducted through the libraries of Durham University (https://library.dur.ac.uk/) and the University of Florida (http://cms.uflib.ufl.edu/), as well as through the journal of the Universidad de Panama (http://www.sibiup.up.ac.pa/otros-enlaces/tecnociencias/tecnociencias.html). I included abstracts from conferences, technical reports from the Ministry of Environment of Panama, and academic theses. I obtained morphological measurements, observed skin coloration patterns, skulls and skeletons or any body part of the specimen, and in some cases obtained pictures from the original Holotype of the species to compare old names recorded, coloration patterns and any important annotations. I visited or contacted curators from the mammal collections at the USGS Patuxent Wildlife Research Center, United States National Museum from Smithsonian Institution, Florida Museum of Natural History, British Natural History Museum, Oxford University Natural History Museum, Vertebrates Museum of the University of Panama, and the Zoological Collection Eustorgio Méndez (CoZem). Furthermore, I contacted scientific collections that were reported to have the type and paratype of Panamanian primate species: the Museum of National History of Nature (MNHN), Muséum National d'Histoire Naturelle - CNRS - Sorbonne Universités, France, the Mammalogy and Herpetology, Vertebrate Section and Zoological Museum of Natural History (MHVSF), National History Museum of Denmark (NHMD), the Department of Physical Anthropology of The Cleveland Museum of Natural History (CMNH) (these acronyms are employed in Table 5.1). Information related to population densities were added based on Méndez-Carvajal (in prep.).

Table 5.1. Natural History Museums consulted from 2015 to 2017.

Museum/Country	Date of consulted emails	Specimens reviewed	Scientific name	Name of Curators
USGS Patuxent Wildlife Research Center, Smithsonian National Museum of Natural History United States	June 16, 2016 to Dec 13, 2016	USNM-21165 (Type) USNM-171489	*Ateles geoffroyi panamensis*	Suzanne Peurach, Kris Helgen
Mammal Section, Life Sciences –Vertebrate, Division	July 2016	BM-65.4.202 (Type)	*Ateles grisescens* *Alouatta palliata coibensis*	Roberto Portela Paula

The Natural History Museum, London United Kingdom (BM British Museum)		BM-2.3.5.9. (Type) BM-3.3.3.13 (Type)	*Cebus imitator*	Jenkins
National History Museum of Denmark (NHMD), Denmark	Oct. 22, 2016-Mar.15, 2017	M 06-CN48 (Type)	*Chrysothrix oerstedii* (*Saimiri oerstedii*)	Daniel Johansson Eline Lorenzen
Muséum National d'Histoire Naturelle - CNRS - Sorbonne Universités MNHNF France	Aug.23, 2016 to Oct. 2, 2016	MNHA-ZM-2007-1530 (Type) MNHN-1871-552 (Type)	*Hapale geoffroyi* (*Saguinus geoffroyi*) *Ateles grisescens*	Cécile Callou
Florida Museum of Natural History (FMNH) University of Florida, United States	Sep. 7, 2015-Sep, 7 2016.	UF-31994 UF-33201 UF-33206 UF-33204	*Ateles fusciceps rufiventris* *Alouatta palliata* *Cebus capucinus* *Saguinus geoffroyi*	Verity Mathis
Department of Physical Anthropology The Cleveland Museum of Natural History(CMNH) United States	Oct. 8, 2016	CMNH PRI 1235(Type)	*Ateles geoffroyi azuerensis*	Lyman Jellema, Timothy Matson, Roberta Muchlheim
Museo de Vertebrados de la Universidad de Panamá (MVUP), Panama	Jul 6, 2917	No specimen found	*Alouatta palliata*	Ricardo Pérez, Victor Tejera
Coleccion Zoologica Dr. Eustorgio Méndez (CoZEM), Panama	Jul 10, 2017	No specimen found	*Cebus imitator* *Alouatta palliata* *Saguinus geoffroyi*	Aydee Cornejo Oscar López

5.2.2 Data Analysis

I analysed the conservation status of the 13 subspecies of primates in Panama using information obtained from the literature, my own studies and from population densities obtained in 2001-2016. I used this combination of different types of data to evaluate each species:

1) Endemism factor: the species is present only in Panama or has shared endemism,
2) Presence or absence of the subspecies in any protected area inside Panama,
3) Exclusive preseence in the Mesoamerican Biological Corridor in Panama,
4) Urban density is less than 0.001ind/km2,
5) Density in fragmentation is less than 0.01 to 10 ind/km2,
6) Density in forested areas is 0.1,
7) Relative total population is < or equal to 500, or > or equal to 500 individuals,
8) Environmental constraints are less than 5 or > than 5 climatic variables (based on MaxEnt study Chapter 3),
9) Information on habitats in deforested areas where the species should be distributed according to MaxEnt study (this study Chapter 3),
10) An analysis of people perception regarding primates, to evaluate how people attitudes could be positive or negative to the primates exposed to humans.
11) Children's perceptions as inferred from their drawings, something that will tell us how children of school age relate our primates to their reality.

5.3 Results and Discussion (Analysis of Taxa and Evalutions)

5.3.1 Analysis of Taxa and Evaluations

5.3.1.1. *Alouatta coibensis coibensis*; Coiba howler monkey

5.3.1.2. Common Names

Mono aullador de Coiba, gun-*gun*, kun-kun, Coiba howler monkey.

5.3.1.3. Phenotypic Characteristics

The pelage of adult *Alouatta coibensis coibensis* is dark brown to complete black over almost the entire body (Lawrence, 1933). Infants have a complete yellow-greyish pelage until they are one month old, and then gradually turn brownish with yellow flanks and lumbar area. This coloration is present in early juveniles, unlike in *A. palliata*. Older juveniles have a deeper black pelage, with yellowish to golden flanks, sometimes slightly orange. The flanks have longer hair than other body areas. The chest, abdomen, and limbs are black, partially covered by short hair, giving a light brownish coloration. The skin around the orbital and muzzle are normally dark gray with pink tones over the lips. Genitals are exposed in adult males and females, both with white skin, which make it easy to determine the sex. Males have long hair along their jaw, creating a beard-like appearance, with the frame of the face occasionally marked with brown hair (Thomas, 1902; Lawrence, 1933; Carpenter, 1934). The holotype was collected in Capina, Herrera province, Panama (Carpenter, 1932) and is in the United States Natural Museum (USNM) as specimen No. USNM 290555 (Clark, 1950) (no type) (Thomas, 1902) (Figure 5.1). **Body Measurements:** Information missing.

5.3.1.4. Taxonomy

Alouatta coibensis coibensis was originally described as *Mycetes villosus* by Gray (1845), reclassified as *Mycetes palliatus* (Gray, 1849), and later re-named *Alouatta palliata inconsonans* (Festa, 1903; Elliot, 1912; Goldman, 1913; Anthony, 1916; Allen and Barbour, 1923; Clark, 1930; Dunn, 1934; Fairchild, 1943). In 1902, *A. coibensis* was proposed as subspecies *A. palliata coibensis* and *A. p. trabeata* (Thomas, 1902). Lawrence (1033) supported the separation of these subspecies. In 1987, studies of the palm ridges and morphology changed the taxonomy to *A. c. coibensis*, endemic to Coiba Island and Jicaron Island and *A. c. trabeata* for Azuero peninsula, both in southwest Panamá (Froehlich and Froehlich, 1987). There is some controversy over its taxonomic status, with one scientific group considering this primate to be a subspecies of the palliata group (i.e., *Alouatta palliata coibensis*), based on mitochondrial DNA evidence (Cortes-Ortiz et al., 2003); however, other scientists still request a strongest evidence to change criteria of Froehlich and Froehlich, (1987), until strongest evidence in mitochondrial DNA is clear, following the conclusions of Rylands et al., 2006. I found evidence of differences in group composition; while *A. palliata aequatorialis* presented multimale-multifemale, the group structure of *A. coibensis*, presented as uni-male multifemale (Méndez-Carvajal, 2010). I found different vocalization patterns when analysing dawn and sunset choruses, and regular barks in four groups from *A. palliata* (Darien and Gamboa), and *A. coibensis* (Azuero peninsula) (Méndez-Carvajal, 2010). There are some other differences regarding the vocalization structure and group size, suggesting that *Alouatta* genus should be differentiated between two groups (the *palliata* and non-*palliata*) where *A. coibensis* seems to be similar to non-palliata group according to Whitehead (1995). Rylands et al., 2006 cited *A. coibensis* as clearly separated from Central American howler monkeys by using a comparison of hyoid structure for the genus *Alouatta* (Groves, 2001; Rylands etal., 2005). In Panama the Environmental Ministry follows the taxonomy recognized by Groves (2005) and Rylands et al., (2006) as *A. c. coibensis.*

5.3.1.5. Distribution

Alouatta coibensis coibensis is only reported from Coiba and Jicaron islands, both 24 km from the south-western Pacific coast of Panama (Thomas, 1902; Lawrence, 1933; Mendez, 1970; Mittermeier and Milton, 1977; Ibañez et al., 1997; Olson, 2008; Méndez-Carvajal, 2002; 2012) (Figure 5.1).

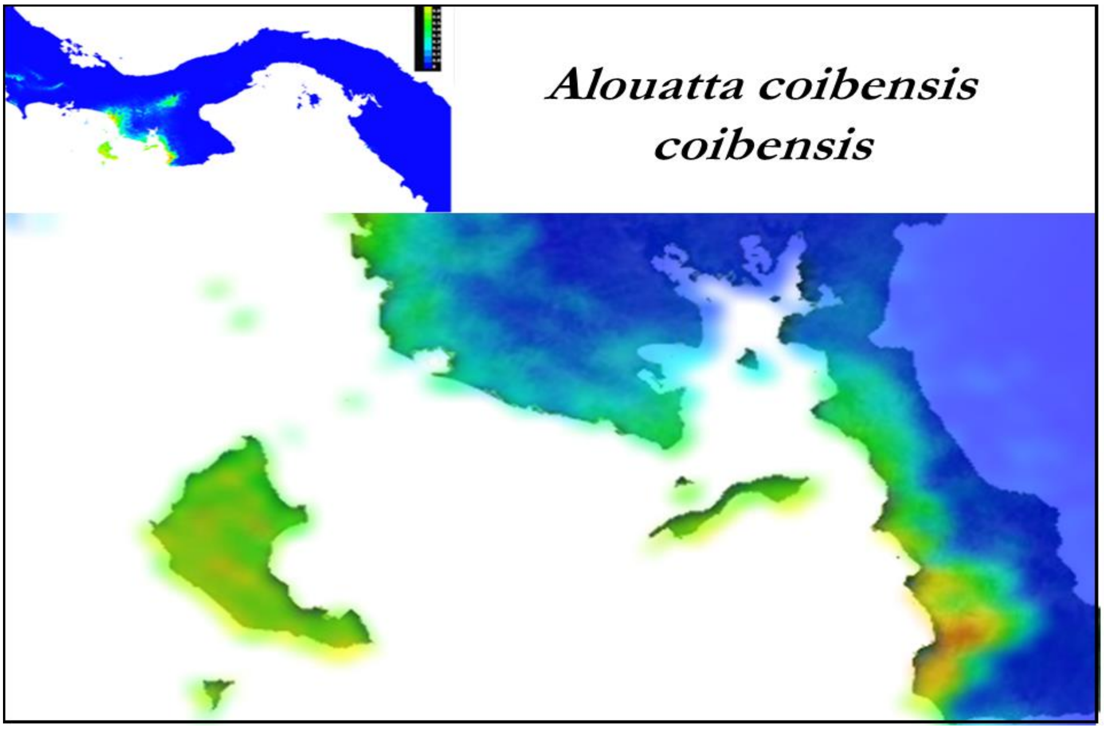

Figure 5.1. MaxEnt distribution map result of *Alouatta coibensis coibensis* (from Chapter 3), overlapped with forest cover map (in red/violet), showing how the distribution of the species matches with the actual vegetation.

5.3.1.6. Population

Based on population research between 2009 and 2010, and long-term data collected by Fundación Pro-Conservación de los Primates Panameños (FCPP), mean densities for this primate in four different sites on Coiba Island were calculated. The resulting figures suggest that there are < 500 total individuals in the wild (Méndez-Carvajal, 2012). Coiba howler groups have a mean of 4 ind/group (range 2-5 individuals per group). The male/female sex ratio was estimated at 1:0.9, and mean group proportions were estimated at 0.36 males, 0.34 females, 0.1 juveniles, and 0.06 infants. Mean density is 4.1 groups/km^2, with approximately 109 howling monkey groups on Coiba Island (Méndez-Carvajal, 2012). Using new information from this study I multiplied total area of Coiba Island and Jicaron (523 Km^2), using densities obtained of 0.8 individuals/Km^2 from this work I obtained a rough population of <420 individuals still in Coiba and Jicaron Islands.

5.3.1.7. Major Threats

Numerous threats are endangering this species. Anthropogenic threats, for example, include: the presence of feral cattle in the area of *A. coibensis coibensis*, which could pose a threat to many of the endemic mammals of Coiba. Cows can heavily affect the forest understory, and could inhibit the regeneration of disturbed areas. A brief mammal survey on Coiba in 2010 detected high densities of hematophagous bats (*Desmodus rotundus*) on the south-eastern side of the island, likely related to the presence of feral cattle in Coiba National Park. This island was a penal colony from 1919 to 2004, and Coiba primates are reported to have been hunted by prisoners during this time (Milton and Mittermeier, 1977; Méndez-Carvajal, 2012). Coiba is now a National Park, so primates are no longer directly exposed to hunting activity. Climatic instability, however, may influence the reproductive success of the island's primate species often in association with long rainy periods and generally poor-quality dietary resources. The Coiba howler monkey needs to be monitored and systematically studied to understand their population dynamics, and any behavioural adaptations they may have made in response to this restricted habitat (Méndez-Carvajal, 2010; 2012a; 2013).

5.3.1.8. IUCN Conservation Status

Alouatta coibensis coibensis is classified as Vulnerable (Cuarón et al., 2008) (Figure 5.2). The FCPP is monitoring the population of *A. c. coibensis* to assist the Panamanian government in creating management plans for the National Park, as well as to provide accurate information for the park's tourism centre (Méndez-Carvajal, 2002a; 2002b; 2010a; 2010b; 2011; 2012).

5.3.1.9. Conservation Status Suggested by This Study

Available data support criteria A (population is decreasing) and E (probability of extinction is ≥20% in 20 years). Using as evidence of declining population the small average found in most of the groups, the absence of infants and the mean size of groups as less than the mean observed in 1977 [5.2 (n=5) (Milton and Mittermeier, 1977) to 4.3 (n=6)], much more long-term data is needed to determine significance (Méndez-Carvajal, 2012), a decrease of 18%. I confirmed from my survey that 69% of individuals are adults from the population composition, which assures potential in reproduction. *A. c. coibensis* should be classified as EN D1**:** Endangered-Very small or restricted population with fewer than 1,000 individuals left in the wild (Figure 5.2).

5.3.1.10. Present in the Following Reserves

Isla Coiba National Park

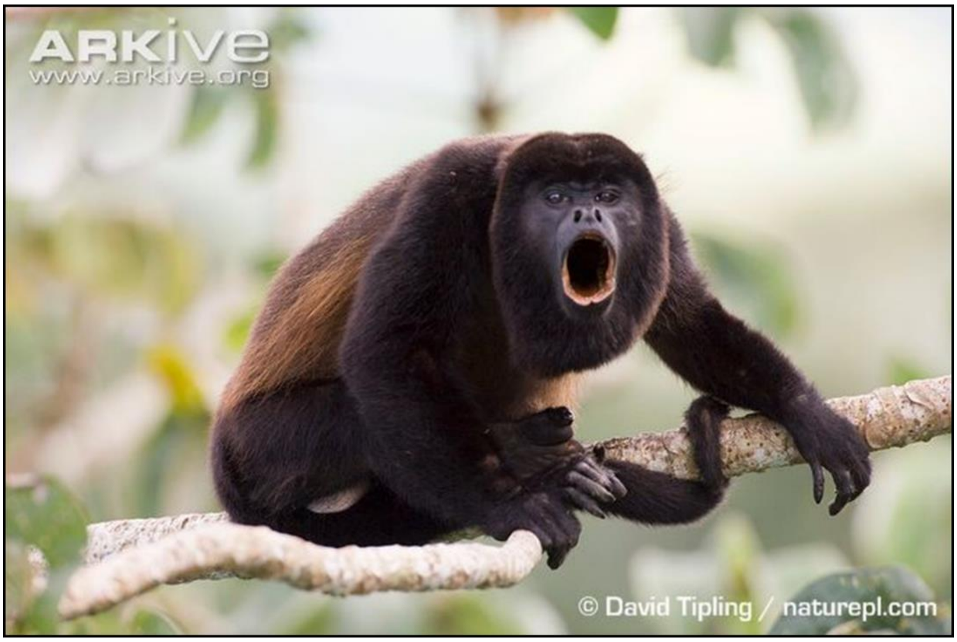

Figure 5.2. *Alouatta coibensis coibensis*, Coiba Island, Panama.

5.3.2 *Alouatta coibensis trabeata*, Azuero howler monkey

5.3.2.1. Common Names

Gun-gun, kun-kun, Azuero howler monkey.

5.3.2.2. Phenotypic Characteristics

Alouatta coibensis trabeata adults have dark brown to complete black pelage (Lawrence, 1933). Infants have a complete yellow-greyish pelage until they are one month old. They then gradually turn brownish with yellow flanks in the lumbar area (Méndez-Carvajal pers. obs.). The flanks have longer hair than other body areas. The chest, abdomen, and inner limb sections are black, partially covered by short hair, sometimes appearing light brown in coloration. The skin around the orbits and muzzle is normally dark grey with pink tones in the lips. The genitals have white skin, with male genitalia becoming exposed as individuals sexually mature. Males have long hair along their jawline creating a beard-like appearance, the face sometimes framed with brown hair (Thomas, 1902; Lawerence, 1933; Carpenter, 1934). The Type specimen of *A.c.trabeata* was collected in Capina, Herrera province, Panama (Carpenter, 1932). It is located in the United States Natural Museum (USNM) as specimen no. USNM (Clark, 1950) (no Type) (Thomas, 1902). **Body Measurements:** total length, 56.0 mm, other measurements not available.

5.3.2.3. Taxonomy

Alouatta coibensis trabeata was originally classified as *Mycetes villosus* by Gray (1845), then as *Mycetes palliatus* (Gray, 1849), after which it was renamed as *Alouatta palliata inconsonans* (Festa, 1903; Elliot, 1912; Goldman, 1913; Anthony, 1916; Allen and Barbour, 1923; Clark, 1930; Dunn, 1934; Fairchild, 1943). It was then classified as *A. c. trabeata* (Thomas, 1902; Lawrence, 1933; Froehlich and Froehlich, 1987). This taxon is recognized by Rylands et al. (2006) as *Alouatta coibensis trabeata* (Groves, 2005). The IUCN use the synonym *Alouatta palliata trabeata* (Cortes-Ortiz et al. 2003) (see previous comments about *A. c. coibensis*).

5.3.2.4. Distribution

The distribution of *Alouatta coibensis trabeata* includes three provinces: Herrera, Los Santos and southeast Veraguas. Recent observations have found this species in the following places: (North) Ocú District including Camarón, Tijeras, Llano Grande, Llano Hato, Las Manuelas, Pedernal, Los Higos. Parita District: Cabuya, Candelaria, Portobelillo, Cerro Tijeras, Llano La Cruz, Río Viejo, Carrizal (Herrera province) (Méndez-Carvajal, 2001; 2002c; 2005; 2013). Las Minas District: El Montuoso Forest Reserve, Tres Puntas, Altos del Higo, Sonadora, El Ñuco, Caras Pintadas, Quebrada Chuérala, Río Tebario, Río La Villa, and Río Suay (Méndez-Carvajal et al., 2002c; Méndez-Carvajal, 2013a). South: Los Santos and east Veraguas: La Tronosa Forest Reserve, south of Cerro Hoya National Park, Guánico, Cobachón, Punta Blanca, Sierra, Varadero and Río Pavo, Tembladera, Ventana, Piro. Also, Pedasí and Tonosí District with Playa Venado and Cañas (Méndez-Carvajal, 2013). East: Los Santos: Macaracas, Las Palmas, Llano de Piedra, Mogollón, Cerro Canajaguas, Cerro El Vijía, Valle Rico, Quebrada Nuario, El Cacarañal, Cerro Quema, La

Llanita, Ciénaga de Las Macanas. Las Tablas District with La Miel, Oria, Cerro Montuoso, and Buena Vista (Méndez-Carvajal, 2013). West: East of Veraguas: Playa Mariato, Torio, Arenas de Quebro, Flores de Arena, Río Playita, Río Pavo, Varadero, Restingue, Cerro Culón, Changuales, La Burra, El Cortezo, and Palo Seco (Rowe, 2010; Méndez-Carvajal, 2013) (Figure 5.3).

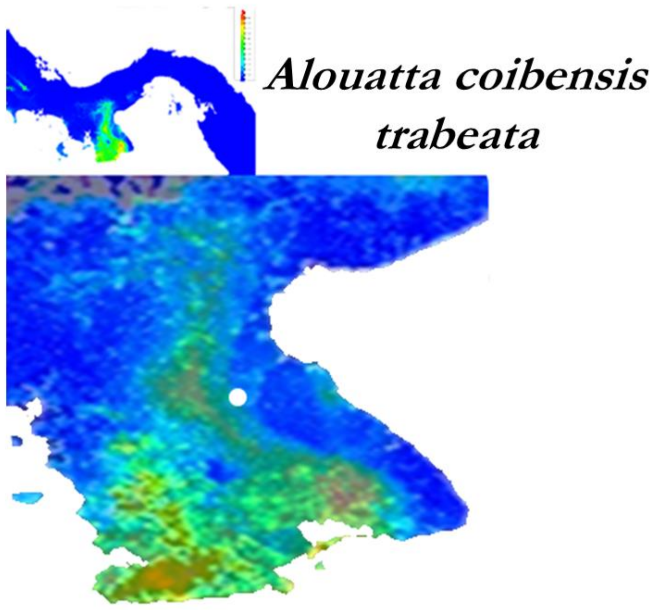

Figure 5.3. MaxEnt distribution map of *Alouatta coibensis trabeata* result (from Chapter 3), over lapped with forest cover map (in red/violet), showing how the distribution of the species matches with the actual vegetation.

5.3.2.5. Population

Alouatta coibensis trabeata has a uni-male multi-female social organisation. Groups are typically composed of 2.5 males, 4.3 females, 1.9 juveniles and 1.8 infants (Méndez-Carvajal, 2013). I observed 45 groups and counted 452 individuals with a mean of 9.6 individuals/group, SE ± 3.3 (range = 3–26). In Azuero peninsula, 322 groups may still exist, with <3,000 individuals remaining in the wild in their range (Méndez-Carvajal, 2013a). The northern (lowland) community of *A. c. trabeata* had an average of 23.8 individuals/group (15–39) (Méndez-Carvajal, 2005) possibly due to overcrowding in fragmented forest areas, while populations in continuous forests have 6.1 – 10.0 individuals/group (Méndez-Carvajal et al. 2004; Méndez-Carvajal, 2010a; 2013a). I did a new calculation based on new data for this study and multiplying the total forest coverage remains for this taxa (450 Km^2) and using the mean density I obtained (5.2 individuals/Km^2), I calculate this population has decreased to 2,340 individuals as a rough population.

5.3.2.6. Major Threats

In 2016, I recorded 25 Azuero howler monkey deaths in different parts of the Peninsula. I attributed these deaths to deforestation caused by farming and cattle ranches, teak plantations, and urban investments. Azuero howler groups living near local residences are also negatively affected by automobiles (32%), electrocution (20%), and inappropriate feeding by people who give the monkeys harmful restaurant leftovers. (12%); then there are those killed by unknown causes (20%), 8% killed by projectiles, and a remaining 8% who die, apparently, of natural causes (related to the extended dry season). As *A. c. trabeata* is mainly folivorous-frugivorous, they may have been exposed to agrochemical contamination by crop-spraying activities in lowlands throughout the southeast. Hunting is also a major threat, as monkeys provide a protein resource for the indigenous Ngäbes-Bugle people, who are hired by cattle rangers to work on their land. Questionnaires given out in 2001 indicated that monkeys are not a vital resource for Azuero local people (Ruiz-Bernard et al. 2010). Hunting accounts for 31% of known *A. c. trabeata* deaths. New threats facing *A. c. trabeata* include land acquisition by new investors, (e.g., teak, mine, and palm oil projects) resulting in more fragmented habitats (Méndez-Carvajal et al., 2013b). Other anthropogenic effects includes the location of human settlements near primate groups, which causes extra waste of energy as howlers and spider monkeys increase their vocalization rates. In the Azuero peninsula, for example, the habitat is mostly fragmented and groups are distributed among patches of forest, connected by living fences and gallery forest. Humans eventually find groups near to their houses at least daily while working their lands (e.g., cattle activities or farming). The howlers are often chased by the local people, so that they tend to avoid humans and try to remain hidden and silent (Méndez-Carvajal, 2010a).

5.3.2.7. IUCN Conservation Status

Alouatta coibensis trabeata is classified as CR (Cuarón et al., 2008). The population is decreasing due to loss of its forest habitat, hunting pressure, realtor investments, changes in land use that replace old practices of living fences (which acted as forest connectors) with new forms of fencing using sticks (which act as forest disconnectors).

These sticks used as new fences are not only replacing the living fences, they are disconnecting important routes that primates use within their home ranges (Méndez-Carvajal, pers. obs.).

5.3.2.8. Conservation Status Suggested by This Study

Alouatta coibensis trabeata should be classified as CR A4acd+B1b. Critically Endangered, with population size reduction. A4: According to the IUCN guide, this category means that an observed population reduction is happening or/ causes of reduction may not have ceased, may not be understood or may not be reversible. Direct observation. In this case, the population is in decline according to my observations since 2001 until 2016, Méndez-Carvajal, 2005; 2006; 2013). Azuero howler is in the category B1b because potential levels of habitat exploitations are happening in their reduced distribution range, then: (B1b) Geographic range <100 km^2, continuing decline observed (Figure 5.4).

5.3.2.9. Present in the Following Reserves

Cerro Hoya National Park, La Tronosa Forest reserve, El Montuoso Forest Reserve, Cienaga de las Macanas, Achiotines Laboratory Center, El Tijeras Reserve.

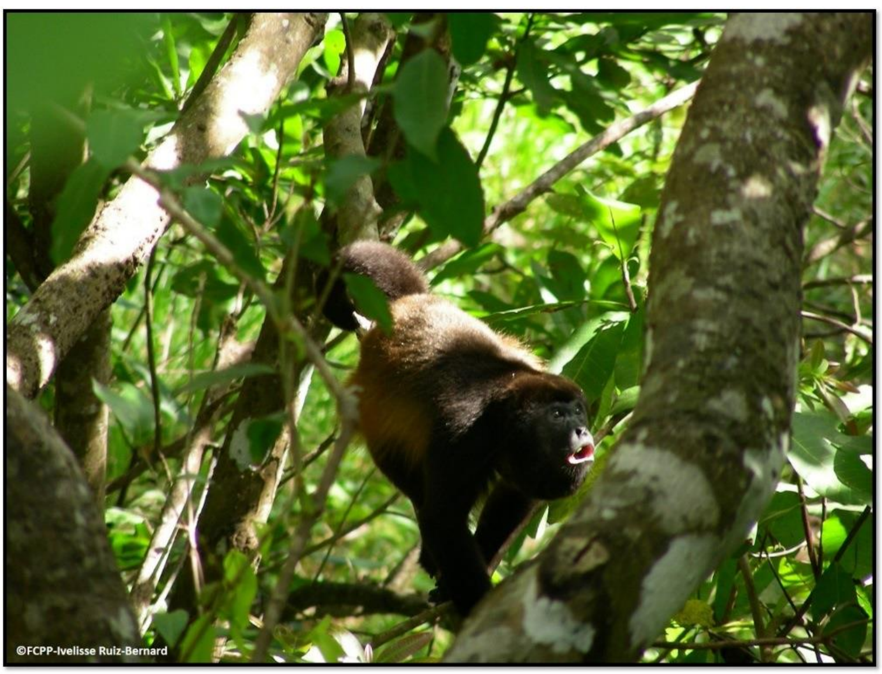

Figure 5.4. *Alouatta coibensis trabeata*, La Miel, Los Santos.

5.3.3 *Alouatta palliata aequatorialis*, Ecuadorian howler monkey

5.3.3.1 Common Names

Mono cotó, mono negro, mono aullador, Ecuadorian howler monkey.

5.3.3.2. Phenotypic Characteristics

Adults of *Alouatta palliata aequatorialis* have dark brown to black hair on almost the whole body (Lawrence, 1933). Infants have a complete white-greyish pelage until one month after birth: they, then gradually turn black or with brown dark coloration. When they are completely black, juveniles then develop yellowish or slightly orange flanks but the dorsal pelage normally remains black. The flanks have longer hair than other areas of the body. The chest, belly, arms and legs are black, partially covered by short hair, giving a light brownish appearance. The skin around the orbits and muzzle is normally dark grey with pinky tones in the lips. Genitals are exposed in adult males and females, in both cases with white skin, which make it easy to determine the sex. Males have long hair along their jawline creating a beard-like appearance, which is sometimes framed with brown hair (Elliot, 1912; Carpenter, 1934). These are two Paratype specimens collected in Cerro Azul and at the head of the Chagres River, Panama (Carpenter, 1932). One of these is in the United States Natural Museum (USNM) as specimen No. USNM 171068 (Goldman, 1913). **Body Measurements:** total length, 1272mm; Large of the Tail, 715mm; hind foot, 143mm. No other measurements available.

5.3.3.3. Taxonomy

Alouatta palliata aequatorialis was initially described as *Mycetes villosus* by Gray (1845), then as *Mycetes palliatus* (Gray, 1849), after which it was re-named *Alouatta palliata inconsonans* (Festa, 1903; Elliot, 1912; Goldman, 1913; Anthony, 1916; Allen and Barbour, 1923; Clark, 1930; Dunn, 1934; Fairchild, 1943). In the 1930s it was divided into *A. palliata palliata*, *A. p. aequatorialis*, *A. p. coibensis*, *A. p. trabeata*, *A. p. pigra*, *A. p. luctuosa*, and *A. p. mexicana* (Lawrence, 1933; Carpenter, 1934). Some studies of the parasitology of non-human primates have cited it as *A. p. inconsonans* (Smith, 1970), and as *Alouatta villosa* (Thatcher and Porter, 1968; Bosworth and Freier, 1975).

5.3.3.4. Distribution

Alouatta palliata aequatorialis is reported to be distributed from east of the Panama Canal zone towards San Blas mountain chain, and the eastern Panama Canal watershed (Altman, 1959; 1960; Chivers, 1968;1969; Mittermeier, 1973; Milton, 1975). It is also reported in all eastern forested areas in Panama, including Darien, San Blas, as well as Colombia and Ecuador (Carpenter, 1934). Instituto Commemorative Gorgas de Estudios de la Salud (ICGES) reported *A. p. aequatorialis* at Achiotes, Colon province, Cerro Azul, Bayano (Cañitas), Pacora, Panama province (Dunn, 1934; Courtney, 1950; Thatcher and Porter, 1968; Srihongse, 1969). In 1969 *A. p. aequatorialis* was reported at Cerro Azul, Mandinga, and Rio Piedras (Galindo and Srihongse, 1967). The FCPP has confirmed the species' presence in the following provinces: North Colon, all Darien province, and San Blas (Méndez-Carvajal, 2014). It is common in the lowlands at the Panama Canal Zone, in Panama province, where the Chagres National Park connects with Colon province's eastern side at Cerro Bruja, at Sierra Llorona (Rowe pers. Com), and from Campo Chagres to Bayano, the Cocobolo Natural Reserve and the San Blas Mountain Chain (Méndez-Carvajal, pers. obs.). *A. p. aequatorialis* was common at Cituro, Trinidad River and Tapalisa, and also at the Tacarcuna Mountain Chain, Darien province (Anthony, 1916) (Figure 5.5).

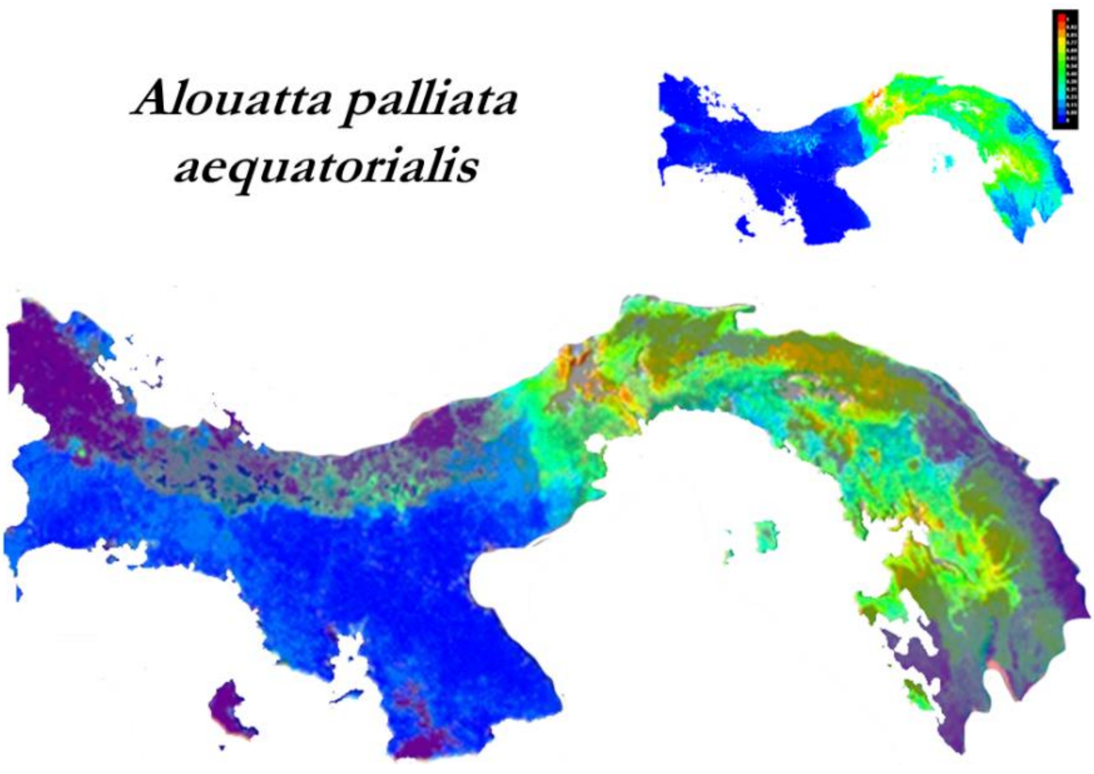

Figure 5.5. MaxEnt distribution of *Alouatta palliata aequatorialis* map result (from Chapter 3), overlapped with forest cover map (in red/violet) to show how the distribution of the species matches with the actual vegetation.

5.3.3.5. Population

I calculated densities *Alouatta palliata aequatorialis* for 33 sites, and directly counted 32 groups with a mean of 0.5 individuals/group (SD±0.8). In order to have a rough estimate of how many mature individuals of this species might survive in this area, I calculated population by multiplying the main area (9,750 km^2 total forest coverage) of the distribution by 0.5 ind/Km^2, the mean of 33 densities. I calculated that 4,875 individuals could be left in the wild. Group size was 13-23 ind/group. Observations in various habitats throughout Panama suggest *A. p. aequatorialis* distribution and densities are decreasing because yellow fever affects the Darien area and every year they experience a certain incidence of mortality, as reported in serology studies carried out by Galindo and Srihongse (1967). New commercial projects have deforested habitats, forcing *A. p. aequatorialis* to move close to human habitation, roads, and agricultural lands, where they are more vulnerable to vehicles and hunting by local people. As long ago as 1930, the Instituto Conmemorativo Gorgas de Estudios de la Salud (ICGES) started to collect primates from different species, so as to test for the presence of antibodies, viruses, antibodies, and helminths, and hunted 98 individuals between February and August 1930 (Clark, 1931). Later, in the 1960s, partial extirpation was reported in Santa Fe, Morti-Sasardi, Aguas Frias, Pirre, Chucunaque River, Rio Mono, Cana, Morti, Darien province, where *A. p. aequatorialis* was sampled for health studies (342 monkeys were hunted 1965-66). Scientists hired Panamanians hunters to collect primates for experiments related to helminth parasites, leading to the killing of about 54 individuals of *A.p. aequatorialis* at San Blas, Barro Colorado Island (Thatcher and Porter, 1968). Galindo and Srihongse (1967) then confirmed that *A. p. aequatorialis* was completely extirpated from those regions: in this case, these researchers were following methods using monkeys as indicators of the jungle yellow fever, experiments carried out by the ICGES. This suggests that this species may be sensitive to hunting. *A. p. aequatorialis* is EN according to the Environmental Ministry of Panama (MiAmbiente).

5.3.3.6. Major Threats

The major threats facing *Alouatta palliata aequatorialis* are those of agrochemical contamination, logging and deforestation, death at the hands of human road traffic, and hunting. Agrochemicals present one potent threat: as this species is mainly folivorous-frugivorous, individuals of *A. p. aequatorialis* have been exposed to contamination from crop-spraying in lowlands, which is performed heavily in the southeast of Panama

(Méndez-Carvajal *et al*., in prep.). Deforestation for farming, cattle ranches, teak plantations, urban investments, hydroelectric and other industrial activities. In Bajo Chiquito, Cemaco, north of Darien province, the Embera-Wounaan indigenous reserve has been part of the logging activity encouraged by the United States Agency of International Development (USAID) and its Community Forestry Program (FCP in Spanish) This has led to forest fragmentation of 4.72 km^2 of tropical forest in the Darien-Choco forest corridor, Tuquesa watershed, which has placed the arboreal fauna at risk, and has compromised the re-colonization of this region by arboreal mammals (Medina, 2013; Méndez-Carvajal, 2014).

Hunting of this primate for its protein resources, and indirectly for the pet trade is carried on by the indigenous Guna Yala, Embera, and Wounaan peoples (Smith, 2005; Méndez-Carvajal, 2012). In the Panama Canal Watershed, *A. p. aequatorialis* was listed as one of the 12 mammal species that local people kill for subsistence: in all, eight communities preferred to hunt, with a poaching intensity score of 4.0 (range 0-5; n=2 years), while other parts of the country were categorised as “rarely hunted”. These numbers are derived from a scale of hunting published in Wright et al. (2000). Road traffic and road kills, meanwhile, accounts for a further fraction of deaths in this species. Many members of this species are accidentally killed while crossing from one patch of vegetation to another, on highways in such forested areas as Soberanía National Park, or on the Gaillard-Madden road which connect Panama City and Chilibre with Camino de Cruces Natural Park and Gamboa town (Méndez-Carvajal, pers. Obs.). I also found *A. p. aequatorialis* in the North and South highways that connect Panama City with Colon province and Tocumen Airport, while others have been killed on the Juan Pablo II road near the Metropolitan Natural Park (Méndez-Carvajal, 2004).

5.3.3.7. IUCN Conservation Status

Alouatta palliata aequatorialis (Figure 5.6) is VU: Vulnerable (Cuarón et al., 2008). The IUCN categorize a species as Vulnerable when the best available evidence indicates that meets any of the criteria A to E for Vulnerable status, and is thus at a high risk of extinction (see Chapter 2 for categories).

5.3.3.8. Conservation Status Suggested by This Study

I observed a decline in the area of distribution for this primate species, which faces destruction of its habitats through high levels of exploitation of their local area by mining and hydroelectric projects. *A. p. aequatorialis* should be EN A2acd+3cd+4acd: Endangered, means this population has, according to IUCN categories, suffered a population reduction that has been observed, estimated, inferred, or suspected. The species has suffered declines in the past where causes of population reduction may not have ceased, may not be understood, or may not be reversible. This species needs to be evaluated by scientists working together with collaborators from other countries that also possess these taxa.

5.3.3.9. Present in the Following Reserves

Alouatta palliata aequatorialis is present in Chagres National Park, Cocobolo National Reserve, Serranía San Blas, Reserva Natural Cocobolo, Universidad Tecnológica (introduced 2005), Bayano, Pacora, Chepo, Chiman, Achiotes, Colon, Gatun, Parque Nacional San Lorenzo, Monumento Natural Isla Barro Colorado, Panama Canal Watershed, Reserva Natural San Francisco de Asís, Reserva Natural Chucanti, Estación Científica Punta Cana, Serranía Pirre, Serranía Sapo, Serranía Jungurundu, Reserva de Bagre, Alto Darién, Parque Nacional Darién, Comarca Indígena Embera-Wounaan, CEMACO, Bajo Chiquito, Chepigana, Cocalito.

Figure 5.6. *Alouatta palliata aequatorialis*, Barro Colorado island, Panama (left) Skull of a specimen from the Florida Museum of Natural History, Mammal Collection, University of Florida, Skull photo by P. Méndez-Carvajal. *A. p. aequatorialis*.

5.3.4 *Alouatta palliata palliata*, Mantled howler monkey

5.3.4.1. Common Names

Nicaraguan mantled howler monkey, mono con-con, mantled howler monkey.

5.3.4.2. Phenotypical Characteristics

Adults of *Alouatta palliata palliata* have dark brown to complete black pelage over their entire body (Lawrence, 1933). Infants of this species have a complete white-greyish pelage until reaching the age of one month, after which they gradually turn black or dark brown. The flanks turn yellowish or slightly orange over the back side of the lumbar area, with the animals' back remaining black. Flanks have longer hair than other areas of the body. Chest, abdomen, and limbs are black, and partially covered by short hair, giving an appearance of a light brownish colouration. The skin around the orbital and muzzle is normally dark grey with pink tones on the lips. Genitals are exposed in adult males and females, both with white skin, which is between the sexes. Males have long hair along their jawline creating a beard-like appearance (Elliot, 1912; Carpenter, 1934). This specimen was collected in Cerro Azul and head of Chagres River, Panama (Carpenter, 1932). It is in the United States Natural History Museum (USNM) as specimen No. USNM 171068 (Goldman, 1913). **Body Measurements:** No measurements found in holotype.

5.3.4.3. Taxonomy

Alouatta palliata palliata has been re-classified since its description as *Mycetes villosus* by Gray (1845), then as *Mycetes palliatus* (Gray, 1849), and later re-named as *Alouatta palliata inconsonans* (Festa, 1903; Elliot, 1912; Goldman, 1913; Anthony, 1916; Allen and Barbour, 1923; Clark, 1930; Dunn, 1934; Fairchild, 1943). In the 1930s, it was divided into *A. palliata palliata*, *A. p. aequatorialis*, *A. p. coibensis*, *A. p. trabeata*, *A. p. pigra*, *A. p. luctuosa*, and *A. p. mexicana* (Lawrence, 1933; Carpenter, 1934). *A. p. palliata* is currently considered the scientific name for this subspecies (Cortes-Ortiz et al. 2003; Groves, 2005; Rylands et al. 2006).

5.3.4.4. Distribution

A. p. palliata is reported to occur west of the Panama Canal Zone, in all west forested areas in Panama, including west Colon, west Panama, Cocle, Veraguas, Chiriqui (Baldwin and Baldwin, 1972; 1976), and in Bocas del Toro provinces, Costa Rica (Glander, 1971; Stuart et al., 1998), and Nicaragua (Carpenter, 1934). Smith (2005) confirmed that this species is still present in Veraguas at Ngäbe Bugle region, and in Veraguas province, especially Calovebora, Rio Limon, and Quebrada Larga. My own research has further determined that this primate also occurs in the following provinces: Northwest Colon, Donoso, Santa Fe National Park, Omar Torrijos National Park, La Amistad International Park, Volcan Baru National Park, and Chorogo Natural Reserve, Punta Burica (Méndez-Carvajal, 2014) (Figure 5.7.).

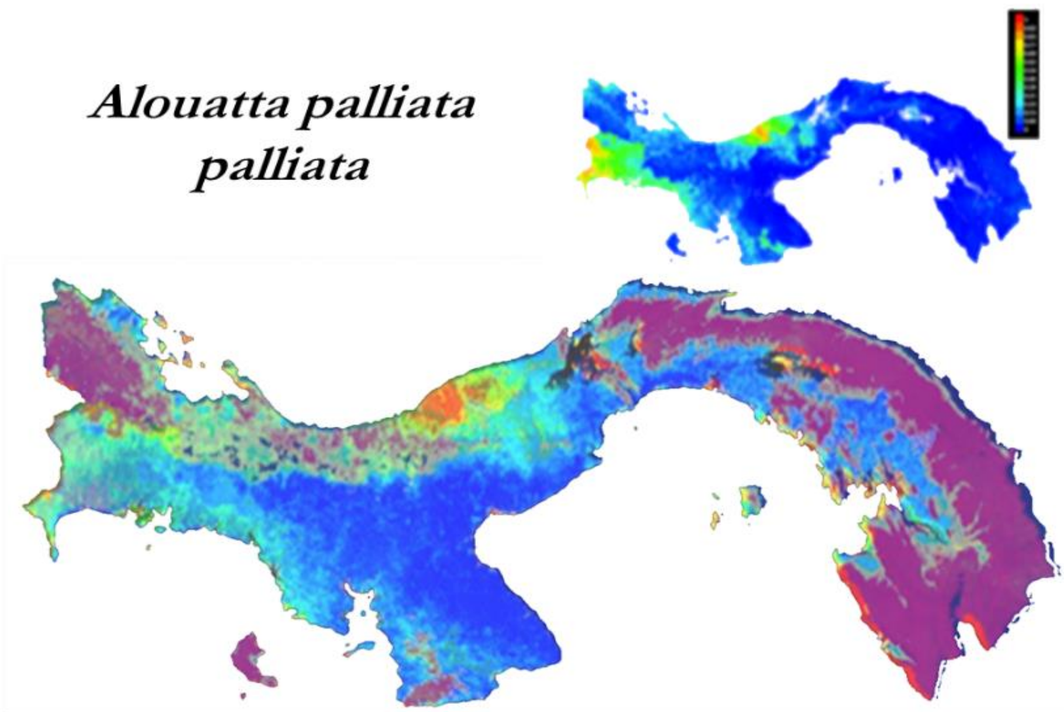

Figure 5.7. MaxEnt distribution map of *Alouatta palliata palliata* result (from Chapter 3), overlapped with forest cover map (in red/violet), to show how the distribution of the species matches with the actual vegetation.

5.3.4.5. Population

I obtained *A. p. palliata* densities for seven sites, and multiplied the total area of vegetation coverage as part of the distribution of this taxa (14,000 Km^2), before calculating that a rough population of <5,600 individuals remains left in the wild. In total, we have directly observed seven groups with 0.71 individuals/group (SD±0.43), and 0.4 ind/km^2. Group size was 4-28 individuals (n=seven groups).

5.3.4.6. Major Threats

Hunting is the major threat to *A. p. palliata*. The species is hunted by indigenous people from the Teribe, Naso, Bri-Bri and Ngäbe-Bugle groups who live in the mountains and hunt for subsistence, with most members of these groups preferring *A. g. panamensis, A. p. palliata*, *Bradypus variegatus*, *Mazama temama*, and *Cuniculus paca* as their main sources of protein (Linares, 1976; Torres de Araúz, 1980; Smith, 2005). Due to artisanal gold mining in the north of Colon province (Coclesito), and Santa Fe, Veraguas province, it is also common to find local people or Colombians clearing forested areas and camping in them, and living on wild meat. Many of these people hunt for bush meat, often enough to sell in the local market or to friends (Méndez-Carvajal pers. obs.). This illegal hunting activity affects *A. g. panamensis*, *A. p. palliata* and *Panthera onca* (Moreno et al., 2016). Other threats are related to four hydroelectric projects located near or inside La Amistad International Park (PILA in Spanish), in the Tabasara Mountain Chain (Chiriqui-Bocas del Toro provinces). Two open-pit mining projects by the Canadian Company First Quantum and Petaquilla Gold S.A., and Minera Panamá S.A. are cutting into the Mesoamerican Corridor, leading to deforestation along a 24 km road from the Caribbean coast to the centre of metal extraction (CATEGORÍA III, E. D. I. A., and MOLEJÓN, P. M. 2007; Cedeño, 2009). In 1934, the ICGES conducted primate studies in relation to entomology. The presence of *Cuterebra baeri* was reported to infect howler monkeys: however no individuals were collected on that trip (Dunn, 1934).

5.3.4.7. IUCN Conservation Status

In 2007, 48 private Panamanian NGOs, local organizations and international NGOs submitted a legal petition to UNESCO, asking them to include the Talamanca-La Amistad Reserve in in the World Heritage Endangered List, as they considered that hydroelectric activities are threatening the biodiversity in this forest (Thorson et al., 2007). Pressures on forest in these areas are still causing impacts on the biodiversity. Recently, this taxon suffered massive death in Nicaragua (50 individuals). The causes of this event were not clear, with severe habitat fragmentation inside the Biological Mesoamerican Corridor due to narco-deforestation being one possible cause (McSweeney et al., 2014). *A. p. palliata* is LC: Least Concern (Cuarón et al., 2008).

5.3.4.8. Conservation Status Suggested by This Study

Alouatta palliata palliata should be VU A2abcde: Vulnerable, (A2), The category A2 means that the population size has been reduced in ≥30, the data could be due to observation, or estimated, inferred, or for past causes. The causes of the reduction may not have ceased, or may not be understood or not reversible, in this case the land is suffering exploitation and forest has been cleared: this category allows or approves any data from direct observation, or any index of abundance presented and appropriate for the taxa, such decline of occupancy/habitat quality, actual level of exploitation, and the effects of introduced pathogens, pollutants, or parasites.

5.3.4.9. Present in the Following Reserves

Presence of this species has been detected in La Amistad International Park (PILA), Volcan Baru National Park, Palo Seco National Park, Santa Fe National Park, General de Brigada Omar Torrijos National Park (COPE), San Lorenzo National Park, Corpachi Natural Trail (Limones, Burica Peninsula).

Figure 5.8. *Alouatta palliata palliata* (Photo by Miguel Siu).

5.3.5 *Aotus zonalis,* Panamanian night monkey

5.3.5.1. Common Names

Douroucouli (indigenous), jujuná, mono bruja, marteja, owl monkey, nocturnal monkey, Panamanian night monkey.

5.3.5.2. Phenotypical Characteristics

Aotus zonalis has grey hair along its forelimbs, hindlimbs and dorsal parts of its body. The ventral hair may be orange or yellow. The hands and rear legs are dark compared with the rest of the body. It has three black lines on its face which extend onto its neck. It has two inverse triangular white marks over the eyes, and white pelage around its muzzle. It has big eyes, normally with orange sclera. The type specimen is from Gatun Lake, Panama Canal Zone, Panama, and is held in the United States National Museum (USNM), 171231, collected in 1911 (Goldman, 1914). **Body Measurements:** total length, 683mm; Tail: 400mm; **Skull Measurements**: greatest length, 60.9mm; zygomatic breadth, 37.5mm; maxillary tooth row, 18.3 mm (Goldman, 1914).

5.3.5.3. Taxonomy

Aotus zonalis was first collected in the Panama Canal Zone, Panama in April 29, 1911, and was identified by Goldman (1914). It was later redesignated as *A. trivirgatus* (Hershkovitz, 1949), then as *Aotus bipunctatus* (Azuero night monkey) and, some time after that, as *Aotus griseimembra* (Bole, 1937). It was considered *A. trivirgatus* by Hill (1960). The name of this primate was subsequently changed from *A. trivirgatus* to *Aotus lemurinus* (Hershkovitz, 1983). Recently, this species has been returned to the original name *A. zonalis* based on karyotype differences (Defler 2003).

5.3.5.4. Distribution

Aotus zonalis is found from the central provinces of Panama to Colombia. It used to be common throughout Panama, and abundant in Tapalisa, Boca de Cupe, Darien province (Allen and Barbour, 1923; Samudio, 2002; Méndez, 1970). My recent observations using strip transects (see Chapter 2) were not successful in finding this species in the Chucanti Nature Reserve (Bajo Chiquito, Cemaco, Darien province), nor in La Llana of Chagres Natural Park (Méndez-Carvajal, 2012, 2014: Svensson *et al*., 2010). The species is present in the San Blas mountain chain, including Chagres National Park, Campo Chagres and Cerro Azul in northeast Panama province (Svensson et al., 2010). During my surveys I observed *A. zonalis* in Panama City (Metropolitan National Park), Ancon Hill (Méndez, 1970; Méndez-Carvajal, pers. obs.), and in the Soberania National Park (Santamaría and Méndez-Carvajal, 2001). It is also confirmed for the rest of the Panama Canal Watershed, including the western side at Arraijan, Chorrera, and Isla Tigre in the Panama Canal (Gatun Lake). The one exception to this last point is that of Barro Colorado Island, where there have been no reports of this primate since the 1970s (Moynihan, 1976; Glanz, 1992; Méndez-Carvajal pers. obs. 1998-2004). *Aotus zonalis* is reported for Panama province up to Cocle province, including Penonome, Pajonal of Membrillo; Cope National Park, Donoso, Colon province (Araúz et al., 2007), but is not reported in Herrera, Los Santos, Azuero Peninsula, nor in that part of Panama as a whole. There are some anecdotal reports of *A.zonalis* in south Veraguas provinces, but these have yet to be confirmed (Méndez-Carvajal, 2011), as do similar reports in Chiriqui and Bocas Del Toro provinces. If surveys are not adequately designed, there is a strong likelihood that *Potos flavus* will be mistakenly reported as *A. zonalis* by local people (Méndez-Carvajal, 2005; Méndez-Carvajal, 2011, 2014). The confirmed limits for this species in Panama (Figure 5.9) are as follows: (Central Panama) Colon Province, Darien province, Panama province (Eastern), La Tábila and Rio Indio, and Cocle province (West) (Araúz *et al*., 2007; Méndez-Carvajal *et al*., in prep).

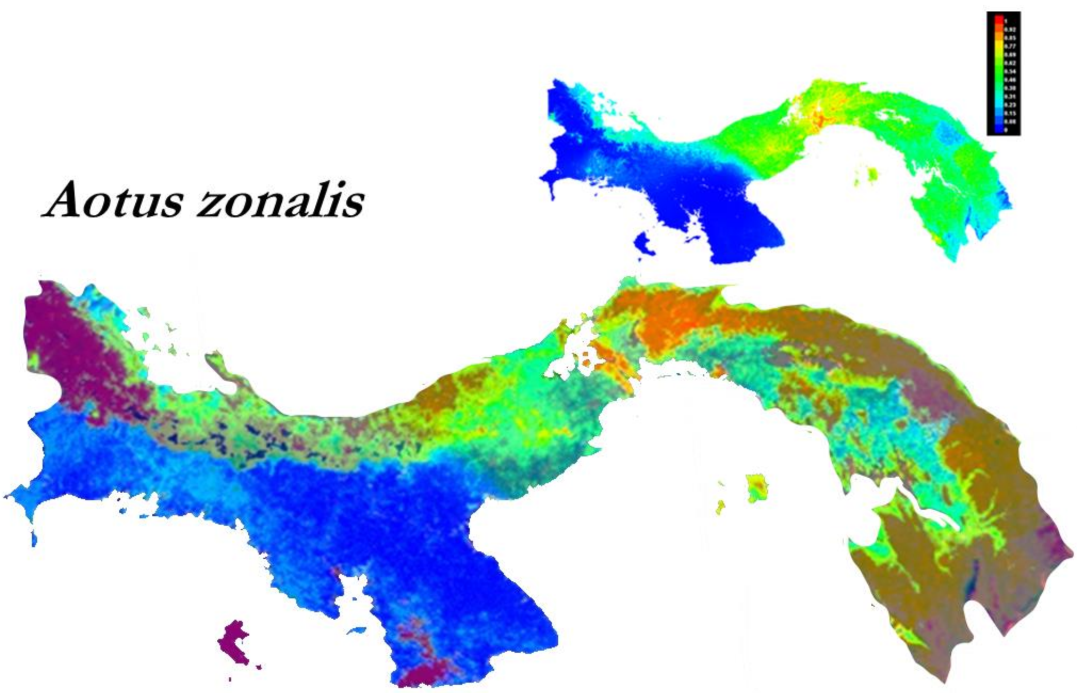

Figure 5.9. MaxEnt distribution map of *Aotus zonalis* results (from Chapter 3), overlapped with forest cover map (in red/violet) to recognize how the distribution of the species match with the actual vegetation.

5.3.5.5. Population

Aotus zonalis has densities of 19.7 ind/km² (Campo Chagres) and 14.3 ind/km² (Cerro Azul): both of these figures are based on strip transects (Svensson *et al*., 2010). The Panamanian population of *Aotus zonalis* was calculated by multiplying the total area of forest where this species is reported with 10,500 km². Using 0.19 ind/km², I obtained a rough estimation of *A. zonalis* population with <1,995 individuals, with estimated densities of 0.19 ind/km^2 (SD±0.14) N=13 (Méndez-Carvajal, in prep.).

5.3.5.6. Major Threats

Deforestation and hunting are the major threats to this primate. The former is taking place in its areas for purposes of farming, cattle ranching, hardwood trading (teak plantations), urban investments, mining, hydroelectric power generation and other industrial activities (Svensson *et al*., 2010; Méndez-Carvajal *et al*., in prep.). This animal has been hunted for biomedical use, and probably for food or cultural myths (Barbour, 1932). Collateral effects of translocation and re-introduction after laboratory treatments have threatened the wild population in zones like Soberania National Park. From the 1970s to 2004 Panama incurred the highest demand of *Aotus zonalis* for biomedical studies, with more than 2,000 individuals being legally removed from the wild (Svensson et al., 2017). *Aotus zonalis* was collected by scientists from the ICGES for research on blood parasites from February to August 1930 at Tuira River, Darien province. Other studies collected helminths from 125 individuals of *A. zonalis,* hiring Gunas hunters at San Blas (Thatcher and Porter, 1968). There are no recent reports of indigenous or local people hunting this primate for protein, but Allen and Barbour (1923), state that this primate is excellent eating. Based on notes from Allen and Barbour (1923), *A. zonalis* was, at this time, an abundant species, easily audible at nights, and many were shot while springing away, as their slow movements made it difficult for them to escape.

5.3.5.7. IUCN Conservation Status

Aotus zonalis is DD**:** Deficient Data (Cuarón et al., 2008).

5.3.5.8. Conservation Status Suggested by This Study

Aotus zonalis is currently presenting as a species experiencing population reduction linked with the destruction of its forest habitats, to its being hunting for food, market and probably also for magic purposes: some recent surveys indicate this animal is perceived in local folklore as possessing mysterious supernatural powers. According to the criteria of the IUCN this species should be seen as one that has been pressured in the past, leading to a reduction in its population that one that is not well understood and may not yet have ceased. If data from direct observation and abundance index are applied, then *A. zonalis* should be classified as VU, A2ab: Vulnerable.

5.3.5.9. Present in the Following Reserves

Soberania National Park, Camino de Cruces National Park, Metropolitan National Park, Chagres National Park, Cocobolo Natural reserve, Darien National Park are all indicated as sites of *A. zonalis* presence.

Figure 5.10. *Aotus zonalis* (Photo by Pedro González-FCPP).

5.3.6 *Ateles fusciceps rufiventris,* Darien black spider monkey

5.3.6.1. Common Names

Darien black spider monkey, black spider monkey, yarré (Embera-Wounaan indigenous group)

5.3.6.2. Phenotypical Characteristics

The body of *Ateles fusciceps rufiventris* has a completely black colouration, with brown tones depending on the light, and some brown colouration along the underside of the chest, forelimbs, throat, and tail. The facial skin is grey, as are the muzzle and the ocular orbits (Gray, 1871; 1872; Elliot, 1913). The difference between *A. f. rufiventris* and *A. f. fusciceps* is the red facial skin, and absence of the white moustache in *A. f. rufiventris*

(Kellogg and Goldman, 1944). *A. f. rufiventris* is from Atrato River, Darien, Colombia: an immature female individual located at the British Museum of Natural History serves as a specimen (Kellogg and Godman, 1944) (Figure 5.11). No measurements were available for this species.

5.3.6.3. Taxonomy

This taxon was first described as a part of *Ateles fusciceps* (Fraser, 1848), but Dr. Philip Lutley Sclater in 1871, revalidated the existence of *A. rufiventris* (or *Ateleus rufiventris*) in 1872 (Elliot, 1913). Between other forms, there was variability in type specimens of blackish spider monkeys described in Gray's "Notice of some New Species of Spider Monkeys (Ateles)" (Gray, 1865). This classification was then changed to *Ateles vellerosus* by P.L. Sclater in 1872 (Kellogg and Goldman, 1944). In 1915, this taxon was considered to be *Ateles robustus* (Allen, 1914), then as *A. dariensis* reported in Limon River at Pirre, Darien, by Goldman (1915), in Tapalisa, Darien, by Anthony (1916), and Bayano by Allen and Barbour (1923). After several reviews using genetic and morphological analyses, the most recent classification considers *A. f. rufiventris* to be the only valid black spider monkey present in Panama (Rylands et al., 2006; Rowe, 2010) (Figure 5.11).

5.3.6.4. Distribution

Darien black spider monkeys in Panama inhabit a range from eastern Panama province, Darien province and Colombia (Groves, 2005; Rylands *et al*., 2006). This species is present in the eastern side of Panama province specifically in the highlands but also found at sea level in living fences if suitable vegetation is present in living fences, such as in Majé Mountain Chain, Bayano, San Francisco Natural Reserve and Chucanti Natural Reserve (Méndez-Carvajal, 2012; 2014; pers. Obs.). It is also present in the northern part of Darien province near to the border with Colombia, being specifically reported in the Tuquesa River area and the Bajo Chiquito mountains, where they are often seen as pets of the indigenous Embera-Wounaan people, in Cemaco Indigenous Reserve (Medina, 2013; Méndez-Carvajal, 2014). *A. f. rufiventris* has been reported in Chepigana, Tuira, Sapo, Jungurundu Mountain Chain and in Pirre and Cana, in Darien National Park, but has been extirpated in villages close to Cocalito (Moreno, 2006; Méndez-Carvajal et al., 2016) (Figure 5.11).

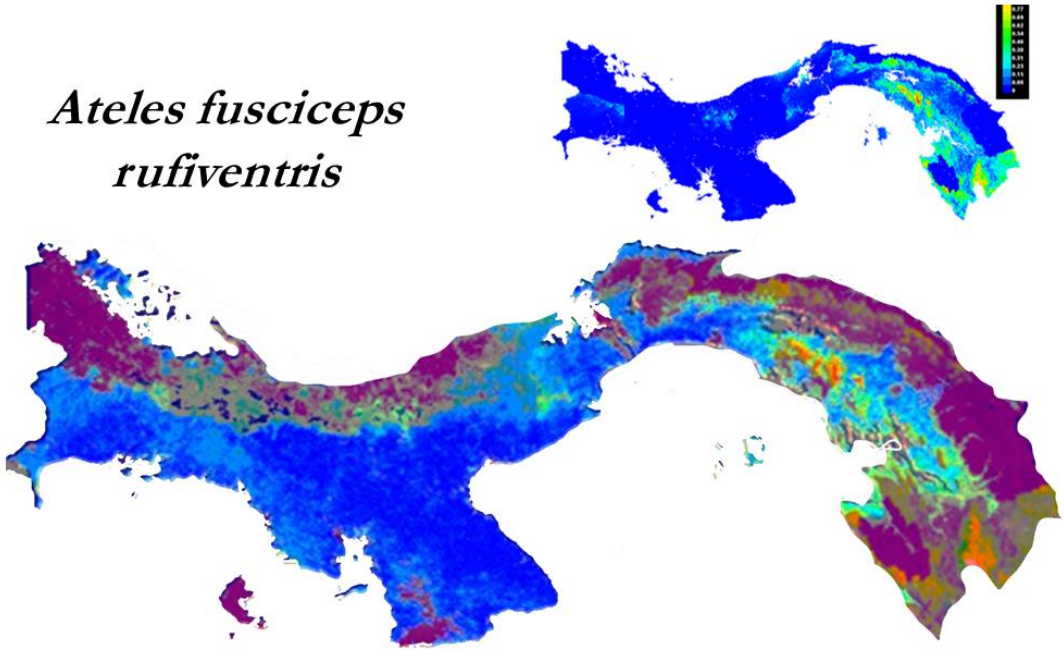

Figure 5.11. MaxEnt distribution map result of *Ateles fusciceps rufiventris* (from Chapter 3), overlapped with forest cover map (in red/violet), to show how the distribution of the species matches the actual vegetation.

5.3.6.5. Population

The FCPP reported a population of ~60 individuals of *Ateles fusciceps rufiventris.* This population is divided into two groups, averaging 20 individuals per group, with an average of 2-4 ind/subgroup at Chucanti Nature Reserve (Méndez-Carvajal, 2012a). Moreno (2006), meanwhile, has reported densities of 4.8 ind/km^2 for Boca de Cupe and Cana, Darien province. I obtained 0.19 ind/Km^2 as densities and multiplied this with the total forest that cover its distribution (9.750 Km^2), resulting in a rough population estimate of <1,850 individuals left in the wild, with an average of 0.19 ind/km^2 (SD±2.1; n=11). Specific densities are also obtained for areas with remnant vegetation in Panama and Darien provinces.

5.3.6.6. Major Threats

Ateles fusciceps rufiventris is currently threatened by the hunting activities of indigenous people such, as those from the Embera-Wounaan ethnic groups resident in the Darien mountain forest, and who survive via subsistence hunting. Most members of this group preferring *A. f. rufiventris*, *Pecari tajacu*, *Mazama temama*, and *Cuniculus paca* as their main sources of protein (Moreno, 2006; Méndez-Carvajal, 2012). The Maje Mountain Chain and the Serrania Bagre are also the scene of a land conflict between locals and the

Santeño Front, made up of people coming from Los Santos province (Azuero Peninsula), who have been clearing forest to use the lowlands to produce rice and sugar-cane, to set up cattle ranches, and also to engage in the extraction and sale of timber, making this one of the more significant threats to *A. f. rufiventris* (Méndez-Carvajal *et al*., in prep.). Logging activity – both legal and illegal – is also reducing forest cover in the main part of Darien forest, with some areas inside the limits of the Darien National Park having already been cleared, and replaced crops produced as subsistence for indigenous Guna and Embera-Wounaan (Méndez-Carvajal, 2014).

5.3.6.7. IUCN Conservation Status

Ateles fusciceps rufiventris is CR: Critically Endangered (Cuarón et al., 2008).

5.3.6.8. Conservation Status Suggested by This Study

Ateles fusciceps rufiventris has experienced an observed population reduction, and a loss of forest coverage. The impact of these changes may not yet have ceased, and may not be reversible. Deforestation has been drastically increasing in the species' area, as a result of new projects related to palm oil production and cattle rearing, developments which have occurred with the approval of the Panamanian government. Based on direct observation, this species is suffering a decline in occupancy; it has habitat loss, and an actual level of exploitation. Population reduction can be inferred up to a maximum of 100 years, and the actual level of exploitation is high, as it is also consumed by Embera-Wounaan indigenous people. Population reduction has occurred in the past, is continuing in the present, and its effect may not be reversible. Data obtained by direct observation serves as evidence of a decline in the area of occupancy and exploitation. *A. f. rufiventris* (Figure 5.12) should be considered CR A2acd+3cd+4acd: Critically Endangered.

5.3.6.9. Present in the Following Reserves

Parque Nacional Darién, Alto Darién, Serranía del Bagre, Serranía del Majé, Serranía de Jungurundú, Cerro Sapo, Cerro Pirre, Estación Biológica Punta Cana, Reserva Natural San Francisco de Asís, Reserva Natural Chucantí, Bayano, Reserva Indígena CEMACO (Embera-Wounaan community) remain areas where this critically endangered species can still be found.

Figure 5.12. *Ateles fusciceps rufiventris*, Darien, Panama (left) Skull of a specimen from the Florida Museum of Natural History, Mammal Collection, University of Florida, Skull's photo by P. Méndez-Carvajal. *A. f. ruviventris* in the wild (right).

5.3.7 *Ateles geoffroyi azuerensis*, Azuero spider monkey

5.3.7.1. Common Names

Charro, charao, Azuero spider monkey.

5.3.7.2. Phenotypical Characteristics

Ateles geoffroyi azuerensis has blackish-brownish colouration on its head, dorsal and upper fore- and hind-limbs. The ventral portions of arms and legs have sienna or ochre mixed coloured hair (Groves, 2005; Rylands et al., 2006). The orbital skin is grey and muzzle skin is pink, while the thigh, belly and flank pelage may sometimes be mixed with yellowish-orange colouration. The chest and throat hair has a cream colour and tends to be longer (Kellog and Goldman, 1944). Colouration patterns of this subspecies vary slightly depending on the region in Azuero, sometimes with very similar colouration pattern to the Azuero howler monkey (Méndez-Carvajal, 2013). The Type Specimen is located in the United States, Cleveland Museum of Natural History (USNM) as specimen No. 1235 (Kellogg and Godman, 1944). Body Measurements: total length, 1170mm; large of the tail, 720mm; hind foot, 177mm. Skull Measurements: greatest length, 110.8mm; width of brain case 56.8mm; zygomatic breadth, 65.1mm; width of braincase, 56.8mm; maxillary tooth row, 27.7 mm (Kellogg and Goldman, 1944) (Figure 5.7).

5.3.7.3. Taxonomy

This taxon was identified, as *Ateles azuerensis*, by Patterson Bole from the Cleveland Museum of Natural History (Bole, 1937). Rylands et al., (2006) later recognized this taxon as *A. g. azuerensis*, using morphological characteristics from Kellogg and Goldman (1944) as reference. Other studies that have attempted to classify this subspecies have been done by Collin and Dubach (2000), Nieves et al. (2005), and Morales-Jiménez (2015). In Panama, the FCPP uses the same classification as suggested by Kellogg and Goldman (1944). Morales-Jiménez obtained results that separate this taxon as a monophyletic species group with a 0.75-million-year separation (Morales-Jiménez et al., 2015). With these results, there are further possibilities that, as initially suggested by Patterson Bole, this subspecies could be recognized as a full species *A. azuerensis*. However, as those samples were taken from only one side of the entire distribution, these authors suggested that further samples are needed to properly analyse this information (Morales-Jiménez et al., 2015).

5.3.7.4. Distribution

Ateles geoffroyi azuerensis (Kellogg and Goldman, 1944) was first classified as a species called *Ateles azuerensis* (Bole, 1937). *A. g. azuerensis* is completely absent in the northern part of the Azuero Peninsula (Herrera province), including the El Montuoso Forest Reserve (Méndez-Carvajal *et al*., 2004), and Punta Burica, Chiriqui Province, and Veraguas Province where they used to live (Carpenter, 1935; Bole, 1937; Méndez, 1970; Méndez-Carvajal, 2005; 2009; 2013). They have lost almost 90% of their natural distribution (Méndez-Carvajal, 2013) and only survive in the protected forest of Cerro Hoya National Park, La Tronosa Forest Reserve (Arosemena-Zeballos *et al*., 2009; Méndez-Carvajal and Ruiz-Bernard, 2009) and adjacent areas in South Azuero (Méndez-Carvajal, 2013). The species has been reported as partially extirpated from El Montuoso Forest Reserve, due to the indigenous and local people who have learned to eat spider and howler monkeys as an alternative, money-saving, method of gaining protein from the wild (Méndez-Carvajal, 2001; *et al*., 2004; 2005) (Figure 5.13).

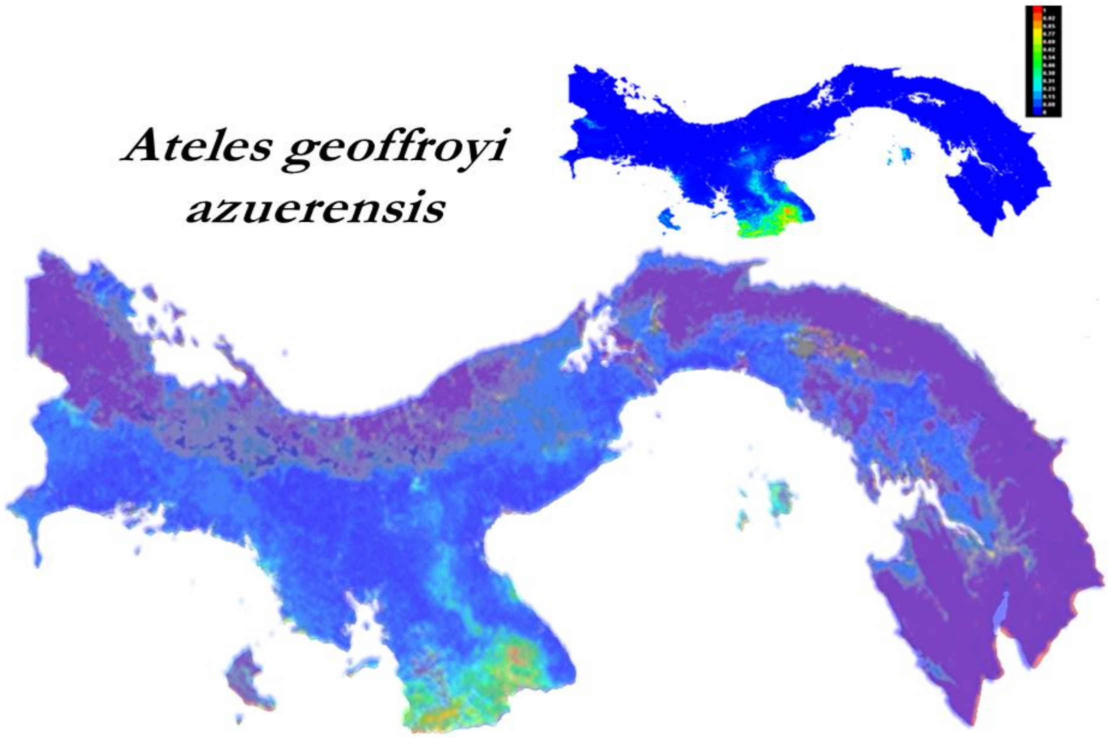

Figure 5.13. MaxEnt distribution map of *Ateles geoffroyi azuerensis* (from Chapter 3), overlapped with forest cover map (in red/violet) to recognize how the distribution of the species match with the actual vegetation.

5.3.7.5. Population

Ruiz-Bernard and I first estimated *Ateles geoffroyi azuerensis* as having only 117 individuals left in the wild, with an average subgroup size of 3.8 individuals, (Méndez-Carvajal and Ruiz-Bernard, 2009). In 2011, after we were able to survey more areas, I recalculated the population as being 145 individuals (Méndez-Carvajal, 2013). In this study I added information not included in the past surveys from 2011 to 2016, and I found in these new calculations only 121 individuals in six sub-groups with densities of 1.4 ind/km^2, 8.4 groups/km^2 (SD±1.5). A new report of an isolated individual of *A. g. azuerensis* detected in the area of Punta Duarte, La Barra of Mariato at Veraguas. This report was made by local landowners Michael Heim and Lyne Arbour-Heim, who are volunteers in our citizen scientists program "Watching the Monkeys".

5.3.7.6. Major Threats

The Azuero peninsula has been deforested, with nearly 90% of the original vegetation having been converted to agriculture and cattle ranching. In adding to the problems the consequent lack of vegetation means for *Ateles geoffroyi azuerensis* the local people in some areas also hunt this primate to use its fat as a folk remedy for asthma. Other population decreases are caused by indigenous people from the Ngäbe-Bugle tribes hunting spider monkeys. New landowners from other countries or more wealthy Panamanians have been changing traditional agricultural practices by replacing living fences with black and white sticks with wires, separating patches of forests and areas that were previously connected with living fences to gallery forests and natural reserves. Other threats for *Ateles geoffroyi azuerensis* are the use of agrochemicals and crop spraying in the southern area of Azuero, specifically in the zones where the Cerro Hoya National Park and La Tronosa Forest Reserve are located. New investors and businesses have been threatening the security of these lands, burning them or engaging in illegal logging activities. Natural reserves lack effective surveillance by the authorities. Local communities have defended the primates in the area, due to the influence of several years of environmental education by local conservationists and the FCPP working together. The Cerro Hoya Natural Park and Canajaguas Natural Reserve were saved from governmental attempts to change their protected status or build infrastructure inside the limits of the parks.

5.3.7.7. IUCN Conservation Status

Ateles geoffroyi azuerensis is CR: Critically Endangered (Cuarón et al., 2008)

5.3.7.8. Conservation Status Suggested by This Study

Ateles geoffroyi azuerensis (Figure 5.14) has an observed and present population reduction, one that may not have ceased, and may not be reversible. Based on direct observation, this species is still going through a decline in occupancy, is continuing to lose habitat for different land management and industrial investments, and suffering a real level of habitat fragmentation. Population reduction has been inferred up to a maximum of 100 years, an actual level of exploitation. This species has a reduction in population observed that could be up to a maximum of 100 years in the future (B2a). Its geographic range of occupancy is small and severely fragmented into several locations (C2a (i). The number of mature individuals is declining per subpopulation. *A. g. azuerensis* should be considered to be CR A2acd+4acd+B2a+C1+C2a (i): Critically Endangered, (A2acd).

5.3.7.9. Present in the Following Reserves

This subspecies is only present in Cerro Hoya National Park, La Tronosa Forest Reserve, and Achiotines from Pedasi, and Canajaguas Forest Reserve.

Figure 5.14. Skull of *Ateles geoffroyi azuerensis* Type Specimen (Left), mature male from Cerro Hoya National Park. Photos courtesy of Lyman M. Jellema, Collections Manager, Department of Physical Anthropology, The Cleveland Museum of Natural History, and Alamy Stock Photo album.

5.3.8 *Ateles geoffroyi grisescens*, Hooded spider monkey

5.3.8.1. Common Names

Hooded spider monkey, Grizzled spider monkey

5.3.8.2. Phenotypic Characteristics

Ateles geoffroyi grisescens has long hair, a blackish colouration mixed with silver hair, in some cases with golden colouration in the base over all limbs, shoulders and the lower part of the back. It has a black tail (tinted yellowish-brown), and long hair on its forehead, and may also have a pale colour in the underside of the tail. The crown, nape, hands and feet are black: the face is dark, skin slightly reddish, orbits black, while its back is a darker gray (Gray, 1865; Elliot, 1913). The difference between *A. grisescens* and *A. cucullatus* is that if a specimen of *A. g. grisescens* is compared to a specimen of *A. cucullatus*, it will be observed that the *A. g. grisescens* specimen is the darker of the two specimens (Elliot, 1913). Chest and throat hairs can be black or dark-grey (Kellogg and Goldman, 1944). The Type Specimen (BM 65.2.202), from Chepigana, Darien, is held at the British Museum of Natural History. The paratype specimen meanwhile, is an immature animal from Colombia, located in the Muséum D'Histore Naturalle (MNHNF) as specimen No. 552 (Kellogg and Godman, 1944). **Body Measurements:** total length, 1,280; large of the tail, 698; hind foot, 159. **Skull Measurements**: greatest length, 103;

zygomatic breadth, 60; width of brain case, 55.6; maxillary tooth row, 26.8 (Kellogg and Goldman, 1944) (Figure 5.15).

5.3.8.3. Taxonomy

This taxon was first described in 1865 by Dr John Edward Gray, who named it *Ateles grisescens*, noting its remarkable characteristics of long and black hair, with interspersed silvery-white hair (Gray, 1865). Gray's note, published as "Notice of some new species of spider monkeys (Ateles)" in the Collection of the British Museum (Gray, 1865), described the pelage coloration patterns of *A. grisescens*, in reference to Sclater, M.S., and his work "Grizzled Spider Monkey", from the List of Vert. Anim. In Zoology Garden (Sclater, 1875). Gray briefly compared the colouration pattern with *A. ater* and *A. paniscus.* The description of *A. grisescens* matches that of *A. cucullatus*. Both animals are predominantly black with long hair on the head, and a reddish face. Scientists recall the individuals of *A. g. grisescens*, were similar to *A. fusciceps*, although, colouration patterns were different and the *A. g. grisescens* has longer hair with brown tips, with the belly light coloured.

Due to the presence of blackish silvery-gray hair in its pelage, *Ateles geoffroyi grisescens* was called a grizzled spider monkey: because its crown was in the shape of a hood, it was later called the hooded spider monkey (Gray, 1865). It was described in the same document as *A. cucullatus* (Sclater, 1871), and was later re-named as *A. melanochir* (Sclater, 1875). In "A review of the primates" by Daniel Giraud Elliot from the American Museum of Natural History *A. g. grisescens* was included in the taxonomic key for "*Ateleus"* (1912-1913). There were three controversial groups of *Ateles*, *A. grisescens* being the specimen with the head and back mixed with silvery or/and golden hair, with back more black than grey (Elliot, 1913). However, Daniel Elliot remarked on doubt about this taxon due to the lack of a location for its type specimens. Provenance of the two specimens obtained as paratypes are one from Tuira River, Panama (Gray, 1865) and other from an unknown location in Colombia, explained in Elliot (1913). One of the *A. grisescens* Type specimen skin identified (and wrongly tagged) as *A. cinerascens*, was from the Paris Museum of Natural History, and had been originally obtained from the Zoological Society of London. Later, this taxon was considered as a subspecies of *A. geoffroyi*, and appears in the "Proceedings of the United States National Museum: Review of the Spider Monkeys" published by Remington Kellogg and Edward A. Goldman in 1944, which suggested a new taxonomic key for the genus *Ateles*. This proposed new key suggested that the more important characteristics of the species were the dusty or darker hairs and black and interspersed with silvery or gold hairs, and cinnamon belly hairs.

The subspecies is now called *Ateles geoffroyi grisescens*. Two drawings were made to illustrate this subspecies, one released by Stephen Nash from the International Union for Conservation of Nature and the other one painted in watercolour by the present author. A recent review of the actual skin 100 years later, show the specimen collected in 1871 #552 at the Paris Museum, France was a bit different in colouration pattern. Other characteristics that may differ for this specimen include the face, which was different in comparison to the northern spider monkeys according to Barbour (1932). Thomas Barbour published this note called "Concerning *Ateles grisescens*" in the *Journal of Mammalogy*, supporting the similarities in facial appearance found between *A. grisescens* and *A. ater,* and *A. geoffroyi*, but insisting at the same time on the difference of *A. grisescens* in the gray coat.

5.3.8.4. Distribution

Ateles geoffroyi grisescens was reported as occurring naturally in an area running from the valley of Rio Tuira, (southern Serrania Sapo, south-eastern Panama) up to the Baudo mountain chain in Colombia (Kellogg and Goldman, 1944). It has also been reported in Chepigana, Darien, and as overlapping in distribution with *A. fusciceps rufiventris* (Synonymous of *A. dariensis*) (Barbour, 1932). This primate was reported as common at the lower zone of Tuira river, with some of them being seen at the Panamanian market (Barbour, 1932), and used in malaria experiments by (ICGES) (Dun and Lambretch, 1908). Recently, I started explorations in Darien National Park to acknowledge distribution of *A. g. grisescens*, and to confirm its existence in Panama. The original areas where this primate used to be common now have less vegetation, or do not report the presence of this subspecies anymore. I confirmed no evidence of its presence in the following areas of Darien province: Bajo Chiquito (Cemaco-Wounaan reserve), Tuira River north and Central part, Maje Mountain Chain, including the Chucanti Nature Reserve and San Francisco de Asis Reserve along the border between Panama and Darien. Cooperative observations by different organisations confirmed absences in the central and south part of Darien, including Torti, Meteti, Marea, La Palma, Garachine, Jaque, Taimiti, Cemaco, Cana, Jaque, Pirre, Sapo, and Paya. It did not prove possible to add new information to new presence locations, so I was unable to create a potential distribution map.

5.3.8.5. Population

The latest attempt to find *Ateles geoffroyi grisescens* took place inMay 2016, and involved the FCPP, Conserv-Action, Nat-Explorers and the Environmental Ministry of

Panama, at the eastern village of Panama, in the Embera-Wounaan community at Cocalito. I also surveyed other localities at the northern Tuira: Pucuru at the Guna community, navigating the Tuira River, and also the locality of Boca de Cupe, passing to Bajo Lepes by foot and near the connection with Situro and on the way to the "Cruce de Monos" trail. So far, this species has not been found in the areas where it used to be reported in the Panamanian territory, and my hypothesis is that there was a mistake in the provenance of the skin, from the specimen collected in Colombia, as this primate was very well described (by Kellogg and Goldman 1944) as having black hair with interspersed white hairs on its entire body, which is also the appearance of *Ateles fusciceps rufiventris*.

Ateles geoffroyi grisescens (Figure 5.16 and 5.17) was clearly selected as part of the samples collected by ICGES during a yellow fever epidemic that killed both monkeys and the scientists who were collecting them (Dunn and Lambrecht, 1963). If this subspecies still exists, it could be already extirpated from Panama, or, at best, reduced to a very small number of individuals in areas close to the Colombian border (e.g. Atrato river, Tacarcuna). I prefer to refer to *A. g. grisescens* as a blackish animal, rather than the white spider monkey illustrated by Stephen Nash. It is important to take into account the fact that at the time people were working with these animals they were also receiving primates from different parts of South America, animals that were received as material for Museum at the Balboa Clun House, and most of which had confused provenance. Darien, also, is well known as an area of traffic from Southern to North America. It appers that y *A. g. grisescens* used to be very well differentiable from *A.fusciceps*, and *A. geoffroyi geoffroyi*: several reports from the ICGES indicate this name very well when referring to their collection of samples in Darien (Dunn and Lambrecht, 1963).

5.3.8.6. Major Threats

Ateles geoffroyi grisescens is threatened by hunting and logging activities in Darien National Park, the Tuira River area, and in Chepigana and surrounding areas based on original description.

5.3.8.7. IUCN Conservation Status

Ateles geoffroyi grisescens (Figure 5.16) is DD**:** Inadequate information exists to make a direct, or indirect, assessment of its risk of extinction, based on its distribution, and/or population status (Cuarón et al., 2008).

5.3.8.8. Conservation Status Suggested by This Study

Ateles geoffroyi grisescens should continue to be designated as DD until such time as more surveys can be completed.

5.3.8.9. Present in the Following Reserves

While *Ateles geoffroyi grisescens* has not recently been observed in Panama, it may possibly still be present in Darien National Park, Choco Region, and on the frontier between Panama and Colombia.

Figure 5.15. Type Specimen of *Ateles geoffroyi grisescens* (Photograph courtesy of Cecile Callou, Manager Collection, MNHN, and facilitated by Barbara Rethore and Julien Chapuis from Conserv-Action and NatExplorers, France).

Figure 5.16. Type Specimens of *Ateles geoffroyi grisescens* from the British Natural Museum (up) and Cleveland Museum of Natural History (down).

5.3.9 *Ateles geoffroyi panamensis*, Panamanian red spider monkey

5.3.9.1. Common Names

Mono colorao, Panamanian red spider monkey

5.3.9.2. Phenotypical Characteristics

The Panamanian red spider monkey *Ateles geoffroyi panamensis* was first described by Edward A. Goldman in 1911. Characteristic of this specimen is its reddish colouration, compared with the *A. g. ornatus*. It is considered a variety of *Ateles*, and synonymous with *A. g. ornatus* (Méndez, 1970; Groves, 2005; Rylands et al., 2006). The Panamanian red spider monkey has a tail that is light mahogany red, at least on the basal half, with cinnamon-black elsewhere; its back and shoulders are dark reddish to blackish, as are the crown cap, and the back of neck; surfaces of fore and hind limbs are either black or blackish to the knees and elbows, while the orbital and snout skin is pinkish (Kellog and Goldman, 1944). This specimen is located in the United States Natural History Museum (USNM) as specimen No. 171489 (Kellogg and Goldman, 1944). **Body Measurements:** total length, 1,280mm; Length of the Tail, 786mm; hind foot, 183mm. **Skull Measurements**: greatest length, 112.8mm; zygomatic breadth, 68mm; width of brain case, 61.2mm; maxillary tooth row, 27.3mm (Kellogg and Goldman, 1944).

5.3.9.3. Taxonomy

Rylands et al., (1997) described the taxonomy of *Ateles* in Panama as consisting of *Ateles geoffroyi azuerensis*, *Ateles geoffroyi grisescens,* and *Ateles geoffroyi panamensis*, using as reference the morphological characteristics defined by Kellogg and Goldman (1944). In 2000, Collin and Dubach published a phylogenetic evaluation of the *Ateles* genus relationships, modifying the taxonomy due to observed contradictions between the colour pelages of *Ateles* genus, and its genetic information. Mitochondrial analyses showed no apparent differences between subspecies of Central American spider monkeys and those considered to be a single subspecies, *Ateles geoffroyi ornatus* (Napier, 1976; Collin and Dubach, 2000; Groves, 2005; Rylands et al., 2006). However, reviewing the locations of the proceeding samples obtained (samples of *A. geoffroyi*, *A. g. panamensis*, *A. g. rufiventris*, *A. fusciceps robustus*), is confusing. Beside the fact that there are no wild populations of these species in that part of Panama (Balboa), the only evidence for *Ateles* samples having come from there lie in a report made by Barbour in 1932, where he claimed to see spider monkeys in captivity, living in big cages at the Balboa Club House. All these caged primates were of unclear provenance, having come from Colombia, Ecuador, and Peru (Barbour, 1932). Even the list of samples shows Panama a meagre three times: at only one point (*A. g. fusciceps*-17) is listed as inside Panama, with the other parts falling in the Colombian region (samples points 15 and 16) (see Collin and Dubach, 2000). Other studies have been trying to re-classify *Ateles* in Mesoamerica, but the results always fail to generate a concrete phylogeny due to mistakes in identification, unknown origin of samples, and insufficient loci information; thus, most conclude that more research is needed (Collin and Dubach, 2000; Nieves et al., 2005; Morales-Jiménez, 2015; Ruiz-García et al., 2016). In Panama, the FCPP uses the same classification as suggested by Kellogg and Goldman (1944), and will do so until a phylogenetic publication can clearly complete the gaps that remain. After 105 years, I completed this review to illustrate the *A. g. panamensis* Type Specimen # 171489. The specimen was collected on

June 8, 1911, at 2000 masl, Cerro Bruja, Colon province, Panama. The adult female collected by E. A. Goldman remains in very good condition with complete skull intact.

5.3.9.4. Distribution

Ateles geoffroyi panamensis was reported as naturally occurring in the northern forested corridor east of the Panama Canal zone, the San Blas mountain chain, the western Panama Canal, and Barro Colorado Island (Eisenberg, 1976; Hladick and Hladick, 1969; Richard, 1970; Bramblett et al., 1974; Freese, 1976), and also in the area from Colon to Chiriqui (Kellogg and Goldman, 1944). Its distribution was subsequently recorded in several studies beginning in the 1930s. In 1929-30, this species was collected in order to study malaria in Chiriqui province, La Vaca River, Coto (Carpenter, 1935), Blanco River (Clark, 1930). During entomological studies from the ICGES, individual specimens were collected in Puerto Armuelles, Pital, La Vaca River, Bogamani and the eastern area of northern Darien (Dunn, 1934), and were also observed (for helminth parasites studies) in Darien and Panama provinces (Thatcher and Porter, 1968). In 1969, individuals were collected for malaria and yellow fever studies at Achiotes, Colon province, and Cerro Azul, Bayano (Cañitas), Pacora, Panama province (Courtney, 1950; Srihongse, 1969). *A. g. panamensis* was used as a 'sentinel monkey' (were left in a trap in isolation in the canopy to observe possible infestation of malaria) at Cerro Azul, Mandinga, and Rio Piedras (Galindo and Srihongse 1967). I report this primate in the following provinces: Bocas del Toro, North Veraguas, North Cocle, North Colon, and I report also that it is still probably present in northern Darien (anecdotal comm. from local people). The Panamanian red spider monkey has been found to inhabit the Panama range from Bocas del Toro and Chiriqui provinces (only highlands: Boquete, Baru, from Cordillera de Chiriqui, the higher part of Talamanca Mountain Chain, and Cordillera Central; Veraguas, Cocle and Colon provinces, at the centre and Caribbean side, and in the Tabasara Mountain Chain. It is not common in the lowland of the Panama Canal Zone, Panama province, but does appear at the Panamanian province in the northeast section of Chagres National Park connecting with Colon province eastern site at Cerro Bruja, Sierra Llorona, and Campo Chagres up to Bayano, Cocobolo Natural Reserve and San Blas Mountain Chain (Méndez-Carvajal, pers. obs.). A group of around 23 individuals remains in Barro Colorado Island, after Dr. Ray Carpenter released seven of them as a part of an adaptation study for spider monkey reintroduction in 1977. They were rescued from a market where persons were attempting to sell them (Méndez-Carvajal and Ruiz-Bernard, 2009). This species is also present in Costa Rica (Rylands *et al*., 2006) (Figure 5.17).

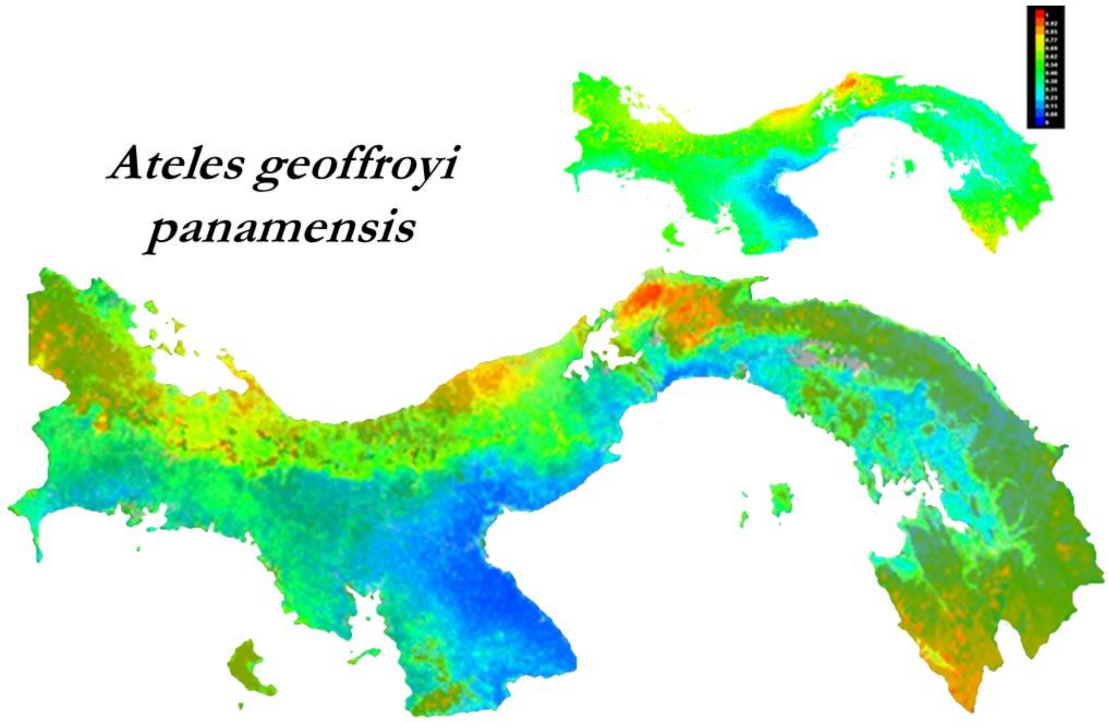

Figure 5.17. MaxEnt distribution map result of *Ateles geoffroyi panamensis (*from Chapter 3), overlapped with forest cover map (orange/reddish) to recognize how the distribution of the species match with the actual vegetation.

5.3.9.5. Population

I estimated the density of *Ateles geoffroyi panamensi*s by using a mean of 0.21 individuals/Km^2, multiplying this with the total area of forest coverage of 15,000 Km^2, thus obtaining for this species a rough population estimate of <3,150 individuals remaining in Panama. *A. g. panamensis* was not found in Cocle del Norte, Rio Indio (despite 83 hours' total searching) (Araúz et al., 2007), nor in Donoso and North of Colon (1,500 hours' effort). In total, the FCPP and I directly observed 66 individuals, with a range of 1-5 individuals/subgroup (SE ±6.5; N=13). Groups observed were from 13-23. Density was calculated as an average of 0.21 ind/km^2 (N=3). Three different densities were calculated, dividing *A. g. panamensis* between three sections in Panama (West, Central and East).

5.3.9.6. Major Threats

Ateles geoffroyi panamensis experiences serious threats from hunting and mining activities, and from hydro-electric power projects. There is also a history of hunting of the species for medical research, which may be relevant to its survival. The species is under heavy hunting pressure from the indigenous Teribe, Naso, Bri-Bri and Ngäbe-Buglé ethnic groups, who are resident in the mountains and who survive via subsistence hunting. Most of these groups prefer *A. g. panamensis*, *Bradypus variegatus*, *Mazama temama*, and *Cuniculus paca* as their main sources of protein (Torres de Araúz, 1980; Smith, 2005). In the north of Colon province (Coclesito), and Santa Fe, Veraguas province, it is common to find locals camping as they search for artisanal gold mining opportunities. These locations often have open gaps in the forest, allowing local people to stay and subsist on wildlife meat, with people hunting *A. g. panamensis* for surplus, to bring bush meat back to their homes, sell in a local market, and provide between friends. Illegal hunting activity also appears to be impacting upon *A. g. panamensis*, *A. palliata* and *Panthera onca*, reducing their presence in the area (Méndez-Carvajal, pers. obs.). Other threats are related to the Bonyic Project, with four hydroelectric plants near or inside to La Amistad International Park (PILA in Spanish), in the Tacarcuna Mountain Chain (Chiriqui-Bocas del Toro provinces). There are also two open-pit mining projects that are deforesting the Mesoamerican Corridor to construct a 24 km principal road from the Caribbean coast to the centre of the mountain, a project undertaken by the Canadian Company First Quantum and Minera Panamá S.A. (CATEGORÍA III and MOLEJÓN, 2007). This subspecies was hunted by scientists in early 1930s: 75 were killed in Atrao-Darien, Colombia for blood sampling and yellow fever (Clark, 1931), 25 spider monkeys were killed for entomological research at La Vaca River (Dunn, 1934), and seven were killed in San Blas Mountain Chain for parasitology studies (Thatcher and Poter, 1968). For serological projects leaded by ICGES, at least 49 individuals were killed in 1965 and 1966 (Galindo and Srihongse, 1967). Finally, 39 were killed for Indiana VSU antibodies studies in Cerro Azul, Pacora and Bayano (Srihongse, 1969). In total at least 188 individuals of *A. g. panamensis* were sacrificed for science.

5.3.9.7. IUCN Conservation Status

Ateles geoffroyi panamensis is considered as EN: Endangered (Cuarón et al., 2008).

5.3.9.8. Conservation Status Suggested by This Study

Ateles geoffroyi panamensis (Figures 5.18 and 5.19) should be considered as CR A2acd+3cd+4acd: Critically Endangered, Population reduction observed, may not have ceased, or may not be reversible. Based on direct observation, a decline in occupancy and habitat loss has occurred, and a real level of exploitation is present. Population reduction can be inferred up to maximum of 100 years, along with the level of exploitation.

Data obtained by direct observation shows evidence of decline in *A .g. panamensis* area of occupancy and exploitation. The main reason this taxa should be moved to a CR status is due to the high deforestation occurring in the Mesoamerican Corridor (McSweeney et al., 2014).

5.3.9.9. Present in the Following Reserves

In Panama, *Ateles geoffroyi panamensis* can be found in La Amistad International Park, Volcan Baru National Park, Palo Seco National Park, Santa Fe National Park, General de Brigada Omar Torrijos National Park (COPE), Portobelo National Park, Chagres National Park, Cocobolo National Reserve. *A. g. panamensis* is also present in the following regions in Costa Rica: The Protected Area of Las Tablas, Chirripo National Park, the Hitoy-Cerere Biological Reserve, Barbilla National Park, Rio Macho Forest Reserve, Tapanti National Park, all of them part of the Mundial Heritage Reserves at the Cordillera Talamanca, including La Amistad National Park (PILA for Spanish name) (Méndez-Carvajal et al., in prep.).

Figure 5.18. *Ateles geoffroyi panamensis*, Skin of Type Specimen No. 171489, from United States Natural Museum (USNM) (Left). *A. g. panamensis* in the wild (right). Courtesy of Roberto Portela Miguez, Curator, Mammal Section Life Sciences –Vertebrate Division, the Natural History Museum.

Figure 5.19. Cranium of *Ateles geoffroyi panamensis*, Type Specimen No. 171489, from Cerro Bruja, Colon, Panama. Courtesy of Roberto Portela Miguez, Curator, Mammal Section Life Sciences –Vertebrate Division, the Natural History Museum.

5.3.10 *Cebus capucinus*, White-faced Capuchin

5.3.10.1. Common Names

Mono cariblanco, capuchino, white-faced capuchin

5.3.10.2. Phenotypical Characteristics

Cebus capucinus has black pelage covering its body, with the exception of the hair on its pectorals, shoulders and the frame of its face, which is normally covered with yellowish hair. The skin of orbital and muzzle is white-pink, normally with brown-dark eyes. The type specimen is missing. There are some specimens at the US National Museum, the American Museum of Natural History, and the Museum of at Harvard University. **Body Measurements:** Not available.

5.3.10.3. Taxonomy

This species was first classified as *Cebus capucinus* (Linnaeus, 1758), then *Cebus hypoleucos* (Geoffroyi, 1813), *Cebus curtus* Bangs (1905), then as *Cebus capucinus* for the eastern part of Panama (Hershkovitz, 1949). In Panama, the FCPP follows the classification of Rylands et al. (2006), and supports that of *C. capucinus* as proposed by Boubli et al. (2012) and Lynch Alfaro et al. (2012) based on mitochondrial DNA (Figure 5.12).

5.3.10.4. Distribution

In Panama, *Cebus capucinus* has been reported in Darien province, San Blas, western Colon and Panama provinces (Clark, 1930; Taliaferro and Cannon, 1934; Courtney, 1950; Galindo and Srihongse, 1967; Taliaferro and Klüver, 1940; Fairchild, 1943; Porter and Young, 1966). It has been collected as part of efforts to study tropical diseases, and also for blood parasites experiments in central provinces of Panama (Sousa et al., 1974). The FCPP confirmed species presence in eastern Panama province, including Cerro Azul, Chepo, Cocobolo Nature Reserve, Bayano, Mamoni, Portobelo National Park, Colon province, Chagres National Park, Bagre, San Blas mountain chain, Maje Mountain Chain including Chucanti Nature Reserve (Méndez-Carvajal, 2012; 2014), Darien National Park and all forested areas in the province including Bajo Chiquito, Tuquesa, Pirre, Paya, Sapo, Piña, Jungurudu, Cocalito, Boca de Cupe, Tuira (Méndez-Carvajal, 2010; 2016). This species is also distributed in Colombia and Ecuador (Rylands et al., 2006) (Figure 5.20).

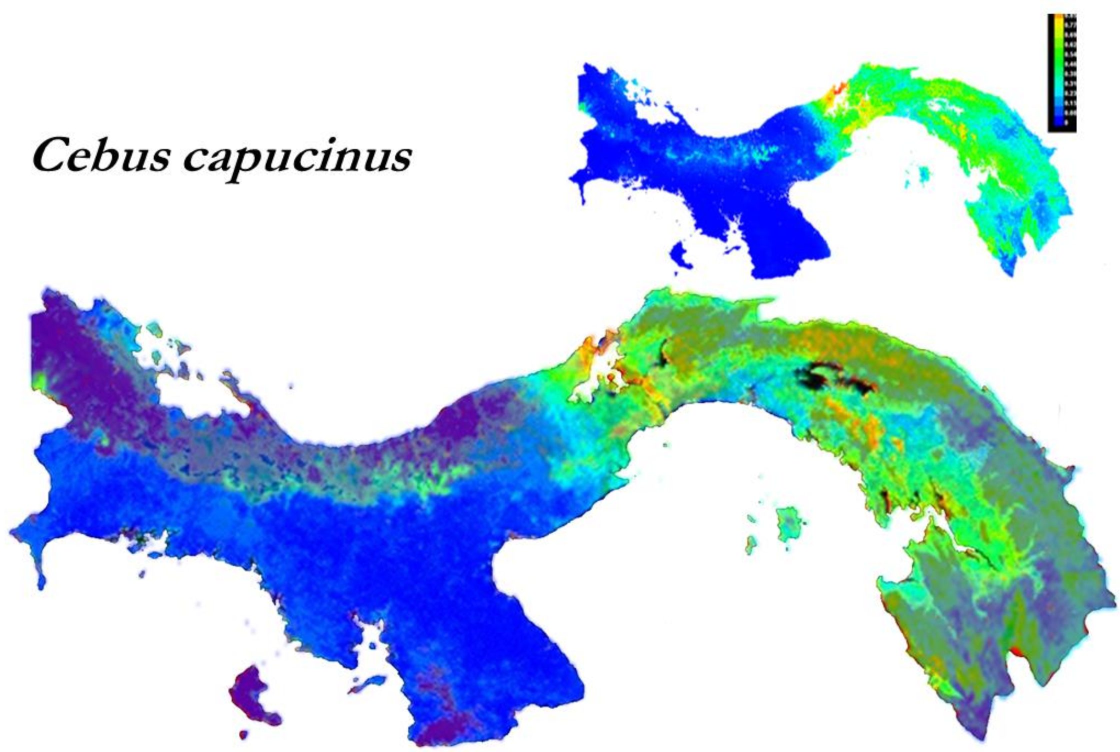

Figure 5.20. MaxEnt distribution map result *Cebus capucinus* (from Chapter 3), overlapped with forest cover map (orange/reddish) showing how the distribution of the species is matched with the vegetation.

5.3.10.5. Population

The total population of *Cebus capucinus* has densities of 0.43 ind/Km^2; N=12 (SD±3.5), with a range of 2-13 individuals per group (Méndez-Carvajal et al., in prep.). To obtain a rough estimate of the population of *C. capucinus*, I multiplied the area of forest coverage for its distribution (9,750 Km^2) by the estimated density 0.43. The resulting rough population estimate for *C. capucinus* was <4,193 individuals left within Panama (this considers only the connective forest areas in the natural parks of Panama).

5.3.10.6. Major Threats

Cebus capucinus has been facing hunting pressure by local people, with a rate of 20 individuals killed per year. It has even been extirpated from different regions in Chepo and Mamoni, near Cocobolo Reserve, as well as from the fragmented areas surveyed by the FCPP around Pacora, Jacuco, Torti, and Meteti (Méndez-Carvajal, pers.obs.). At least 78 individuals of *C. capucinus* were collected by ICGES for serological studies in Bayano, Sabana River, Rio Piedras, and Cerro Azul (Galindo and Srihongse, 1967). Another major threat to this species is logging activity in Darien, and being killed in agricultural areas due to crop-foraging (maize, sugar cane) (Loría and Méndez-Carvajal, in prep.).

5.3.10.7. IUCN Conservation Status

Cebus capucinus (Figure 5.21) is LC: Least concern. This criteria means that the species do not meet the requirements to qualify as a threatened taxon (Cuarón et al., 2008). As it is impacted by industries and illegal hunting pressure inside and outside Natural Reserves, its actual population is still likely to decrease or even disappear in certain regions.

5.3.10.8. Conservation Status Suggested by This Study

Cebus capucinus should be EN A2acd+3cd+4acd: Endangered, population reduction observed, estimated, inferred, or suspected in the past where causes of reduction may not have ceased or may not be understood or may not be reversible. Direct observation, a decline in area, occurrence or habitat quality. This primate also faces potential levels of exploitation. This species need to be evaluated with other collaborators from the other countries share distribution.

5.3.10.9. Present in the Following Reserves

Chagres National Park, Cocobolo National Reserve, Serranía San Blas, Reserva Natural Cocobolo, Bayano, Pacora, Chepo, Chiman, Achiotes, Colon, Gatun, Colon, Parque Nacional San Lorenzo, Monumento Natural Isla Barro Colorado, Panama Canal Watershed, Reserva Natural San Francisco de Asis, Reserva Natural Chucanti, Estacion Cientifica Punta Cana Serranía Pirre, Serranía Sapo, Serranía Jungurundu, Reserva de Bagre, Alto Darién, Parque Nacional Darién, Comarca Indígena Embera-Wounaan, CEMACO, Bajo Chiquito, Chepigana, Cocalito, Tuira, Boca de Cupe, Cruce de mono, Cana.

Figure 5.21. *Cebus capucinus*, Panama (left); Skull of a specimen from the Florida Museum of Natural History, Mammal Collection, University of Florida. Skull photo by P. Méndez-Carvajal. Courtesy of Verity Mathis, Manager, FMNH, Gainesville, Florida.

5.3.11 *Cebus imitator,* Panamanian White-faced Capuchin

5.3.11.1. Common Names

Mono cariblanco, carilla, mono blanco, Panamanian white-faced capuchin

5.3.11.2. Phenotypical Characteristics

Cebus imitator has black pelage over its entire body, except for the hair from pectorals, shoulders and frame of the face, which is normally yellowish. Skin of orbital and muzzle is white-pink, normally with brown-dark eyes. The type specimen is from Chiriqui province, Boquete, western Panama. It is secured at the British Museum Natural History, No.1903.3.3.13 (Napier, 1976). **Body Measurements:** No body measurements are available for this species.

5.3.11.3. Taxonomy

Cebus imitator was first classified as *Cebus capucinus* (Linnaeus, 1758), then changed to *Cebus capucinus imitator* in the western part of Panama (Thomas, 1903; Hershkovitz, 1949). Today classifications of the species in Panama, follow Rylands et al. (2006) classification, *C. imitator* as proposed by Boubli et al. (2012) and Lynch Alfaro et al. (2012) based on mitochondrial DNA.

5.3.11.4. Distribution

Cebus imitator has been reported in Bogomani, Chiriqui (Clark 1930: Dunn 1934), in Divala, Alanje, Puerto Armuelles (Baldwin and Baldwin, 1977), in Rio La Vaca, Coto (Carpenter, 1935), and Coiba Island (Milton and Mittermeier, 1977). *C. imitator* was collected in central provinces of Panama for blood parasite experiments (Sousa et al., 1974). The FCPP has confirmed the species presence in Bocas del Toro and Chiriqui Province, as well as in the Burica Peninsula, the La Vaca River area, Volcan Baru National Park, Cordillera Central Tabasara, San Pedro Island, Veraguas, Cocle, in the Azuero Peninsula, which includes Herrera, Los Santos provinces, Coiba and Jicaron Island, and also in Panama province (Méndez, 1970: Samudio, 2002; Méndez-Carvajal 2012). This species also maintains population distributions within Costa Rica and, to the north, in Nicaragua (Rylands et al., 2006) (Figure 5.22).

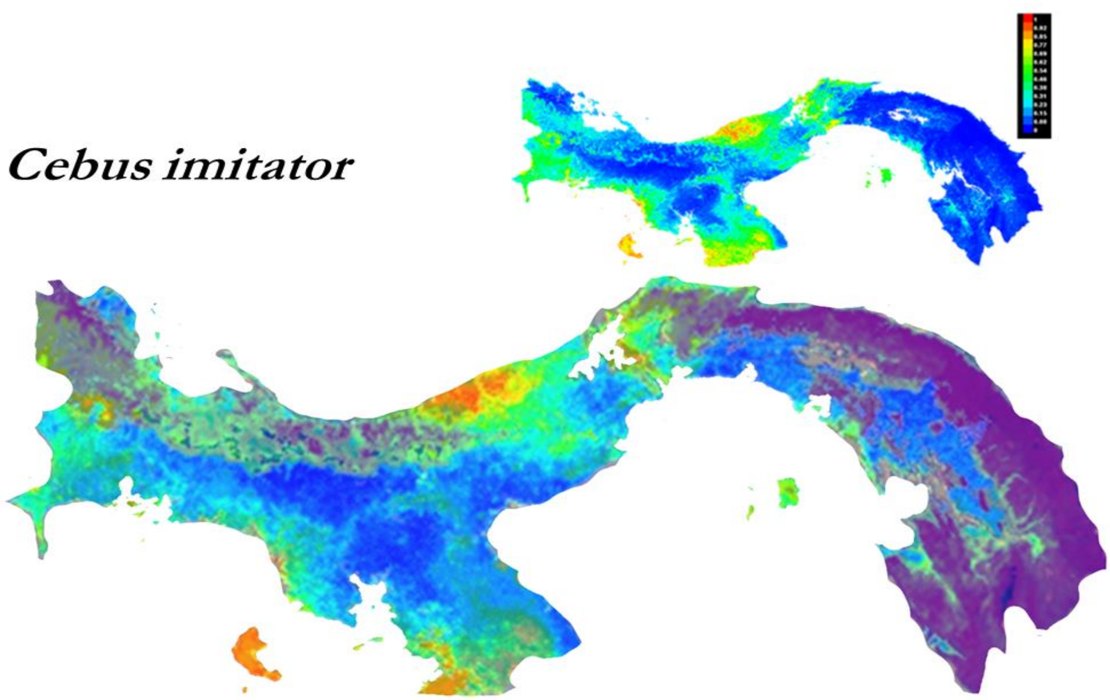

Figure 5.22. Distribution map result for *Cebus imitator* (from Chapter 3), overlapped with forest cover map (orange/reddish). This shows how the habitat suitability of the species matches with the actual vegetation.

5.3.11.5. Population

Densities of *Cebus imitator* vary according to region, but averages are calculated to be 0.24 ind/km2; N=8; SD±0.25; range = 4-20 individuals/group. The population of Coiba Island was calculated as being around 600 individuals, with 58 groups living on the island, and with each group having a mean group size of 10.75 individuals (range: 5–16) (Méndez-Carvajal, 2012). C. imitator has been facing hunting pressure by local people, and has been extirpated in regions of the Azuero Peninsula, dropping the species density to 0.025 ind/km^2 for fragmented areas surveyed by the FCPP. In general, using the forest coverage corresponding to its distribution (9,750 Km^2), and multiplying with actual density calculated 0.43 individuals/Km^2, I obtained a rough population estimate of <3,552 individuals in the wild.

5.3.11.6. Major Threats

In the agricultural and fragmented forest zones it inhabits, *Cebus imitator* is experiencing pressure. Differences between the two zones are almost imperceptible unless long-term observations track this species, which covers large areas searching for food (Méndez-Carvajal, 2010c). Their densities have been diminishing in places like Punta Burica, Chiriqui province, Herrera, Los Santos and Veraguas. The three provinces in the Azuero peninsula have the highest rate of deforestation and are the leading provinces where agricultural activities in the country are concerned (Méndez-Carvajal *et al*, 2013ab). In the highlands at Chiriqui and Bocas del Toro provinces, threats are related to Bonyic Project, the hydroelectric projects near or inside La Amistad International Park (PILA in Spanish), and in the Tabasara Mountain Chain, where the pressures are due to open mine projects that are causing patterns of fragmentation that extend into the Mesoamerican Corridor. In agricultural areas such as Boquete and Volcan, this species is reported to be under high pressure due to crop-foraging (Loría and Méndez-Carvajal, in prep.). Sightings of this monkey have been scarce in Rio Indio, Caño Sucio and Cocle del Norte from Colon province and north Cocle province, (Araúz *et al*., 2007). On Coiba Island, the FCPP confirmed that this species has adapted to eat coconut, and use anvils as a tool to break the coconuts that are growing alongside the coasts of the island

(Méndez-Carvajal and Valdés-Diaz, in prep.). For the Panama Canal Watershed, this species is still well conserved at the Soberania National Park, Camino de Cruces National Park, Achiotes, San Lorenzo National Park and in the forests near Gamboa (Méndez-Carvajal pers. obs.).

5.3.11.7. IUCN Conservation Status

Cebus imitator is LC: Least concern. This classification means that the species does not meet the requirements necessary to qualify for the status of a threatened taxon (Cuarón et al., 2008). The impacts of industries and illegal hunting pressures inside and outside the Natural Reserves are causing its actual population to decrease or regionally disappear. Strategies for its conservation have been started by the FCPP, including environmental education in Chiriqui province (radio, community talks and newspaper articles). The FCPP has initiated a long-term project (Proyecto de Conservación del Mono Cariblanco en Agroecosistemas-FCPP), to mitigate the influence of *C. imitator* in agricultural areas, monitoring habitat use, activity patterns, and crop-foraging by using canopy-level camera traps (Loría and Méndez-Carvajal in prep.).

5.3.11.8. Conservation Status Suggested by This Study

Cebus imitator (Figure 5.23) should be VU A3cd: Vulnerable. The best available evidence indicates that the species meets any criteria A to E for Vulnerable, and should therefore be considered as facing a highest risk of extinction in the wild. (A3cd) Population reduction can projected, inferred, or suspected to be met in the future (up to a maximum of 100 years), as can decline in area of occupancy, and real levels of exploitation.

5.3.11.9. Present in the Following Reserves

Cebus imitator can be found in La Amistad International Park, Volcan Baru National Park, Chorogo National Reserve, Corpachi Trail, Punta Burica, Palo Seco National Park, Santa Fe National Park, General Omar Torrijos National Park (COPE), Portobelo National Park, Soberania National Park, Camino de Cruces National Park, Cerro Hoya National Park, La Tronosa Forest Reserve, El Montuoso Forest Reserve, El Tijeras Private Reserve, Campana National Park, Panama Canal Watershed, and Isla Coiba National Park.

Figure 5.23. *Cebus imitator* eating Inga spp. Photograph by Miguel Siu.

5.3.12 *Saguinus geoffroyi*, Geoffroy's tamarin

5.3.12.1. Common Names

Red-Crested Bare-Face tamarin, Rufous-Naped tamarin, mono tití, Geoffroy`s tamarin.

5.3.12.2. Phenotypical Characteristics

Saguinus geoffroyi has white hair with slight yellow on the ventrum, the distal part of the limbs and hands, and bordering the face. Its neck hair is mahogany in colour, and the dorsal and lumbar areas have a mixed black and yellow colouration. The hair of the head is short with a white line of hair in the frontal part. The skin of the face is dark grey, similar to the hands and hind limb skin. The tail is bicolour, with the first base half mahogany and second tip half black. It lacks a prehensile tail. The type specimen is from Panama Canal Zone, Panama province, Panama. It is secured at the Paris Museum Natural History as *Hapale geoffroyi* (*Saguinus geoffroyi*), MNHN-ZM-2007-1530, female, Origin: Panama; collector; Courtine. This specimen died in the menagerie of the Museum on August 25 1845. It is preserved as a mounted skin: the skull has been removed, and is not available. **Body Measurements**: Body measurements are not available.

5.3.12.3. Taxonomy

This species was first classified as *Saguinus geoffroyi* (Pucheran, 1845), followed by Hershkovitz (1949). There have been several changes in its taxonomy; *Oedipomidas spixi*, *Midas geoffroyi* (Reichenbach, 1862; Hill, 1957; Rylands et al., 2006), *Simia geoffroyi* (Humbolt, 1812; Cabrera, 1940), then *Marikina geoffroyi* (Hershkovitz, 1949), *Leontocebus geoffroyi*, then, *Oedipomidas geoffroyi* (Elliot, 1912; Rylands et al., 2006).

5.3.12.4. Distribution

Saguinus geoffroyi is distributed throughout a zone running from the central provinces of Panama to Colombia. In Panama, this species inhabits all of Darien province (Anthony, 1916; Goldman, 1920; Allen and Barbour, 1923; Samudio, 2002; Moreno, 2006, 2008; Méndez-Carvajal, 2012, 2014), Panama province, including forested areas into the Panama City such as Ancon Hill and Metropolitan National Park (Méndez, 1970; Glanz, 1992; Méndez-Carvajal, 1999), and the Panama Canal Watershed (Méndez-Carvajal, 2013, 2014). The Western distribution extends to Arraijan, Chorrera, Puerto Caimito, San Carlos, Bejuco, Capira, Campana National Park, Coronado, San Carlos, Picacho, Las Lajas, Cocle province including Anton, Penonome, Cope National Park, Donoso, Colon province (Araúz *et al*., 2008; Méndez-Carvajal, pers. obs.). It is not found naturally in Azuero Peninsula, but two adult females and two adult males of this species were recorded in captivity in Ocú, Santa Monica Farm (Méndez-Carvajal, 2005; Méndez-Carvajal, 2011). In 2008, local people attempted to introduce *S. geoffroyi* at Flores, Veraguas and Cerro Culón (part of west of Azuero Peninsula), but this attempt was apparently unsuccessful (Méndez-Carvajal, 2008). Contrary to what has been reported (Groves, 2005), the species is not present along the Panamanian-Costa Rican border, and potentially has been wrongly identified as present in that area due to a misunderstanding with the local name of *Saimiri oerstedii*, which is also called titi monkey by the Chirican people. Confirmed limits for this species in Panama are: North; Colon Province and San Blas-Guna Yala, South: Darien, Panama province. In Panama, its eastern limit will be the Darien frontier with Colombia, and the western limit will be La Tabila and Rio Indio, Cocle province (Araúz *et al*., 2008) (Figure 5.24).

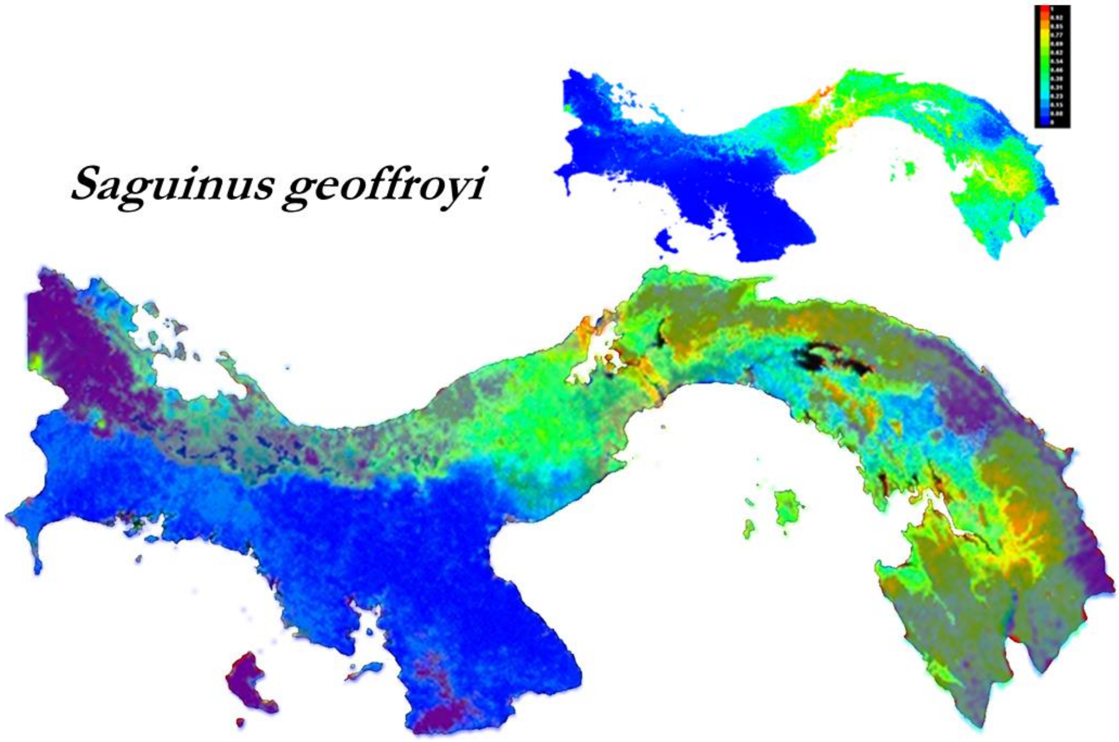

Figure 5.24. Distribution map result of *Saguinus geoffroyi* (from Chapter 3), overlapped with forest cover map (orange/reddish) to recognize how the distribution of the species match with the actual vegetation.

5.3.12.5. Population

The Panamanian population of *Saguinus geoffroyi* consists of approximately 5,250 individuals, a figure generated from 20 specifics densities in various reserves, urban and protected areas (85% of the natural distribution in Panama). Densities obtained are (0.50±0.51 ind/km^2) N=6 for urban forest in Panama province, (0.133±0.08) N=5 for agricultural and logging zones, and (1.53±5.59 ind/km^2) N=16 for forested areas. I obtained density range of 0.03 to 1.5 ind/km^2 for Darien province (Méndez-Carvajal, 2012; Moreno, 2006), which appears to be decreasing compared to data recounted in a review carried out in the 1920s (Allen and Barbour, 1923). The FCPP's work on the densities of *S. geoffroyi* indicated that its populations in urban areas were becoming overcrowded, due to habitat reduction. Results from Penonome (Cocle province) showed densities ranging from 0.03 to 0.125 ind/km^2, and 0.02 to 1.5 ind/km^2 for ANCON Hill and Balboa area at Panama Canal Zone (Méndez-Carvajal *et al.*, in prep.).

5.3.12.6. Major Threats

Like so many other Panamanian primates, *Saguinus geoffroyi* faces threats from deforestation, hunting, road traffic accidents and environmental degradation. Deforestation through farming, cattle ranches, teak plantations, urban investments, mines, hydroelectric and other industrial activities is only one major threat this species faces. In Bajo Chiquito, Cemaco, north of Darien province, the Embera-Wounaan indigenous reserve has been a part of the logging activity led by the United States Agency of International Development (USAID) and its Community Forestry Program (FCP in Spanish), causing forest fragmentation of 4.72 km^2 of Tropical Rain Forest of the Darien-Choco forest corridor, Tuquesa watershed. This has put arboreal fauna at risk and has compromised the re-colonization of arboreal mammals within this region (Medina, 2013; Méndez-Carvajal, 2014). Hunting, another threat to the species, takes place for a number of reasons, including the acquisition of protein resources by indigenous from Guna Yala, and also to supply pet trade. In the Panama Canal Watershed, *S. geoffroyi* has been listed as one of the twelve mammal species local people from eight communities prefer to hunt, obtaining a poaching intensity score of 4.0 (range 0-5; n=2 years), while other parts of the country obtained the category of "rarely hunted" (Wright et al., 2000). Road kills continue to exact to a toll on this species, which has been suffering road killing along such highways as Soberanía National Park, Gaillard-Madden road which connect Panama City and Chilibre with Camino de Cruces Natural Park and Gamboa town (Méndez-Carvajal, pers. obs.). *S. geoffroyi* has been found killed in North and South corridors, highways that connect Panama City with Colon province and Tocumen Airport. Others have been road killed at the Metropolitan Natural Park (Méndez-Carvajal, 2001). The ecological factor must also be taken into account: studies on Barro Colorado Island in the Panama Canal have shown that high canopy there may not be suitable for *S. geoffroyi*, thus, vegetation could be an important factor when using landscape characteristics to determine species presence, abundance or absence. At least 42 individuals of *S. geoffroyi* were killed for serological projects by the ICGES (Galindo and Srihongse, 1967).

5.3.12.7. IUCN Conservation Status

Saguinus geoffroyi (Figure 5.25) is classified as **LC**: Least concern. This means that the species does not have what is required to qualify for the status of a threatened taxon (Cuarón et al., 2008). The number of individuals per group is decreasing compared with old reports on mature forest like Chucanti, and Tortí from Darien province (Méndez-Carvajal, 2014). Additionally, populations of *S. geoffroyi* have been suffering isolation through loss of natural habitat due to urbanization activities in the areas between Las Cumbres, Pacora, loss of mangroves and secondary forests due to the Panama City Airport expansion. The Petaquilla Gold S.A. and Minera Panama S.A run large-scale mining extraction projects for cooper and gold and are located in the centre of the Mesoamerican Biological Corridor, a massive area of Tropical Rain Forest that should theoretically be protected. Densities of *S. geoffroyi* in Barro Colorado Island and Soberanía National Park have been decreasing slightly year by year to 56% of its original population (Méndez-Carvajal, pers. obs.). However, this number is not influenced by anthropogenic effects but rather by habitat condition preferences. In the forest of Darien the species is threatened by both daily illegal logging and legal timber exploitation and hunting (Méndez-Carvajal, 2014).

5.3.12.8. Conservation Status Suggested by This Study

S. geoffroyi should be considered **NT**, or Near Threatened: it is a taxon that has been evaluated against the criteria but does not, for now, qualify for Critically Endangered, Endangered or Vulnerable status. It could be, however, close to qualifying for or is likely to qualify for a threatened category in the near future.

5.3.12.9. Present in the Following Reserves

The presence of this species has been detected in Omar Torrijos National Park, San Lorenzo National Park, Campana National Park, Ancon Hill, Soberania National Park, Camino de Cruces National Park, Chagres National Park, Metropolitan Natural Park, Cocobolo Natural Reserve, and Darien National Park.

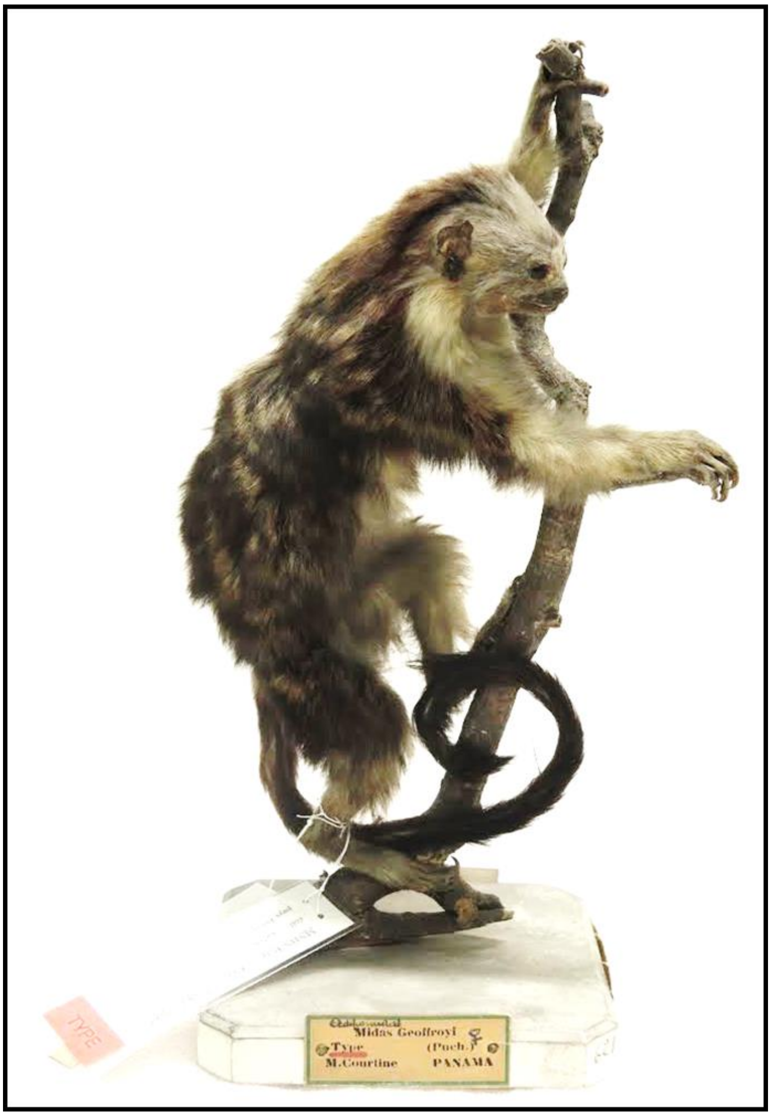

Figure 5.25. Type Specimen of *Saguinus geoffroyi* Courtesy of Cecile Callou, Manager Collection, MNHN, Paris, France.

5.3.13 *Saimiri oerstedii oerstedii,* Black-crowned Central American squirrel monkey

5.3.13.1. Common Names

Chiriqui titi monkey, Red backed squirrel monkey, Central American Squirrel monkey, Gothic squirrel monkey, and black-crowned Central American squirrel monkey

5.3.13.2. Phenotypical Characteristics

Saimiri oerstedii oerstedii has short orange hair on its limbs and main body. The dorsal area is more reddish, with its chest and throat being white, while the black crown displays a widow's peak. This last characteristic has given the species the name of Gothic squirrel monkey. The orange pelage could be intermixed with olive or brown hair, or yellow, giving the animal a somewhat green shade in the legs. The face is white with obscured eyes surrounded by pink skin, while the muzzle is black. The type specimen is from David, Chiriqui province, Panama, and was captured at some time between January of 1847 and 1848. It was processed on September 25 of 1849 by Prof. Anders Sandoe Ørsted. Type specimen ZMUC No. CN 48 is preserved at the Natural History Museum of Denmark, Zoological Museum, Københavns Universitet. **Body Measurements:** body measurements are not available in this case (Figure 5.26).

5.3.13.3. Taxonomy

Saimiri oerstedii oerstedii was initially classified as *Chrysothrix örstedii* (Reinhardt, 1872), followed by *Saimiri oerstedii* (Hill, 1960). More recently, it has been considered to be two subspecies: *S. o. citrinellus* and *S. o. oerstedii* (Hershkovitz, 1984; Groves, 2005; Rylands et al., 2006).

5.3.13.4. Distribution

Saimiri oerstedii oerstedii has been reported in Chiriqui province, Panama, specifically near El Progreso, El Pital, and Puerto Armuelles, Coto and Rio La Vaca (Clark, 1934, Dunn, 1934; Carpenter, 1935; Méndez, 1970; Baldwin and Baldwin, 1977). It occurs in Burica, Renacimiento, Guarumal, Gariché, Boquerón, Alanje, David, Concepción, and Jacú, and there are, potentially, smaller populations occurring in fragmented forests throughout 11 different places in Chiriqui province (Rodríguez-Vargas, 2003; Miranda-Jiménez and Méndez-Carvajal, 2011, 2012ab). *S. o. oerstedii* is endemic to Costa Rica and Panama (Figure 5.26).

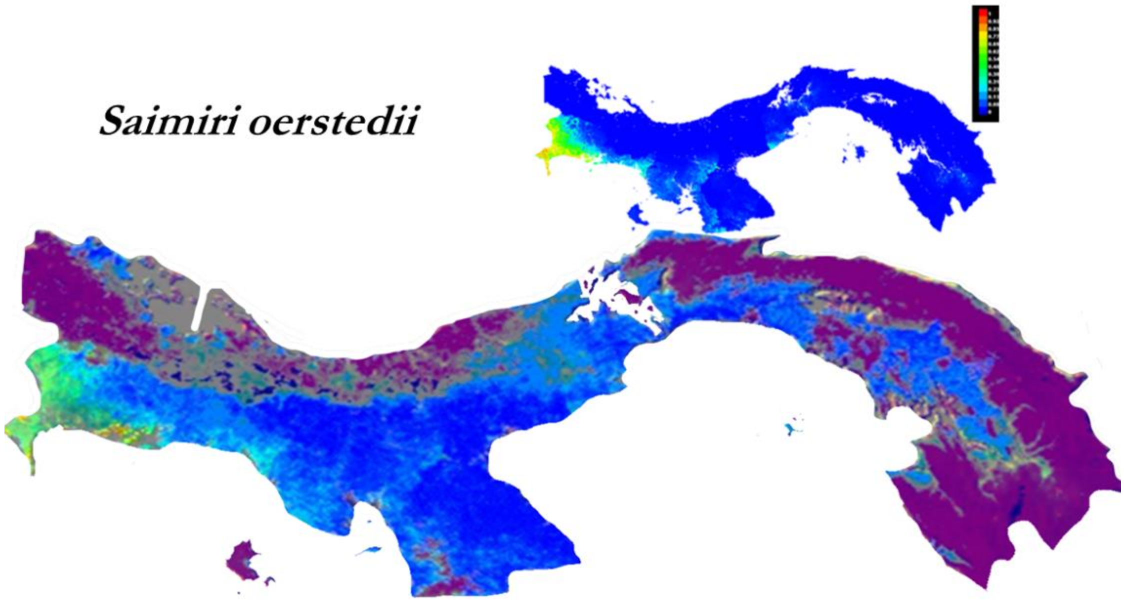

Figure 5.26. Distribution map result for *Saimiri oerstedii oerstedii* (from Chapter 3), overlapped with forest cover map (orange/reddish) to recognize how the distribution of the species match with the actual vegetation.

5.3.13.5. Population

In 2010, I started a long-term primate project at the Chiriqui titi monkey project "Proyecto de Conservación del Mono Titi Chiricano" or "Project for the Conservation of the Titi Monkey" (*Saimiri oerstedii oerstedii*). The goal of this project was to assess the species' current population and apply relevant conservation activities. *S. o. oerstedii* was found to have a total of 4,750 individuals and an average number of 15-18.5 ind/group (Rodríguez-Vargas, 1999, 2007). However, new calculations from this study determined, by multiplying the forest coverage correspondent to its distribution (2,613 Km^2) and multiplying with its mean density of 0.19 individuals/Km^2, that a rough population of <496 individuals remained in the wild. Based on preliminary results from 2010 to 2016, I conclude that *S. o. oerstedii* is remaining in the wild with an average of 49.4 ind/group (n=12, SD±41) for connected forest, as in the Reserva Chorogo and Burica Peninsula, Chiriqui province, and between 7-20 ind/group for populations in fragmented forest (Méndez-Carvajal, 2014; Miranda-Jiménez *et al*., 2014).

5.3.13.6. Major Threats

The titi monkey (*Saimiri oerstedii oerstedii*) is threatened by deforestation, agro-chemical pollution and the pet trade. Deforestation, in this case, involves the following activities: farming, cattle ranches, teak plantations, palm oil plantations, urban investments, hydroelectric and other industrial activities (Miranda-Jiménez and Méndez-Carvajal 2012; Méndez-Carvajal *et al*., in prep.). In Charco Azul, Puerto Armuelles, and on the Pacific Coast of Burica Peninsula, the Petroterminal Panama S.A. has, in combination with Northville Industries from United States, been generating significant impacts on local natural habitats. As this species is mainly insectivorous-frugivorous, individuals of *S. o. oerstedii* may have been exposed to pesticide contamination in lowlands. This is increasing year by year, underlining the threat contamination from agrochemicals poses to the species. Six individuals were recently confiscated from persons involved in the pet trade by the ecological police on the Panamanian-Costa Rican border. These monkeys were then returned to their habitat, but the case highlights the threat that the pet trade poses to *S. o. oerstedii*.

5.3.13.7. IUCN Conservation Status

Saimiri oerstedii oerstedii (Figure 5.27 and 5.28) is VU Vulnerable: the best available evidence indicates that it meets any of the criteria A to E for Vulnerable, and should therefore be considered as facing a high risk of extinction in the wild. The population of *S. o. oerstedii* has been decreasing dramatically since it was last evaluated (84%), and it has already been eradicated from at least three locations where it was previously recorded as present. Although various survey methods have been applied between Rodríguez-Vargas (2003) and Méndez-Carvajal *et al*., (in prep.), high levels of deforestation have been occurring in Panama since 2009, when forest cover had slightly recovered from 2005 (45%) to 2009 (52%) according to the Panamanian National Association for the Conservation of Nature (ANCON). The new action plans for reforestation by the Panamanian government in 2014, however, involve using a monoculture of a million hectares of Teak Plantation in order to reforest Panama, which represents a significant threat to the biodiversity of the country. As *S. o. oerstedii* already has a reduced regional endemism and the future of the nearest continuous forest is uncertain, we propose that this species should be up-listed from Endangered to Critically Endangered by IUCN (Méndez-Carvajal, pers. Obs.).

5.3.13.8. Conservation Status Suggested by This Study

Saimiri oerstedii oerstedii should be EN A2acde+ B1ab(ii,iii): Endangered, population reduction observed, estimated, inferred, or suspected in the past where causes of reduction may not have ceased or may not be understood or may not be reversible. (**A2acde**): Direct observation, a decline in area, occurrence or habitat quality. This primate also faces actual potential levels of exploitation. This species need to be evaluated with other collaborators from the other countries where it is found. Effect of introduced taxa (*Saimiri oerstedii citrinellus*), interaction with parasites can affect the population. (**B1ab (ii, iii)**): Geographical information, extent of occurrence, severely fragmented, and continuing decline.

5.3.13.9. Present in the Following Reserves

Chorogo Natural Reserve, Sendero Natural Corpachi de Limones, Santuario Mono Feliz de Burica.

Figure 5.27. *Saimiri oerstedii oerstedii*, Chiriqui province, Panama.

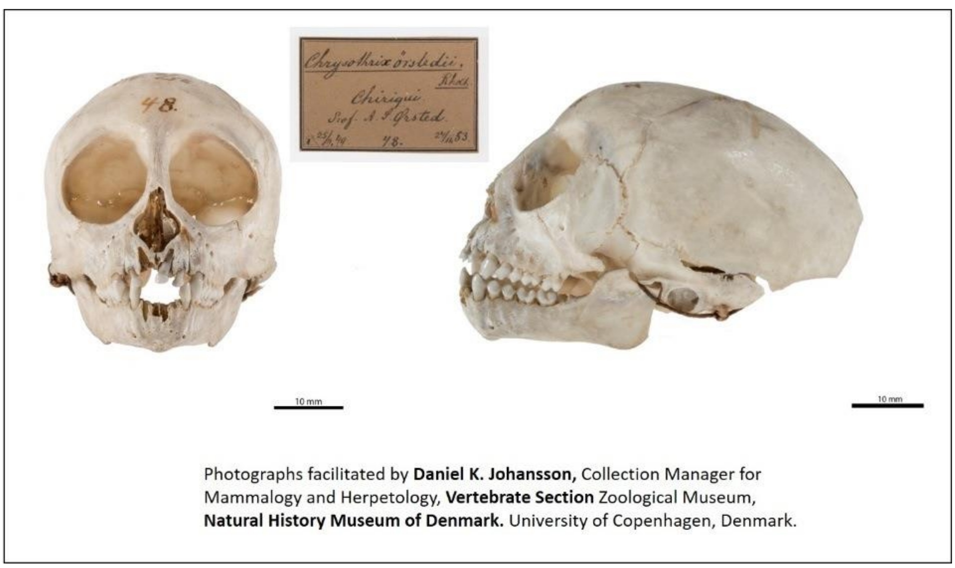

Figure 5.28. Type Specimen of *Chrysothrix orstedii* (Reinhardt, 1872).

5.3.4. Densities and Total Population per Subspecies

A total of 273 strip transects were completed for nine provinces and three indigenous reserves, with at least an hour's effort being expended in each location: Bocas del Toro and Chiriqui (648), Veraguas (1,560), Cocle (360), Los Santos and Herrera (12,184), Colon (144), Panama (1,440), San Blas Guna Reserve (1,152), Darien (2,160), Cemaco Embera-Wounaan Reserve (960), totalling 20,308 hours efforts in 15 years long term data. This research covered the following protected areas: La Amistad International Park, Isla Coiba National Park, Chorogo Forest Reserve, Volcan National Park, La Tronosa Forest Reserve, El Montuoso Forest Reserve, Cerro Hoya National Park, Santa Fe National Park, General Omar Torrijos National Park, Campana National Park, Soberania National Park, Camino de Cruces National Park, Metropolitan Natural Park, Barro Colorado Natural Monument, Chagres National Park, San Lorenzo National Park, Portobelo National Park, Cocobolo Natural Reserve, San Francisco de Asis Natural Reserve, Chucanti Natural Reserve, Darien National Park (Table 5.2. Shows those provinces where each subspecies was detected).

Table 5.2. Provinces where each subspecies was detected. NST: Number of Strip transect; TPE: Total population. BC(Bocas del Toro), CO(Cocle), CH (Chiriqui), VE(Veraguas), HE(Herrera), LS(Los Santos), CN(Colon), PA(Panama), GY(Guna Yala), DA(Darien). The gray squares indicate presence of the primates. Detections per methods are explained well in Chapter 3, Tables from 3.1 to 3.9.

# NST	Subspecies	BC	CO	CH	VE	HE	LS	CN	PA	GY	DA	Total area (km^2)	Grand Average Density ± SD	TPE
13	*Aotus zonalis*											10,500	0.19±2.0	1995
15	*Saimiri oerstedii*											2,613	0.19*	496
13	*Saguinus geoffroyi*											10,500	0.5±4.2	5,250
8	*Alouatta palliata palliata*											14,000	0.4±8.7	5,600
33	*Alouatta palliata aequatorials*											9,750	0.5±0.8	4,875
4	*Alouatta coibensis coibensis*											523	0.8±0.03	<420
12	*Alouatta coibensis trabeata*											450	5.2±4.8	2,340
12	*Ateles geoffroyi*											87	1.4±1.5	121

	azuerensis													
18	*Ateles geoffroyi panamensis*											15,000	0.21±0.47	3,150
12	*Ateles geoffroyi grisescens*											9,750	0	0
11	*Ateles fusciceps rufiventris*											9,750	0.19±3.5	1,850
11	*Cebus capucinus*											9,750	0.43±3.5	4,192
25	*Cebus imitator*											14,800	0.24±0.25	3,552
	# of Towns surveyed	**7**	**45**	**12**	**45**	**58**	**39**	**9**	**18**	**2**	**38**			

5.4 Conclusion

In this chapter I have updated the information for distribution, population, actual threats and conservation activities currently on going in relation to 13 subspecies of non-human primates in Panama. A major goal of this chapter and the work it describes has been to improve the evaluation of the conservation status of those 13 non-human primate subspecies. Panamanian primates include nine species, and 13 subspecies, but in Mesoamerica, most of them vary in requirements as found in this study (Chapter 3). They may even share the same ecosystem while differing slightly in lifestyle, group organization, home range and survival needs. One of the key pieces of information necessary for the assessment of primate species' status is an estimation of population density and the relative total population of the species. The IUCN should focus on the first group of categories, so as to measure population reduction, and recognize if the causes of this effect in the species or habitat will be reversible over the long or short term. I have presented in this chapter the calculations of the relative total population of the primates in Panama, stressing their threatened categories. In general, knowledge of the numbers of individuals per species could be helpful to maintain a long-term monitoring system that will keep Panamanian experts 'on alert', and help inform those authorities related to a species and their habitats and the threats. There are some species that used to enjoy apparently good stability, but are now listed among the threatened species. The second contribution made with this chapter was the compilation of published information that had, previously, been dispersed or lost due to the difficulty involved in obtaining old documents or access to the internet. The information will encourage scientists and authorities in Panama and at international level to recognize necessary priorities in the study of non-human primates in the Neotropics and develop a more scientific approach to primatology. The long-term monitoring proposed in this thesis, based on several methods that can be applied in as many areas as possible around the country but, will help guide the promotion of conservation efforts, with special attention on landscape and on also on the neglected ecology of the arboreal fauna and their forest canopy homes. This is really important to understand if we want to know how the natural processes of regeneration, mammal interactions and agonism induced stress occur in reduced areas and fragmented landscapes. This overview does not assume the species will automatically be saved if they are inside the reserves, but it has also made an attempt to analyse the ones that are outside those reserves and living in the middle of crop fields, making evaluation of their conservation statuses more realistic. Results from the study of the people`s perception of primates in Azuero underlines the point that an ethnoprimatological approach should be applied for each region, to understand how the people think about the primates that surround them, and how anthropogenic pressure can be expected to change (or not change) in future. Such an approach will allow us to predict, in a better way, what is happening in each case for each subspecies. The idea is to have this evaluation at the subspecies level because Panama has a very regional population; each part of the country is full of region-specific traditions that are part of the country's diversity of cultures. Panama, however, has never looked at nature as a potential source of income, until the present day, when eco-tourism has emerged as an economic activity. There are other practices that could damage the remaining populations of primates. This chapter provides, therefore, a better idea about what we have and a guide for other researchers seeking to focus their efforts without losing time. With this in mind, we (national, international researchers, government, and private companies) can all together develop in same direction, towards better conservation activities and research for each subspecies in Panama. This material will also support conservationists by providing them with scientifically-informed arguments they can use when speaking out to defend forests from destruction.

6 Discussion and Conclusion

6.1 Introduction

This thesis has evaluated the ecological aspects of primate distribution and population in Panama, and has reviewed the past and present factors influencing the conservation status of the Panamanian primates, including human perceptions of wildlife in the area of Panama which suffers from the country's worst level of habitat fragmentation. In the fifth, penultimate, chapter of this thesis, I provided an up-to-date evaluation of the conservation status of the Panamanian primates using both the IUCN criteria of 2001 and my own parameters: I used these latter parameters as a new proposed method for quickly establishing the conservation status of a species by taking into account specific aspects of that species' condition. A significant part of the methods I used involved the investigation of attitudes towards primates held by local people in those communities adjacent to primate ranges. I found that although some local people held positive attitudes towards primates and were motivated to help animals, some human activities could also exert negative effects on primates. Some individuals, for example, reported feeding bananas or restaurant left-overs to primates, or even asking people to capture monkeys in other areas in central Panama to translocate them to their land. They subsequently said that they had been unaware that these activities could have a negative effect on primates: this is one just one example of the need for education regarding these aspects of relations between human and non-human primates. Farmers, meanwhile, pointed to a lack of governmental attention to the problems farmers face in carrying on agricultural production, and considered the presence of vegetation as negative, arguing that the shade produced by the trees (and which primates need) kills the grass that the cattle need for grazing. They also argued that trees roots absorb water from the land, leaving domestic animals dehydrated, belief that is generally prevalent in the Azuero peninsula (Heckadon-Moreno, 2001; González, 2002; Méndez-Carvajal, 2005). Perceptions of wildlife held by the people of that peninsula (the Azuerenses) are an important factor to consider if we hope to maintain and increase primate populations in that area. Environmental education in that region of Panama is made even more important by the fact that Azuerenses people are migrating to other parts of the country, and may bring to their new homes the same problems as in the peninsula, including fragmentation and habitat loss. In 2001, I found that there was a lack of knowledge about the importance of trees, wildlife and basic biological information, in addition to the value of primates as important seed dispersers. I learned from this preliminary research that environmental education is a long-term challenge, where local people will have varying reactions to the educational material or new information disseminated to them. If, however, the educational material or activities used in a community include themes or topics that are directly related to their culture, then the members of that community will tend to pay more attention to the educational efforts. Eventually, they will incorporate those ideas and that information into their everyday lives, making them enthusiastic and ready to help the cause of primate conservation. To achieve this outcome, a commitment is required from each person who practices conservation – a commitment to invest time in designing different, and appropriate, techniques for making local people aware of the importance of their natural environment. We need, in other words, to create effective forms of management that will aid people in quantifying and preventing damage to their local, natural environment, and its native primate population (Else and Lee, 1986; Pirta et al., 1997; Lee and Priston, 2005).

My subsequent evaluation, in 2016, tested how Azuerenses people currently perceive primates. Most people explained that they consider primates to be animals that bring them happiness, that remind them of their day-to-day duties, and are amusing; they told me, in short, that they like having them around. However, problems have been increasing as wild primates have been getting closer to human property (trespassing on the kitchens of people's homes, their cars, or houses), due to deforestation in the few patches of forest that remain in the Azuero peninsula. My evaluation, therefore, aimed to understand how people's attitudes about the forest have changed, and whether people have retained information from my community talks and newspaper publications. My plan, in the short term, is to increase the intensity of education for adults aged between 19-49 years, as my results showed that this demographic is less informed about the value of the natural vegetation around them, while also being highly important to decision-making in their communities. It is important, also, to include women, as my interviews showed women to have greater consciousness of the value of nature, at least if compared to men's pragmatic and practical attitude to the use of nature and its resources.

Species distribution and population dynamics are important in conservation planning (Nichols and Williams, 2006). The presence of primate species in a given area is related to food availability, which is related, in turn, to environmental variables (Campbell et al., 2016). Consequently, understanding the key environmental variables underlying primate distribution is a very important issue for conservation (Ciochon and

Nisbet, 1998; Thorn et al., 2009). Humans transform the landscapes around them, and in so doing directly affect the distribution of non-human primates. It is therefore vital to involve local people in conservation activities, and to understand local human perceptions of wildlife, as this will help to detect any implications, misconceptions, or negative behaviours that may impact on wildlife and forest resources. It is relevant, here, to encourage increased mutual cooperation, producing positive changes in local peoples' behaviour (Chapman and Peres, 2001; Kerr and Ostrovsky, 2003). This final chapter reviews my main findings based on species distribution modelling (Chapter 3), and provides a test of activities in primate conservation that could be a source of alternative methods for obtaining information on primate populations, an important aspect in assessing the level of risk a species faces.

6.2 MaxEnt Species Distribution Modelling: its Application to the Understanding of the Distribution and Species Richness of Primates in Panama.

An underlying assumption of land change science is that animal use of habitats is determined by the ways key environmental variables modify the distribution and abundance of species across landscapes without bringing other variables into play (Turner et al., 2007). The results presented in Chapter 3 of this thesis evaluate the species distribution models of Panamanian primates using Maximum Entropy techniques. I found that anthropogenic variables, in particular human population and indigenous reserves, negatively affect primate populations when people consume primates. NDVI modifies the habitat suitability for the subspecies tested with more definition than EVI. This, in turn, matches other studies of species distribution (Kerr and Ostrovsky, 2005). NDVI data are derived from satellite imagery, a method which entails some disadvantages, the most important of which is cloud colour interfering with the imagery's layers (Petrorelli et al., 2006). It is still possible to obtain good models using only environmental variables if a species has a large distribution (e.g., *Ateles* or *Alouatta*). For example, a distribution model for *Ateles geoffroyi* in Mexico produced distribution maps without vegetation indexes of anthropogenic variables due to the large distribution of that species (Vidal-Garcia and Serio-Silva, 2011). However, for primates under pressure from poaching, or in the case of studies of several species, it is better to understand the anthropogenic variables recommended in this study because this will generate a more realistic output, and will allow the detection of areas where the species could be influenced or affected by human activities. One example is the evaluation of the distribution of three species of *Nycticebus* in Borneo (Thorn et al, 2009). In Panama, primate distribution depends on three variables: Mean Diurnal Range, Temperature Seasonality, and Precipitation Seasonality. Models two and three, as used in this thesis, are adding other limitations which have helped the present author to obtain a better omission curve and training gain, making the programme more effective. Species distribution patterns are likely to be related to food availability and phenology, but more research on this aspect needs be done on a long-term scale (Chapter 3). The information used in advance to compare the data generated from MaxEnt by using the information presented in Chapter 5, is relevant here, as at least one of the species was not expected to be there. For measuring the effectiveness of the models, researchers should take care to employ the best possible graphs of omission and predicted areas, as this will serve to refine new models.

Use of the auxiliary SDM toolbox helped me realise the importance of vegetation in maintaining primate's biodiversity, was important to recognize the zones in the country where the protection of primate diversity was most convenient. The Panama (northern area) and Darien province are the most diverse areas in Panama, in terms of primates, with six subspecies present in those areas. This is to be expected, because these areas are connected to the Colombian department of Choco, a region famously rich in biodiversity. This means that those areas will serve as a donor habitat, from where species will continue to coming north from South America. The Mesoamerican Biological Corridor needs the central area of Panama province and Darien province for forest continuity. The diversity maps are valuable for conservation, identifying places for translocations that eventually will be needed for the management and planning the reintroduction or introduction of primate species to particular areas. In particular, theywill help prevent the introduction of primate species into the wrong habitats, and also for monitoring programs for those species currently bearing threatened statuses according to the IUCN categories. An extra effort in the field is recommended, so that areas that have not yet been visited can be surveyed to verify the presence or absence of primate species. In Panama, these include areas in the mangroves bordering the Montijo Gulf and Mosquitoes Gulf: these are of importance as they have already been marked, according to the program, as habitats suitable for primate species such as *Alouatta* and *Cebus*.

6.3 Evaluation of Local Peoples' Perceptions Living in Fragmented Habitats Interacting with Non-Human Primates Population

Changes in how people manage or use nature are a major concern for conservation, as people's need for food, benefits, or income can lead to deforestation (Fuentes and Hockings, 2010). Local people are crucial for conservation, and education is the most important factor in improving their perceptions of nature, which make local people conscious of the long-term benefits of being surrounded by vegetation (Jacobson et al., 2007). Income generation for local people can be important (Horwich and Lyon, 1986), but training to increase local knowledge about their resources is more powerful than money in conserving natural resources (Horwich et al., 2013). In this project, I have used structured and informal interviews to evaluate the knowledge and perception of local people in a deforested area of the Azuero peninsula, a region where I have been promoting the conservation of two critically endangered primates for 15 years. I investigated the Azuerenses people's points of view about the value of the forest, and about the species that can cause economic problems for these people. I have been active in conservation in this area since 2001. My activities have included environmental education, and scientific projects which examined the biology of the primates living in this fragmented landscape. In2016 I performed evaluations to determine whether and how my project was changing the initially negative attitudes of local people towards the forest and the primates who live in it.

6.4 Updating Panamanian Primate Conservation Status Through Ecological Niche Modelling and a Review of Relevant Literature

In order to obtain information on the presence of non-human primates in Panama I conducted surveys across the entire country. By using information from the relevant literature and applying six methods for the detection of non-human primates, I was able to estimate population densities for each subspecies. The Panamanian protected forest has changed faster than I could survey it, but I calculated a density per species by taking the measurements of our national parks and multiplying the density mean of several sampled areas. I used the results to propose revisions to IUCN's evaluation of the conservation status of the non-human primates of Panama, and to demonstrate that there is an urgent need to improve efforts directed towards their conservation. I complemented this evaluation with photographic material of holotype specimens for each species from natural history museums around the world, including France, Sweden, United Kingdom, United States, and Panama itself. I obtained photographs of the specimens that had been collected in Panama, and briefly reviewed literature on the 13 primate subspecies, including the results of previous evaluations and the evaluations suggested by this study. I evaluated each subspecies using these data based on training with the IUCN and the opportunity to participate in the process of evaluating the data with the Neotropical Primate Specialist Group. My evaluations suggest that *Alouatta palliata palliata* is the primate with the highest total population in Panama, numbering around 5,600 animals, and that it is Vulnerable. *Saguinus geoffroyi* is the second largest, with about 5,250 individuals and is Near Threatened. *Alouatta palliata aequatorialis* has 4,875 individuals and is Endangered. *Cebus capucinus capucinus* has 4,193 individuals and is Endangered. *Cebus imitator* has 3,552 individuals and is Vulnerable. *Ateles geoffroyi panamensis* has 3,150 individuals and is Critically Endangered. *Alouatta coibensis trabeata* has 2,340 individuals and is Critically Endangered. *Aotus zonalis* 1,995 individuals and is Data Deficient. *Ateles fusciceps rufiventris* has 1,850 individuals and is Critically Endangered. *Saimiri oerstedii oerstedii* has 496 individuals and is Endangered. *Alouatta coibensis coibensis* has 450 individuals and is Endangered. *Ateles geoffroyi azuerensis* has 121 individuals and is Critically Endangered. Finally, the species *Ateles geoffroyi grisescens* is Data Deficient, and has not been detected so far in Tuira River, where it used to be found. These results suggest that present conditions in Panama are contributing negatively towards primate conservation in the country, and that the proportion of primate species in the country that is threatened has increased from 63% (Estrada et al., 2017) to 75%. Urgent action is therefore required to protect Panamanian primates. This is a serious concern, because conservation is faced with decreasing cooperation from the government, and the development of Neotropical countries is focused on commercial interests, falsely promoted as “progress”.

6.5 The Significance of the Contributions Made by this Thesis

In writing this thesis, I have made several contributions to our knowledge of primate conservation and primate status in Panama and elsewhere. Firstly, I have created an extensive literature review and compilation of all available sources that are related to scientific publications on Panamanian primates. This will facilitate the work of other primatologists from Panama and elsewhere, especially if their research is focussed on a particular species. This is the first time that such a literature review has been put together. A further contribution I have made with this thesis is the addition of new information never previously obtained about population densities per subspecies and the most precise distribution possible, using updated technology and an improved set of variables. It is important to provide information at the subspecies level to improve conservation efforts. Another aspect of this thesis that represents innovation is the provision of complementary information referring to primate presence/absence around several points in Panama. This was obtained using different methods, including a new method called “the Orion Camera System”, which enables researchers to reach and observe the forest canopy without climbing the trees. The final contribution made by this thesis is that provided by the evaluation of the human perception of primates in Azuero peninsula, the most fragmented area in Panama. This area is home to the endemic howler monkey, and the first place where I started my educational campaign to encourage primate conservation in 2001. I am happy I was able to complete these goals at Durham University.

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Appendix 1

Appendix 1.1. Sampling information for Herrera, Los Santos and South Veraguas, Azuero Peninsula.

Date	Locality	#Observers	#Days	Hours /effort	Methods	Landscape type
04/21-25/2001	Ocú	6	5	12/360	Survey: diurnal/education	Fragmented
05/21-25/2001	Ocú	6	5	12/360	Survey: diurnal /education	Fragmented
08/8-12/2001	El Montuoso	3	5	12/180	Survey: diurnal & nocturnal /education	Natural Reserve
12/5-9/2001	Ocú	2	5	12/120	Survey: diurnal /education	Fragmented
01/15-25/2002	El Montuoso	9	10	18/1620	Survey: diurnal & nocturnal /education	Natural Reserve
02/21-25/2002	El Montuoso	2	5	18/180	Survey: diurnal & nocturnal /education	Natural Reserve
04/21/2002 05/1/2002	El Montuoso	9	10	18/1620	Survey: diurnal & nocturnal /education	Natural Reserve
07/11-15/2002	El Montuoso	2	5	18/180	Survey: diurnal & nocturnal /education	Natural Reserve
03/07-16/2003	Ocú, La Miel, Arenas	3	10	12/360	Survey: diurnal & nocturnal/education	Fragmented
01/24/2004 02/02/2004	La Miel, Valle Riquito, Flores, Tonosí, Cañas	7	10	12/840	Survey: diurnal/education	Fragmented

05/1-10/2005	La Miel, Tonosí, Cañas	2	10	12/240	Survey: diurnal/education	Fragmented
05/25/2006 06/03/2006	Cambutal, La Tronosa, Tonosi, Ocú, Las Tablas	3	10	12/360	Survey: diurnal/education	Fragmented
01/5-15/2007	Ocú, Las Tablas, Arenas, Cerro Hoya, Cambutal, Ventana, Tonosí	6	11	12/792	Survey: diurnal/education	Fragmented/Natural Reserve
05/19-29/2008	Ocú, Las Tablas, Arenas, Cerro Hoya, La Tronosa, Cambutal, Ventana, Tonosí	8	10	12/960	Survey: diurnal/education	Fragmented/Natural Reserve
04/25/2009 05/25/2009	Ocú, Las Tablas, Arenas, El Montuoso, Güera, Manglillo, Ventana, Tonosí, Venao, Pedasí, Flores	7	10	12/840	Survey: diurnal/education/road signs	Fragmented/Natural Reserve
3/15-18/2010	Ocú, Arenas	3	4	12/144	Survey: diurnal/education	Fragmented
4/6-10/2010	Arenas	2	5	12/120	Survey: diurnal/education	Fragmented
9/12-15/2010	Ocú, La Miel, Cañas, Tonosí	2	4	12/96	Survey: diurnal/education	Fragmented
9/8-11/2012	La Miel	3	4	12/144	Survey: diurnal/education	Fragmented
11/2-7/2012	La Miel	3	6	12/216	Survey: diurnal/education	Fragmented
11/14-18/2012	Arenas, Ocú	3	4	12/144	Survey: diurnal/education	Fragmented
2/20-23/2013	La Miel	2	4	18/144	Survey: diurnal & nocturnal /education/camera traps	Fragmented

4/15-25/2013	Montijo	8	11	18/1584	Survey: diurnal & nocturnal /education/camera traps	Natural Reserve
11/27/2013 12/1/2013	Montijo, Pitaloza, Tonosí, Güera, Cañas, Venao, La Miel Canajaguas	2	6	14/168	Survey: diurnal /education/camera traps (Canajaguas)	Fragmented/Natural Reserve
2/25-28/2014	Venao, Tonosí, Canas, La Miel	2	4	14/112	Survey: diurnal & nocturnal/ education	Fragmented
3/20-24/2014	Portobelillo, Parita, Paris	3	5	12/180	Survey: diurnal/education	Fragmented
4/11-15/2014	Güera, Cañas, Cambutal, Tonosí, La Miel, Venao, Canajaguas	2	5	12/120	Survey: diurnal/education/finish camera trap in Canajaguas. Start camera trap in Cañas.	Fragmented

Appendix 1.2. Sampling information for Coiba Island, Coibita Island and Jicaron Island.

Date	Locality	#Observers	#Days	Hours /effort	Methods	Landscape type
6/18-28/2009	La Torre, La Falla, Cerro Equis, Rosario, Rancheria, Los Pozos, Isla Coibita, Isla Jicaron	2	10	240/480	Strip Transect/Location posts	Natural Reserve
4/6-10/2010	Los Pozos, Cerro Equis	3	5	120/360	Strip Transect/Location posts	Natural Reserve
9/16-21/2010	Rancheria, Los Pozos, Isla Coibita, Isla Jicaron	3	5	120/360	Strip Transect/Location posts	Natural Reserve

Appendix 1.3. Sampling information for Darien province.

Date	Locality	#Observers	#Days	Hours /effort	Methods	Landscape type
5/27-31/2008	Chucanti, Maje	2	5	120/240	Strip Transect/Location posts	Natural Reserve
7/19-23/2012	Chucanti, Maje	2	5	120/240	Strip Transect/Location posts/OCS(3)	Natural Reserve
11/19-23/2012	Torti, San Francisco Reserve, Guacuco	7	5	120/840	Strip Transect/Location posts/OCS(5)	Natural Reserve/Fragmented
3/2-7/2013	Chucanti	1	6	144/144	Strip Transect/Location posts/OCS	Natural Reserve
4/3-13/2013	Bajo Chiriquito, Tuira River, Tuqueza, Cemaco Embera-Wounaan	4	12	288/1152	Strip Transect/Location posts/OCS(5)	Fragmented
4/12-14/2013	Chucanti	1	3	72/72	Strip Transect/Location posts	Natural Reserve
7/4-7/2013	Chucanti, Maje	2	4	96/192	Strip Transect/Location posts/OCS(5)	Natural Reserve
2/26-29/2014	Chucanti, Maje	1	4	20/20	Strip Transect/Location posts/OCS(5)	Natural Reserve
4/19-28/2014	Sapo, Garachine, Jaque, Cocalito, Embera-Wounaan, Tuira, Quimba, Boca de Cupe, Quimba, Yaviza, Pucuru (Guna), Bajo Lepe (Embera), Cituro.	6	10	144/1440	Strip Transect/Location posts/OCS(5)	Natural Reserve

Appendix 1.4. Sampling information for Panama province.

Date	Locality	#Observers	#Days	Hours /effort	Methods	Landscape type
1/10-15/2001	P.N. Soberania, P.N. Camino de Cruces, Ancon Hill, P.N. Metropilitano	1	5	120/120	Presence/absence, Strip Transect	Natural Reserve
2/12-15/2001	P.N. Soberania, P.N. Camino de Cruces, Ancon Hill, P.N. Metropilitano	1	5	120/120	Presence/absence, Strip Transect	Natural Reserve
6/20-28/2001	P.N. Soberania, P.N. Camino de Cruces, Ancon Hill, P.N. Metropilitano	1	5	120/120	Presence/absence, Strip Transect	Natural Reserve
9/14-20/2001	P.N. Soberania, P.N. Camino de Cruces, Ancon Hill, P.N. Metropilitano	1	5	120/120	Presence/absence, Strip Transect	Natural Reserve
7/20-25/2001	BCI	1	5	120/120	Presence/absence, Strip Transect	Natural Reserve
8/12-17/2001	BCI	1	5	120/120	Presence/absence, Strip Transect	Natural Reserve
8/20-27/2001	BCI	1	5	120/120	Presence/absence, Strip Transect	Natural Reserve
9/29-30/2001	BCI	1	2	48/96	Presence/absence, Strip Transect	Natural Reserve

3/18-24/2002	P.N. Soberania, P.N. Camino de Cruces, Ancon Hill, P.N. Metropilitano	1	5	120/120	Presence/absence, Strip Transect	Natural Reserve/Urban
4/11-19/2002	Lagartera, las Pavas, Chorrera, Panama Canal	2	9	216/432	Presence/absence, Strip Transect	Fragmented
4/25-30/2002	Lagartera, las Pavas, Chorrera, Panama Canal	2	6	144/288	Presence/absence, Strip Transect	Fragmented
5/13-19/2002	Lagartera, las Pavas, Chorrera, Panama Canal	2	7	168/336	Presence/absence, Strip Transect	Fragmented
5/24-30/2002	Lagartera, las Pavas, Chorrera, Panama Canal	2	7	168/336	Presence/absence, Strip Transect	Fragmented
6/6-12/2002	Lagartera, las Pavas, Chorrera, Panama Canal	2	7	168/336	Presence/absence, Strip Transect	Fragmented
6/17-22/2002	Lagartera, las Pavas, Chorrera, Panama Canal	2	6	144/288	Presence/absence, Strip Transect	Fragmented
7/8-13/2002	Lagartera, las Pavas, Chorrera, Panama Canal	2	6	144/288	Presence/absence, Strip Transect	Fragmented
3/22-25/2014	Chorrera, Caimito	2	4	96/192	Presence/absence, Strip Transect	Urban/Fragmented

9/22-25/2014	Chorrera, Caimito	2	4	96/192	Presence/absence, Strip Transect	Urban/Fragmented
11/10-13/2014	Chorrera, Caimito	2	4	96/192	Presence/absence, Strip Transect	Urban/Fragmented
3/5-8/2015	Chorrera, Caimito	2	4	96/192	Presence/absence, Strip Transect	Urban/Fragmented
3/20-23/2016	Chorrera, Caimito	2	4	96/192	Presence/absence, Strip Transect	Urban/Fragmented

Appendix 1.5. Sampling information for Colon province.

Date	Locality	#Observers	#Days	Hours /effort	Methods	Landscape type
7/14-19/2002	Lagartera, las Pavas, Chorrera, Panama Canal (Colon side)	2	6	144/288	Presence/absence, Strip Transect	Fragmented
4/24-26/2008	Portobelo/Gatun	2	3	72/144	Presence/absence, Strip Transect	Fragmented, Natural Reserve
9/22-28/2012	San Lorenzo, Achiotes, Portobelo	2	7	168/336	Presence/absence, Strip Transect	Fragmented, Natural Reserve
4/18-22/2014	San Blas Mountain Chain, Cocobolo Natural Reserve	2	5	120/240	Presence/absence, Strip Transect	Natural Reserve

Appendix 1.6. Sampling information for Cocle province.

Date	Locality	#Observers	#Days	Hours /effort	Methods	Landscape type
3/21-25/2012	Donoso, La Vieja, Chigore, Chi-guiri	2	5	120/240	Presence/absence, Strip Transect	Natural Reserve
5/8-12/2012	Donoso, La Vieja, Chigore, Chi-guiri	2	5	120/240	Presence/absence, Strip Transect	Natural Reserve
6/26-30/2012	Donoso, La Vieja, Chigore, Chi-guiri	2	5	120/240	Presence/absence, Strip Transect	Natural Reserve
5/5-9/2013	Chiguiri, La Vieja	2	5	120/240	Presence/absence, Strip Transect	Fragmented
5/20-24/2014	Pajonal, Cerro Colorado	2	5	120/240	Presence/absence, Strip Transect	Fragmented

Appendix 1.7. Sampling information for Chiriqui province.

Date	Locality	#Observers	#Days	Hours /effort	Methods	Landscape type
5/25-30/2012	Boquete, Hartman	2	6	168/336	Presence/absence, Strip Transect/OCS	Coffee Plantation/ Natural Reserve
9/5-11/2012	Burica peninsula, Limones, Corpachi Trail, Puerto Armuelles, Petroterminal	2	7	168/336	Presence/absence, Strip Transect	Fragmented

2/18-22/2013	Burica peninsula, Limones, Corpachi Trail, Puerto Armuelles, Petroterminal	2	5	120/240	Presence/absence, Strip Transect	Fragmented
6/6-10/2014	Isla San Pedro, Pedregal, Boquete, Volcan	2	5	120/240	Presence/absence, Strip Transect	Natural Reserve/ Coffee plantation
5/12-16/2015	Isla San Pedro, Pedregal, Boquete, Volcan	2	5	120/240	Presence/absence, Strip Transect	Natural Reserve/ Coffee plantation

Appendix 2

Appendix 2.1. Locations for presence of *Saguinus geoffroyi*; DTF: Dry Tropical Forest; TRF: Tropical Rain Forest; FF: Fragmented Forest; LF: Living Fences; SFR: San Francisco Reserve; A: Area; D: Relative density; N: North; W: West. Blank space means no information available.

# site	Province	Study site	Habitat/ Use	Latitude	Longitude	Ind.	A (km^2)	D	Source
1	Panama	Ancon	DTF/Urban	-79.203166	9.309638	4	40	0.1	FCPP
2	Panama	Ancon	DTF/Urban Forest	-79.205833	9.315277	32	40	0.8	FCPP
3	Panama	BCI	RTF/Reserve	-79.205972	9.300527			4.7	Dawson, 1977
4	Panama	BCI	RTF/Reserve	-79.206638	9.301277			0.07	Glanz, 1992
5	Panama	BCI	RTF/Reserve	-79.205222	9.297555			3.6	Eisenberg, 1979
6	Panama	BCI	RTF/Reserve	-79.204916	9.3075		1	3	FCPP
7	Panama	BCI	RTF/Reserve	-79.841766	9.153621	2		0.23	ANAM
8	Panama	BCI	RTF/Reserve	-79.704722	8.988361	8	40	0.2	ANAM
9	Panama	Peninsula Gigante	RTF/Reserve	-79.68925	9.33416	7		1.16	ANAM
10	Panama	Peninsula Gigante	RTF/Reserve	-80.677555	8.925638			0.1	ANAM
11	Panama	Las Pavas	FF/Teak Plant.	-79.205583	8.295027	6	60	0.17	FCPP
12	Panama	El Charco	TRF/Reserve	-79.515194	9.104833	3	80	0.0375	FCPP
13	Panama	Plantacion	TRF/Reserve	-80.178223	8.651626	28		3.14	ANAM
14	Panama	Plantacion	TRF/Reserve	-79.968796	8.714752	3	80	0.0375	ANAM
15	Panama	Las Cruces	TRF/Reserve	-79.808807	8.668597	17		2.39	ANAM

16	Panama	Carretera-25	TRF/Reserve	-80.300446	8.562689	17		2	ANAM
17	Panama	Rio Macho	TRF/Reserve	-80.367737	8.557936	1		0.11	ANAM
18	Panama	Gamboa	TRF/Urban	-80.520172	8.680136	12	80	0.15	FCPP
19	Panama	Mandinga	TRF/Reserve	-80.724792	8.895926	25		3.42	ANAM
20	Panama	Limbo	TRF/Reserve	-80.397949	9.053277	1		0.12	ANAM
21	Panama	Arraijan	FF/Urban.	-79.988708	9.245804			0	FCPP
22	Panama	Chorrera	FF/Urban.	-79.845886	9.156333			0	FCPP
23	Panama	Chorrera	FF/Urban.	-79.73877	9.074976			0	FCPP
24	Panama	Chorrera	FF/Teak Plant.	-79.571228	9.026153	4	60	0.06	FCPP
25	Panama	Quintas Del Lago	TRF-LF/Urban	-79.550629	8.989531	3	150	0.02	FCPP
26	San Blas	San Blas	TRF/Reserve	-79.593201	9.176669	5	80	0.06	FCPP
27	San Blas	San Blas	TRF/Reserve	-79.3927	9.039715	3	80	0.03	FCPP
28	Colon	El Guabo	TRF/Cooper Mine	-79.372101	9.279688	5	20	0.25	MWH/FCPP
29	Colon	Donoso	TRF/Cooper Mine	-79.124908	9.065483	12	200	0.06	MWH/FCPP
30	Colon	Palmarazo	TRF/Reserve	-79.109802	9.401646	1	8	0.125	MWH/FCPP
31	Colon	Cerro Miguel	TRF/Reserve	-79.436646	9.396226	1	4	0.25	MWH/FCPP
32	Colon	La Mina	TRF/Reserve	-78.751373	9.049209	1	4	0.25	MWH/FCPP
33	Colon	Rio Indio Nac.	TRF/Reserve	-78.097687	7.536764	1	10	0.1	MWH/FCPP
34	Cocle	El Limon	TRF/Reserve	-77.585449	7.757259	1	3	0.33	Araúz et al.,2008

35	Cocle	La Tabila	TRF/Reserve	-77.555237	8.066028	1	5	0.2	Araúz et al.,2008
36	Cocle	La Sargenta	TRF/Reserve	-77.408295	8.393583	1	8	0.125	Araúz et al.,2008
37	Cocle	Chiguiri	FF/Urban	-77.733765	8.495463		1	0	FCPP
38	Cocle	Churuquita	TRF/Urban	-77.658234	8.775154	9	20	0.45	FCPP
39	Cocle	Cocle Del Norte	TRF/Reserve	-77.746124	8.297111		1	0	FCPP
40	Darien	Bajo Chiquito	TRF/Logging Act.	-78.138885	8.332442	4	60	0.06	Medina
41	Darien	Chucanti	TRF/Reserve	-78.159485	8.507687	6	200	0.03	FCPP
42	Darien	Chucanti	TRF/Reserve	-78.490448	8.534849	12	200	0.06	FCPP
43	Darien	Rio Pavo	LF/Farming-Cattle	-78.601685	8.75208	5	40	0.125	FCPP
44	Darien	Torti	LF-Panameri-can/Urban	-78.43689	8.844365	3	2	1.5	FCPP
45	Darien	Torti	TRF/Reserve	-78.585205	8.948836	2	40	0.05	FCPP
46	Darien	Boca De Cupe	TRF/Reserve	-78.739014	9.062771	4	4	0.147	Moreno, 2006
47	Darien	Sendero Jaguar	TRF/Reserve	-79.038391	9.347448	4	4	0.133	Moreno, 2006
48	Darien	Pirre	TRF/Reserve	-79.240265	9.45448	4	4	0.016	Moreno, 2006
49	Darien	Cana	TRF/Reserve	-79.946361	9.266611	4	1	0.147	Moreno, 2006
50	Darien	Cana	TRF/Reserve	-79.946583	9.267027	90	1	22.5	Moreno, 2006
51	Darien	Cana	TRF/Reserve	-79.946694	9.267222				FCPP
52	Darien	Cana	TRF/Reserve	-79.947361	9.266027				FCPP
53	Darien	Cana	TRF/Reserve	-79.948416	9.266805				FCPP

54	Darien	Cana	TRF/Reserve	-79.946	9.268638				FCPP
55	Darien	Cana	TRF/Reserve	-79.945972	9.272027				FCPP
56	Darien	Cana	TRF/Reserve	-79.930972	9.276138				FCPP
57	Darien	Cana	TRF/Reserve	-79.927194	9.291333				FCPP
58	Darien	Cana	TRF/Reserve	-79.929277	9.292222				FCPP
59	Darien	Cana	TRF/Reserve	-79.931361	9.287694				FCPP
60	Darien	Cana	TRF/Reserve	-79.926166	9.295805				FCPP
61	Darien	Cana	TRF/Reserve	-79.9125	9.28588				FCPP
62	Darien	Cana	TRF/Reserve	-79.919216	9.252738				FCPP
63	Darien	Torti	TRF/Reserve	-78.456527	8.791972				FCPP
64	Darien	Torti	TRF/Reserve	-78.461277	8.795027				FCPP
65	Darien	Torti	TRF/Reserve	-78.462222	8.798055				FCPP
66	Darien	Torti	TRF/Reserve	-78.460444	8.794694				FCPP
67	Darien	Torti	TRF/Reserve	-78.452111	8.789916				FCPP
68	Darien	Torti	TRF/Reserve	-78.450416	8.791333				FCPP
69	Darien	Torti	TRF/Reserve	-77.674027	8.459027				FCPP

Appendix 2.2. Locations for presence of *Aotus zonalis*; DTF: Dry Tropical Forest; TRF: Tropical Rain Forest; FF: Fragmented Forest; LF: Living Fences; SFR: San Francisco Reserve; HE: Hours of effort; A: Area; D: Relative density; N: North; W: West. Where spaces are blank this means that no information was available.

# site	Province	Study site	Habitat/ Use	Latitude	Longitude	Ind.	A(km^2)	D	Source
1	Panama	Ancon	DTF/URBAN	-79.203166	9.309638	4	40	0.1	FCPP
2	Panama	Las Pavas	FF/TEAK PLANT.	-79.205833	9.315277		60	0	FCPP
3	Panama	La Plantacion	TRF/RESERVE	-79.205972	9.300527	6	80	0.75	FCPP
4	Panama	El Charco Trail	TRF/RESERVE	-79.206638	9.301277		80	0	FCPP
5	Panama	Bci	TRF/RESERVE	-79.205222	9.297555		X	0	FCPP/Glanz 1992
6	Panama	Gamboa	TRF/URBAN	-79.204916	9.3075	2	80	0.025	FCPP
7	Panama	Arraijan/Buque	FF/URBAN.	-79.841766	9.153621		X	0	FCPP
8	Panama	Chorrera	FF/URBAN.	-79.704722	8.988361	4	20	0.2	FCPP
9	Panama	Chorrera	FF/URBAN.	-79.68925	9.33416	9	20	0.45	FCPP
10	Panama	La Llana	TRF/RESERVE	-80.677555	8.925638		1440	0	Svensson et al., 2010
11	Panama	Campo Chagres	TRF/RESERVE	-79.205583	8.295027	25	2540	3.1	Svensson et al., 2010
12	Panama	Cerro Azul	TRF/RESERVE	-79.515194	9.104833	8	1120	7.14	Svensson et al., 2010
13	Colon	El Guabo	TRF/MINE	-80.178223	8.651626	5	20	0.25	FCPP
14	Colon	Donoso	TRF/COOPER MINE	-79.968796	8.714752	2	200	0.01	FCPP/MWH
15	Colon	Palmarazo	TRF/RESERVE	-79.808807	8.668597	1	8	0.125	Araúz et al., 2008

16	Colon	La Mina	TRF/RESERVE	-80.300446	8.562689	1	4	0.25	Araúz et al., 2008
17	Colon	La Tabila	TRF/RESERVE	-80.367737	8.557936	1	5	0.2	Araúz et al., 2008
18	Colon	San Lorenzo	TRF/RESERVE	-80.520172	8.680136	1	0	0	Weaver, Bauer, 2004
19	Cocle	Churuquita	TRF/URBAN	-80.724792	8.895926	5	20	0.25	Araúz et al., 2008
20	Darien	Bajo Chiquito	TRF/LOGGING ACT.	-80.397949	9.053277		60	0	FCPP/Medina
21	Darien	Chucanti	TRF/ RESERVE	-79.988708	9.245804		200	0	FCPP
22	Darien	Chucanti	TRF/ RESERVE	-79.73877	9.074976		200	0	FCPP
23	Darien	Rio Pavo	LF/FARMING- CAT-TLE	-79.571228	9.026153		40	0	FCPP
24	Darien	Torti	LF/URBAN	-79.550629	8.989531		2	0	FCPP
25	Darien	Torti	TRF/ RESERVE	-79.593201	9.176669		40	0	FCPP
26	Darien	Boca De Cupe	TRF/RESERVE	-79.3927	9.039715		4	0	Moreno et al., 2006
27	Darien	Sendero Jaguar	TRF/RESERVE	-79.372101	9.279688		4	0	Moreno et al., 2006
28	Darien	Pirre	TRF/RESERVE	-79.124908	9.065483		4	0	Moreno et al., 2006
29	Darien	Cana	TRF/RESERVE	-79.109802	9.401646		4	0	Moreno et al., 2006
30	Darien	Cana	TRF/RESERVE	-79.436646	9.396226		4	0	Moreno et al., 2006

31	San Blas	San Blas	TRF/RESERVE	-78.751373	9.049209		0	0	FCPP
32	San Blas	San Blas	TRF/RESERVE	-78.097687	7.536764				FCPP
33	Cocle	Mina, Peno-nome	TRF/RESERVE	-77.585449	7.757259				FCPP
34	Cocle	Mina, Peno-nome	TRF/RESERVE	-77.555237	8.066028				FCPP
35	Cocle	Mina, Peno-nome	TRF/RESERVE	-77.408295	8.393583				FCPP
36	Cocle	Mina, Peno-nome	TRF/RESERVE	-77.733765	8.495463				FCPP
37	Cocle	Mina, Peno-nome	TRF/RESERVE	-77.658234	8.775154				FCPP
38	Cocle	Mina, Peno-nome	TRF/RESERVE	-77.746124	8.297111				FCPP
39	Cocle	Mina, Peno-nome	TRF/RESERVE	-78.138885	8.332442				FCPP
40	Cocle	Mina, Peno-nome	TRF/RESERVE	-78.159485	8.507687				FCPP
41	Cocle	Mina, Peno-nome	TRF/RESERVE	-78.490448	8.534849				FCPP
42	Cocle	Mina, Peno-nome	TRF/RESERVE	-78.601685	8.75208				FCPP
43	Cocle	Mina, Peno-nome	TRF/RESERVE	-78.43689	8.844365				FCPP
44	Cocle	Mina, Peno-nome	TRF/RESERVE	-78.585205	8.948836				FCPP

45	Cocle	Mina, Peno-nome	TRF/RESERVE	-78.739014	9.062771				FCPP
46	Cocle	Mina, Peno-nome	TRF/RESERVE	-79.038391	9.347448				FCPP
47	Cocle	Mina, Peno-nome	TRF/RESERVE	-79.240265	9.45448				FCPP
48	Cocle	Mina, Peno-nome	TRF/RESERVE	-80.200944	8.663694				FCPP
49	Cocle	Mina, Peno-nome	TRF/RESERVE	-80.20075	8.661722				FCPP
50	Cocle	Mina, Peno-nome	TRF/RESERVE	-80.200861	8.663638				FCPP
51	Cocle	Mina, Peno-nome	TRF/RESERVE	-80.201055	8.663805				FCPP
52	Cocle	Mina, Peno-nome	TRF/RESERVE	-80.20075	8.662638				FCPP
53	Cocle	Mina, Peno-nome	TRF/RESERVE	-80.200611	8.662638				FCPP
54	Cocle	Mina, Peno-nome	TRF/RESERVE	-79.3581345	9.56633732				FCPP
55	Cocle	Mina, Peno-nome	TRF/RESERVE	-79.3581345	9.56633732				FCPP

Appendix 2.3. Locations for presence of *Saimiri oerstedii*; DTF: Dry Tropical Forest; TRF: Tropical Rain Forest; FF: Fragmented Forest; LF: Living Fences; SFR: San Francisco Reserve; A: Area; D: Relative density; N: North; W: West. Blank space means no information available.

# site	Province	Study site	Habitat/ Use	Latitude	Longitud	Ind.	A (km^2)	D	Source
1	Chiriqui	Nvo Mexico	GALLERY/FARMING	-82.739066	8.406416				FCPP
2	Chiriqui	Divala	GALLERY/FARMING	-82.533916	8.394339				FCPP
3	Chiriqui	La Barqueta	FF/FARMING	-82.572127	8.306411				FCPP
4	Chiriqui	Canta Gallo	GALLERY/FARMING	-82.630763	8.370091				FCPP
5	Chiriqui	Santo Tomas	LF/FARMING	-82.756236	8.328686				FCPP
6	Chiriqui	Querevalo	MANGROVE	-82.487097	8.328686				FCPP
7	Chiriqui	Palo Grande	MANGROVE	-82.591936	8.329286				FCPP
8	Chiriqui	Guarumal	MANGROVE	-82.526019	8.341361				FCPP
9	Chiriqui	El Tejar	MANGROVE	-82.608516	8.448266				FCPP
10	Chiriqui	Gariche	MANGROVE	-82.753669	8.480688				FCPP
11	Chiriqui	Baco	MANGROVE	-82.756236	8.318072				FCPP
12	Chiriqui	Puerto Armuelles	MANGROVE	-82.909969	8.244072				FCPP
13	Chiriqui	Baru	LF	-82.891061	8.152697				FCPP
14	Chiriqui	Baru	LF	-82.888286	8.173108				FCPP
15	Chiriqui	Baru	LF	-82.876394	8.056944				FCPP

16	Chiriqui	Baru	LF	-82.112613	8.364422				FCPP
17	Chiriqui	Baru	LF	-82.705347	8.596594				FCPP
18	Chiriqui	Baru	LF	-82.463436	8.481725				FCPP
19	Chiriqui	Baru	LF	-82.430144	8.365775				FCPP
20	Chiriqui	Baru	LF	-82.174497	8.27405				FCPP
21	Chiriqui	Chorogo	TRF/Reserve	-82.805741	8.557666				FCPP
22	Chiriqui	Limones	TRF/Reserve	-82.856633	8.706866				FCPP
23	Chiriqui	Burica	TRF/Reserve	-82.834669	8.766175				FCPP
24	Chiriqui	Las Huacas		-82.757241	8.820669				FCPP
25	Chiriqui	Paraiso		-82.437638	8.449894				FCPP
26	Chiriqui	Las Monjas		-82.807186	8.606141				FCPP
27	Chiriqui	San Andres		-82.773316	8.715477				FCPP
28	Chiriqui	Jacu		-82.839761	8.738486				FCPP
29	Chiriqui	Porton		-82.86733	8.828933				FCPP
30	Chiriqui	Gariche		-82.87325	8.096944				FCPP
31	Chiriqui	Bugaba		-82.874416	8.098277				FCPP
32	Chiriqui	San Carlos		-82.873416	8.096777				FCPP

33	Chiriqui	Pedregal		-82.873027	8.098805				FCPP
34	Chiriqui	Potrerillos		-82.872611	8.098888				FCPP
35	Chiriqui	Chorchas		-82.872416	8.099				FCPP
36	Chiriqui	San Pedro		-82.871388	8.097861				FCPP
37	Chiriqui	Breñon		-82.878611	8.235027				FCPP
38	Chiriqui	Cañas Gordas		-82.480661	8.286864				FCPP
39	Chiriqui	Dominical		-82.878722	8.235611				FCPP
40	Chiriqui	Monte Lirio		-82.878722	8.235611				FCPP
41	Chiriqui	Plaza Caisan		-82.878722	8.235611				FCPP
42	Chiriqui	Rio Sereno		-82.878722	8.235611				FCPP
43	Chiriqui	Santa Cruz		-82.878722	8.235611				FCPP
44	Chiriqui	Santa Clara		-82.878722	8.235611				FCPP

Appendix 2.4. Locations for presence of ***Cebus imitator***; DTF: Dry Tropical Forest; TRF: Tropical Rain Forest; FF: Fragmented Forest; LF: Living Fences; SFR: San Francisco Reserve; A: Area; D: Relative density; N: North; W: West. Where spaces are blank this means that no information was available.

# site	Province	Study site	Habitat/ Use	Latitude	Longitude	Ind.	A (km^2)	D	Source
1	Panama	Ancon	DTF/URBAN	-80.308611	7.577778	2	40	0.05	(pers. Obs. 1986) Now extirpated
2	Panama	Las Pavas	FF/TEAK PLANT.	-80.179194	7.42025	5	60	0.08	FCPP
3	Panama	La Plantacion	TRF/RESERVE	-80.356722	7.439222	12	80	0.15	FCPP
4	Panama	El Charco	TRF/RESERVE	-80.183056	7.4185	5	80	0.06	FCPP
5	Panama	Bci	TRF/RESERVE	-80.1942	7.551306		15	20	Glanz, 1992
6	Panama	Gamboa	TRF/URBAN	-80.326792	7.482469	3	80	0.03	FCPP
7	Panama	Arraijan	FF/URBAN.	-80.346708	7.573467		X	0	FCPP
8	Panama	Chorrera	FF/URBAN.	-80.351692	7.450228		20	0	FCPP
9	Panama	Chorrera	FF/URBAN.	-80.551203	7.344703		20	0	FCPP
10	Colon	El Guabo	TRF/MINE	-80.474064	7.353044		20	0	FCPP
11	Colon	Donoso	TRF/COOPER MINE	-80.260967	7.449475	3/3 5	200	0.02	FCPP
12	Colon	Donoso	TRF/COOPER MINE	-80.25925	7.448853	1/3 5	200	0.01	FCPP
13	Colon	Donoso	TRF/COOPER MINE	-80.319861	7.886944	1/3 5	200	0.01	FCPP
14	Colon	Donoso	TRF/COOPER MINE	-80.321667	7.557222	3/3 5	200	0.02	FCPP

15	Colon	Donoso	TRF/COOPER MINE	-80.2975	7.561389	6/35	200	0.03	FCPP
16	Colon	Donoso	TRF/COOPER MINE	-80.293889	7.545	1/35	200	0.01	FCPP
17	Colon	Donoso	TRF/COOPER MINE	-80.294167	7.543889	1/3	200	0.01	FCPP
18	Colon	Donoso	TRF/COOPER MINE	-80.288889	7.536667	1/35	200	0.01	FCPP
19	Colon	Donoso	TRF/COOPER MINE	-79.549444	8.957222	1/35	200	0.01	FCPP
20	Colon	Donoso	TRF/COOPER MINE	-79.876039	9.099325	4/35	200	0.02	FCPP
21	Colon	Donoso	TRF/COOPER MINE	-79.656283	9.071147	35	200	0.05	FCPP
22	Colon	Donoso	TRF/COOPER MINE	-79.665114	9.082558	6/35	200	0.03	FCPP
23	Colon	Palmarazo	TRF/RESERVE	-79.836897	9.166397	1	8	0.175	FCPP
24	Colon	La Mina	TRF/RESERVE	-79.696814	9.119097	1	4	0.175	FCPP
25	Colon	La Llana	TRF/RESERVE	-79.649169	8.947622		1440		Svensson et al., 2010
26	Colon	Campo Chagres	TRF/RESERVE	-79.752081	8.871236	25	2540		Svensson et al., 2010
27	Colon	Cerro Azul	TRF/RESERVE	-80.084333	9.090667	8	1120		Svensson et al., 2010
28	Colon	Cascajal	TRF/GALLERY	-80.560028	8.984156				FCPP
29	Colon	San Lorenzo	TRF/RESERVE	-80.652278	9.724083				Weaver/Bauer, 2004

30	Cocle	La Tabila	TRF/RESERVE	-80.279889	8.568972	1	5		Araúz et al., 2008
31	Cocle	Churuquita	TRF/URBAN	-82.886353	8.124491		20		Araúz et al., 2008
32	Herrera	Montuoso	TRF/RESERVE	-82.935791	8.233237				
33	Herrera	Ocu		-80.238647	8.819939				
34	Veraguas	Coiba Island	RTF/RESERVE	-80.068359	9.178025		560	0.08	Méndez-Carvajal, 2005
35	Veraguas	Rosario Beach	RTF/RESERVE	-80.425415	9.015302		560	0.08	Méndez-Carvajal, 2005
36	Veraguas	The Tower	RTF/RESERVE	-80.650635	8.982749		560	0.08	Méndez-Carvajal, 2005
37	Veraguas	“X” Hill	RTF/RESERVE	-80.820923	8.61361		560	0.08	Méndez-Carvajal, 2005
38	Veraguas	Springs	RTF/RESERVE	-81.447144	8.559294		560	0.08	Méndez-Carvajal, 2005
39	Veraguas	Cerro Hoya	TRF/RESERVE	-81.831665	8.624472				Méndez-Carvajal, 2005
40	Veraguas	Coiba Island	TRF/RESERVE	-82.172241	8.646196				
41	Herrera	Cerro Tijeras	DTF/RESERVE	-82.408447	9.069551				
43	Los Santos	Venao		-82.424927	8.885072				
44	Los Santos	Zahina		-82.677612	8.933914				
45	Bocas del Toro	I. Bastimentos	TRF/ISLAND	-82.924805	8.200616				
46	Chiriqui	Limones	TRF/RESERVE	-79.961243	8.544356			0.03	FCPP

47	Chiriqui	Boquete	TRF/Coffee Pl.	-80.148697	8.656378			0.004	FCPP
48	Panama		RAIN FOREST	-79.961243	8.544356				FCPP
49	Panama		RAIN FOREST	-79.84108	9.119046				FCPP
50	Panama		RAIN FOREST	-80.298386	9.144808				FCPP
51	Panama		RAIN FOREST	-80.532532	9.01259				FCPP
52	Panama		RAIN FOREST	-80.348022	8.811797				FCPP
53	Panama		RAIN FOREST	-82.53067	8.809082				FCPP
54	Panama		RAIN FOREST	-82.499084	8.724933				FCPP
55	Panama		RAIN FOREST	-82.403227	8.331083				FCPP
56	Panama		RAIN FOREST	-81.117554	7.842976				FCPP
57	Panama		RAIN FOREST	-81.0379	7.720518				FCPP
58	Panama		RAIN FOREST	-81.731415	7.566715				FCPP
59	Panama		RAIN FOREST	-81.838531	7.550378				FCPP
60	Panama		RAIN FOREST	-81.793213	7.396515				FCPP
61	Panama		RAIN FOREST	-81.697083	7.391067				FCPP
62	Panama		RAIN FOREST	-81.805573	7.245322				FCPP
63	Panama		RAIN FOREST	-82.904205	8.095941				FCPP

64	Panama		RAIN FOREST	-81.748897	7.645147				FCPP
65	Panama		RAIN FOREST	-81.750858	7.640605				FCPP
66	Panama		RAIN FOREST	-81.752416	7.639672				FCPP
67	Panama		RAIN FOREST	-81.753558	7.635727				FCPP
68	Panama		RAIN FOREST	-81.757877	7.634436				FCPP
69	Panama		RAIN FOREST	-81.760361	7.636691				FCPP
70	Panama		RAIN FOREST	-81.854263	7.525544				FCPP
71	Panama		RAIN FOREST	-81.849669	7.511522				FCPP
72	Panama		RAIN FOREST	-81.868361	7.515119				FCPP
73	Panama		RAIN FOREST	-81.738425	7.617727				FCPP
74	Panama		RAIN FOREST	-81.735655	7.609477				FCPP
75	Panama		RAIN FOREST	-81.731244	7.609358				FCPP
76	Panama		RAIN FOREST	-81.730652	7.612341				FCPP
77	Panama		RAIN FOREST	-81.722991	7.438333				FCPP
78	Panama		RAIN FOREST	-81.735286	7.435327				FCPP
79	Panama		RAIN FOREST	-81.754916	7.440752				FCPP
80	Panama		RAIN FOREST	-81.762436	7.461494				FCPP

81	Panama		RAIN FOREST	-80.688833	9.009166				FCPP
82	Panama		RAIN FOREST	-80.704722	8.988361				FCPP
83	Panama		RAIN FOREST	-80.704777	8.985				FCPP
84	Panama		RAIN FOREST	-80.705111	9.82361				FCPP
85	Panama		RAIN FOREST	-80.705361	8.981861				FCPP
86	Panama		RAIN FOREST	-80.705305	8.981388				FCPP
87	Panama		RAIN FOREST	-80.705472	8.980416				FCPP
88	Panama		RAIN FOREST	-80.706111	8.969138				FCPP
89	Panama		RAIN FOREST	-80.705611	8.968055				FCPP
90	Panama		RAIN FOREST	-80.705388	8.965305				FCPP
91	Panama		RAIN FOREST	-80.705361	8.981861				FCPP
92	Panama		RAIN FOREST	-80.704722	8.988361				FCPP
93	Panama		RAIN FOREST	-80.701944	8.963388				FCPP
94	Panama		RAIN FOREST	-80.701166	8.965194				FCPP
95	Panama		RAIN FOREST	-80.700972	8.960611				FCPP
96	Panama		RAIN FOREST	-80.699416	8.956083				FCPP
97	Panama		RAIN FOREST	-80.697527	8.955444				FCPP

98	Panama		RAIN FOREST	-80.693194	8.946638				FCPP
99	Panama		RAIN FOREST	-80.693027	8.946722				FCPP
100	Panama		RAIN FOREST	-80.6925	8.941944				FCPP
101	Panama		RAIN FOREST	-80.68925	8.933416				FCPP
102	Panama		RAIN FOREST	-80.688833	9.009277				FCPP
103	Panama		RAIN FOREST	-80.687555	8.932527				FCPP
104	Panama		RAIN FOREST	-80.664944	8.917138				FCPP
105	Panama		RAIN FOREST	-80.658972	8.910861				FCPP
106	Panama		RAIN FOREST	-80.646777	8.895277				FCPP
107	Panama		RAIN FOREST	-80.690888	9.016805				FCPP
108	Panama		RAIN FOREST	-80.688833	9.009166				FCPP
109	Panama		RAIN FOREST	-80.704722	8.988361				FCPP
110	Panama		RAIN FOREST	-80.705361	8.981861				FCPP
111	Panama		RAIN FOREST	-80.706111	8.969138				FCPP
112	Panama		RAIN FOREST	-80.705611	8.968055				FCPP

Appendix 2.5. Locations for presence of *Cebus capucinus*; DTF: Dry Tropical Forest; TRF: Tropical Rain Forest; FF: Fragmented Forest; LF: Living Fences; SFR: San Francisco Reserve; A: Area; D: Relative density; N: North; W: West. Blank space means no information available.

# site	Province	Study site	Habitat/ Use	Latitude	Longitude	Ind.	A (km^2)	D	Source
1	Panama	La Llana	TRF/RESERVE	-79.845886	9.156333		1440		Svensson et al., 2010
2	Panama	Chagres	TRF/RESERVE	-79.73877	9.074976	25	2540		Svensson et al., 2010
3	Panama	Cerro Azul	TRF/RESERVE	-79.571228	9.026153	8	1120		Svensson et al., 2010
4	Panama	Bayano	TRF/RESERVE	-79.550629	8.989531				FCPP
5	Darien	Chucanti	TRF/RESERVE	-79.593201	9.176669		200	2	FCPP
6	Darien	Chucanti	TRF/RESERVE	-79.3927	9.039715		200	2	FCPP
7	Darien	Rio Pavo	LF/FARMING-CAT-TLE	-79.372101	9.279688		40	2	FCPP
8	Darien	Torti	LF/URBAN	-79.124908	9.065483		2	2	FCPP
9	Darien	Torti	TRF/RESERVE	-79.109802	9.401646		40	2	FCPP
10	Darien	Boca De Cupe	TRF/RESERVE	-79.436646	9.396226		4	13.5	Moreno et al., 2006
11	Darien	Sende Jaguar	TRF/RESERVE	-78.751373	9.049209		4	13.5	Moreno et al., 2006
12	Darien	Pirre	TRF/RESERVE	-78.097687	7.536764		4	13.5	Moreno et al., 2006

13	Darien	Cana	TRF/RESERVE	-77.585449	7.757259		4	13.5	Moreno et al., 2006
14	Darien	Cana	TRF/RESERVE	-77.555237	8.066028		4	13.5	Moreno et al., 2006
15	Panama	Serrania San Blas	TRF/RESERVE	-77.408295	8.393583				FCPP
16	Panama		TRF/RESERVE	-77.733765	8.495463				FCPP
17	Panama		TRF/RESERVE	-77.658234	8.775154				FCPP
18	Panama		TRF/RESERVE	-77.746124	8.297111				FCPP
19	Darien		TRF/RESERVE	-78.138885	8.332442				FCPP
20	Darien		TRF/RESERVE	-78.159485	8.507687				FCPP
21	Darien		TRF/RESERVE	-78.490448	8.534849				FCPP
22	Darien		TRF/RESERVE	-78.601685	8.75208				FCPP
23	Darien		TRF/RESERVE	-78.43689	8.844365				FCPP
24	Darien		TRF/RESERVE	-78.585205	8.948836				FCPP
25	Darien		TRF/RESERVE	-78.739014	9.062771				FCPP
26	Darien		TRF/RESERVE	-79.038391	9.347448				FCPP
27	Darien		TRF/RESERVE	-79.240265	9.45448				FCPP
28	Darien		TRF/RESERVE	-79.946361	9.266611				FCPP

29	Panama		TRF/RESERVE	-79.946583	9.267027				FCPP
30	Panama		TRF/RESERVE	-79.946694	9.267222				FCPP
31	Panama		TRF/RESERVE	-79.947361	9.266027				FCPP
32	Panama		TRF/RESERVE	-79.948416	9.266805				FCPP
33	Darien		TRF/RESERVE	-79.946	9.268638				FCPP
34	Darien		TRF/RESERVE	-79.945972	9.272027				FCPP
35	Darien		TRF/RESERVE	-79.930972	9.276138				FCPP
36	Darien		TRF/RESERVE	-79.927194	9.291333				FCPP
37	Darien		TRF/RESERVE	-79.929277	9.292222				FCPP
38	Darien		TRF/RESERVE	-79.931361	9.287694				FCPP
39	Darien		TRF/RESERVE	-79.926166	9.295805				FCPP
40	Darien		TRF/RESERVE	-79.9125	9.28588				FCPP
41	Darien		TRF/RESERVE	-79.919216	9.252738				FCPP
42	Darien		TRF/RESERVE	-78.456527	8.791972				FCPP
43	Panama		TRF/RESERVE	-78.461277	8.795027				FCPP
44	Panama		TRF/RESERVE	-78.462222	8.798055				FCPP
45	Panama		TRF/RESERVE	-78.460444	8.794694				FCPP

46	Panama		TRF/RESERVE	-78.452111	8.789916				FCPP
47	San Blas		TRF/RESERVE	-78.450416	8.791333				FCPP
48	San Blas		TRF/RESERVE	-78.418055	8.780527				FCPP
49	San Blas		TRF/RESERVE	-78.460916	8.798				FCPP
50	San Blas		TRF/RESERVE	-78.458805	8.796361				FCPP
51	San Blas		TRF/RESERVE	-78.45125	8.789444				FCPP
52	San Blas		TRF/RESERVE	-78.469583	8.935663				FCPP
53	San Blas		TRF/RESERVE	-78.450444	8.788888				FCPP
54	San Blas		TRF/RESERVE	-78.45275	8.789333				FCPP
55	San Blas		TRF/RESERVE	-77.6507921	7.82211785				FCPP
56	San Blas		TRF/RESERVE	-77.9539667	8.36335109				FCPP
57	Panama		TRF/RESERVE	-77.732434	8.01972424				FCPP
58	Panama		TRF/RESERVE	-79.731065	9.14906664				FCPP
59	Panama		TRF/RESERVE	-79.7285517	9.14611998				FCPP
60	Panama		TRF/RESERVE	-79.731065	9.14906664				FCPP
61	Panama		TRF/RESERVE	-79.7456397	9.16037437				FCPP
62	Panama		TRF/RESERVE	-79.7285517	9.14611998				FCPP

63	Panama		TRF/RESERVE	-77.732434	8.01972424				FCPP

Appendix 2.6. Locations for presence of *Alouatta palliata palliata*; DTF: Dry Tropical Forest; TRF: Tropical Rain Forest; FF: Fragmented Forest; LF: Living Fences; SFR: San Francisco Reserve; A: Area; D: Relative density; N: North; W: West. Blank space mean information not available.

# site	Province	Study site	Habitat/ Use	Latitude	Longitude	Ind.	A (km^2)	D	Source
1	Panama	Las Pavas	FF/TEAK PLANT.	-82.739066	8.406416		60	0.08	Méndez-Carvajal, 2012
2	Panama	La Plantacion	TRF/RESERVE	-82.533916	8.394339		80	0.15	FCPP
3	Panama	El Charco Trail	TRF/RESERVE	-82.572127	8.306411		80	0.06	FCPP
4	Panama	BCI	TRF/RESERVE	-82.630763	8.370091		15	20	Glanz, 1992
5	Panama	Chorrera	FF/URBAN	-82.756236	8.328686				FCPP
6	Panama	Cerro Cama	FF/URBAN	-82.487097	8.328686	30	0.07	2.1	FCPP
7	Panama	Gamboa	TRF/URBAN	-82.591936	8.329286		80	0.03	FCPP
8	Panama	Bayano	TRF/RESERVE	-82.526019	8.341361				FCPP
9	Colon	Achiote	TRF/URBAN	-82.608516	8.448266				FCPP
10	Colon	Donoso	TRF/COOPER MINE	-82.753669	8.480688	35	200		FCPP
11	Colon	Donoso	TRF/COOPER MINE	-82.756236	8.318072	35	200		FCPP
12	Colon	Donoso	TRF/COOPER MINE	-82.909969	8.244072	35	200		FCPP

13	Colon	Donoso	TRF/COOPER MINE	-82.891061	8.152697	35	200		FCPP
14	Colon	Donoso	TRF/COOPER MINE	-82.888286	8.173108	35	200		FCPP
15	Colon	Donoso	TRF/COOPER MINE	-82.876394	8.056944	35	200		FCPP
16	Colon	Donoso	TRF/COOPER MINE	-82.112613	8.364422	35	200		FCPP
17	Colon	Donoso	TRF/COOPER MINE	-82.705347	8.596594	35	200		FCPP
18	Colon	Donoso	TRF/COOPER MINE	-82.463436	8.481725	35	200		FCPP
19	Colon	Donoso	TRF/COOPER MINE	-82.430144	8.365775	35	200		FCPP
20	Colon	Donoso	TRF/COOPER MINE	-82.174497	8.27405	35	200		FCPP
21	Colon	Donoso	TRF/COOPER MINE	-82.805741	8.557666	35	200		FCPP
22	Colon	Donoso	TRF/COOPER MINE	-82.856633	8.706866	35	200		FCPP
23	Cocle	Palmarazo	TRF/RESERVE	-82.834669	8.766175	8		0.175	FCPP
24	Cocle	La Mina	TRF/RESERVE	-82.757241	8.820669	4		0.175	FCPP
25	Veraguas	Santiago	FF/FARMING-CAT-TLE	-82.437638	8.449894	1			FCPP
26	Chiriqui	Paraiso	FF/FARMING-CAT-TLE	-82.807186	8.606141	1			FCPP
27	Chiriqui	Las Monjas	FF/FARMING-CAT-TLE	-82.773316	8.715477	1			FCPP
28	Chiriqui	Limones	TRF/RESERVE	-82.839761	8.738486				FCPP

29	Chiriqui	Burica	TRF/RESERVE	-82.86733	8.828933				FCPP
30	Chiriqui	Baru	TRF/RESERVE	-82.87325	8.096944	1			FCPP
31	Chiriqui	Baru	TRFT/RESERVE	-82.874416	8.098277	1			FCPP
32	Chiriqui	P. Armuelles	FF/FARMING-CAT-TLE	-82.873416	8.096777	3			FCPP
33	Chiriqui	P. Armuelles	FF/FARMING-CAT-TLE	-82.873027	8.098805	1			FCPP
34	Chiriqui	Rio Yerbazales	FF/FARMING-CAT-TLE	-82.872611	8.098888	7			FCPP
35	Chiriqui	Rio Yerbazales	FF/FARMING-CAT-TLE	-82.872416	8.099	4			FCPP
36	Chiriqui	Rio Yerbazales	FF/FARMING-CAT-TLE	-82.871388	8.097861	4			FCPP
37	Panama	I. Bastimentos	TRF/ISLAND	-82.878611	8.235027				FCPP
38	Panama	I. Bastimentos	FF/FARMING-CAT-TLE	-82.878722	8.235611				FCPP
39	Panama		TRF/RESERVE	-82.762756	9.230893				FCPP
40	Panama		TRF/RESERVE	-82.462006	8.753437				FCPP
41	Panama		TRF/RESERVE	-82.819061	8.849793				FCPP
42	Panama		TRF/RESERVE	-82.662506	9.547938				FCPP
43	Panama		TRF/RESERVE	-82.411194	8.913564				FCPP

44	Panama		TRF/RESERVE	-82.128296	8.656699				FCPP
45	Panama		TRF/RESERVE	-81.89209	8.708644				FCPP
46	Panama		TRF/RESERVE	-81.359253	8.668597				FCPP
47	Panama		TRF/RESERVE	-81.043396	8.537565				FCPP
48	Panama		TRF/RESERVE	-80.587463	8.985462				FCPP
49	Panama		TRF/RESERVE	-80.166462	8.889142				FCPP
50	Panama		TRF/RESERVE	-80.425415	9.062771				FCPP
51	Panama		TRF/RESERVE	-80.690888	9.018055				FCPP
52	Panama		TRF/RESERVE	-80.688833	9.009166				FCPP
53	Panama		TRF/RESERVE	-80.704722	8.988361				FCPP
54	Panama		TRF/RESERVE	-80.704777	8.985				FCPP
55	Panama		TRF/RESERVE	-80.705111	9.82361				FCPP
56	Panama		TRF/RESERVE	-80.705361	8.981861				FCPP
57	Panama		TRF/RESERVE	-80.705305	8.981388				FCPP
58	Panama		TRF/RESERVE	-80.705472	8.980416				FCPP
59	Panama		TRF/RESERVE	-80.706111	8.969138				FCPP
60	Panama		TRF/RESERVE	-80.705611	8.968055				FCPP

61	Panama		TRF/RESERVE	-80.705388	8.965305				FCPP
62	Panama		TRF/RESERVE	-80.705361	8.981861				FCPP
63	Panama		TRF/RESERVE	-80.704722	8.988361				FCPP
64	Panama		TRF/RESERVE	-80.701944	8.963388				FCPP
65	Panama		TRF/RESERVE	-80.701166	8.965194				FCPP
66	Panama		TRF/RESERVE	-80.700972	8.960611				FCPP
67	Panama		TRF/RESERVE	-80.699416	8.956083				FCPP
68	Panama		TRF/RESERVE	-80.697527	8.955444				FCPP
69	Panama		TRF/RESERVE	-80.693194	8.946638				FCPP
70	Panama		TRF/RESERVE	-80.693027	8.946722				FCPP
71	Panama		TRF/RESERVE	-80.6925	8.941944				FCPP
72	Panama		TRF/RESERVE	-80.68925	8.933416				FCPP
73	Panama	Panama W	TRF/RESERVE	-80.688833	9.009277				FCPP
74	Panama		TRF/RESERVE	-80.687555	8.932527				FCPP
75	Panama		TRF/RESERVE	-80.664944	8.917138				FCPP
76	Panama		TRF/RESERVE	-80.658972	8.910861				FCPP
77	Panama		TRF/RESERVE	-80.646777	8.895277				FCPP

78	Panama		TRF/RESERVE	-80.690888	9.016805				FCPP
79	Panama		TRF/RESERVE	-80.688833	9.009166				FCPP
80	Panama		TRF/RESERVE	-80.704722	8.988361				FCPP
81	Panama	Colon	TRF/RESERVE	-80.705361	8.981861				FCPP
82	Panama		TRF/RESERVE	-80.706111	8.969138				FCPP
83	Panama		TRF/RESERVE	-80.705611	8.968055				FCPP
84	Panama		TRF/RESERVE	-80.701944	8.963388				FCPP
85	Panama		TRF/RESERVE	-80.701166	8.965194				FCPP
86	Panama		TRF/RESERVE	-80.700922	8.960611				FCPP
87	Panama	Panama W	TRF/RESERVE	-80.699416	8.956083				FCPP
88	Panama		TRF/RESERVE	-80.699333	8.955861				FCPP
89	Panama		TRF/RESERVE	-80.693194	8.946638				FCPP
90	Panama		TRF/RESERVE	-80.693027	8.946722				FCPP
91	Panama		TRF/RESERVE	-80.687555	8.932527				FCPP
92	Panama		TRF/RESERVE	-80.658972	8.910861				FCPP

Appendix 2.7. Locations for presence of *Alouatta palliata aequatorialis*; DTF: Dry Tropical Forest; TRF: Tropical Rain Forest; FF: Fragmented Forest; LF: Living Fences; SFR: San Francisco Reserve; A: Area; D: Relative density; N: North; W: West. Where spaces are blank this means that no information was available.

# site	Province	Study site	Habitat/ Use	Latitude	Longitude	Ind.	A (km^2)	D	Source
1	Panama	Ancon	DTF/URBAN	-79.203166	9.309638	4	40	0.1	FCPP
2	Panama	Las Pavas	FF/TEAK PLANT.	-79.205833	9.315277		60		FCPP
3	Panama	La Plantacion	TRF/RESERVE	-79.205972	9.300527	6	80	0.75	FCPP
4	Panama	El Charco Trail	TRF/RESERVE	-79.206638	9.301277		80		FCPP
5	Panama	Bci	TRF/RESERVE	-79.205222	9.297555				FCPP/Glanz 1992
6	Panama	Gamboa	TRF/URBAN	-79.204916	9.3075	2	80	0.02	FCPP
7	Panama	Arraijan/Buque	FF/URBAN.	-79.841766	9.153621				FCPP
8	Panama	Chorrera	FF/URBAN.	-79.704722	8.988361	4	20	0.2	FCPP
9	Panama	Chorrera	FF/URBAN.	-79.68925	9.33416	9	20	0.45	FCPP
10	Panama	La Llana	TRF/RESERVE	-79.205583	8.295027		1440		Svensson et al., 2010
11	Panama	Campo Chagres	TRF/RESERVE	-79.515194	9.104833	25	2540	3.1	Svensson et al., 2010
12	Panama	Cerro Azul	TRF/RESERVE	-79.968796	8.714752	8	1120	7.14	Svensson et al., 2010
13	Colon	El Guabo	TRF/MINE	-79.808807	8.668597	5	20	0.25	FCPP
14	Colon	Donoso	TRF/COOPER MINE	-79.988708	9.245804	2	200	0.01	FCPP/MWH
15	Colon	Palmarazo	TRF/RESERVE	-79.73877	9.074976	1	8	0.125	Araúz et al., 2008

16	Colon	La Mina	TRF/RESERVE	-79.571228	9.026153	1	4	0.25	Araúz et al., 2008
17	Cocle	La Tabila	TRF/RESERVE	-79.550629	8.989531	1	5	0.2	Araúz et al., 2008
18	Colon	San Lorenzo	TRF/RESERVE	-79.593201	9.176669	1			Weaver, Bauer, 2004
19	Cocle	Churuquita	TRF/URBAN	-79.3927	9.039715	5	20	0.25	Araúz et al., 2008
20	Darien	Bajo Chiquito	TRF/LOGGING ACT.	-79.372101	9.279688		60		FCPP/Medina
21	Darien	Chucanti	TRF/ RESERVE	-79.124908	9.065483	85	200	28.4	Méndez-Carva-jal, 2012
22	Darien	Chucanti	TRF/ RESERVE	-79.109802	9.401646		200	28.4	Méndez-Carva-jal, 2012
23	Darien	Rio Pavo	LF/FARMING- CAT-TLE	-79.436646	9.396226		40		Méndez-Carva-jal, 2012
24	Darien	Torti	LF/URBAN	-78.751373	9.049209		2		Méndez-Carva-jal, 2012
25	Darien	Torti	TRF/ RESERVE	-78.097687	7.536764		40		Méndez-Carva-jal, 2012
26	Darien	Boca De Cupe	TRF/RESERVE	-77.585449	7.757259		4	4.8	Moreno et al., 2006
27	Darien	Sen. Jaguar	TRF/RESERVE	-77.555237	8.066028		4	4.8	Moreno et al., 2006
28	Darien	Pirre	TRF/RESERVE	-77.408295	8.393583		4	4.8	Moreno et al., 2006

29	Darien	Cana	TRF/RESERVE	-77.733765	8.495463		4	4.8	Moreno et al., 2006
30	Darien	Cana	TRF/RESERVE	-77.658234	8.775154		4	4.8	Moreno et al., 2006
31	Darien	Base	TRF/RESERVE	-77.746124	8.297111				Méndez-Carva-jal, 2012
32	Darien	Chucanti	TRF/RESERVE	-78.138885	8.332442				Méndez-Carva-jal, 2012
33	Darien	Base	TRF/RESERVE	-78.159485	8.507687				Méndez-Carva-jal, 2012
34	Darien	Talauma	TRF/RESERVE	-78.490448	8.534849				Méndez-Carva-jal, 2012
35	Darien	Talauma	TRF/RESERVE	-78.601685	8.75208				Méndez-Carva-jal, 2012
36	Darien	Water Intake	TRF/RESERVE	-78.43689	8.844365				Méndez-Carva-jal, 2012
37	Darien	Water Intake	TRF/RESERVE	-78.585205	8.948836				Méndez-Carva-jal, 2012
38		Water Intake	TRF/RESERVE	-78.739014	9.062771				Méndez-Carva-jal, 2012
39	Darien	Water Intake	TRF/RESERVE	-79.038391	9.347448				Méndez-Carva-jal, 2012
40	Darien	Water Intake	TRF/RESERVE	-79.240265	9.45448				Méndez-Carva-jal, 2012
41	Darien	San Blas	TRF/RESERVE	-79.944	9.265916				FCPP
42	Darien	San Blas	TRF/RESERVE	-79.94525	9.26625				FCPP

43	Darien	San Blas	TRF/RESERVE	-79.946361	9.266611				FCPP
44	Panama		RAIN FOREST	-79.946583	9.267027				FCPP
45	Panama		RAIN FOREST	-79.946694	9.267222				FCPP
46	Panama		RAIN FOREST	-79.947361	9.266027				FCPP
47	Panama		RAIN FOREST	-79.948416	9.266805				FCPP
48	Panama		RAIN FOREST	-79.946	9.268638				FCPP
49	Panama		RAIN FOREST	-79.945972	9.272027				FCPP
50	Panama		RAIN FOREST	-79.930972	9.276138				FCPP
51	Panama		RAIN FOREST	-79.927194	9.291333				FCPP
52	Panama		RAIN FOREST	-79.929277	9.292222				FCPP
53	Panama		RAIN FOREST	-79.931361	9.287694				FCPP
54	Panama		RAIN FOREST	-79.926166	9.295805				FCPP
55	Panama		RAIN FOREST	-79.9125	9.28588				FCPP
56	Panama		RAIN FOREST	-79.919216	9.252738				FCPP
57	Panama		RAIN FOREST	-78.456527	8.791972				FCPP
58	Panama		RAIN FOREST	-78.461277	8.795027				FCPP
59	Panama		RAIN FOREST	-78.462222	8.798055				FCPP
60	Panama		RAIN FOREST	-78.460444	8.794694				FCPP
61	Panama		RAIN FOREST	-78.452111	8.789916				FCPP
62	Panama		RAIN FOREST	-78.450416	8.791333				FCPP
63	Panama		RAIN FOREST	-78.453472	8.789638				FCPP

64	Panama		RAIN FOREST	-78.462166	8.797305				FCPP
65	Panama		RAIN FOREST	-78.462444	8.798194				FCPP
66	Panama		RAIN FOREST	-78.450233	8.793277				FCPP
67	Panama		RAIN FOREST	-78.470277	8.935602				FCPP
68	Panama		RAIN FOREST	-78.467255	8.935038				FCPP
69	Panama		RAIN FOREST	-78.452972	8.789833				FCPP
70	Panama		RAIN FOREST	-77.6458249	7.89137173				FCPP
71	Panama		RAIN FOREST	-77.6314453	7.9379374				FCPP
72	Panama		RAIN FOREST	-77.6743449	7.72572035				FCPP
73	Panama		RAIN FOREST	-77.9477389	8.36027188				FCPP
74	Panama		RAIN FOREST	-77.9384743	8.40453478				FCPP
75	Panama		RAIN FOREST	-77.939545	8.41899909				FCPP
76	Panama		RAIN FOREST	-77.9384743	8.40453478				FCPP
77	Panama		RAIN FOREST	-77.9528799	8.36237452				FCPP
78	Panama		RAIN FOREST	-77.9392658	8.38072451				FCPP
79	Panama		RAIN FOREST	-77.9385396	8.36010548				FCPP
80	Panama		RAIN FOREST	-77.9771885	8.50899715				FCPP
81	Panama		RAIN FOREST	-77.9675713	8.36909396				FCPP
82	Panama		RAIN FOREST	-77.7729556	8.33091627				FCPP
83	Panama		RAIN FOREST	-78.2372804	8.70094305				FCPP
84	Panama		RAIN FOREST	-78.3965615	8.92426741				FCPP

85	Panama		RAIN FOREST	-78.5539217	9.02761193				FCPP
86	Panama		RAIN FOREST	-78.5539217	9.02761193				FCPP
87	Panama		RAIN FOREST	-78.5453314	9.04498721				FCPP
88	Panama		RAIN FOREST	-78.524933	9.06727979				FCPP
89	Panama		RAIN FOREST	-77.732434	8.01972424				FCPP
90	Panama		RAIN FOREST	-77.7117879	8.20952939				FCPP
91	Panama		RAIN FOREST	-77.7165998	8.23159811				FCPP
92	Panama		RAIN FOREST	-79.1864089	9.52835356				FCPP
93	Panama		RAIN FOREST	-79.7160893	9.13072782				FCPP
94	Panama		RAIN FOREST	-79.7266358	9.14337977				FCPP
95	Panama		RAIN FOREST	-79.7270167	9.14374283				FCPP
96	Panama		RAIN FOREST	-79.7149283	9.12209683				FCPP
97	Panama		RAIN FOREST	-79.7456397	9.16037437				FCPP
98	Panama		RAIN FOREST	-79.6560975	9.08742256				FCPP
99	Panama		RAIN FOREST	-79.6453123	9.11033286				FCPP
100	Panama		RAIN FOREST	-79.6443377	9.11542927				FCPP
101	Panama		RAIN FOREST	-79.1864089	9.52835356				FCPP
102	Panama		RAIN FOREST	-79.7160893	9.13072782				FCPP
103	Panama		RAIN FOREST	-79.7270167	9.14374283				FCPP
104	Panama		RAIN FOREST	-79.6560975	9.08742256				FCPP
105	Panama		RAIN FOREST	-78.6213933	9.19822397				FCPP

106	Panama		RAIN FOREST	-78.5539217	9.02761193				FCPP
107	Panama		RAIN FOREST	-78.5453314	9.04498721				FCPP
108	Panama		RAIN FOREST	-79.733755	9.15236667				FCPP
109	Panama		RAIN FOREST	-79.736035	9.15300166				FCPP
110	Panama		RAIN FOREST	-77.9384743	8.40453478				FCPP
111	Panama		RAIN FOREST	-77.939545	8.41899909				FCPP
112	Panama		RAIN FOREST	-77.9384743	8.40453478				FCPP
113	Panama		RAIN FOREST	-77.732434	8.01972424				FCPP
114	Panama		RAIN FOREST	-77.7117879	8.20952939				FCPP
115	Panama		RAIN FOREST	-77.7165998	8.23159811				FCPP
116	Panama		RAIN FOREST	-77.9528799	8.36237452				FCPP
117	Panama		RAIN FOREST	-77.9392658	8.38072451				FCPP
118	Panama		RAIN FOREST	-77.9477389	8.36027188				FCPP
119	Panama		RAIN FOREST	-77.9385396	8.36010548				FCPP
120	Panama		RAIN FOREST						FCPP

Appendix 2.8. Locations for presence of *Alouatta coibensis coibensis*; DTF: Dry Tropical Forest; TRF: Tropical Rain Forest; FF: Fragmented Forest; LF: Living Fences; SFR: San Francisco Reserve; A: Area; D: Relative density; N: North; W: West. Blank space means there is no information.

# site	Province	Study site	Habitat/ Use	Latitude	Longitude	Ind.	A (km^2)	D	Source
1	Veraguas	Isla Coiba	RTF/RESERVE	-81.748897	7.645147		560	0.08	Méndez-Carvajal, 2012
2	Veraguas	Rosario beach	RTF/RESERVE	-81.750858	7.640605		560	0.08	Méndez-Carvajal, 2012
3	Veraguas	The tower	RTF/RESERVE	-81.752416	7.639672		560	0.08	Méndez-Carvajal, 2012
4	Veraguas	"X" Hill	RTF/RESERVE	-81.753558	7.635727		560	0.08	Méndez-Carvajal, 2012
5	Veraguas	Springs	RTF/RESERVE	-81.757877	7.634436		560	0.08	Méndez-Carvajal, 2012
6	Veraguas	Isla Jicaron	RTF/RESERVE	-81.760361	7.636691		20		Méndez-Carvajal, 2012
7	Veraguas	Isla Coiba	RTF/RESERVE	-81.854263	7.525544				Méndez-Carvajal, 2012
8	Veraguas	Isla Coiba	RTF/RESERVE	-81.849669	7.511522				Méndez-Carvajal, 2012
9	Veraguas	Isla Coiba	RTF/RESERVE	-81.868361	7.515119				Méndez-Carvajal, 2012
10	Veraguas	Isla Coiba	RTF/RESERVE	-81.738425	7.617727				Méndez-Carvajal, 2012
11	Veraguas	Isla Coiba	RTF/RESERVE	-81.735655	7.609477				Méndez-Carvajal, 2012
12	Veraguas	Isla Coiba	RTF/RESERVE	-81.731244	7.609358				Méndez-Carvajal, 2012

13	Veraguas	Isla Coiba	RTF/RESERVE	-81.730652	7.612341				Méndez-Carvajal, 2012
14	Veraguas	Isla Coiba	RTF/RESERVE	-81.722991	7.438333				Méndez-Carvajal, 2012
15	Veraguas	Isla Coiba	RTF/RESERVE	-81.735286	7.435327				Méndez-Carvajal, 2012
16	Veraguas	Isla Coiba	RTF/RESERVE	-81.754916	7.440752				Méndez-Carvajal, 2012
17	Veraguas	Isla Coiba	RTF/RESERVE	-81.762436	7.461494				Méndez-Carvajal, 2012
18	Veraguas	Isla Coiba	RTF/RESERVE	-81.809692	7.267119				Méndez-Carvajal, 2012
19	Veraguas	Isla Coiba	RTF/RESERVE	-81.789093	7.27359				Méndez-Carvajal, 2012

Appendix 2.9. Locations for presence of *Alouatta coibensis trabeata*; DTF: Dry Tropical Forest; TRF: Tropical Rain Forest; FF: Fragmented Forest; LF: Living Fences; SFR: San Francisco Reserve; A: Area; D: Relative density; N: North; W: West. Blank space means there is no information

# site	Province	Study site	Habitat/ Use	Latitude	Longitude	Ind.	A (km^2)	D	Source
1	Herrera	Llano Grande	FF/FARMING-CATTLE	-80.691944	7.996083			40.6	Méndez-Carvajal, 2005
2	Herrera	Llano Grande	FF/FARMING-CATTLE	-80.697556	8.004222			40.6	Méndez-Carvajal, 2005
3	Herrera	Llano Grande	FF/FARMING-CATTLE	-80.693861	7.997222			40.6	Méndez-Carvajal, 2005
4	Herrera	Llano Grande	FF/FARMING-CATTLE	-80.311333	7.547444			40.6	Méndez-Carvajal, 2005

5	Herrera	Llano Grande	FF/FARMING-CATTLE	-80.312694	7.539306			40.6	Méndez-Carvajal, 2005
6	Herrera	Llano Hato	FF/FARMING-CATTLE	-80.299917	7.546806			40.6	Méndez-Carvajal, 2005
7	Herrera	R. La Villa	TRF/RESERVE	-80.294583	7.545306			0.5	Méndez-Carvajal, 2013
8	Herrera	Caras Pintadas	TRF/RESERVE	-80.293444	7.54425			0.5	Méndez-Carvajal, 2013
9	Herrera	El Ñuco	TRF/RESERVE	-80.319306	7.5535			0.5	Méndez-Carvajal, 2013
10	Herrera	Tres Puntas	TRF/RESERVE	-80.301583	7.54775			0.5	Méndez-Carvajal, 2013
11	Herrera	Altos Del Higo	TRF/RESERVE	-80.294	7.545278			0.5	Méndez-Carvajal, 2013
12	Herrera	Sonadora	TRF/RESERVE	-80.282139	7.548806			0.5	Méndez-Carvajal, 2013
13	Los Santos	La Miel	LF/URBAN	-80.303556	7.572306			42.6	Méndez-Carvajal, 2013
14	Los Santos	La Miel	LF/URBAN	-80.868056	7.378611			42.6	Méndez-Carvajal, 2013
15	Los Santos	La Miel	LF/URBAN	-80.550278	7.484444			42.6	Méndez-Carvajal, 2013
16	Los Santos	La Miel	LF/URBAN	-80.589167	7.429444			42.6	Méndez-Carvajal, 2013
17	Los Santos	La Miel	LF/URBAN	-80.533889	7.450833			42.6	Méndez-Carvajal, 2013

18	Los Santos	La Miel	LF/URBAN	-80.193889	7.435278			42.6	Méndez-Carvajal, 2013
19	Los Santos	La Miel	LF/URBAN	-80.781389	7.335833			42.6	Méndez-Carvajal, 2013
20	Los Santos	La Miel	LF/URBAN	-80.785278	7.343333			42.6	Méndez-Carvajal, 2013
21	Los Santos	Toña	LF/URBAN	-80.87	7.378611			42.6	Méndez-Carvajal, 2013
22	Los Santos	De Pallo	LF/URBAN	-80.904444	7.254444			42.6	Méndez-Carvajal, 2013
23	Los Santos	De Pillo	LF/URBAN	-80.890833	7.252778			42.6	Méndez-Carvajal, 2013
24	Los Santos	De Toño	LF/URBAN	-80.781944	7.230278			42.6	Méndez-Carvajal, 2013
25	Los Santos	Rio Oria	GALLERY/URBAN	-80.753419	7.291906			42.6	Méndez-Carvajal, 2013
26	Veraguas	Flores	GALLERY/URBAN	-80.698611	7.985833			5.1	Méndez-Carvajal, 2013
27	Veraguas	Río Güera	GALLERY/URBAN	-80.692722	7.992278			5.1	Méndez-Carvajal, 2013
28	Veraguas	La Tronosa	DTF/RESERVE	-80.692556	7.990083			5.1	Méndez-Carvajal, 2013
29	Veraguas	Bajo Limpo	GALLERY/URBAN	-80.868056	7.378611			5.1	Méndez-Carvajal, 2013
30	Los Santos	Venao	FF/URBAN	-80.691944	7.996083			5.1	Méndez-Carvajal, 2013

31	Los Santos	Arenas	LF/URBAN	-80.697556	8.004222			17.2	Méndez-Carvajal, 2013
32	Veraguas	Arenas	LF/URBAN	-80.868056	7.378611			17.2	Méndez-Carvajal, 2013
33	Veraguas	Rio Pavo	LF/URBAN	-80.311333	7.547444			17.2	Méndez-Carvajal, 2013
34	Veraguas	Restingue	LF/URBAN	-80.312694	7.539306			5.1	Méndez-Carvajal, 2013
35	Veraguas	Cerro Culón	LF/URBAN	-80.299917	7.546806			5.1	Méndez-Carvajal, 2013
36	Veraguas	Río Ventana	LF/URBAN	-80.294583	7.545306			5.1	Méndez-Carvajal, 2013
37	Veraguas		LF/URBAN	-80.293444	7.54425				FCPP
38	Veraguas		LF/URBAN	-80.341111	7.587778				FCPP
39	Veraguas		LF/URBAN	-80.393056	7.4925				FCPP
40	Veraguas		LF/URBAN	-80.308611	7.577778				FCPP
41	Veraguas		LF/URBAN	-80.321667	7.557222				FCPP
42	Veraguas		LF/URBAN	-80.2975	7.561389				FCPP
43	Veraguas		LF/URBAN	-80.293889	7.545				FCPP
44	Veraguas		LF/URBAN	-80.294167	7.543889				FCPP
45	Veraguas		LF/URBAN	-80.288889	7.536667				FCPP
46	Veraguas		LF/URBAN	-80.286667	7.536667				FCPP
47	Veraguas		LF/URBAN	-80.393056	7.4925				FCPP
48	Veraguas		LF/URBAN	-80.341111	7.587778				FCPP

49	Veraguas		LF/URBAN	-80.34125	7.587778				FCPP
50	Veraguas		LF/URBAN	-80.316583	7.566806				FCPP
51	Veraguas		LF/URBAN	-80.321472	7.558111				FCPP
52	Veraguas		LF/URBAN	-80.312028	7.547694				FCPP
53	Veraguas		LF/URBAN	-80.321472	7.558111				FCPP
54	Veraguas		LF/URBAN	-80.321028	7.556306				FCPP
55	Veraguas		LF/URBAN	-80.319583	7.554472				FCPP
56	Veraguas		LF/URBAN	-80.300167	7.550528				FCPP
57	Herrera		LF/URBAN	-80.321306	7.559889				FCPP
58	Herrera		LF/URBAN	-80.296889	7.546056				FCPP
59	Herrera		LF/URBAN	-80.287333	7.537389				FCPP
60	Herrera		LF/URBAN	-80.283056	7.543944				FCPP
61	Herrera		LF/URBAN	-80.283583	7.545861				FCPP
62	Herrera		LF/URBAN	-80.284944	7.546694				FCPP
63	Herrera		LF/URBAN	-80.311444	7.547806				FCPP
64	Herrera		LF/URBAN	-80.285083	7.538056				FCPP
65	Herrera		LF/URBAN	-80.283222	7.547139				FCPP
66	Herrera		LF/URBAN	-80.281444	7.547833				FCPP
67	Herrera		LF/URBAN	-80.28925	7.545083				FCPP
68	Herrera		LF/URBAN	-80.285694	7.547167				FCPP
69	Herrera		LF/URBAN	-80.319722	7.555333				FCPP

70	Herrera		LF/URBAN	-80.305056	7.546722				FCPP
71	Herrera		LF/URBAN	-80.29075	7.542944				FCPP
72	Herrera		LF/URBAN	-80.319306	7.5535				FCPP
73	Herrera		LF/URBAN	-80.301583	7.564417				FCPP
74	Herrera		LF/URBAN	-80.294	7.545278				FCPP
75	Herrera		LF/URBAN	-80.282139	7.548806				FCPP
76	Herrera		LF/URBAN	-80.290361	7.540278				FCPP
77	Herrera		LF/URBAN	-80.292333	7.545472				FCPP
78	Herrera		LF/URBAN	-80.315694	7.550167				FCPP
79	Herrera		LF/URBAN	-80.326222	7.559556				FCPP
80	Herrera		LF/URBAN	-80.307194	7.546889				FCPP
81	Herrera		LF/URBAN	-80.303472	7.547028				FCPP
82	Herrera		LF/URBAN	-80.316306	7.577833				FCPP
83	Herrera		LF/URBAN	-80.310611	7.577278				FCPP
84	Herrera		LF/URBAN	-80.299806	7.576583				FCPP
85	Herrera		LF/URBAN	-80.298333	7.567				FCPP
86	Herrera		LF/URBAN	-80.303556	7.572306				FCPP
87	Herrera		LF/URBAN	-80.329861	7.55875				FCPP
88	Herrera		LF/URBAN	-80.3335	7.551139				FCPP
89	Herrera		LF/URBAN	-80.327611	7.544861				FCPP
90	Herrera		LF/URBAN	-80.326889	7.545472				FCPP

91	Herrera		LF/URBAN	-80.546583	7.546583				FCPP
92	Herrera		LF/URBAN	-80.324361	7.55575				FCPP
93	Herrera		LF/URBAN	-80.2945	7.545278				FCPP
94	Herrera		LF/URBAN	-80.291778	7.541778				FCPP
95	Herrera		LF/URBAN	-80.311972	7.547972				FCPP
96	Herrera		LF/URBAN	-80.781389	7.335833				FCPP
97	Herrera		LF/URBAN	-80.785278	7.343333				FCPP
98	Herrera		LF/URBAN	-80.87	7.378611				FCPP
99	Herrera		LF/URBAN	-80.859167	7.352222				FCPP
100	Herrera		LF/URBAN	-80.862222	7.372222				FCPP
101	Herrera		LF/URBAN	-80.869444	7.378611				FCPP
102	Herrera		LF/URBAN	-80.861111	7.385833				FCPP
103	Herrera		LF/URBAN	-80.861667	7.385556				FCPP
104	Herrera		LF/URBAN	-80.856944	7.385278				FCPP
105	Herrera		LF/URBAN	-80.904444	7.254444				FCPP
106	Herrera		LF/URBAN	-80.868056	7.378611				FCPP
107	Herrera		LF/URBAN	-80.857194	7.364361				FCPP
108	Herrera		LF/URBAN	-80.854444	7.36075				FCPP
109	Herrera		LF/URBAN	-80.864917	7.38275				FCPP
110	Herrera		LF/URBAN	-80.868139	7.380278				FCPP
111	Herrera		LF/URBAN	-80.861806	7.373472				FCPP

112	Herrera		LF/URBAN	-80.870444	7.37975				FCPP
113	Herrera		LF/URBAN	-80.86425	7.383333				FCPP
114	Herrera		LF/URBAN	-80.311167	7.547389				FCPP
115	Herrera		LF/URBAN	-80.319722	7.554917				FCPP
116	Herrera		LF/URBAN	-80.319611	7.554639				FCPP
117	Herrera		LF/URBAN	-80.861028	7.384667				FCPP
118	Herrera		LF/URBAN	-80.868139	7.380278				FCPP
119	Herrera		LF/URBAN	-80.294167	7.545				FCPP
120	Herrera		LF/URBAN	-80.308611	7.577778				FCPP
121	Herrera		LF/URBAN	-80.861111	7.385833				FCPP
122	Herrera		LF/URBAN	-80.861667	7.385556				FCPP
123	Herrera		LF/URBAN	-80.87	7.378611				FCPP
124	Herrera		LF/URBAN	-80.872222	7.377778				FCPP
125	Herrera		LF/URBAN	-80.781389	7.335833				FCPP
126	Herrera		LF/URBAN	-80.309944	7.5785				FCPP
127	Herrera		LF/URBAN	-80.314889	7.578333				FCPP
128	Herrera		LF/URBAN	-80.312028	7.547694				FCPP
129	Herrera		LF/URBAN	-80.312694	7.539306				FCPP
130	Herrera		LF/URBAN	-80.305083	7.54675				FCPP
131	Herrera		LF/URBAN	-80.299917	7.546806				FCPP
132	Herrera		LF/URBAN	-80.294583	7.545306				FCPP

133	Herrera		LF/URBAN	-80.293444	7.54425				FCPP
134	Herrera		LF/URBAN	-80.285722	7.538222				FCPP
135	Herrera		LF/URBAN	-80.284361	7.540389				FCPP
136	Herrera		LF/URBAN	-80.283306	7.545222				FCPP
137	Herrera		LF/URBAN	-80.283972	7.542944				FCPP
138	Herrera		LF/URBAN	-80.781389	7.335833				FCPP
139	Herrera		LF/URBAN	-80.781944	7.230278				FCPP
140	Herrera		LF/URBAN	-80.393056	7.4925				FCPP
141	Herrera		LF/URBAN	-80.87	7.378611				FCPP
142	Herrera		LF/URBAN	-80.872222	7.377778				FCPP
143	Herrera		LF/URBAN	-80.864722	7.380833				FCPP
144	Herrera		LF/URBAN	-80.859167	7.352222				FCPP
145	Herrera		LF/URBAN	-80.869444	7.378611				FCPP
146	Herrera		LF/URBAN	-80.904444	7.254444				FCPP
147	Herrera		LF/URBAN	-80.868056	7.378611				FCPP
148	Herrera		LF/URBAN	-80.839556	7.738611				FCPP
149	Herrera		LF/URBAN	-80.856028	7.734556				FCPP
150	Herrera		LF/URBAN	-80.34125	7.587778				FCPP
151	Herrera		LF/URBAN	-80.589194	7.4295				FCPP
152	Herrera		LF/URBAN	-80.589417	7.427222				FCPP
153	Herrera		LF/URBAN	-80.588722	7.416139				FCPP

154	Herrera		LF/URBAN	-80.586333	7.408556				FCPP
155	Herrera		LF/URBAN	-80.550333	7.4845				FCPP
156	Herrera		LF/URBAN	-80.533889	7.451083				FCPP
157	Herrera		LF/URBAN	-80.529972	7.454111				FCPP
158	Herrera		LF/URBAN	-80.510611	7.345111				FCPP
159	Herrera		LF/URBAN	-80.193889	7.435306				FCPP
160	Herrera		LF/URBAN	-80.218583	7.437889				FCPP
161	Herrera		LF/URBAN	-80.311333	7.547444				FCPP
162	Herrera		LF/URBAN	-80.312694	7.539306				FCPP
163	Herrera		LF/URBAN	-80.305083	7.54675				FCPP
164	Herrera		LF/URBAN	-80.299917	7.546806				FCPP
165	Herrera		LF/URBAN	-80.294583	7.545306				FCPP
166	Herrera		LF/URBAN	-80.293444	7.549861				FCPP
167	Herrera		LF/URBAN	-80.311972	7.547972				FCPP
168	Herrera		LF/URBAN	-80.308083	7.545694				FCPP
169	Herrera		LF/URBAN	-80.326	7.556306				FCPP
170	Herrera		LF/URBAN	-80.31925	7.553444				FCPP
171	Herrera		LF/URBAN	-80.320722	7.556917				FCPP
172	Herrera		LF/URBAN	-80.321222	7.559889				FCPP
173	Herrera		LF/URBAN	-80.19625	7.4335				FCPP
174	Herrera		LF/URBAN	-80.589167	7.429444				FCPP

175	Herrera		LF/URBAN	-80.533889	7.450833				FCPP
176	Herrera		LF/URBAN	-80.193889	7.435278				FCPP
177	Herrera		LF/URBAN	-80.811389	7.725				FCPP
178	Herrera		LF/URBAN	-80.800278	7.7325				FCPP
179	Herrera		LF/URBAN	-80.832222	7.758056				FCPP
180	Herrera		LF/URBAN	-80.814444	7.748611				FCPP
181	Herrera		LF/URBAN	-80.835556	7.725556				FCPP
182	Herrera		LF/URBAN	-80.866667	7.718611				FCPP
183	Herrera		LF/URBAN	-80.6925	7.99				FCPP
184	Herrera		LF/URBAN	-80.6925	7.988889				FCPP
185	Herrera		LF/URBAN	-80.904444	7.254444				FCPP
186	Herrera		LF/URBAN	-80.890833	7.252778				FCPP
187	Herrera		LF/URBAN	-80.781944	7.230278				FCPP
188	Herrera		LF/URBAN	-80.868056	7.378611				FCPP
189	Herrera		LF/URBAN	-80.550278	7.484444				FCPP
190	Herrera		LF/URBAN	-80.693611	7.996667				FCPP
191	Herrera		LF/URBAN	-80.693889	7.996667				FCPP
192	Herrera		LF/URBAN	-80.393056	7.4925				FCPP
193	Herrera		LF/URBAN	-80.308611	7.577778				FCPP
194	Herrera		LF/URBAN	-80.321667	7.557222				FCPP
195	Herrera		LF/URBAN	-80.2975	7.561389				FCPP

196	Herrera		LF/URBAN	-80.293889	7.545				FCPP
197	Herrera		LF/URBAN	-80.286667	7.536667				FCPP
198	Herrera		LF/URBAN	-80.781389	7.335833				FCPP
199	Herrera		LF/URBAN	-80.869444	7.378611				FCPP
200	Herrera		LF/URBAN	-80.861111	7.385833				FCPP
201	Herrera		LF/URBAN	-80.859167	7.352222				FCPP
202	Herrera		LF/URBAN	-80.308611	7.577778				FCPP
203	Herrera		LF/URBAN	-80.856944	7.385278				FCPP
204	Herrera		LF/URBAN	-80.6925	7.99				FCPP
205	Herrera		LF/URBAN	-80.6925	7.988889				FCPP
206	Herrera		LF/URBAN	-80.699722	7.999722				FCPP
207	Herrera		LF/URBAN	-80.6925	7.992222				FCPP
208	Herrera		LF/URBAN	-80.811389	7.725				FCPP
209	Herrera		LF/URBAN	-80.800278	7.7325				FCPP
210	Herrera		LF/URBAN	-80.832222	7.758056				FCPP
211	Herrera		LF/URBAN	-80.814444	7.748611				FCPP
212	Herrera		LF/URBAN	-80.835556	7.725556				FCPP
213	Herrera		LF/URBAN	-80.856667	7.718611				FCPP
214	Herrera		LF/URBAN	-80.904444	7.254444				FCPP
215	Herrera		LF/URBAN	-80.890833	7.252778				FCPP
216	Herrera		LF/URBAN	-80.781944	7.230278				FCPP

217	Herrera		LF/URBAN	-80.868056	7.378611				FCPP
218	Herrera		LF/URBAN	-80.550278	7.484444				FCPP
219	Herrera		LF/URBAN	-80.589167	7.429444				FCPP
220	Herrera		LF/URBAN	-80.533889	7.450833				FCPP
221	Herrera		LF/URBAN	-80.193889	7.435278				FCPP
222	Herrera		LF/URBAN	-80.341111	7.587778				FCPP
223	Herrera		LF/URBAN	-80.693889	7.996667				FCPP
224	Herrera		LF/URBAN	-80.393056	7.4925				FCPP
225	Herrera		LF/URBAN	-80.308611	7.577778				FCPP
226	Herrera		LF/URBAN	-80.321667	7.557222				FCPP
227	Herrera		LF/URBAN	-80.2975	7.561389				FCPP
228	Herrera		LF/URBAN	-80.293889	7.545				FCPP
229	Herrera		LF/URBAN	-80.294167	7.543889				FCPP
230	Herrera		LF/URBAN	-80.288889	7.536667				FCPP
231	Herrera		LF/URBAN	-80.286667	7.536667				FCPP
232	Herrera		LF/URBAN	-80.781389	7.335833				FCPP
233	Herrera		LF/URBAN	-80.781389	7.378611				FCPP
234	Herrera		LF/URBAN	-80.869444	7.378611				FCPP
235	Herrera		LF/URBAN	-80.861111	7.385833				FCPP
236	Herrera		LF/URBAN	-80.859167	7.352222				FCPP
237	Herrera		LF/URBAN	-80.856944	7.385278				FCPP

238	Herrera		LF/URBAN	-80.353361	7.446306				FCPP
239	Herrera		LF/URBAN	-80.345694	7.454083				FCPP
240	Herrera		LF/URBAN	-80.356722	7.439222				FCPP
241	Herrera		LF/URBAN	-80.691778	7.995778				FCPP
242	Herrera		LF/URBAN	-80.368528	7.450556				FCPP
243	Herrera		LF/URBAN	-80.342333	7.589861				FCPP
244	Herrera		LF/URBAN	-80.342417	7.579306				FCPP
245	Herrera		LF/URBAN	-80.691833	7.995722				FCPP
246	Herrera		LF/URBAN	-80.32075	7.556833				FCPP
247	Herrera		LF/URBAN	-80.321389	7.5595				FCPP
248	Herrera		LF/URBAN	-80.322167	7.561917				FCPP
249	Herrera		LF/URBAN	-80.324694	7.555444				FCPP
250	Herrera		LF/URBAN	-80.183056	7.4185				FCPP
251	Herrera		LF/URBAN	-80.303361	7.661222				FCPP
252	Herrera		LF/URBAN	-80.294889	7.5455				FCPP
253	Herrera		LF/URBAN	-80.293611	7.542778				FCPP
254	Herrera		LF/URBAN	-80.293806	7.540778				FCPP
255	Herrera		LF/URBAN	-80.293806	7.53975				FCPP
256	Herrera		LF/URBAN	-80.283	7.544528				FCPP
257	Los Santos		LF/URBAN	-80.283667	7.545917				FCPP

258	Los San-tos		LF/URBAN	-80.283361	7.547				FCPP
259	Los San-tos		LF/URBAN	-80.319861	7.886944				FCPP
260	Los San-tos		LF/URBAN	-80.319111	7.553167				FCPP
261	Los San-tos		LF/URBAN	-80.310472	7.547278				FCPP
262	Los San-tos		LF/URBAN	-80.308417	7.544583				FCPP
263	Los San-tos		LF/URBAN	-80.406139	7.493306				FCPP
264	Los San-tos		LF/URBAN	-80.275222	7.446722				FCPP
265	Los San-tos		LF/URBAN	-80.273111	7.446972				FCPP
266	Los San-tos		LF/URBAN	-80.321028	7.556306				FCPP
267	Los San-tos		LF/URBAN	-80.319583	7.554472				FCPP
268	Los San-tos		LF/URBAN	-80.297861	7.555111				FCPP
269	Los San-tos		LF/URBAN	-80.300167	7.550528				FCPP
270	Los San-tos		LF/URBAN	-80.777433	7.279758				FCPP

271	Los San-tos		LF/URBAN	-80.813306	7.263278				FCPP
272	Los San-tos		LF/URBAN	-80.785772	7.290967				FCPP
273	Los San-tos		LF/URBAN	-80.736444	7.279872				FCPP
274	Los San-tos		LF/URBAN	-80.745125	7.331514				FCPP
275	Los San-tos		LF/URBAN	-80.055222	7.768417				FCPP
276	Los San-tos		LF/URBAN	-80.551203	7.344703				FCPP
277	Los San-tos		LF/URBAN	-80.474064	7.353044				FCPP
278	Los San-tos		LF/URBAN	-80.260967	7.449475				FCPP
279	Los San-tos		LF/URBAN	-80.25925	7.448853				FCPP
280	Los San-tos		LF/URBAN	-80.260711	7.451303				FCPP
281	Los San-tos		LF/URBAN	-80.351692	7.450228				FCPP
282	Los San-tos		LF/URBAN	-80.406078	7.493425				FCPP
283	Los San-tos		LF/URBAN	-80.391142	7.499986				FCPP

284	Los San-tos		LF/URBAN	-80.387769	7.509147				FCPP
285	Los San-tos		LF/URBAN	-80.383211	7.455111				FCPP
286	Los San-tos		LF/URBAN	-80.261067	7.449964				FCPP
287	Los San-tos		LF/URBAN	-80.174986	7.427328				FCPP
288	Los San-tos		LF/URBAN	-80.900106	7.529892				FCPP
289	Los San-tos		LF/URBAN	-80.830642	7.840931				FCPP
290	Los San-tos		LF/URBAN	-80.573967	7.036503				FCPP
291	Los San-tos		LF/URBAN	-80.783489	7.711072				FCPP
292	Los San-tos		LF/URBAN	-80.933331	7.8667				FCPP
293	Los San-tos		LF/URBAN	-80.933319	7.850222				FCPP
294	Los San-tos		LF/URBAN	-80.875056	7.859308				FCPP
295	Los San-tos		LF/URBAN	-80.875058	7.859308				FCPP
296	Los San-tos		LF/URBAN	-80.651461	7.972353				FCPP

297	Los San-tos		LF/URBAN	-80.635078	8.029503				FCPP
298	Los San-tos		LF/URBAN	-80.679072	7.98295				FCPP
299	Los San-tos		LF/URBAN	-80.693611	7.9879				FCPP
300	Los San-tos		LF/URBAN	-80.6975	7.987361				FCPP
301	Los San-tos		LF/URBAN	-80.693633	7.988067				FCPP
302	Los San-tos		LF/URBAN	-80.843472	7.730022				FCPP
303	Los San-tos		LF/URBAN	-80.838633	7.717053				FCPP
304	Los San-tos		LF/URBAN	-80.844158	7.728122				FCPP
305	Los San-tos		LF/URBAN	-80.732028	7.838361				FCPP
306	Los San-tos		LF/URBAN	-80.692019	7.989078				FCPP
307	Los San-tos		LF/URBAN	-80.532969	7.449764				FCPP
308	Los San-tos		LF/URBAN	-80.693861	7.997222				FCPP
309	Los San-tos		LF/URBAN	-80.311167	7.664056				FCPP

310	Los San-tos		LF/URBAN	-80.409381	7.647275				FCPP
311	Los San-tos		LF/URBAN	-80.591233	7.988117				FCPP
312	Los San-tos		LF/URBAN	-80.650489	7.971583				FCPP
313	Los San-tos		LF/URBAN	-80.757953	8.016908				FCPP
314	Los San-tos		LF/URBAN	-80.1942	7.551306				FCPP
315	Los San-tos		LF/URBAN	-80.326792	7.482469				FCPP
316	Los San-tos		LF/URBAN	-80.346708	7.573467				FCPP
317	Los San-tos		LF/URBAN	-80.19625	7.4335				FCPP
318	Los San-tos		LF/URBAN	-80.317442	7.435211				FCPP
319	Los San-tos		LF/URBAN	-80.368758	7.435808				FCPP
320	Los San-tos		LF/URBAN	-80.318772	7.551481				FCPP
321	Los San-tos		LF/URBAN	-80.32115	7.559889				FCPP
322	Los San-tos		LF/URBAN	-80.320722	7.556917				FCPP

323	Los San-tos		LF/URBAN	-80.31925	7.553444				FCPP
324	Los San-tos		LF/URBAN	-80.326	7.556306				FCPP
325	Los San-tos		LF/URBAN	-80.308083	7.545694				FCPP
326	Los San-tos		LF/URBAN	-80.311972	7.547972				FCPP
327	Los San-tos		LF/URBAN	-80.693369	7.987928				FCPP
328	Los San-tos		LF/URBAN	-80.694697	7.987997				FCPP
329	Los San-tos		LF/URBAN	-80.693831	7.987597				FCPP
330	Los San-tos		LF/URBAN	-80.694917	7.987656				FCPP
331	Los San-tos		LF/URBAN	-80.692986	7.989408				FCPP
332	Los San-tos		LF/URBAN	-80.861247	7.373564				FCPP
333	Los San-tos		LF/URBAN	-80.861506	7.375764				FCPP
334	Los San-tos		LF/URBAN	-80.862336	7.37475				FCPP
335	Los San-tos		LF/URBAN	-80.860139	7.371347				FCPP

336	Los San-tos		LF/URBAN	-80.865731	7.375814				FCPP
337	Los San-tos		LF/URBAN	-80.861806	7.373472				FCPP
338	Los San-tos		LF/URBAN	-80.86425	7.383333				FCPP
339	Los San-tos		LF/URBAN	-80.870444	7.37975				FCPP
340	Los San-tos		LF/URBAN	-80.694194	7.989528				FCPP
341	Los San-tos		LF/URBAN	-80.622806	8.065489				FCPP
342	Los San-tos		LF/URBAN	-80.575028	8.031694				FCPP
343	Los San-tos		LF/URBAN	-80.692756	7.987694				FCPP
344	Los San-tos		LF/URBAN	-80.694011	7.987553				FCPP
345	Los San-tos		LF/URBAN	-80.690269	7.986847				FCPP
346	Los San-tos		LF/URBAN	-80.694397	7.987194				FCPP

Appendix 2.10. Locations for presence of *Ateles geoffroyi azuerensis*; DTF: Dry Tropical Forest; TRF: Tropical Rain Forest; FF: Fragmented Forest; LF: Living Fences; SFR: San Francisco Reserve; A: Area; D: Relative density; N: North; W: West. Blank space means there is no information.

# site	Province	Study site	Habitat/ Use	Latitude	Longitude	Ind.	A (km^2)	D	Source
1	Los Santos	La Miel	LF/URBAN	-80.691944	7.996083			13.7	Méndez-Carvajal, 2013
2	Los Santos	La Miel	LF/URBAN	-80.697556	8.004222			13.7	Méndez-Carvajal, 2013
3	Los Santos	La Miel	LF/URBAN	-80.693861	7.997222			13.7	Méndez-Carvajal, 2013
4	Los Santos	La Miel	LF/URBAN	-80.311333	7.547444			13.7	Méndez-Carvajal, 2013
5	Los Santos	La Miel	LF/URBAN	-80.312694	7.539306			13.7	Méndez-Carvajal, 2013
6	Los Santos	La Miel	LF/URBAN	-80.299917	7.546806			13.7	Méndez-Carvajal, 2013
7	Los Santos	La Miel	LF/URBAN	-80.294583	7.545306			13.7	Méndez-Carvajal, 2013
8	Los Santos	La Miel	LF/URBAN	-80.293444	7.54425			13.7	Méndez-Carvajal, 2013
9	Los Santos	Toña	LF/URBAN	-80.319306	7.5535			13.7	Méndez-Carvajal, 2013
10	Los Santos	De Pallo	LF/URBAN	-80.301583	7.54775			13.7	Méndez-Carvajal, 2013
11	Los Santos	De Pillo	LF/URBAN	-80.294	7.545278			13.7	Méndez-Carvajal, 2013

12	Los Santos	De Toño	LF/URBAN	-80.282139	7.548806			13.7	Méndez-Carvajal, 2013
13	Los Santos	Rio Oria	GALLERY/URBAN	-80.303556	7.572306			13.7	Méndez-Carvajal, 2013
14	Los Santos	Flores	GALLERY/URBAN	-80.868056	7.378611			20	Méndez-Carvajal, 2013
15	Los Santos	Río Güera	GALLERY/URBAN	-80.550278	7.484444			20	Méndez-Carvajal, 2013
16	Los Santos	La Tronosa	DTF/RESERVE	-80.589167	7.429444			20	Méndez-Carvajal, 2013
17	Los Santos	Bajo Limpo	GALLERY/URBAN	-80.533889	7.450833			20	Méndez-Carvajal, 2013
18	Los Santos	Venao	FF/URBAN	-80.193889	7.435278			7	Méndez-Carvajal, 2013
19	Veraguas	Arenas	LF/URBAN	-80.781389	7.335833			7	Méndez-Carvajal, 2013
20	Veraguas	Arenas	LF/URBAN	-80.785278	7.343333			7	Méndez-Carvajal, 2013
21	Veraguas	Rio Pavo	LF/URBAN	-80.87	7.378611			7	Méndez-Carvajal, 2013
22	Veraguas	Restingue	LF/URBAN	-80.904444	7.254444			7	Méndez-Carvajal, 2013
23	Veraguas	Cerro Culón	LF/URBAN	-80.890833	7.252778			7	Méndez-Carvajal, 2013
24	Veraguas	Río Ventana	LF/URBAN	-80.781944	7.230278			7	Méndez-Carvajal, 2013

25	Los Santos	Cerro Hoya	RTF/RESERVE	-80.753419	7.291906			7	Méndez-Carvajal, 2013
26	Los Santos		RTF/RESERVE	-80.2975	7.561389				FCPP
27	Los Santos		RTF/RESERVE	-80.293889	7.545				FCPP
28	Los Santos		RTF/RESERVE	-80.294167	7.543889				FCPP
29	Los Santos		RTF/RESERVE	-80.288889	7.536667				FCPP
30	Los Santos		RTF/RESERVE	-80.286667	7.536667				FCPP
31	Los Santos		RTF/RESERVE	-80.393056	7.4925				FCPP
32	Los Santos		RTF/RESERVE	-80.341111	7.587778				FCPP
33	Los Santos		RTF/RESERVE	-80.34125	7.587778				FCPP
34	Los Santos		RTF/RESERVE	-80.316583	7.566806				FCPP
35	Los Santos		RTF/RESERVE	-80.321472	7.558111				FCPP
36	Los Santos		RTF/RESERVE	-80.312028	7.547694				FCPP
37	Los Santos		RTF/RESERVE	-80.321472	7.558111				FCPP

38	Los Santos		RTF/RESERVE	-80.321028	7.556306				FCPP
39	Los Santos		RTF/RESERVE	-80.319583	7.554472				FCPP
40	Los Santos		RTF/RESERVE	-80.300167	7.550528				FCPP
41	Los Santos		RTF/RESERVE	-80.321306	7.559889				FCPP
42	Los Santos		RTF/RESERVE	-80.296889	7.546056				FCPP
43	Los Santos		RTF/RESERVE	-80.287333	7.537389				FCPP
44	Los Santos		RTF/RESERVE	-80.283056	7.543944				FCPP
45	Los Santos		RTF/RESERVE	-80.283583	7.545861				FCPP
46	Los Santos		RTF/RESERVE	-80.284944	7.546694				FCPP
47	Los Santos		RTF/RESERVE	-80.311444	7.547806				FCPP
48	Los Santos		RTF/RESERVE	-80.285083	7.538056				FCPP
49	Los Santos		RTF/RESERVE	-80.283222	7.547139				FCPP
50	Los Santos		RTF/RESERVE	-80.281444	7.547833				FCPP

51	Los San-tos		RTF/RESERVE	-80.28925	7.545083				FCPP
52	Los San-tos		RTF/RESERVE	-80.285694	7.547167				FCPP
53	Los San-tos		RTF/RESERVE	-80.319722	7.555333				FCPP
54	Los San-tos		RTF/RESERVE	-80.305056	7.546722				FCPP
55	Los San-tos		RTF/RESERVE	-80.29075	7.542944				FCPP
56	Los San-tos		RTF/RESERVE	-80.319306	7.5535				FCPP
57	Los San-tos		RTF/RESERVE	-80.301583	7.564417				FCPP
58	Los San-tos		RTF/RESERVE	-80.294	7.545278				FCPP
59	Los San-tos		RTF/RESERVE	-80.282139	7.548806				FCPP
60	Los San-tos		RTF/RESERVE	-80.290361	7.540278				FCPP
61	Los San-tos		RTF/RESERVE	-80.292333	7.545472				FCPP
62	Los San-tos		RTF/RESERVE	-80.315694	7.550167				FCPP
63	Los San-tos		RTF/RESERVE	-80.326222	7.559556				FCPP

64	Los San-tos		RTF/RESERVE	-80.307194	7.546889				FCPP
65	Los San-tos		RTF/RESERVE	-80.303472	7.547028				FCPP
66	Los San-tos		RTF/RESERVE	-80.316306	7.577833				FCPP
67	Los San-tos		RTF/RESERVE	-80.310611	7.577278				FCPP
68	Los San-tos		RTF/RESERVE	-80.299806	7.576583				FCPP
69	Los San-tos		RTF/RESERVE	-80.298333	7.567				FCPP
70	Los San-tos		RTF/RESERVE	-80.303556	7.572306				FCPP
71	Los San-tos		RTF/RESERVE	-80.329861	7.55875				FCPP
72	Los San-tos		RTF/RESERVE	-80.3335	7.551139				FCPP
73	Los San-tos		RTF/RESERVE	-80.327611	7.544861				FCPP
74	Los San-tos		RTF/RESERVE	-80.589167	7.429444				FCPP
75	Los San-tos		RTF/RESERVE	-80.533889	7.450833				FCPP
76	Los San-tos		RTF/RESERVE	-80.193889	7.435278				FCPP

77	Los San-tos		RTF/RESERVE	-80.904444	7.254444				FCPP
78	Los San-tos		RTF/RESERVE	-80.890833	7.252778				FCPP
79	Los San-tos		RTF/RESERVE	-80.781944	7.230278				FCPP
80	Los San-tos		RTF/RESERVE	-80.868056	7.378611				FCPP
81	Los San-tos		RTF/RESERVE	-80.550278	7.484444				FCPP
82	Los San-tos		RTF/RESERVE	-80.693611	7.996667				FCPP
83	Los San-tos		RTF/RESERVE	-80.693889	7.996667				FCPP
84	Los San-tos		RTF/RESERVE	-80.393056	7.4925				FCPP
85	Los San-tos		RTF/RESERVE	-80.308611	7.577778				FCPP
86	Los San-tos		RTF/RESERVE	-80.321667	7.557222				FCPP
87	Los San-tos		RTF/RESERVE	-80.2975	7.561389				FCPP
88	Los San-tos		RTF/RESERVE	-80.293889	7.545				FCPP
89	Los San-tos		RTF/RESERVE	-80.341111	7.587778				FCPP

90	Los Santos		RTF/RESERVE	-80.693889	7.996667				FCPP
91	Los Santos		RTF/RESERVE	-80.393056	7.4925				FCPP
92	Los Santos		RTF/RESERVE	-80.308611	7.577778				FCPP
93	Los Santos		RTF/RESERVE	-80.321667	7.557222				FCPP
94	Los Santos		RTF/RESERVE	-80.2975	7.561389				FCPP
95	Los Santos		RTF/RESERVE	-80.293889	7.545				FCPP
96	Los Santos		RTF/RESERVE	-80.294167	7.543889				FCPP
97	Los Santos		RTF/RESERVE	-80.288889	7.536667				FCPP
98	Los Santos		RTF/RESERVE	-80.286667	7.536667				FCPP
99	Los Santos		RTF/RESERVE	-80.356722	7.439222				FCPP
100	Los Santos		RTF/RESERVE	-80.32075	7.556833				FCPP
101	Los Santos		RTF/RESERVE	-80.321389	7.5595				FCPP
102	Los Santos		RTF/RESERVE	-80.322167	7.561917				FCPP

103	Los San-tos		RTF/RESERVE	-80.324694	7.555444				FCPP
104	Los San-tos		RTF/RESERVE	-80.183056	7.4185				FCPP
105	Los San-tos		RTF/RESERVE	-80.183056	7.4185				FCPP
106	Los San-tos		RTF/RESERVE	-80.303361	7.661222				FCPP
107	Los San-tos		RTF/RESERVE	-80.294889	7.5455				FCPP
108	Los San-tos		RTF/RESERVE	-80.293611	7.542778				FCPP
109	Los San-tos		RTF/RESERVE	-80.293806	7.540778				FCPP
110	Los San-tos		RTF/RESERVE	-80.293806	7.53975				FCPP
111	Los San-tos		RTF/RESERVE	-80.283	7.544528				FCPP
112	Los San-tos		RTF/RESERVE	-80.283667	7.545917				FCPP
113	Los San-tos		RTF/RESERVE	-80.283361	7.547				FCPP
114	Los San-tos		RTF/RESERVE	-80.319861	7.886944				FCPP
115	Los San-tos		RTF/RESERVE	-80.319111	7.553167				FCPP

116	Los San-tos		RTF/RESERVE	-80.310472	7.547278				FCPP
117	Los San-tos		RTF/RESERVE	-80.308417	7.544583				FCPP
118	Los San-tos		RTF/RESERVE	-80.777433	7.279758				FCPP
119	Los San-tos		RTF/RESERVE	-80.813306	7.263278				FCPP
120	Los San-tos		RTF/RESERVE	-80.785772	7.290967				FCPP
121	Los San-tos		RTF/RESERVE	-80.736444	7.279872				FCPP
122	Los San-tos		RTF/RESERVE	-80.745125	7.331514				FCPP
123	Los San-tos		RTF/RESERVE	-80.055222	7.768417				FCPP
124	Los San-tos		RTF/RESERVE	-80.551203	7.344703				FCPP
125	Los San-tos		RTF/RESERVE	-80.474064	7.353044				FCPP
126	Los San-tos		RTF/RESERVE	-80.260967	7.449475				FCPP
127	Los San-tos		RTF/RESERVE	-80.25925	7.448853				FCPP
128	Los San-tos		RTF/RESERVE	-80.260711	7.451303				FCPP

129	Los San-tos		RTF/RESERVE	-80.351692	7.450228				FCPP
130	Los San-tos		RTF/RESERVE	-80.406078	7.493425				FCPP
131	Los San-tos		RTF/RESERVE	-80.391142	7.499986				FCPP
132	Los San-tos		RTF/RESERVE	-80.387769	7.509147				FCPP
133	Los San-tos		RTF/RESERVE	-80.383211	7.455111				FCPP
134	Los San-tos		RTF/RESERVE	-80.261067	7.449964				FCPP
135	Los San-tos		RTF/RESERVE	-80.174986	7.427328				FCPP
136	Los San-tos		RTF/RESERVE	-80.900106	7.529892				FCPP
137	Los San-tos		RTF/RESERVE	-80.311167	7.664056				FCPP
138	Los San-tos		RTF/RESERVE	-80.1942	7.551306				FCPP
139	Los San-tos		RTF/RESERVE	-80.326792	7.482469				FCPP
140	Los San-tos		RTF/RESERVE	-80.346708	7.573467				FCPP
141	Los San-tos		RTF/RESERVE	-80.19625	7.4335				FCPP

142	Los San-tos		RTF/RESERVE	-80.317442	7.435211				FCPP
143	Los San-tos		RTF/RESERVE	-80.368758	7.435808				FCPP
144	Los San-tos		RTF/RESERVE	-80.318772	7.551481				FCPP
145	Los San-tos		RTF/RESERVE	-80.32115	7.559889				FCPP
146	Los San-tos		RTF/RESERVE	-80.32115	7.559889				FCPP
147	Los San-tos		RTF/RESERVE	-80.320722	7.556917				FCPP
148	Los San-tos		RTF/RESERVE	-80.31925	7.553444				FCPP
149	Los San-tos		RTF/RESERVE	-80.326	7.556306				FCPP
150	Los San-tos		RTF/RESERVE	-80.308083	7.545694				FCPP
151	Los San-tos		RTF/RESERVE	-80.311972	7.547972				FCPP
152	Los San-tos		RTF/RESERVE	-80.5819	7.303				FCPP

Appendix 2.11. Locations for presence of *Ateles geoffroyi panamensis*; DTF: Dry Tropical Forest; TRF: Tropical Rain Forest; FF: Fragmented Forest; LF: Living Fences; SFR: San Francisco Reserve; A: Area; D: Relative density; N: North; W: West. Where spaces are blank this means that no information was available.

# site	Province	Study site	Habitat/ Use	Latitude	Longitude	Ind.	A km^2	D	Source
1	San Blas	San Blas	TRF/RESERVE	-82.749027	9.286465				FCPP
2	Colon	Campo Chagres	TRF/RESERVE	-82.589722	9.06205				FCPP
3	San Blas	Cocobolo	TRF/RESERVE	-82.30957	9.001739				FCPP
4	Colon	Colon	TRF/RESERVE	-82.243652	8.836223				FCPP
5	Colon	Colon	TRF/RESERVE	-81.372986	8.703214				FCPP
6	Colon	Cerro Bruja	TRF/RESERVE	-79.623413	9.413839				FCPP
7	Bocas del Toro	La Amistad	TRF/RESERVE	-79.477844	9.45719				FCPP
8	Bocas del Toro	Palo Seco	TRF/RESERVE	-79.205638	9.295305				FCPP
9	Chiriqui	Fortuna	TRF/RESERVE	-79.20375	9.308555				FCPP
10	Chiriqui	Fortuna	TRF/RESERVE	-79.203166	9.309638				FCPP
11	Chiriqui	Fortuna	TRF/RESERVE	-79.205833	9.315277				FCPP
12	Chiriqui	Fortuna	TRF/RESERVE	-79.205972	9.300527				FCPP
13	Chiriqui	Fortuna	TRF/RESERVE	-79.206638	9.301277				FCPP
14	Chiriqui	Fortuna	TRF/RESERVE	-79.205222	9.297555				FCPP

15	Chiriqui	Fortuna	TRF/RESERVE	-79.204916	9.3075				FCPP
16	Chiriqui	Fortuna	TRF/RESERVE	-79.841766	9.153621				FCPP
17	Chiriqui	FORTUNA	TRF/RESERVE	-79.200183	9.314033				FCPP

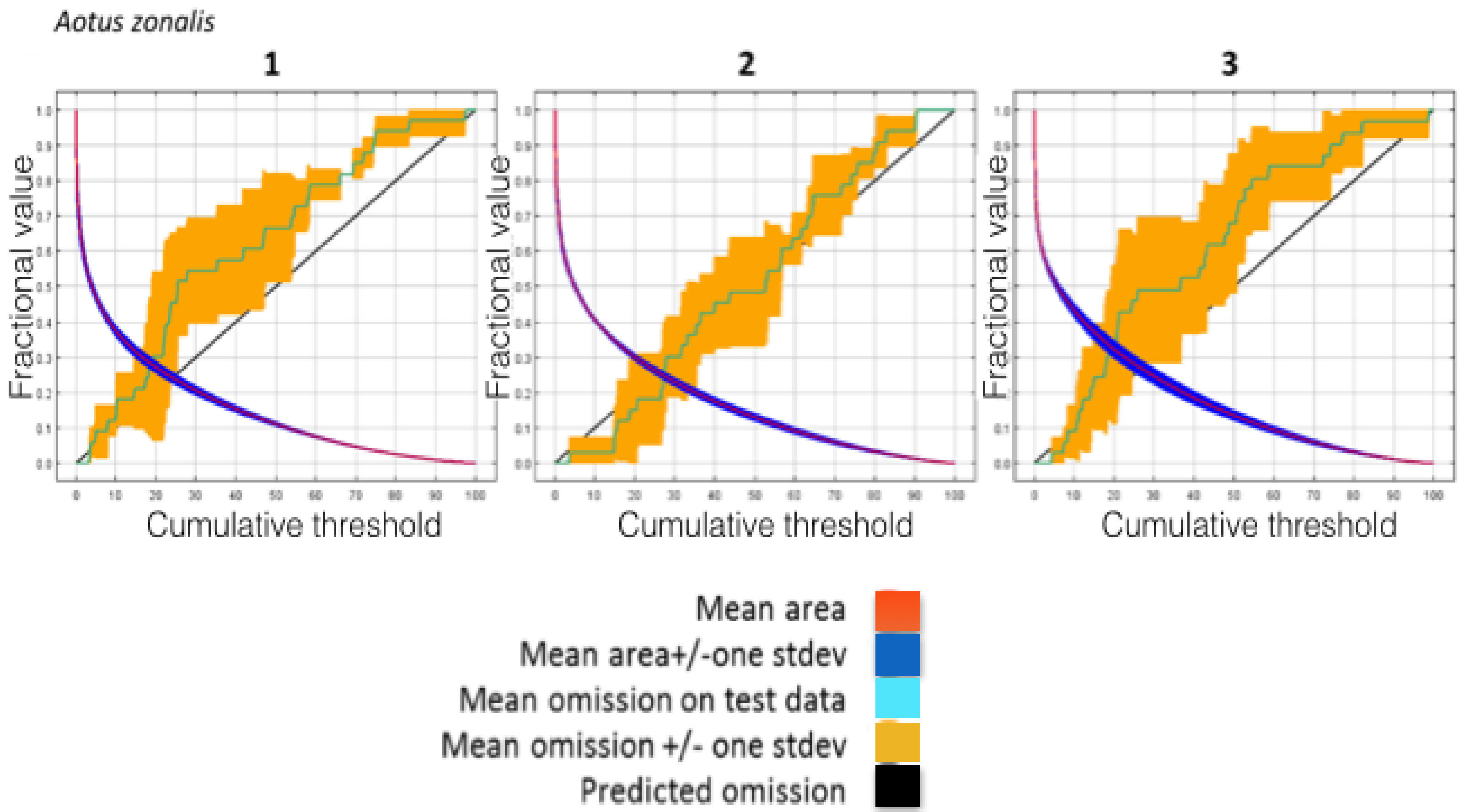
Appendix 2.12. Locations for presence of *Ateles fusciceps rufiventris*; DTF: Dry Tropical Forest; TRF: Tropical Rain Forest; FF: Fragmented Forest; LF: Living Fences; SFR: San Francisco Reserve; A: Area; D: Relative density; N: North; W: West. Where spaces are blank this means that no information was available.

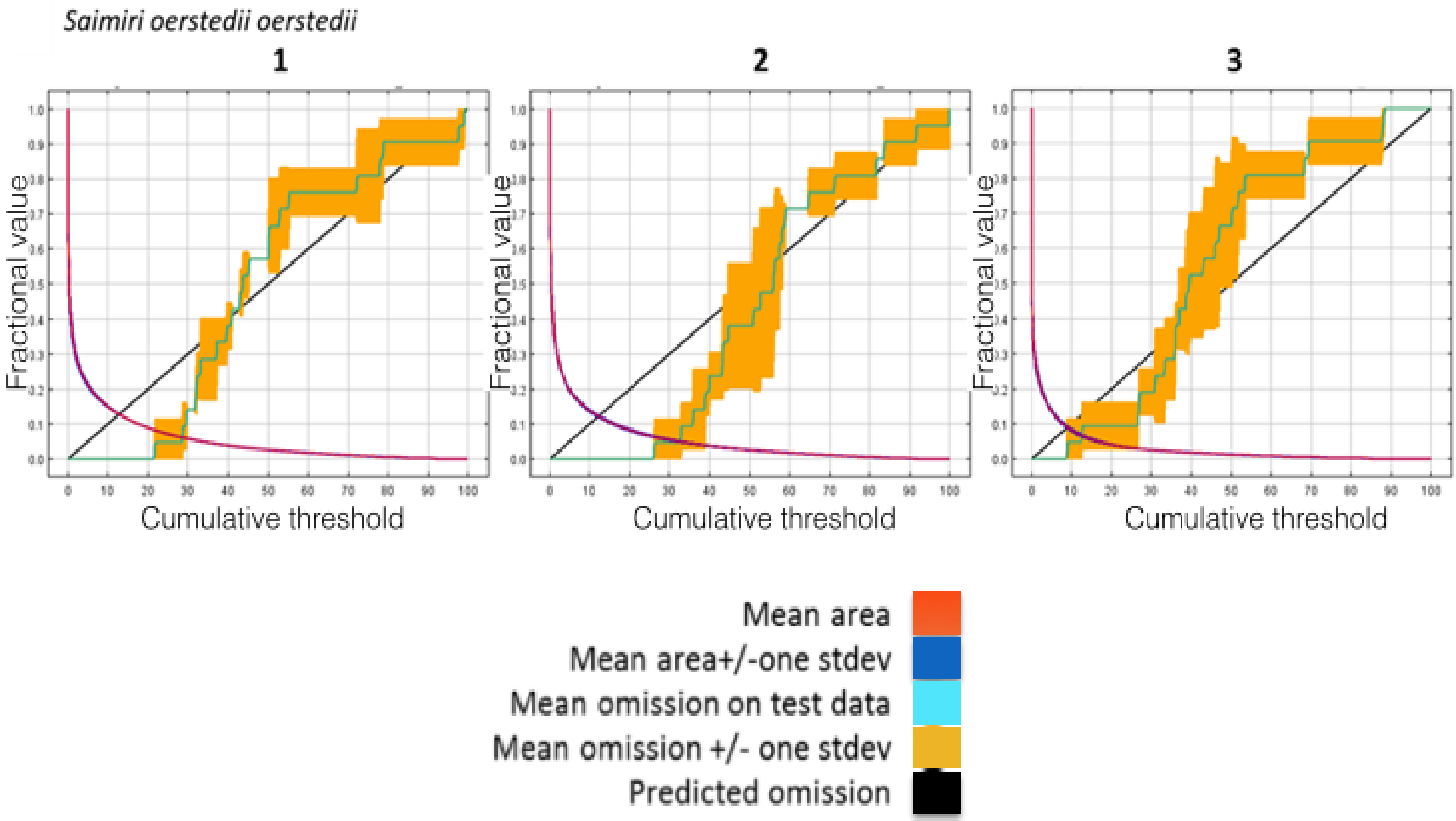
# site	Province	Study site	Habitat/ Use	Latitude	Longitude	Ind.	A (km^2)	D	Source
1	Panama	Bayano	TRF/RESERVE	-79.919216	9.252738	7			FCPP
2	Darien	Chucanti	TRF/RESERVE	-78.456527	8.791972	60	200	9.3	Méndez-Carvajal, 2012
3	Darien	Chucanti	TRF/RESERVE	-78.461277	8.795027	60	200	9.3	Méndez-Carvajal, 2012
4	Darien	Rio Pavo	LF/FARMING-CATTLE	-78.462222	8.798055	60	40	9.3	Méndez-Carvajal, 2012
5	Darien	Torti	LF/URBAN	-78.460444	8.794694	60	2	9.3	Méndez-Carvajal, 2012
6	Darien	Torti	TRF/RESERVE	-78.452111	8.789916	4	40		
7	Darien	Boca De Cupe	TRF/RESERVE	-78.450416	8.791333	1	4	3.6	Moreno et al., 2006
8	Darien	Sendero Jaguar	TRF/RESERVE	-78.418055	8.780527	1	4	3.6	Moreno et al., 2006
9	Darien	Pirre	TRF/RESERVE	-78.460916	8.798	1	4	3.6	Moreno et al., 2006

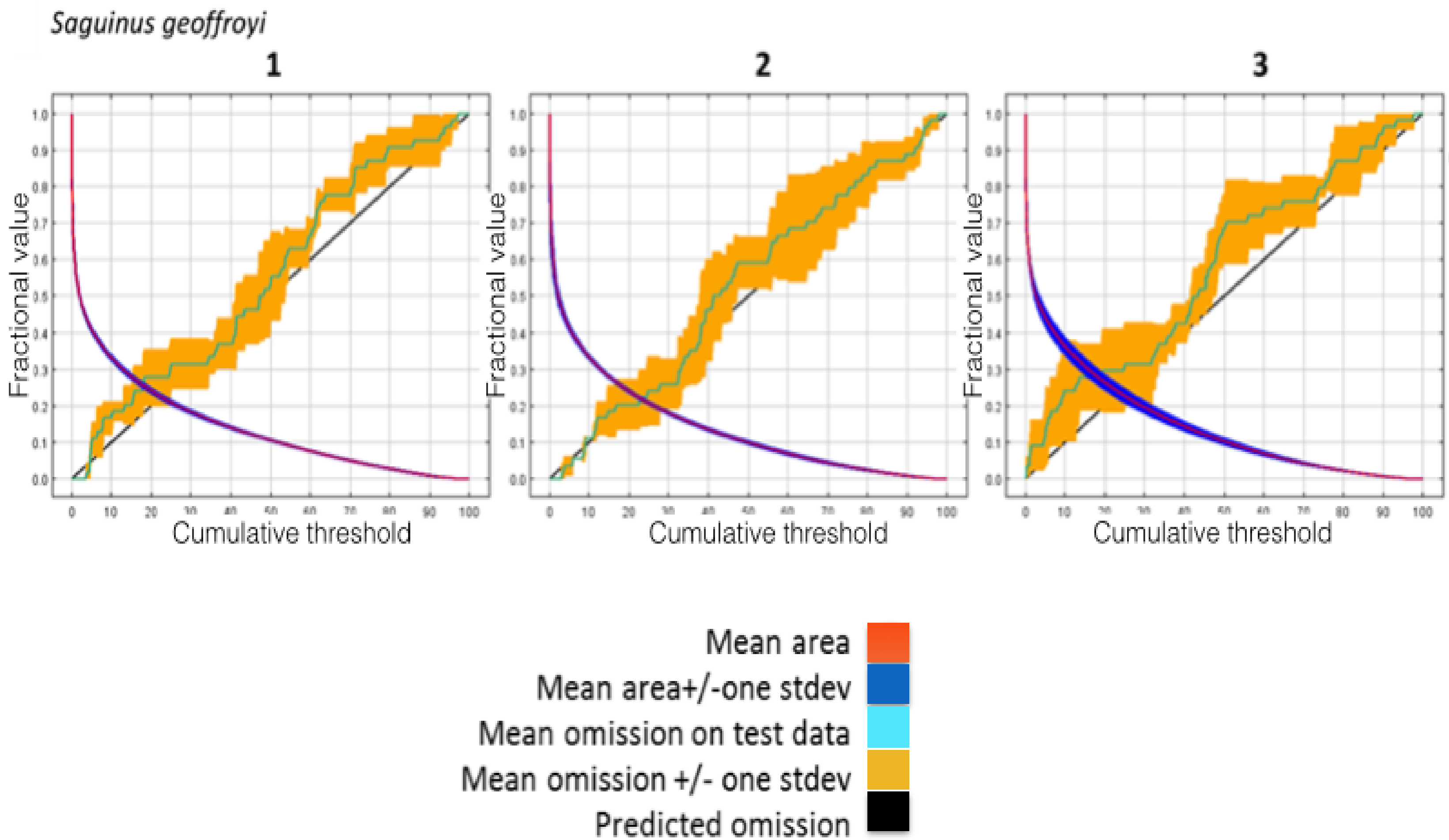
10	Darien	Cana	TRF/RESERVE	-78.458805	8.796361	1	4	3.6	Moreno et al., 2006
11	Darien	Cana	TRF/RESERVE	-78.45125	8.789444	1	4	3.6	Moreno et al., 2006
12	Darien	Bagre	TRF/RESERVE	-78.453944	8.797111	1			FCPP
13	Darien	Chepigana	TRF/RESERVE	-78.453666	8.798611	1			FCPP
14	Darien	Serrania Darien	TRF/RESERVE	-78.452388	8.804027	1			FCPP
15	Darien	Filo Del Tallo	TRF/RESERVE	-78.482222	8.936036	1			FCPP
16	Darien	Tuira	TRF/RESERVE	-78.466936	8.935908	1			FCPP
17	Darien	Canglon	TRF/RESERVE	-78.472861	8.935147	1			FCPP
18	Darien	Punta Patiño	TRF/RESERVE	-78.459777	8.952227	1			FCPP
19	Darien		TRF/RESERVE	-78.467527	8.797555				FCPP
20	Darien		TRF/RESERVE	-78.458277	8.793472				FCPP
21	Darien		TRF/RESERVE	-78.458083	8.79375				FCPP
22	Darien		TRF/RESERVE	-78.453	8.797416				FCPP
23	Darien		TRF/RESERVE	-78.451083	8.789638				FCPP
24	Darien		TRF/RESERVE	-78.744507	9.05599				FCPP
25	Darien		TRF/RESERVE	-77.584076	8.063309				FCPP
26	Darien		TRF/RESERVE	-77.698059	7.940916				FCPP

27	Darien		TRF/RESERVE	-77.672323	7.73504622				FCPP
28	Darien		TRF/RESERVE	-77.6497349	7.7094929				FCPP
29	Darien		TRF/RESERVE	-77.6557751	7.71414218				FCPP
30	Darien		TRF/RESERVE	-77.6758662	7.76888154				FCPP

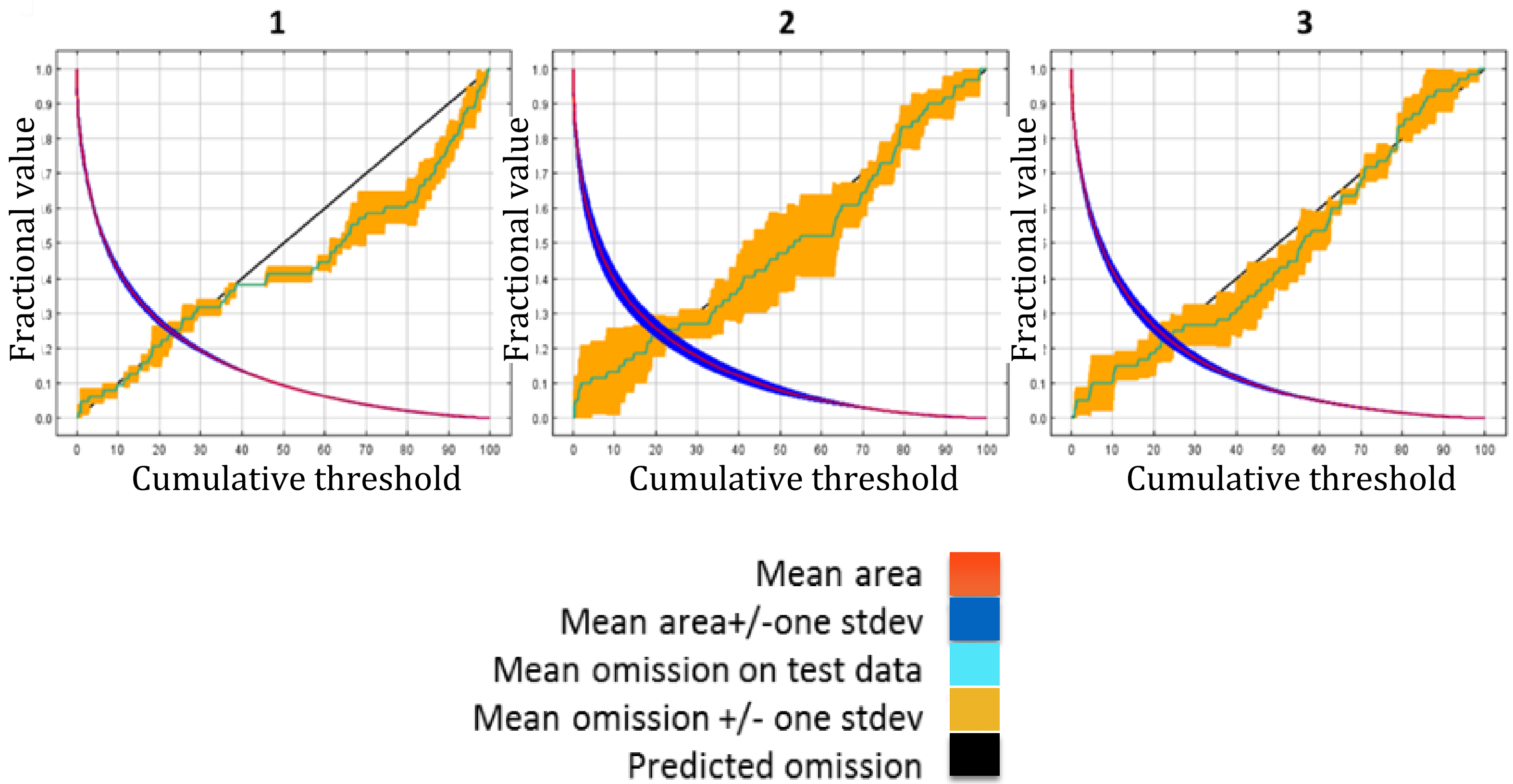
Appendix 3 MaxEnt Results

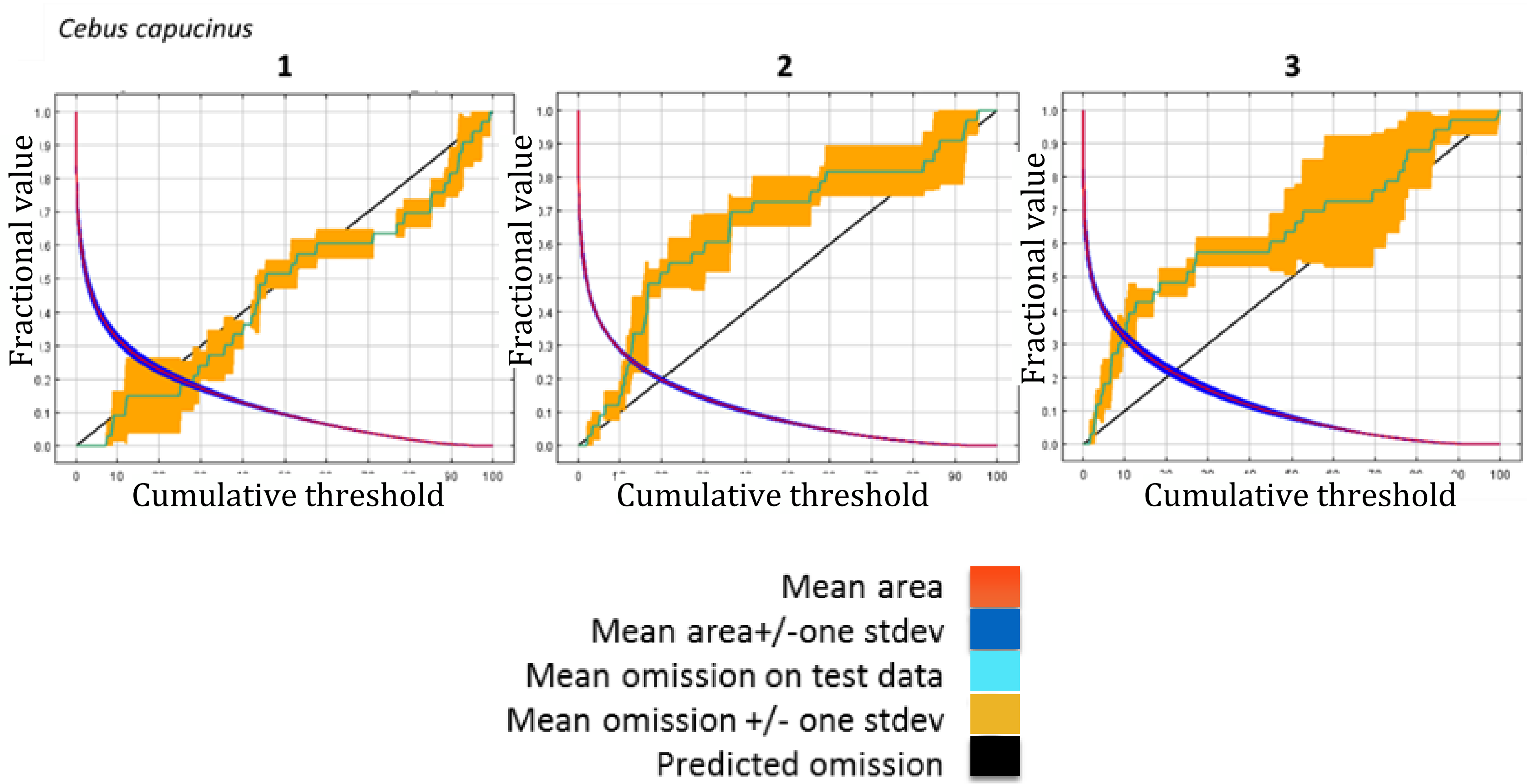


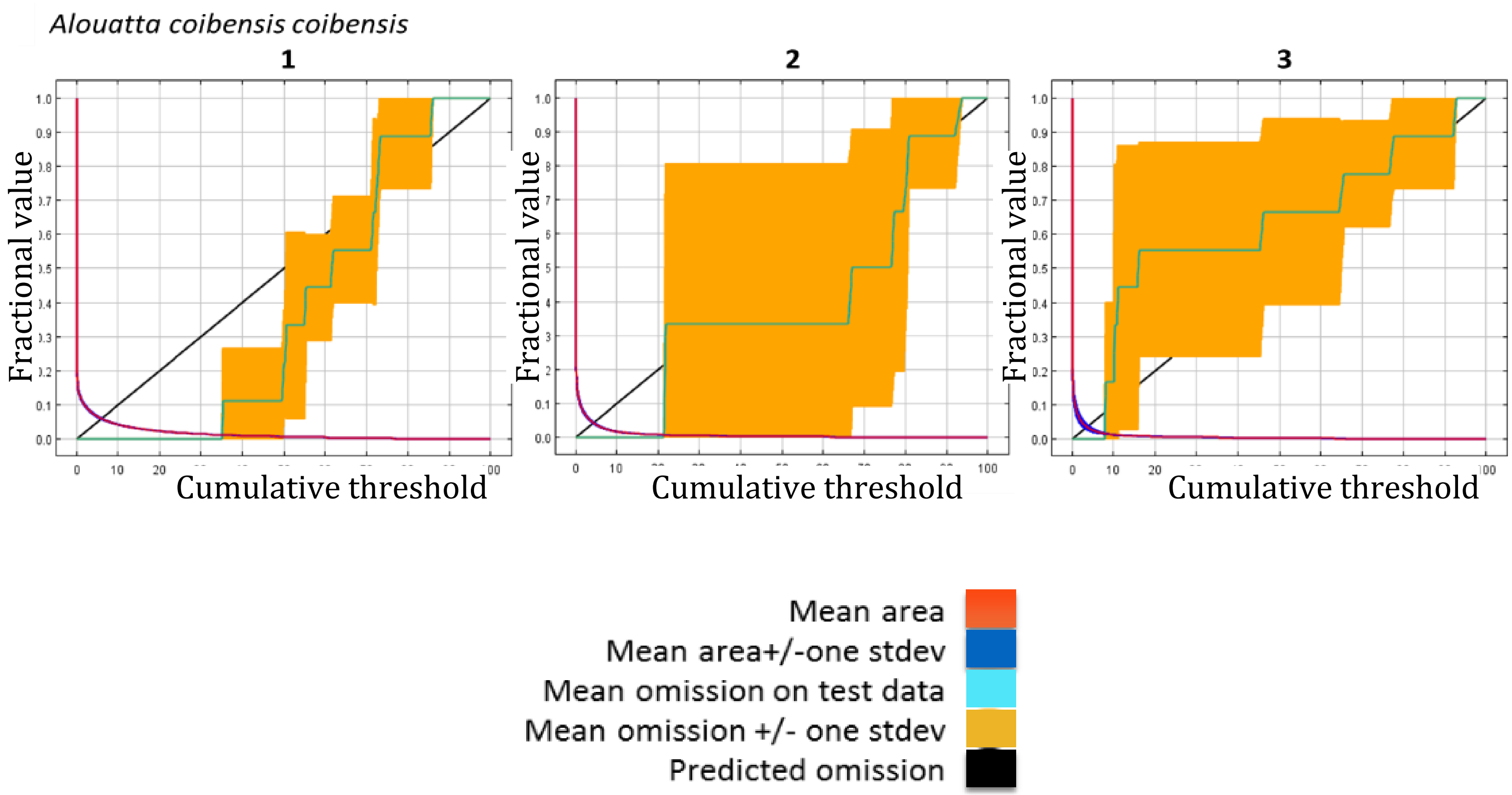

Saimiri oerstedii oerstedii
1
2
3
Fractional value
Cumulative threshold
Mean area
Mean area+/-one stdev
Mean omission on test data
Mean omission +/- one stdev
Predicted omission


Saguinus geoffroyi
1
2
3
Fractional value
Fractional value
Fractional value
Cumulative threshold
Cumulative threshold
Cumulative threshold
Mean area
Mean area+/-one stdev
Mean omission on test data
Mean omission +/- one stdev
Predicted omission

Cebus imitator

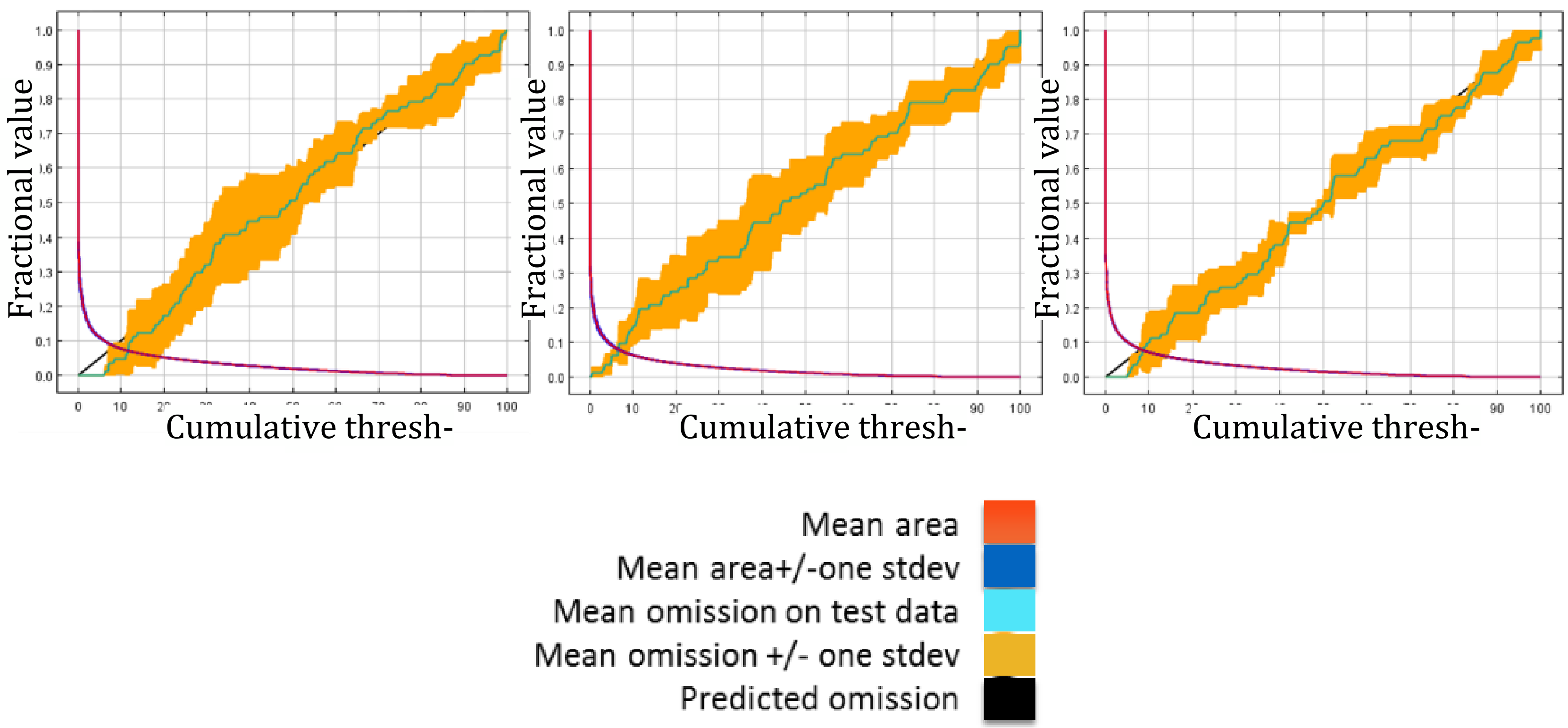


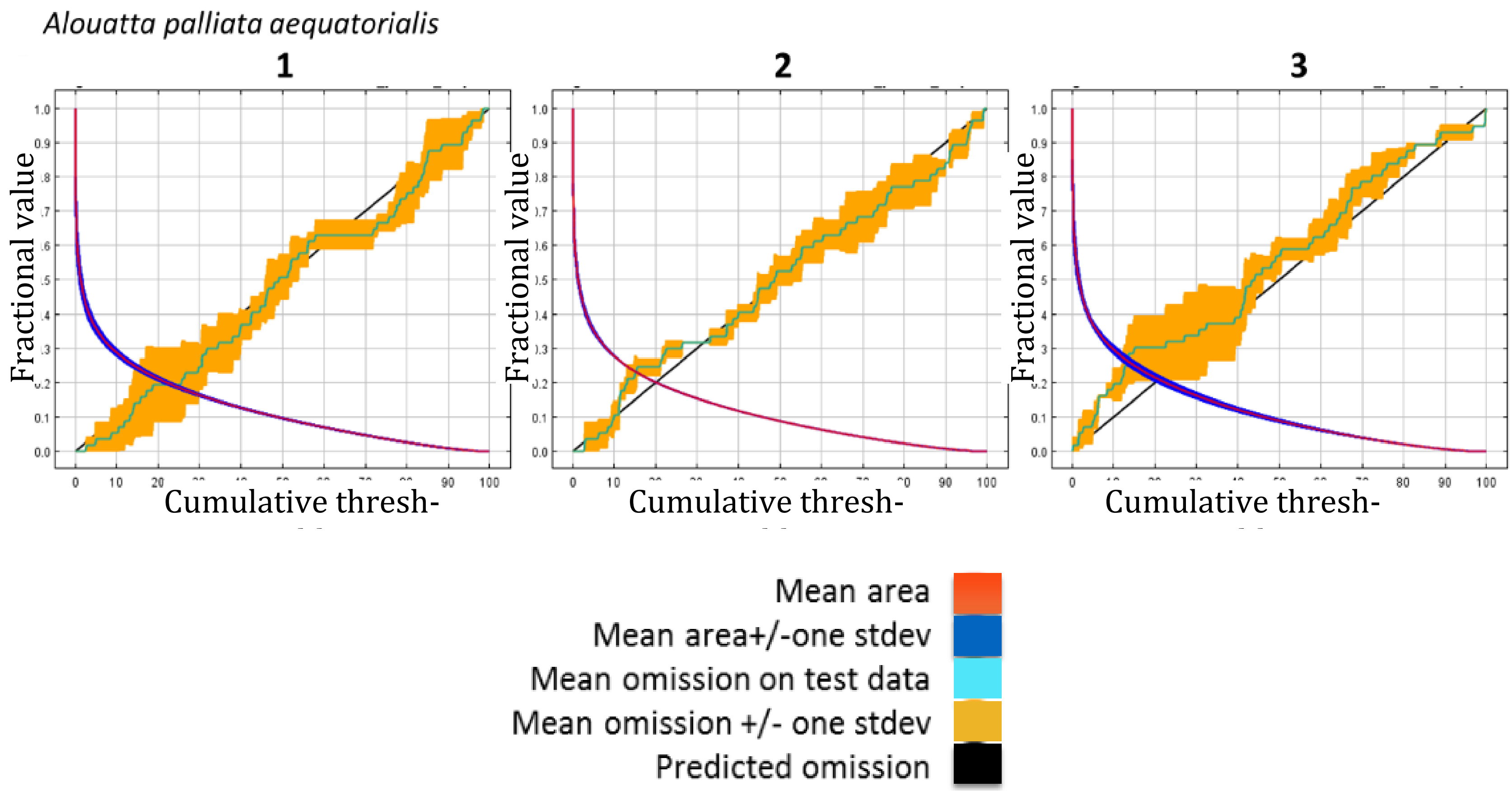

Cebus capucinus
1
2
3
Fractional value
Cumulative threshold
Mean area
Mean area+/-one stdev
Mean omission on test data
Mean omission +/- one stdev
Predicted omission

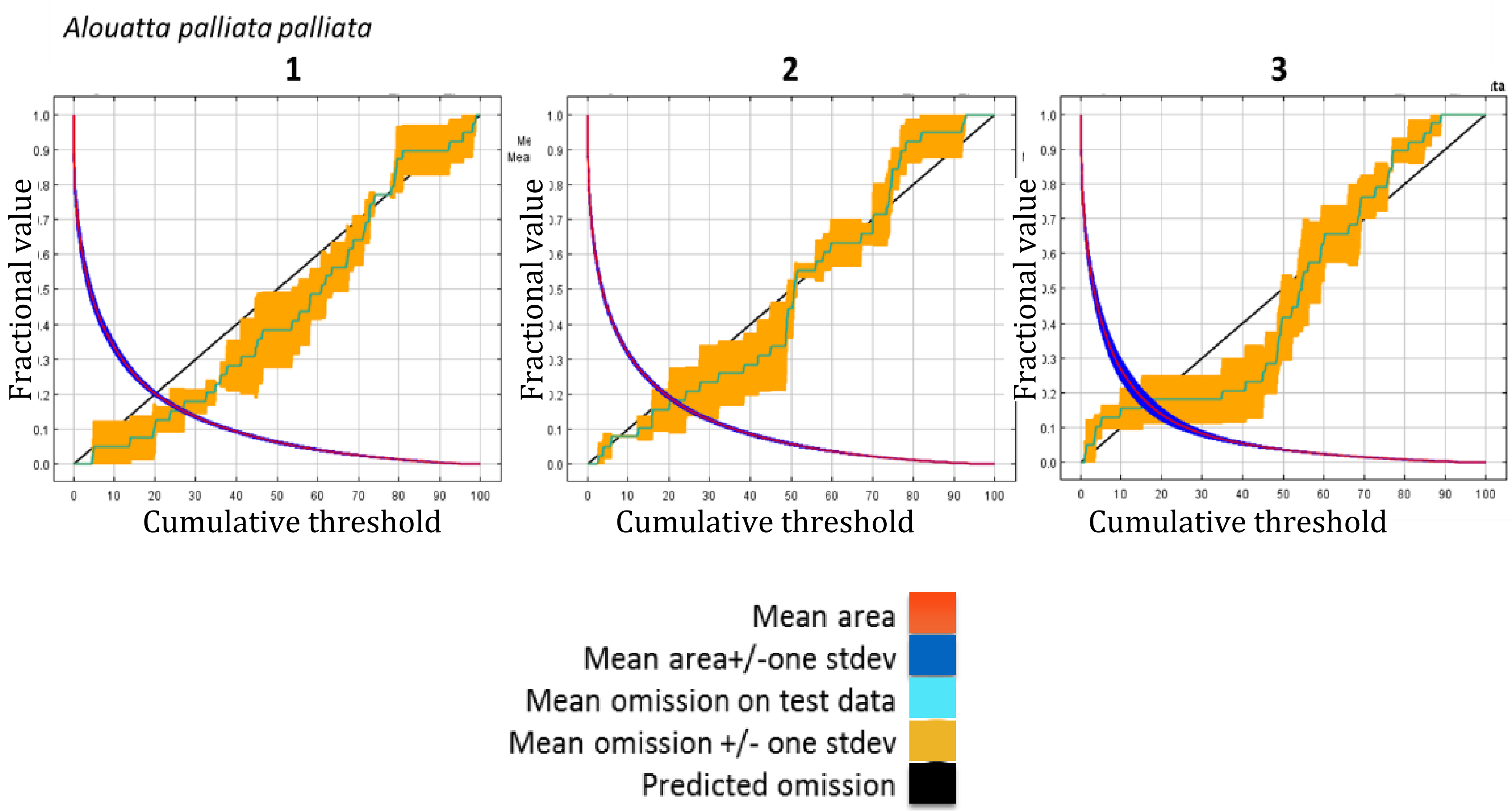

Alouatta coibensis coibensis
1
2
3
Fractional value
Cumulative threshold
Mean area
Mean area+/-one stdev
Mean omission on test data
Mean omission +/- one stdev
Predicted omission

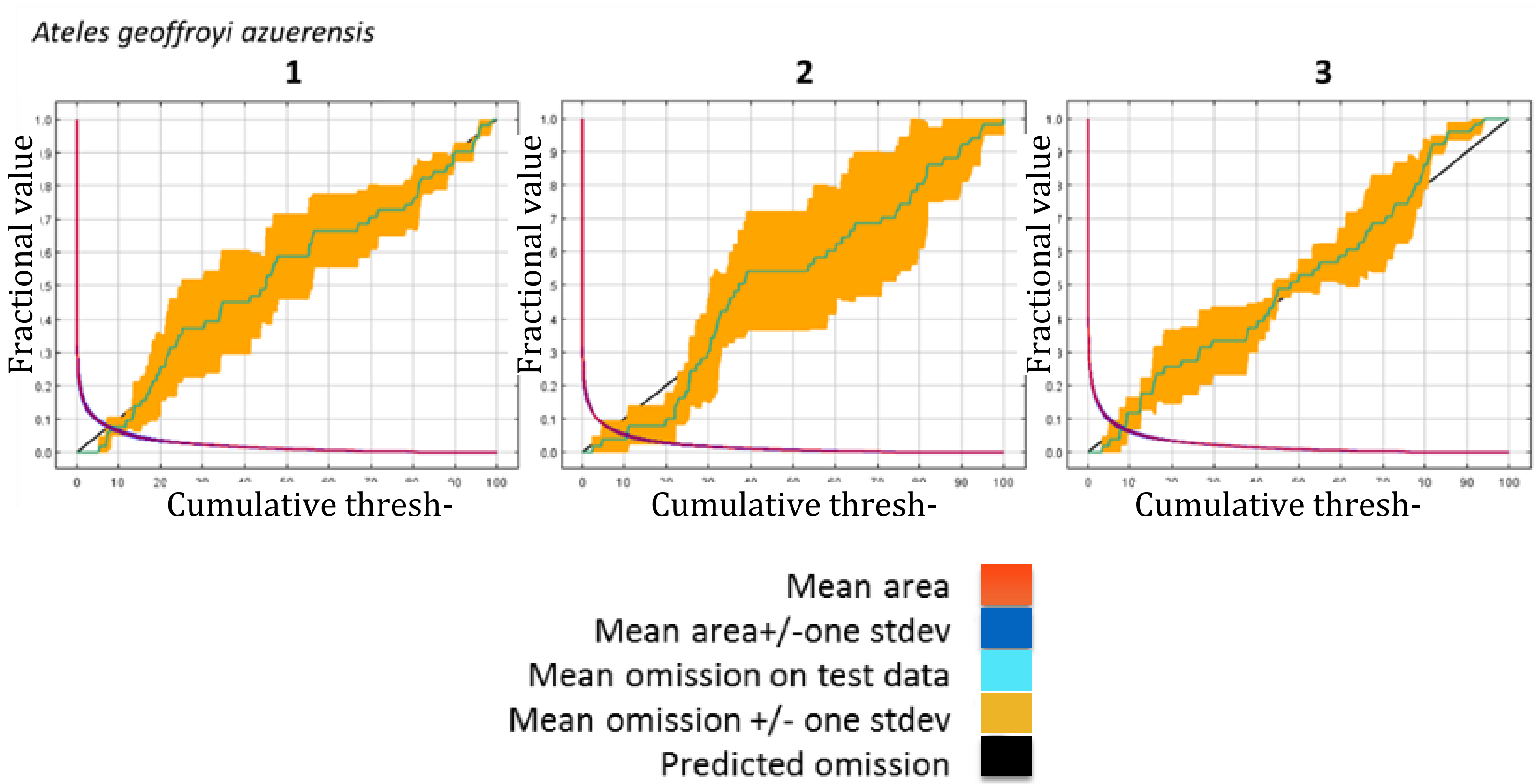
Alouatta coibensis trabeata

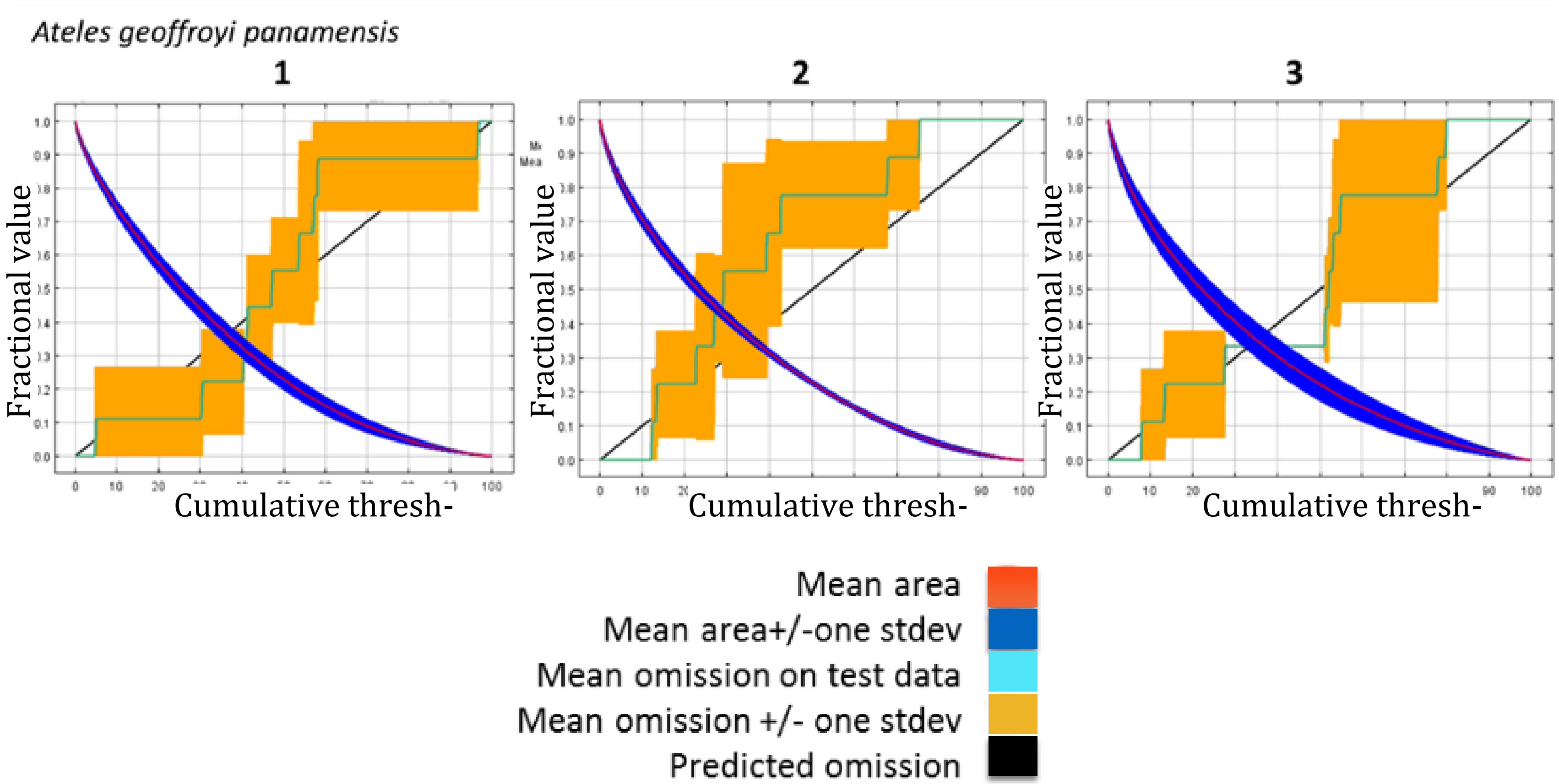
1 **2** **3**



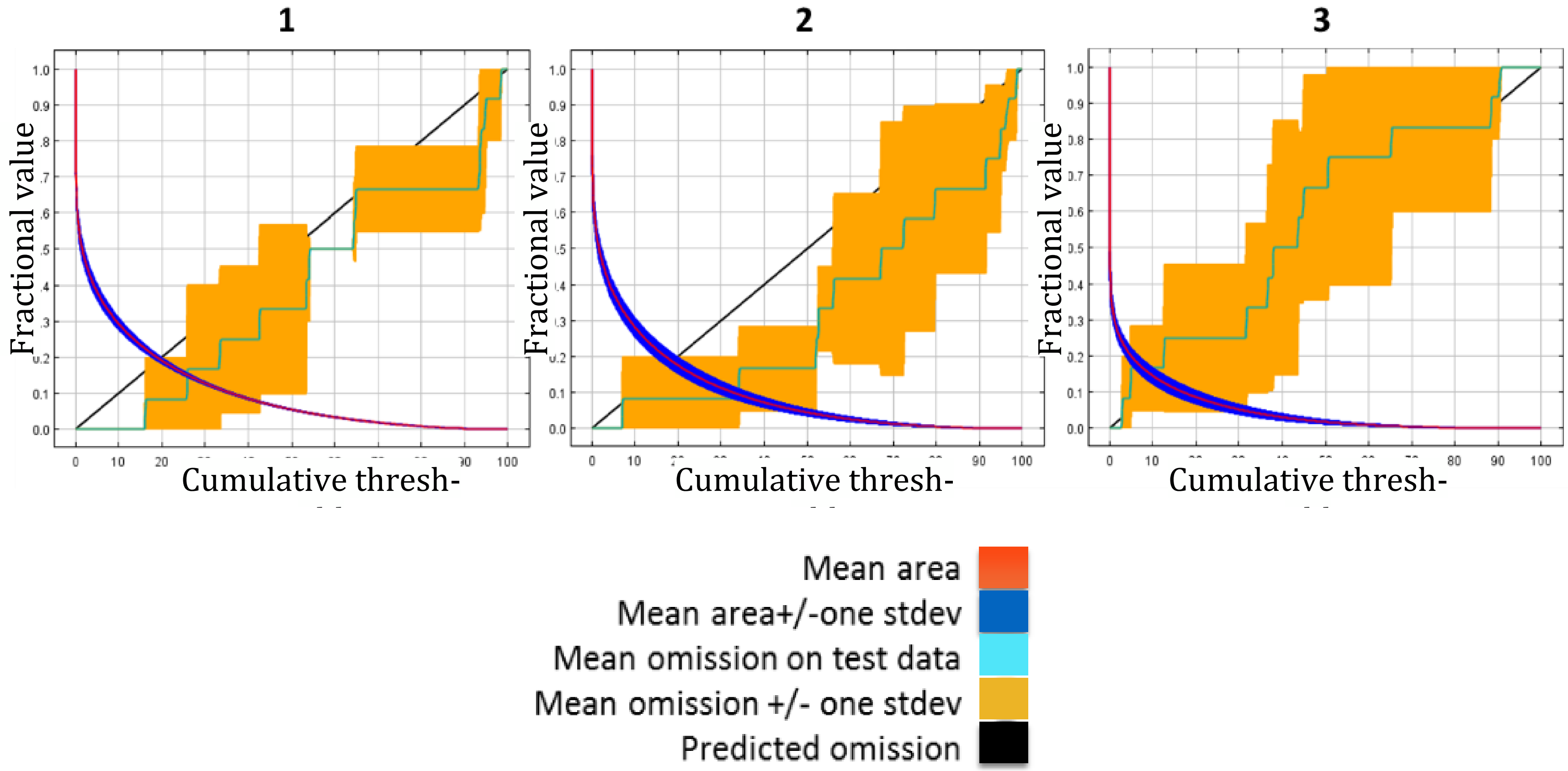

Alouatta palliata aequatorialis
1
2
3
Fractional value
Cumulative thresh-
Mean area
Mean area+/-one stdev
Mean omission on test data
Mean omission +/- one stdev
Predicted omission


Alouatta palliata palliata
1
2
3
Fractional value
Cumulative threshold
Mean area
Mean area+/-one stdev
Mean omission on test data
Mean omission +/- one stdev
Predicted omission

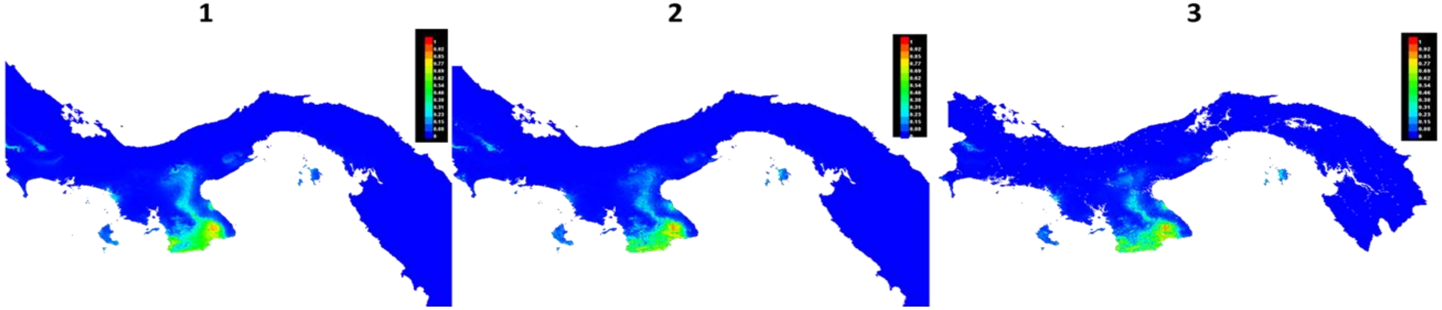

Ateles geoffroyi azuerensis
1
2
3
Fractional value
Cumulative thresh-
Mean area
Mean area+/-one stdev
Mean omission on test data
Mean omission +/- one stdev
Predicted omission


Ateles geoffroyi panamensis
1
2
3
Fractional value
Cumulative thresh-
Mean area
Mean area+/-one stdev
Mean omission on test data
Mean omission +/- one stdev
Predicted omission

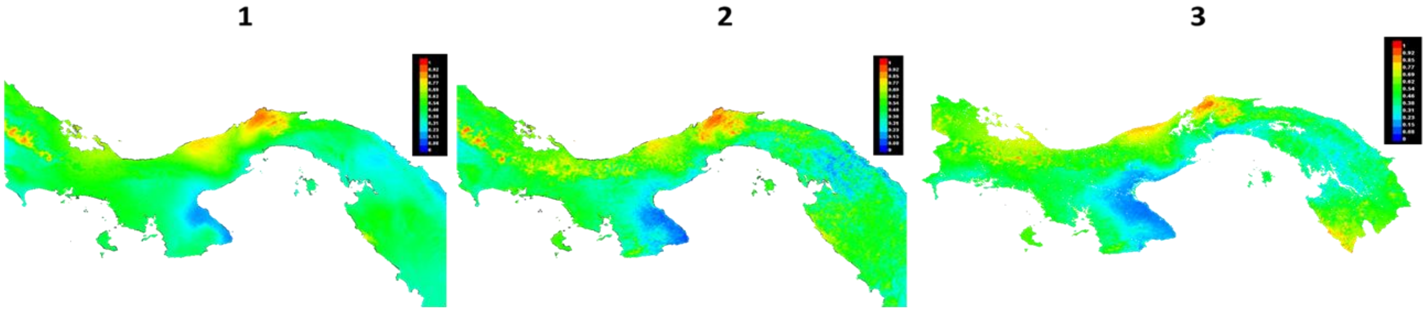
Ateles fusciceps rufiventris



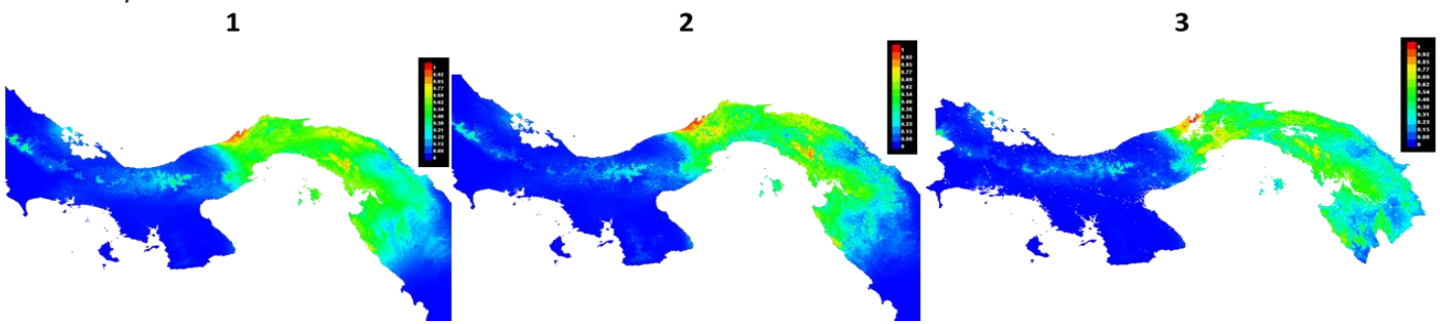
Ateles geoffroyi azuerensis



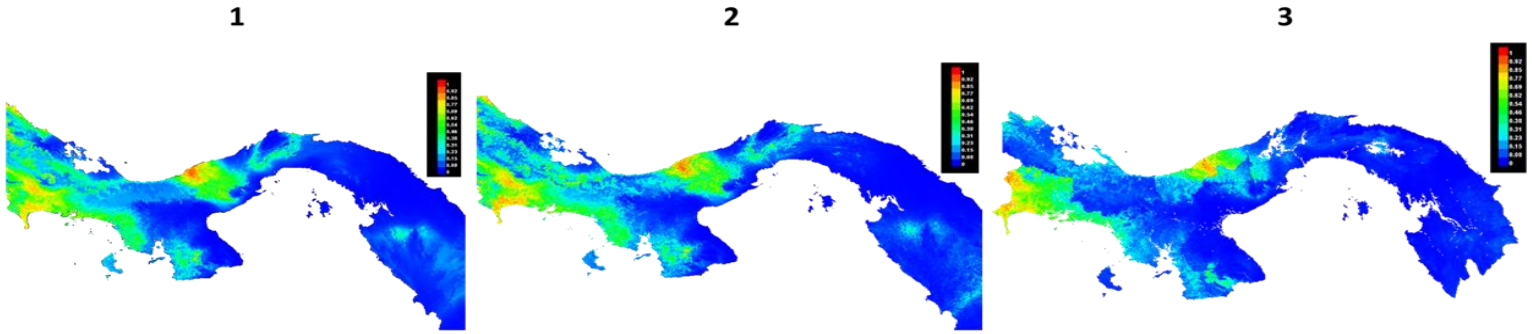
Ateles geoffroyi panamensis



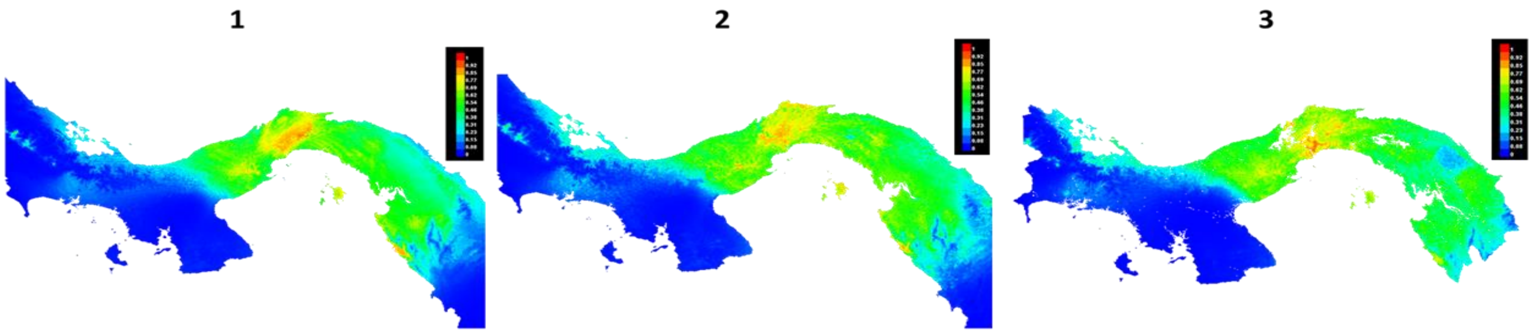
Cebus capucinus



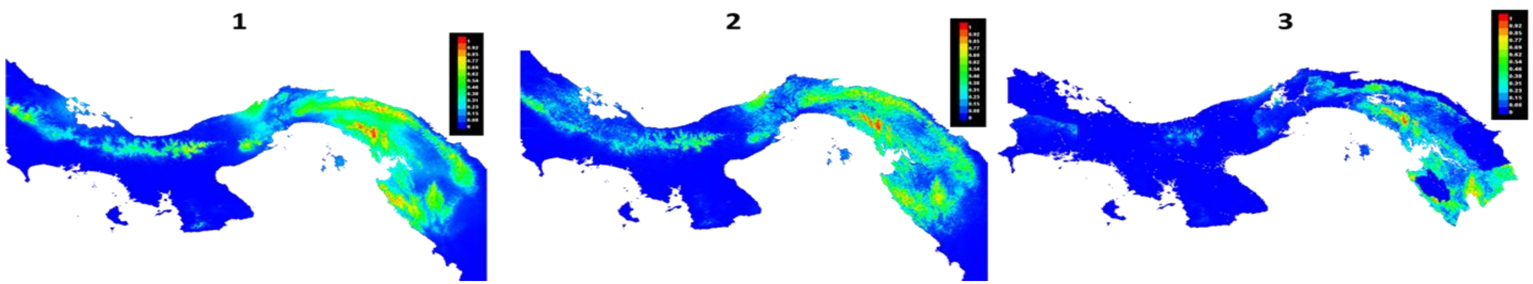
Alouatta palliata palliata



Aotus zonalis

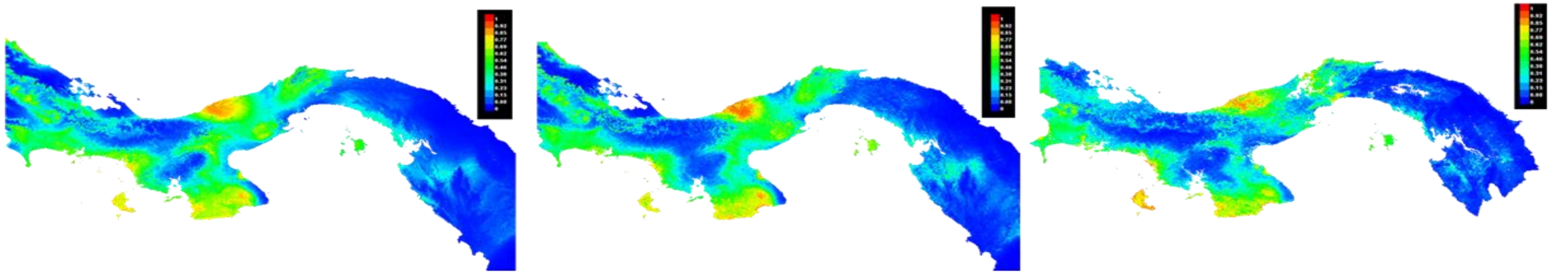


Ateles fusciceps rufiventris



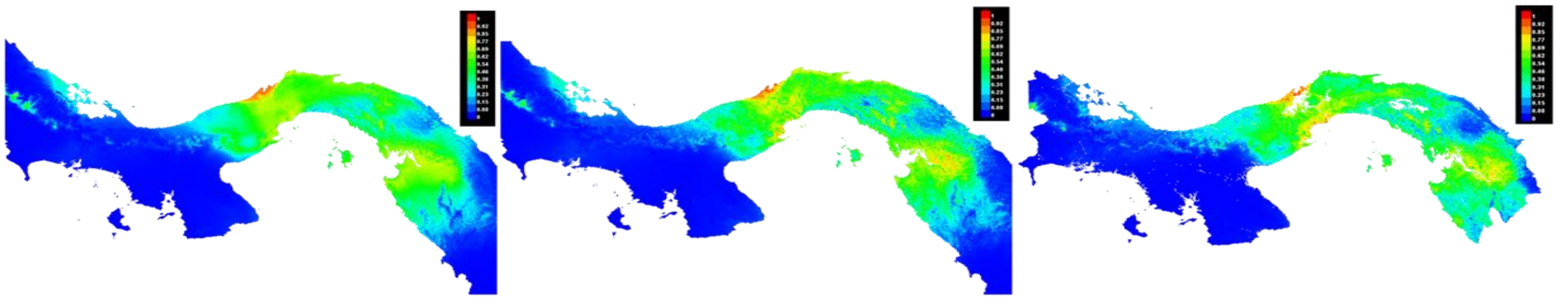
Cebus imitator

1 **2** **3**



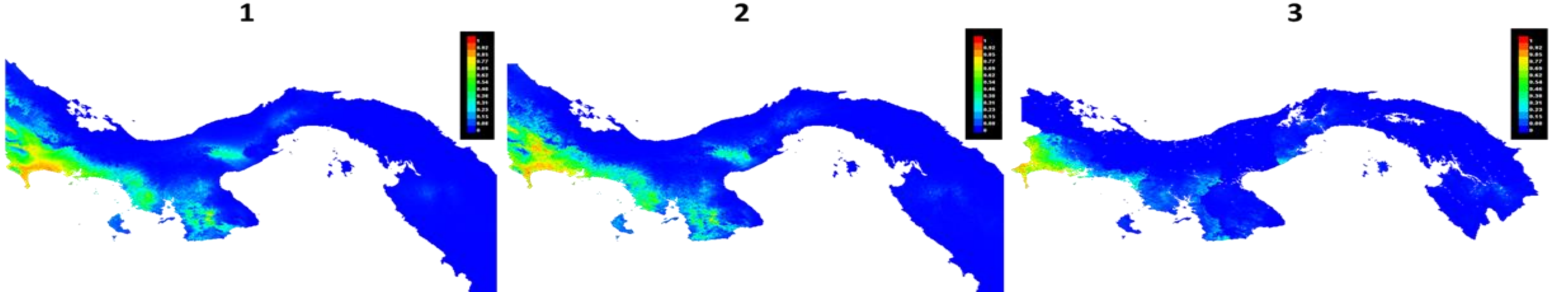
Saguinus geoffroyi

1 **2** **3**



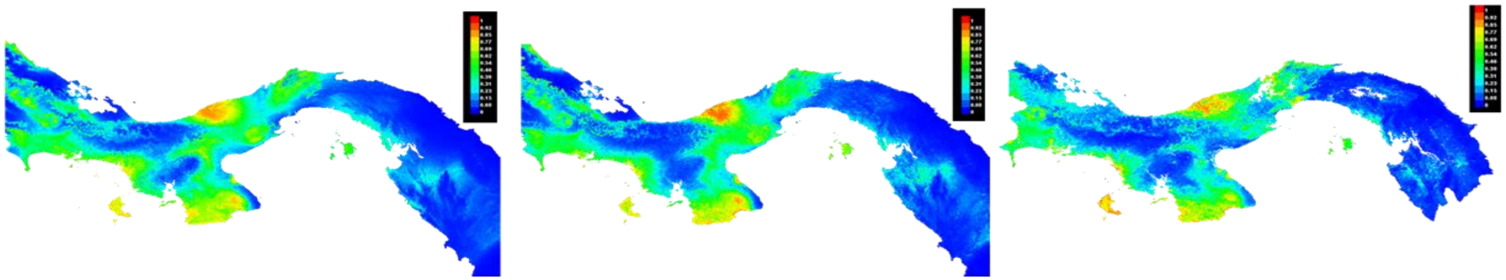
Saimiri oerstedii oerstedii

1 **2** **3**



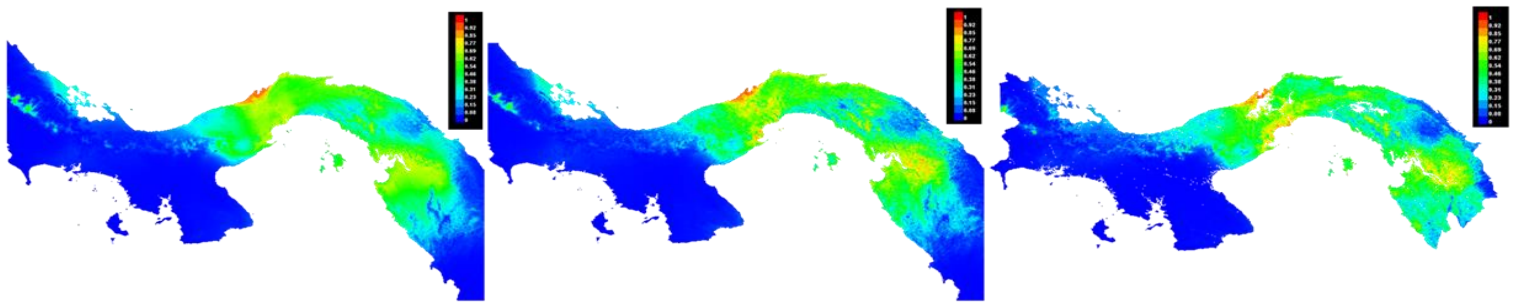
Cebus imitator

1 **2** **3**



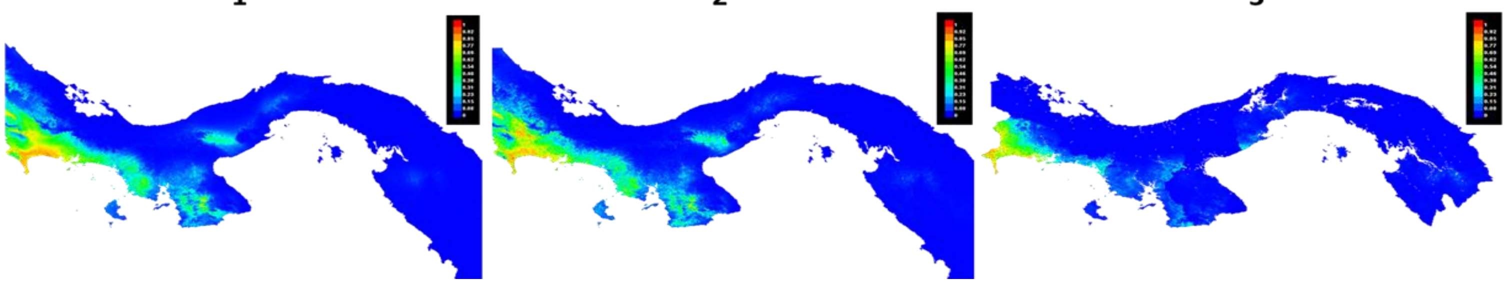
Saguinus geoffroyi

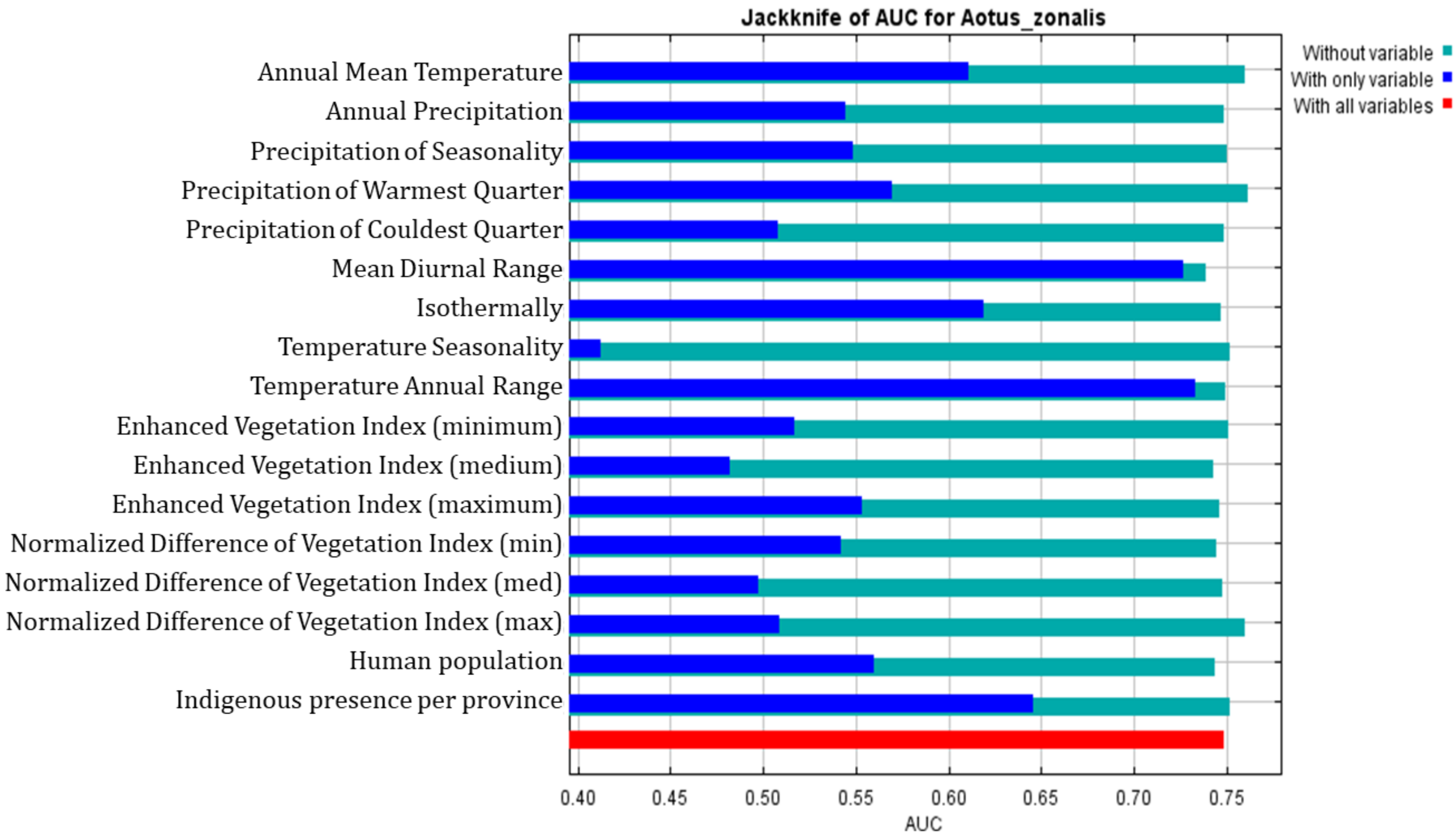
1 **2** **3**

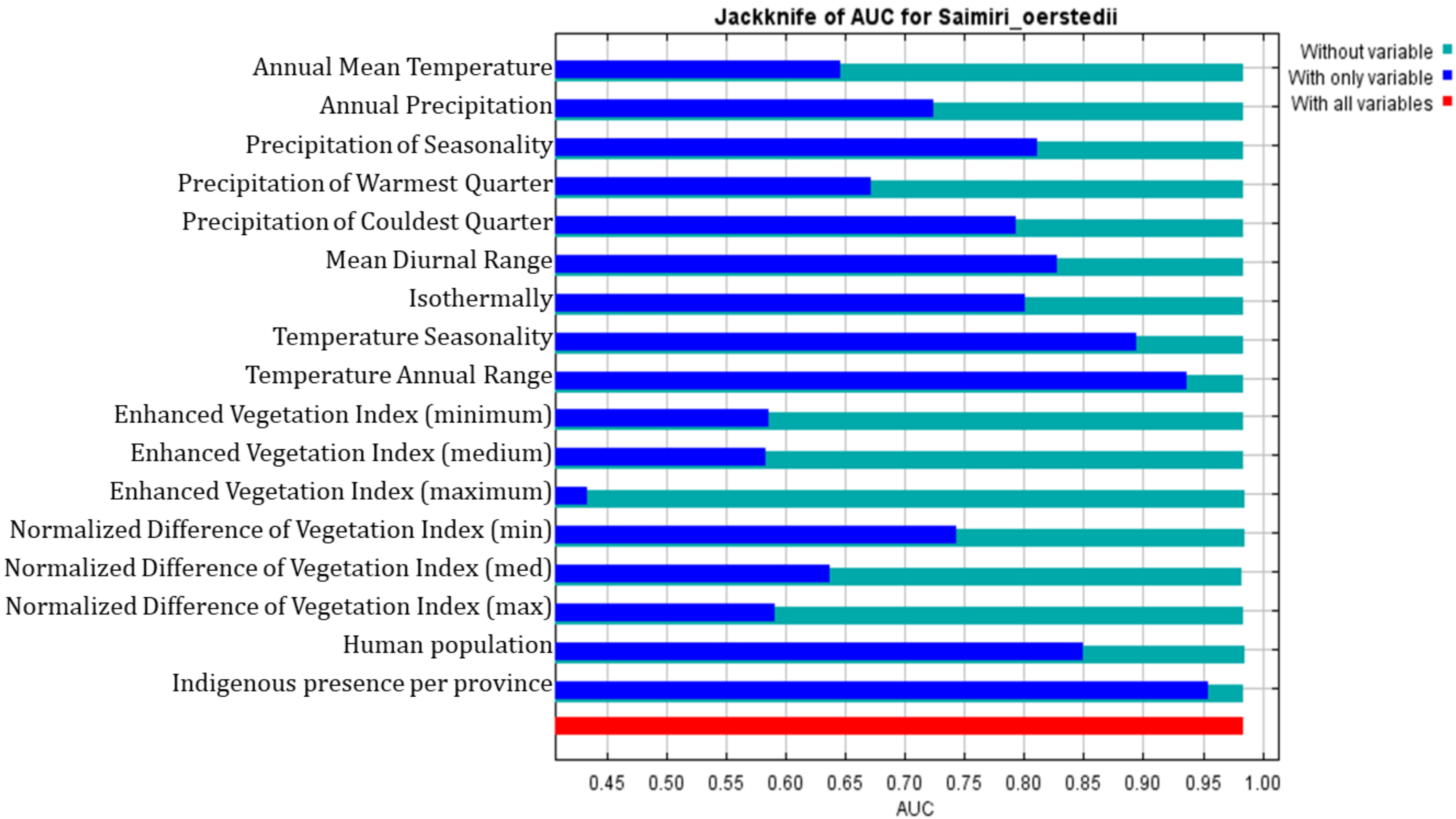


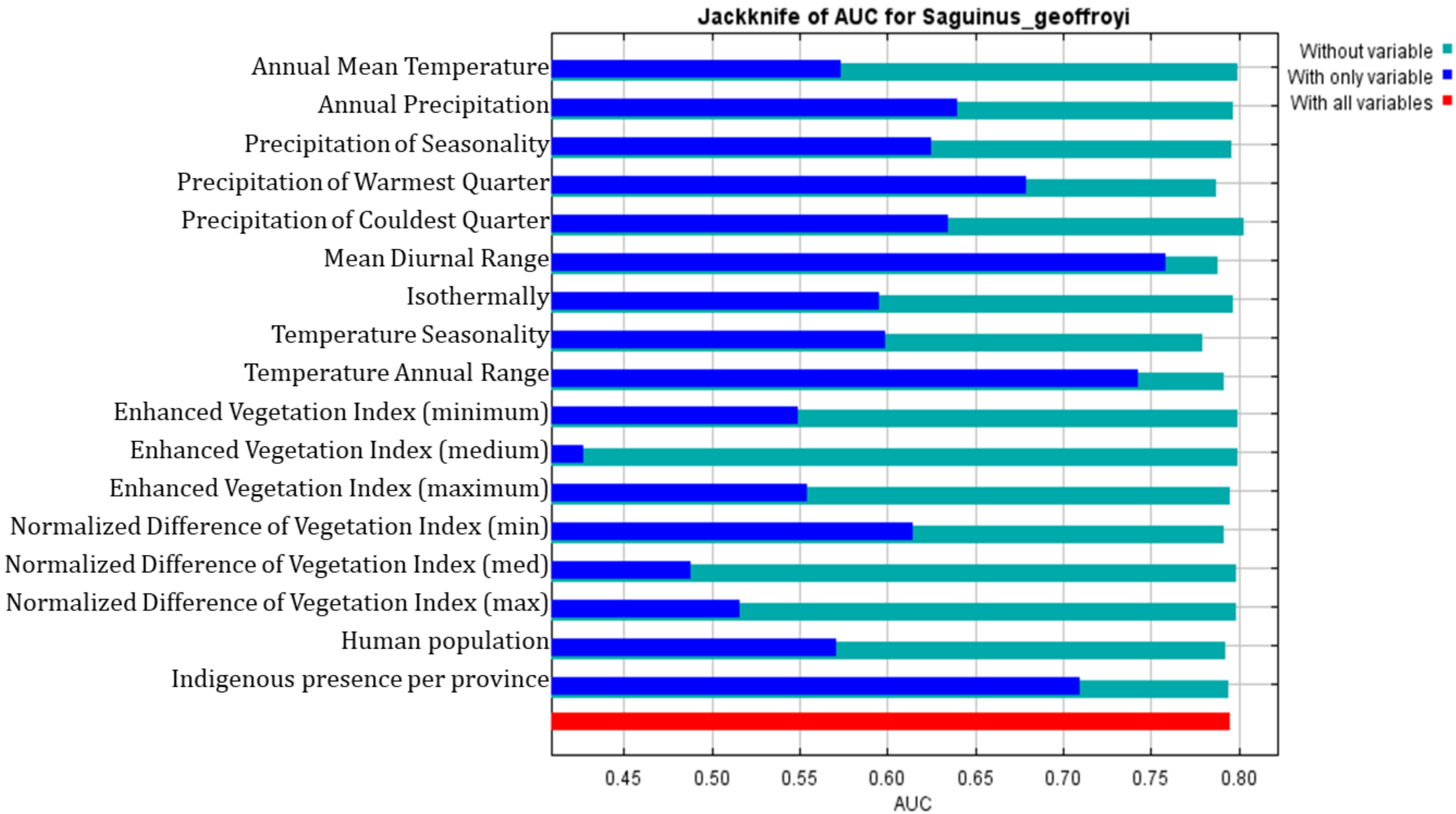
Saimiri oerstedii oerstedii

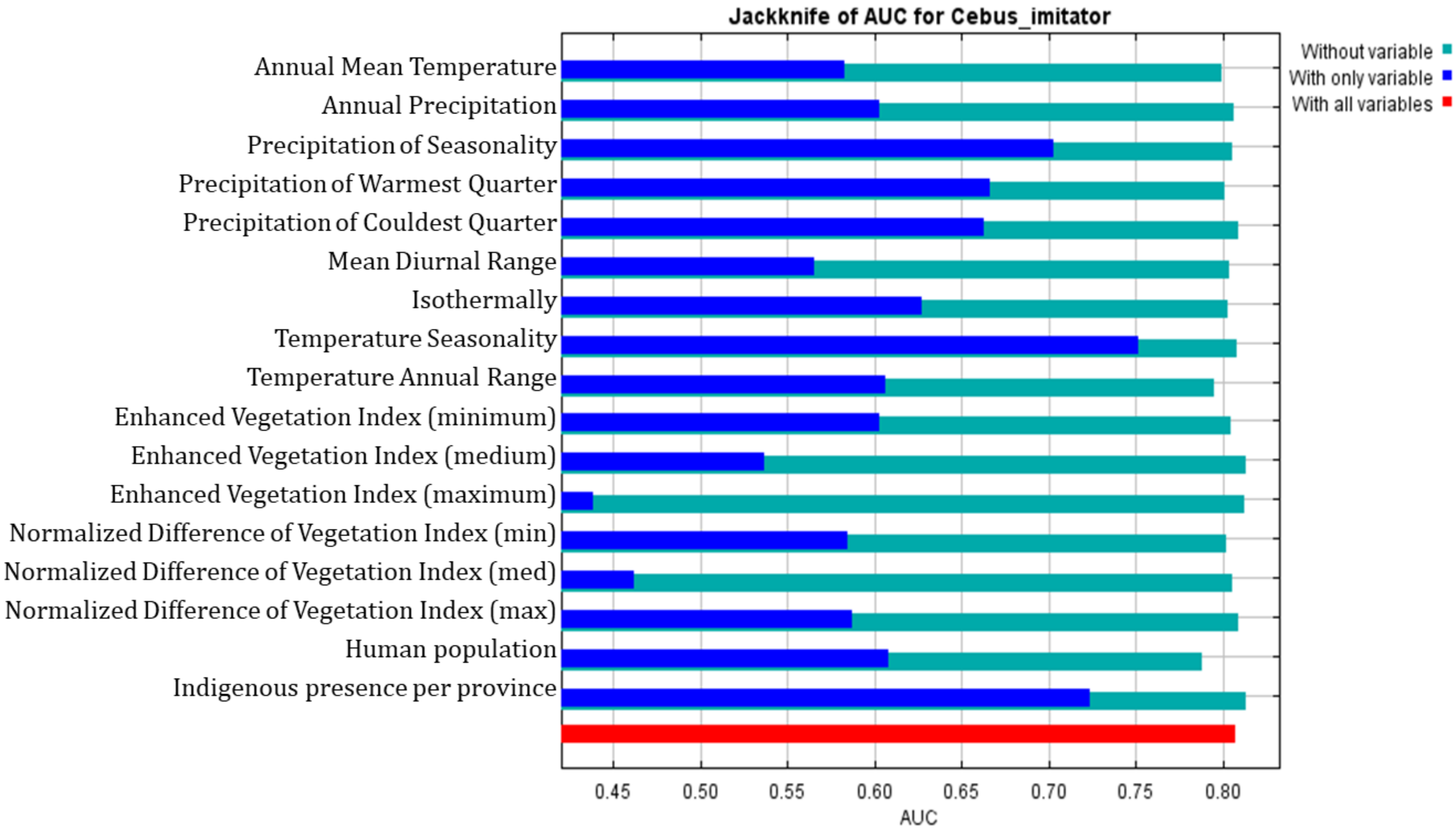
1 **2** **3**

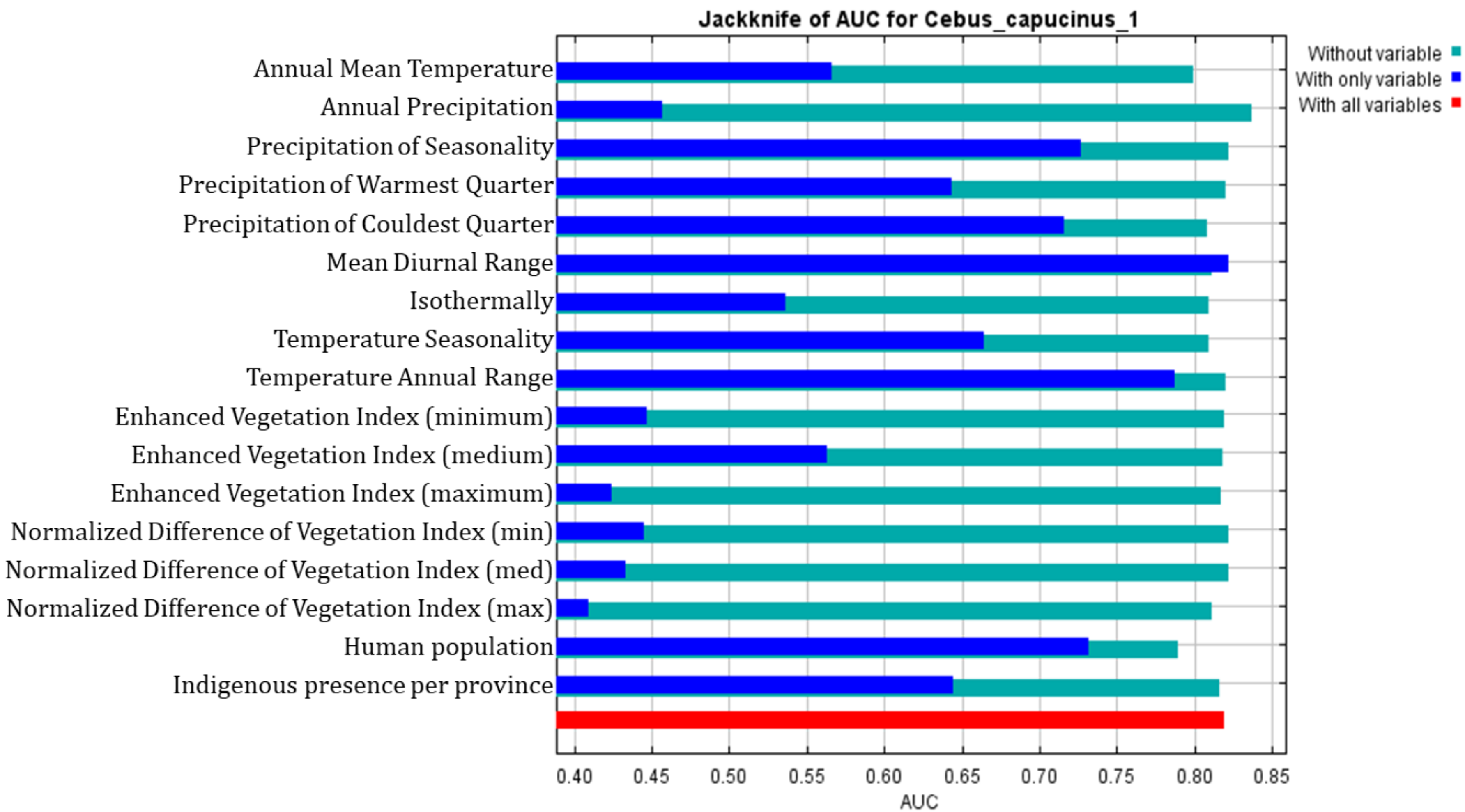


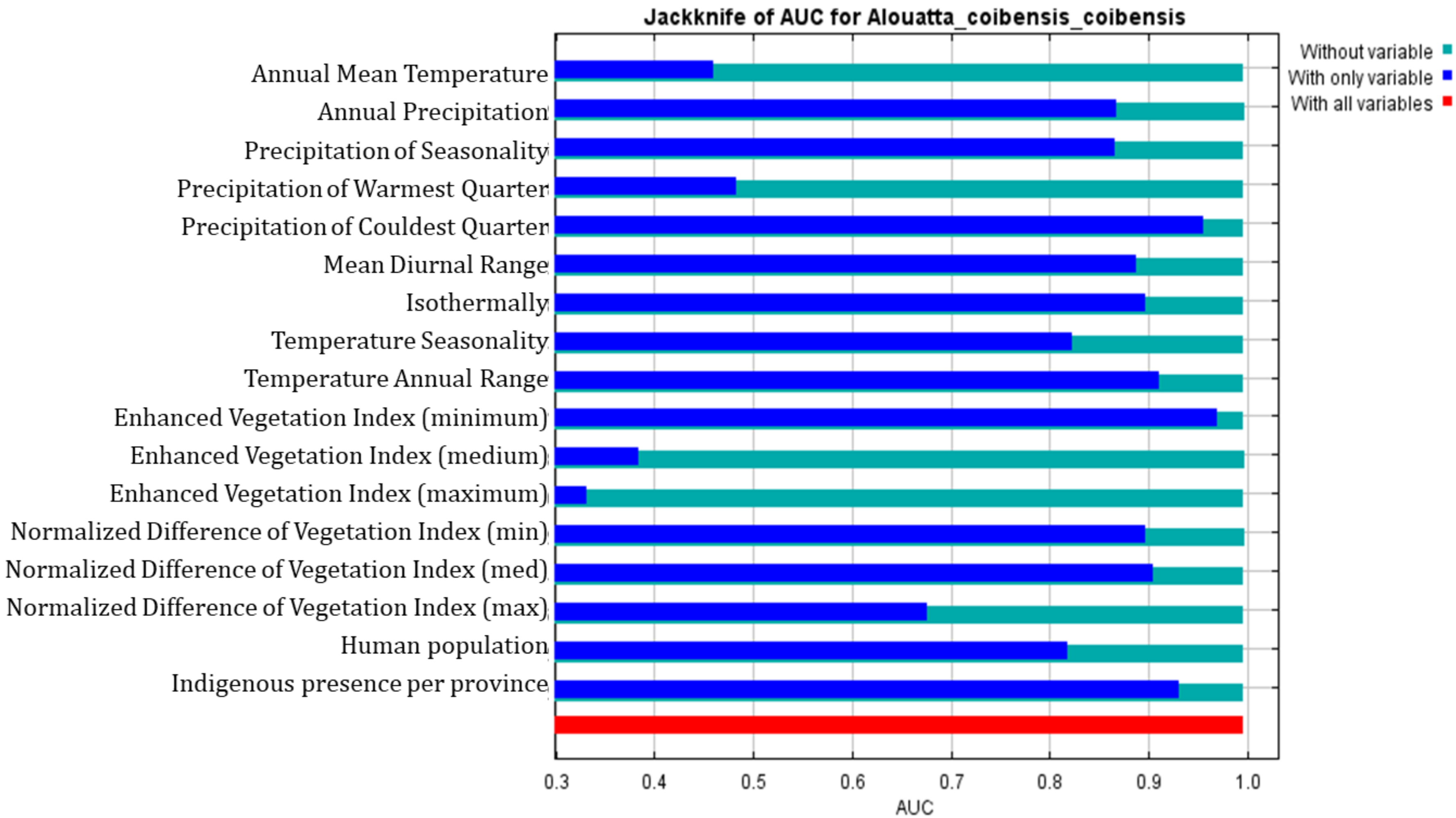

Jackknife of AUC for Aotus_zonalis
Without variable
With only variable
With all variables
Annual Mean Temperature
Annual Precipitation
Precipitation of Seasonality
Precipitation of Warmest Quarter
Precipitation of Couldest Quarter
Mean Diurnal Range
Isothermally
Temperature Seasonality
Temperature Annual Range
Enhanced Vegetation Index (minimum)
Enhanced Vegetation Index (medium)
Enhanced Vegetation Index (maximum)
Normalized Difference of Vegetation Index (min)
Normalized Difference of Vegetation Index (med)
Normalized Difference of Vegetation Index (max)
Human population
Indigenous presence per province
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75
AUC

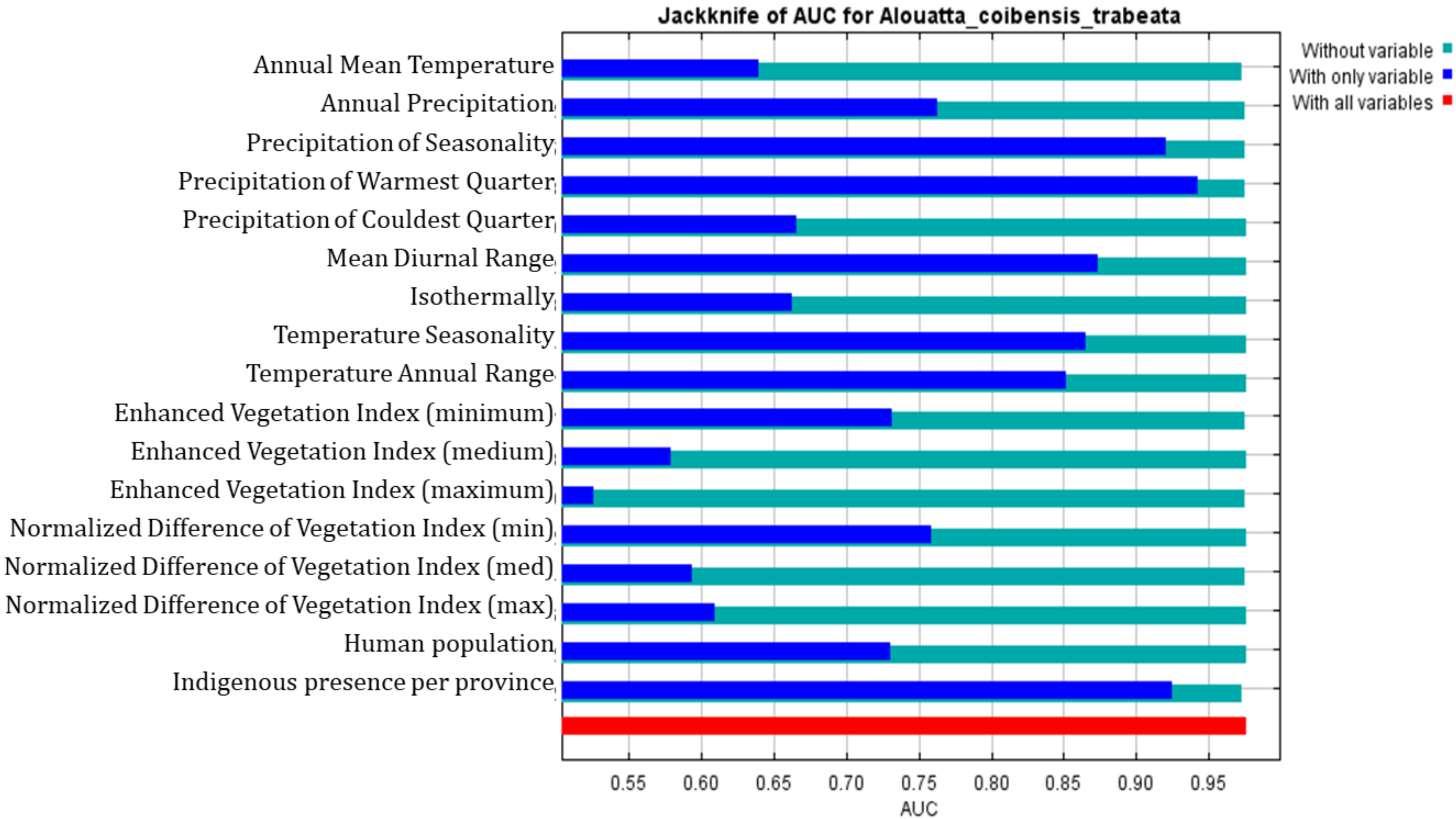

Jackknife of AUC for Saimiri_oerstedii
Annual Mean Temperature
Annual Precipitation
Precipitation of Seasonality
Precipitation of Warmest Quarter
Precipitation of Couldest Quarter
Mean Diurnal Range
Isothermally
Temperature Seasonality
Temperature Annual Range
Enhanced Vegetation Index (minimum)
Enhanced Vegetation Index (medium)
Enhanced Vegetation Index (maximum)
Normalized Difference of Vegetation Index (min)
Normalized Difference of Vegetation Index (med)
Normalized Difference of Vegetation Index (max)
Human population
Indigenous presence per province
Without variable
With only variable
With all variables
0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00
AUC

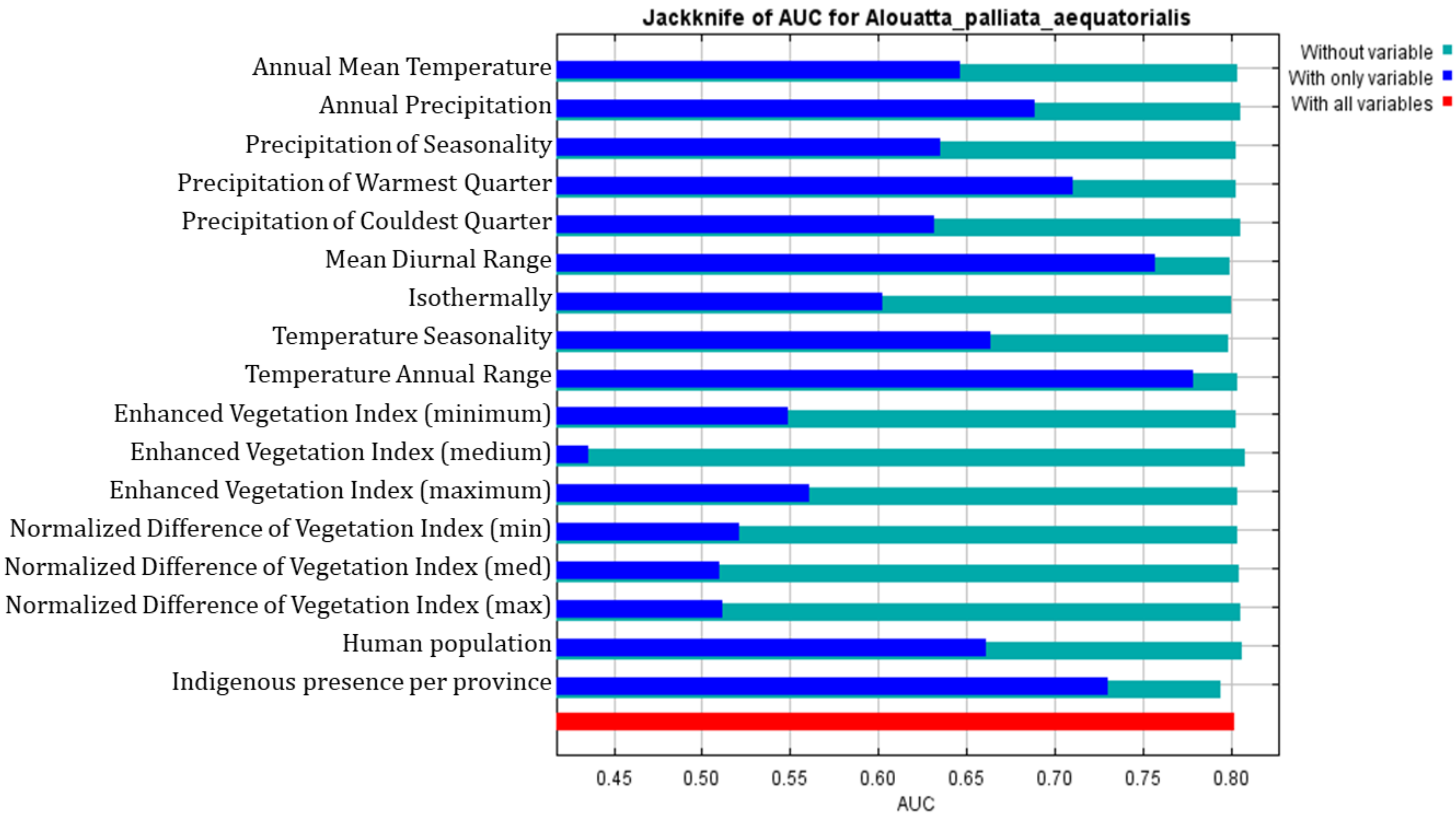

Jackknife of AUC for Saguinus_geoffroyi
Annual Mean Temperature
Annual Precipitation
Precipitation of Seasonality
Precipitation of Warmest Quarter
Precipitation of Couldest Quarter
Mean Diurnal Range
Isothermally
Temperature Seasonality
Temperature Annual Range
Enhanced Vegetation Index (minimum)
Enhanced Vegetation Index (medium)
Enhanced Vegetation Index (maximum)
Normalized Difference of Vegetation Index (min)
Normalized Difference of Vegetation Index (med)
Normalized Difference of Vegetation Index (max)
Human population
Indigenous presence per province
Without variable
With only variable
With all variables
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
AUC

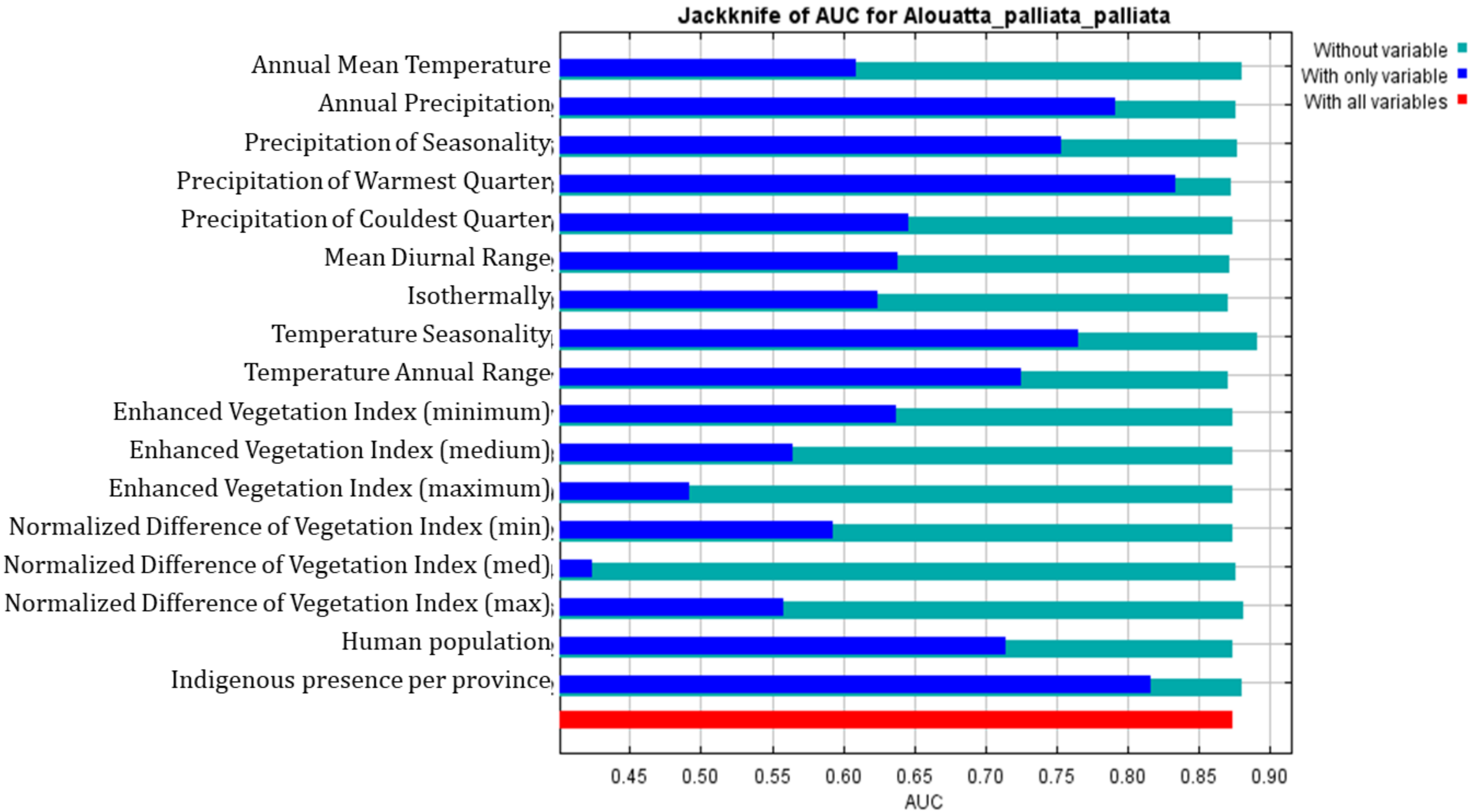

Jackknife of AUC for Cebus_imitator
Annual Mean Temperature
Annual Precipitation
Precipitation of Seasonality
Precipitation of Warmest Quarter
Precipitation of Couldest Quarter
Mean Diurnal Range
Isothermally
Temperature Seasonality
Temperature Annual Range
Enhanced Vegetation Index (minimum)
Enhanced Vegetation Index (medium)
Enhanced Vegetation Index (maximum)
Normalized Difference of Vegetation Index (min)
Normalized Difference of Vegetation Index (med)
Normalized Difference of Vegetation Index (max)
Human population
Indigenous presence per province
Without variable
With only variable
With all variables
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
AUC

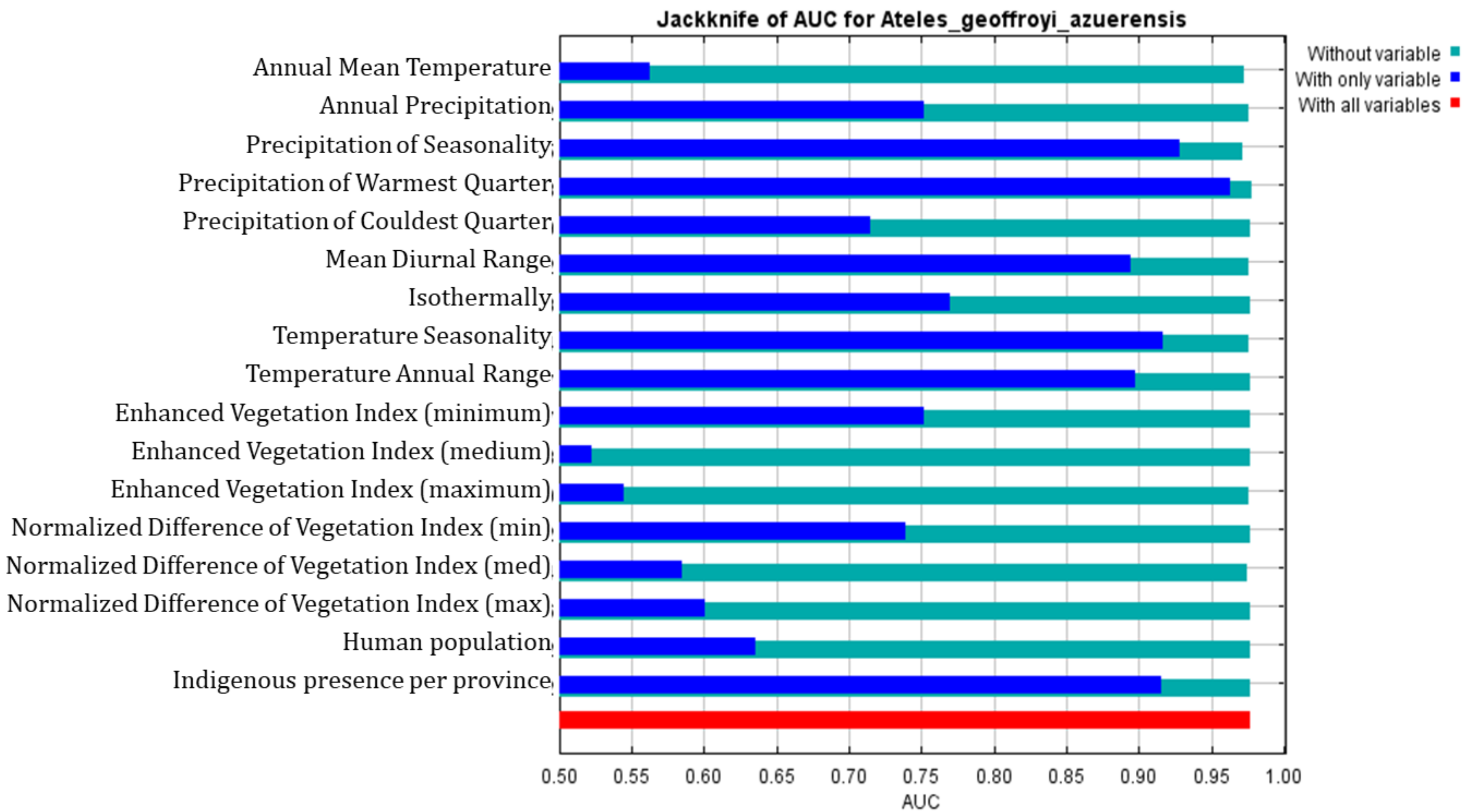

Jackknife of AUC for Cebus_capucinus_1
Annual Mean Temperature
Annual Precipitation
Precipitation of Seasonality
Precipitation of Warmest Quarter
Precipitation of Couldest Quarter
Mean Diurnal Range
Isothermally
Temperature Seasonality
Temperature Annual Range
Enhanced Vegetation Index (minimum)
Enhanced Vegetation Index (medium)
Enhanced Vegetation Index (maximum)
Normalized Difference of Vegetation Index (min)
Normalized Difference of Vegetation Index (med)
Normalized Difference of Vegetation Index (max)
Human population
Indigenous presence per province
Without variable
With only variable
With all variables
0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85
AUC

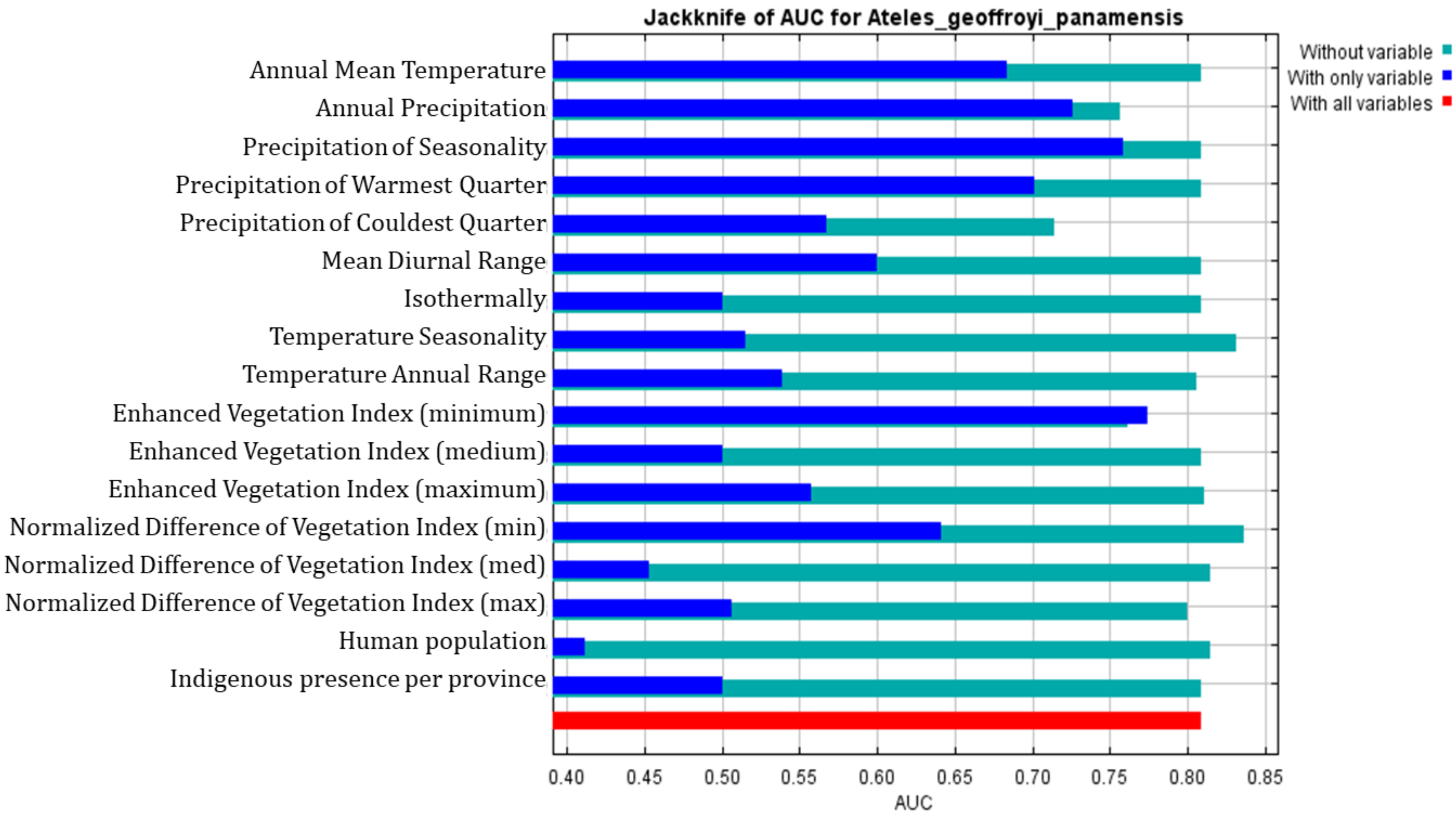

Jackknife of AUC for Alouatta_coibensis_coibensis
Annual Mean Temperature
Annual Precipitation
Precipitation of Seasonality
Precipitation of Warmest Quarter
Precipitation of Couldest Quarter
Mean Diurnal Range
Isothermally
Temperature Seasonality
Temperature Annual Range
Enhanced Vegetation Index (minimum)
Enhanced Vegetation Index (medium)
Enhanced Vegetation Index (maximum)
Normalized Difference of Vegetation Index (min)
Normalized Difference of Vegetation Index (med)
Normalized Difference of Vegetation Index (max)
Human population
Indigenous presence per province
Without variable
With only variable
With all variables
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
AUC

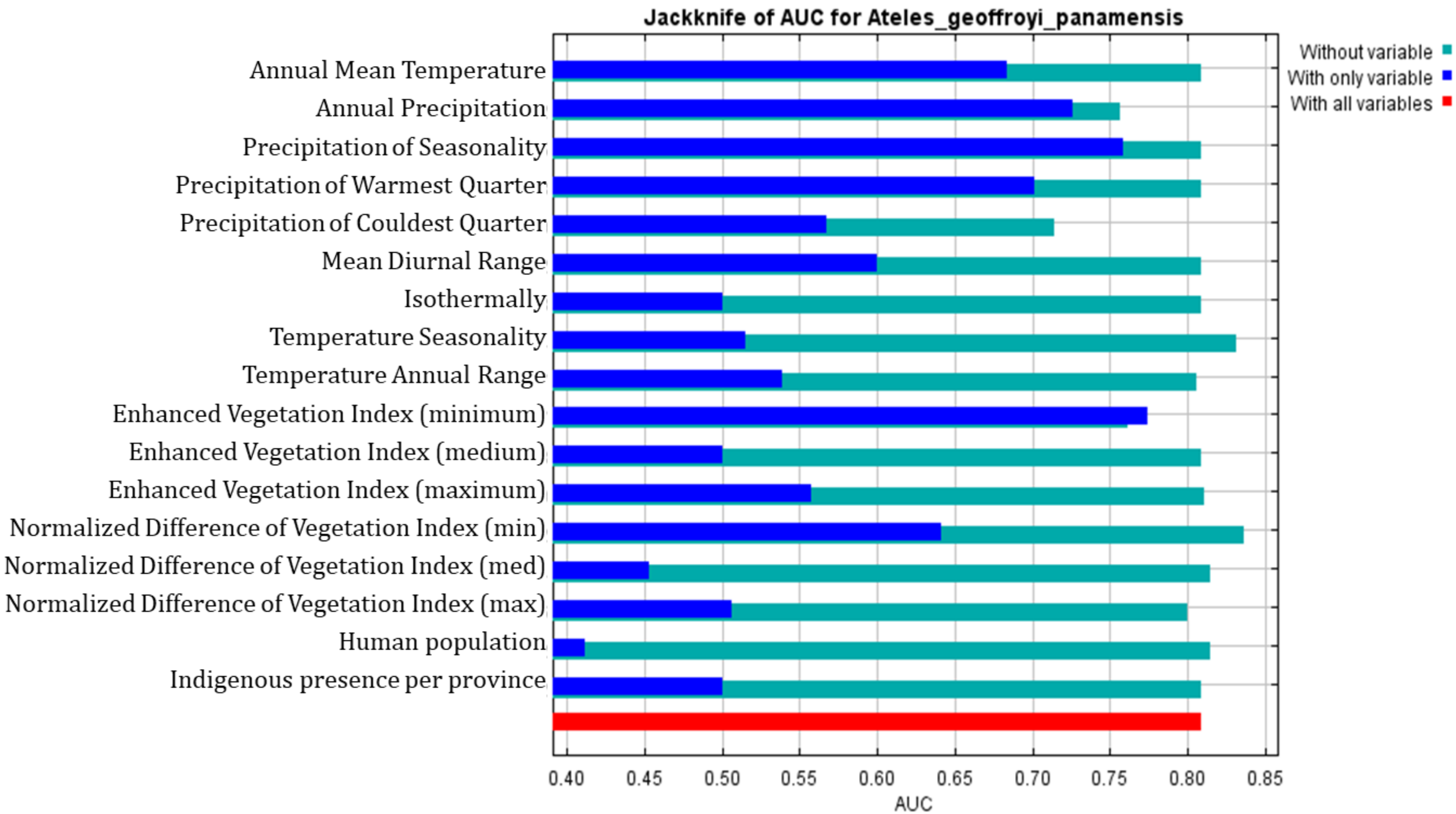

Jackknife of AUC for Alouatta_coibensis_trabeata
Annual Mean Temperature
Annual Precipitation
Precipitation of Seasonality
Precipitation of Warmest Quarter
Precipitation of Couldest Quarter
Mean Diurnal Range
Isothermally
Temperature Seasonality
Temperature Annual Range
Enhanced Vegetation Index (minimum)
Enhanced Vegetation Index (medium)
Enhanced Vegetation Index (maximum)
Normalized Difference of Vegetation Index (min)
Normalized Difference of Vegetation Index (med)
Normalized Difference of Vegetation Index (max)
Human population
Indigenous presence per province
Without variable
With only variable
With all variables
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
AUC


Jackknife of AUC for Alouatta_palliata_aequatorialis
Annual Mean Temperature
Annual Precipitation
Precipitation of Seasonality
Precipitation of Warmest Quarter
Precipitation of Couldest Quarter
Mean Diurnal Range
Isothermally
Temperature Seasonality
Temperature Annual Range
Enhanced Vegetation Index (minimum)
Enhanced Vegetation Index (medium)
Enhanced Vegetation Index (maximum)
Normalized Difference of Vegetation Index (min)
Normalized Difference of Vegetation Index (med)
Normalized Difference of Vegetation Index (max)
Human population
Indigenous presence per province
Without variable
With only variable
With all variables
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
AUC


Jackknife of AUC for Alouatta_palliata_palliata
Annual Mean Temperature
Annual Precipitation
Precipitation of Seasonality
Precipitation of Warmest Quarter
Precipitation of Couldest Quarter
Mean Diurnal Range
Isothermally
Temperature Seasonality
Temperature Annual Range
Enhanced Vegetation Index (minimum)
Enhanced Vegetation Index (medium)
Enhanced Vegetation Index (maximum)
Normalized Difference of Vegetation Index (min)
Normalized Difference of Vegetation Index (med)
Normalized Difference of Vegetation Index (max)
Human population
Indigenous presence per province
Without variable
With only variable
With all variables
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
AUC


Jackknife of AUC for Ateles_geoffroyi_azuerensis
Annual Mean Temperature
Annual Precipitation
Precipitation of Seasonality
Precipitation of Warmest Quarter
Precipitation of Couldest Quarter
Mean Diurnal Range
Isothermally
Temperature Seasonality
Temperature Annual Range
Enhanced Vegetation Index (minimum)
Enhanced Vegetation Index (medium)
Enhanced Vegetation Index (maximum)
Normalized Difference of Vegetation Index (min)
Normalized Difference of Vegetation Index (med)
Normalized Difference of Vegetation Index (max)
Human population
Indigenous presence per province
Without variable
With only variable
With all variables
0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00
AUC


Jackknife of AUC for Ateles_geoffroyi_panamensis
Annual Mean Temperature
Annual Precipitation
Precipitation of Seasonality
Precipitation of Warmest Quarter
Precipitation of Couldest Quarter
Mean Diurnal Range
Isothermally
Temperature Seasonality
Temperature Annual Range
Enhanced Vegetation Index (minimum)
Enhanced Vegetation Index (medium)
Enhanced Vegetation Index (maximum)
Normalized Difference of Vegetation Index (min)
Normalized Difference of Vegetation Index (med)
Normalized Difference of Vegetation Index (max)
Human population
Indigenous presence per province
Without variable
With only variable
With all variables
0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85
AUC


Jackknife of AUC for Ateles_geoffroyi_panamensis
Annual Mean Temperature
Annual Precipitation
Precipitation of Seasonality
Precipitation of Warmest Quarter
Precipitation of Couldest Quarter
Mean Diurnal Range
Isothermally
Temperature Seasonality
Temperature Annual Range
Enhanced Vegetation Index (minimum)
Enhanced Vegetation Index (medium)
Enhanced Vegetation Index (maximum)
Normalized Difference of Vegetation Index (min)
Normalized Difference of Vegetation Index (med)
Normalized Difference of Vegetation Index (max)
Human population
Indigenous presence per province
Without variable
With only variable
With all variables
0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85
AUC

Appendix 4 Ethics and Data Protection

Expanding your world

Durham University

Ethics and Data Protection Monitoring Form

All teaching, learning, research and other projects that involve human participants and/or raise ethical issues by all academic and related Staff and Students in the Department is subject to the standards set out in the appropriate Code of Practice. The Sub-Committee will assess the research against the discipline guidelines [e.g. Association of Social Anthropologists; Economic and Social Research Council; British Sociological Society Association; British Psychological Society].

It is a requirement that prior to the commencement of all projects this form must be completed and submitted to the Department's Ethics and Data Protection Subcommittee. The Subcommittee will be responsible for issuing certification that the project meets acceptable ethical standards and will, if necessary, require changes to the methodology or reporting strategy.

Please fill out the entire form where appropriate – so that there will be no additional Ethics paperwork. Please note that Travel and Risk Assessment forms are not part of the ethics approval process. Any queries relating to travel insurance and risk assessment should be directed to Judith Manghan, Health and Safety Manager (Judith.Manghan@durham.ac.uk)

Name: PEDRO G. MENDEZ-CARVAJAL

Email: MENDEZ.P.G@DURHAM.AC.UK

Title of project: PRIMATE CONSERVATION: A CASE STUDY IN PANAMA

Country where research will be carried out: PANAMA

Proposed start & end date of research: April 25 to June 5, 2016

Funding (if applicable): RUFFORD BOOSTER GRANT, PANAMANIAN GOVERNMENT SCHOLARSHIP, and ENVIRONMENTAL AUTHORITY OF PANAMA.

Name of co-investigator(s), position (i.e. staff, PGR, PGT), institution: Dr Jo Setchell, Dr Russ Hill

Delete as appropriate:

Staff

Start Date of Supervised Study (if applicable): April 2014

End Date of Supervised Study (if applicable): SEPTEMBER 2017

Name of Supervisors: Dr Jo Setchell and Dr Russ Hill

QUESTIONNAIRE

A. Describe your project and research methods:

In 2001, I founded the Fundación Pro-Conservación de los Primates Panameños (FCPP), a Panamanian NGO that studies and conserves threatened primate species and their habitats in Panama. My long-term goal is to promote primate conservation through habitat conservation and community participation.

My work concentrates on the Azuero peninsula, which is home to two Critically Endangered endemic primate sub-species *Alouatta coibensis trabeata* and *Ateles geoffroyi azuerensis* and *Cebus imitator*, classified as Least Concern (IUCN, 2008). The habitat of these primates has been heavily affected by farming activities and cattle ranches, which have made Azuero the most fragmented area in Panama. In some areas, the human communities depend on natural resources for subsistence, but most people own farms and depend on crops and cattle.

I aim to:

1. Assess the perceptions of the local communities concerning the importance of natural resource and the Azuero primates
2. Compare assessments made in 2015 with those from 2001-5, to determine whether there have been any changes
3. Evaluate whether peoples have retained information made available to them in my educational campaigns.

This ethics application concerns (i) my earlier activities, which I conducted independently of any institution, and (ii) new data collection to evaluate the effects of my conservation activities.

I appreciate that retrospective ethical approval is extremely unusual. However, my circumstances are also very unusual. I trained as a Biologist and started my Primate Conservation project independent of any other organisation. I do my best to respect my participants, because this is crucial for a successful conservation project. I have permission from the Panamanian Environmental Authorities, and obtain written consent from land-owners when working on their land. However, before I began my PhD at Durham University (in 2014), I had not come across the concern of formal ethics approval for work with people.

METHODS

The study area

The Azuero peninsula is located on the south-western Pacific side of Panama, and covers three provinces: Los Santos, Herrera, and Veraguas. Azuero has a total area of 8,000 km^2, the human population density is 1,197.6/km^2 in Los Santos, 47.3 ind/km^2 in Herrera, and 20.9 ind/km^2 in Veraguas. The main population in Azuero are people of combined European and Amerindian descent, and Azuero is also home to Ngöbe-Buglé indigenous people. 80% of the land is deforested and composed of farming landscapes. The rest of the vegetation is mainly secondary forest, mostly Tropical Dry Forest, and Pre-Mountain Forest.

Earlier activities

Between 2001 and 2005 I interviewed 150 individuals from 24 communities to identify and evaluate threats to primates, establish conservation priorities, find sites for future research, and understand peoples' perceptions of and behaviour towards primates. I also took the opportunity to educate people about the primates of Azuero to stimulate their cooperation in protecting Azuero primates.

I used semi-structured interviews, based around a questionnaire, but allowing for additional discussion, to collect information on peoples' knowledge and perceptions of primates in their area (please see the questionnaire, below). I approached people in their houses or in the street and introduced myself as a biologist from the Proyecto Pro-Conservación de los Primates Endémicos de Azuero (my project). I explained that I was interested in understanding their perceptions of the monkeys in the region, and wanted to collect information to help to the primates to survive. I asked people if they would be happy to answer some questions, and for permission to take pictures of them and/or film them. I explained that would not use any of this information against them in any way, and that I do not work for the Panamanian environmental authority. I stressed that I was simply interested in their point of view. If they gave me their verbal consent, I asked them to fill in a questionnaire. If they said that they did not know how to write (only one case), I offered to help them by filling the form for them, using the exact words they said.

The form included some personal information (please see below) and I informed participants that I would keep this confidential and reassured them that I will not share this information with any company or governmental authority. I made it clear that these questions were optional and that they could leave them blank (some did so). I also took notes of the conversation we had.

When I filmed interviews with participants, I asked verbally for permission to film (I did not have a written consent form). If they agreed, then I proceeded. If at any stage they asked not be filmed, or to delete the material, I did so.

New data collection

Since 2001, people in most of the towns in Azuero have been exposed to my environmental educational activities, through educational talks to elementary and secondary schools, radio appearances and newspaper publications, t-shirts with educational messages, road signs, training in primatology for local biologists, and direct contact with researchers.

My new data collection aims to evaluate the effects of this education on peoples' understanding of and perceptions of primates. I will use the same questionnaire that I used originally to interview local residents. I will cover as many communities as possible in the Azuero peninsula in 15 days. The questionnaire aims to understand local peoples' perceptions of the environment and the Azuero primates. I have added new questions to examine peoples' knowledge of primate species, habitat preferences, threats and conservation problems.

I have prepared an information sheet, which I will also explain to participants verbally (below). I will request that they sign a consent form (below) and proceed only if they do so. I will interview using a note-book and questionnaires. For questions that involve the identification of animals, I will use illustrations from the mammal guides Emmons (1997) and Reid (1997). I will also request permission to film interviews.

B. Please copy & paste below an information sheet on your project which could serve as a written and/or verbal summary for participants and/or gatekeepers

My name is Pedro Méndez-Carvajal. I am a PhD student from Durham University, England, and will be staying in (name of town/village, Azuero Peninsula) for the next few days. I am interested in your knowledge of the monkeys that live in this area. This information will help me to improve my activities to conserve the monkeys of the Azuero peninsula. It also forms part of my PhD research at Durham University.

I would like to interview you, asking questions about the primates of Azuero. If you agree, then I will either film our interview, or take notes of your answers, depending on your preferences. If you feel uncomfortable with this please let me know at any stage during the interview. If you prefer not to answer individual questions, please just say so. If you wish to stop the interview, please let me know and I will do so. If you wish to withdraw from the study, please let me know and I will delete any information you do not wish me to use.

I really appreciate your time and collaboration in this project. Please let me know if you have any questions at any time, I will give you my contact details. If you would like receive the material I publish at the end of this project, please let me know.

If you agreed to be filmed during the interviews, please state below whether you would prefer your information to be destroyed after completion of the research project or to be retained by the individual researcher for future research use. I will not share it with anyone other than my supervisors at Durham University.

I will ensure that all participants are anonymised in all reports that I write using the data I collect. If it is not possible to anonymise the data such that the participant cannot be identified, I will not include it. We anticipate that the data will be summarised numerically as the results of questionnaires, with additional context from my long experience in the area, but with few or any direct quotes. Where I do use quotes, I will ensure that they cannot be attributed to individuals.

Thank you for your participation in my research project.

Original interview questions (to be repeated in my new study for comparison with existing data)

Name (Optional):

Age:

Sex:

Occupation:

How long have you lived in this town / area

Where are you from originally?

What is the main commercial activity in this area?

What is the main subsistence activity in this area?

#	Question in Spanish	Translation in English	Objective
1	¿Ha visto en este pueblo a alguno de los monos que se muestra en la guía?	Have you seen any of these monkeys in this town? If so, where?	Presence/absence and key locations of primates
2	¿Cómo se llaman los diferentes monos que usted conoce en esta región?	What do you call the monkeys that live in this area?	Presence/absence and key locations of primates
3	¿Qué piensa sobre estos monos?	What do you think about these monkeys?	To understand local perceptions of primates
4	¿Cómo se relacionan estos monos con su día a día?	What sort of relationship do you have with these monkeys in day to day life?	To understand problems related to primates
5	¿Qué utilidad tienen estos monos?	Are the monkeys useful?	To understand hunting pressure and reasons for hunting
6	¿Qué tipo de lugares prefieren estos monos?	What kind of habitats do these monkeys prefer? (I give some options)	To understand which areas are potentially important
7	¿Sabe que comen estos monos?	Do you know what these monkeys eat? (I give some options)	To measure local knowledge about monkeys
8	¿Qué tan fácil es encontrarlos (a los monos) por esta zona?	How easy is it to find monkeys in this area?	To measure local concern about monkeys

9	¿Son importantes estos monos? ¿Porque?	Are these monkeys important? Why/ why not?	To understand local perception about monkeys
10	¿Está de acuerdo con la protección a éstos animales?	Do you think that these animals should be protected?	To know how they think they could help the monkeys survive
11	¿Alguna vez ha tratado de ayudar a estos monos? ¿Cómo?	Have you ever tried to help the monkeys? If so, how?	To understand how humans react to co-existing with non-human primates
12	¿Sabe de algún animal Silvestre que estaba antes y ya no lo ve? ¿Hace cuánto no lo ve? ¿O alguno nuevo?	Are there any wild animals that you no longer find here? When did they disappear? Are there any new animals?	To estimate presence/absence and diversity, local extinction and migration
13	¿Hay alguna persona o institución interesada en la protección y estudio de los monos en este lugar?	Do you know of any person or institution interested in protecting or studying the monkeys of this region?	To know if there is another project working in the area, for possible collaboration or to standardize approaches
14	¿Ha recibido usted alguna información referente a los monos de esta área y su importancia?	Have you received any information related to the monkeys of the area and its importance?	To know if they remember FCPP or other NGOs
15	¿Sabía que estos monos son únicos de Panamá y están por desaparecer del área?	Did you know that these monkeys are unique to Panama and are disappearing from the area?	To understand local knowledge of primate conservation status

16	¿Qué piensa sobre la Autoridad Nacional del Ambiente?	What do you think about the Panamanian Environmental Authority?	To understand their relationship with the authorities

ADDITIONAL QUESTIONS FOR NEW DATA COLLECTION

	Capture to have a pet	Capture to sell	Kill and leave	Kill to eat	Just look	Other
Howler monkey						
Spider monkey						
Capuchin mon-key						
Snake						
Deer						
Coyote						
Jaguar						
Bird						

1) What is your reaction when you see these animals?
2) Have you ever hunted wild animals?
3) If so, why?
4) If you have stopped hunting wild animals, why did you stop?
5) What is your preferred game species

QUESTIONS TO TEST KNOWLEDGE GAIN AFTER EXPOSURE TO FCPP ACTIVITIES

1) Do you recognize this animal (I show them pictures)
2) What do they eat?
3) Which trees do they use?
4) Why do howler monkeys howl?
5) Why do fruits fall out of the trees when they are eating?
6) Are they important to you? If so, why? If not, why not?
7) Should conserve them? If so, why? If not, why not?
8) Can we help them? If so, how?
9) How many spider monkeys are there?
10) How many howler monkeys are there?

QUESTIONS TO ASSESS PEOPLE'S PERCEPTIONS OF PRIMATES

1) You consider yourself lucky to live close to the forest? If so why? If not, why not?
2) What environmental services does nature provide?
3) What benefits does nature provide?
4) Are animals beneficial to us? If so, why? If not, why not?
5) Are the howler monkey populations changing? (same for the other species)
6) Can you estimate how many howler monkeys there are?

7) Are primates important? If so, why? If not, why not?

8) Who protects the primates in this region?

9) How you have learned what you know about primates?

A. Where appropriate, please copy and paste below the consent form you intend to use, tailored to your project, featuring your name, contact information and project title. This could be used either as the basis of a verbal summary, or as a document provided to key participants and/or key gatekeepers

Consent form to participate in Pedro Méndez-Carvajal's PhD research project at Durham University, P.G.MENDEZ@DURHAM.AC.UK

Date: January 16, 2016

This declaration certifies that I, (name of the person here), give my full consent to participate in the research project conducted by Pedro Mendez-Carvajal, Durham University. I have understood the aims and objectives of the research project and treatment of the final data set. The nature of the research has been fully explained to me including my rights to remain anonymous and withdraw from the research project at any time without further need for justification.

I (delete as appropriate) do/ do not give permission to be filmed during interviews. I understand that this information will only be used to transcribe the interview.

		YES	NO	
1.	**Does your project involve living human participants?**	YES		IF NO, go to Q12a. If YES go to Q3a
2.	**Does your project involve only the analysis of large, secondary and anonymised datasets?**		NO	IF YES, go to DECLARATION at the end

3a	**Will you provide informants with a written information sheet explaining your project and the uses of any data that you might generate?**	YES (for new work)	NO (for previous work)	If NO, please provide further details and go to Q3b. If YES, please go to Q4
3b	**Please explain how you will deal with the issue of informed consent, as appropriate to your study and based on the code of practice of the relevant professional association**			Please explain in the 'further details' box below
4.	**Does your work involve intentionally covert surveillance?***		NO	If YES, explain in further detail below
5a	**Will your information *automatically* be anonymised in your work?**	YES		If YES, go to Q6. If NO, please explain in further detail and go to 5b
5b	**Will you explicitly give *all* your informants the right to remain anonymous?**	YES		If NO, explain in further detail below
6.	**Will recording devices be used openly and only with the permission of informants?**	YES		If NO, explain in further detail below
7.	**Will your informants be provided with a summary of your project findings?**	YES		If NO, explain in further detail below
8.	**Will the outcomes of your project be available to informants and the general public without restrictions placed by sponsoring authorities?**	YES		If NO, explain in further detail below
9.	**Have you considered the implications of your project intervention on your informants?**	YES		Please explain in further details below
10.	**Are there any other ethical issues arising from your project?**		NO	If YES, Please explain in further details below

Further details – Please specify details with reference to above Question Numbers.

Q3a: In my new data collection, I will provide a written information sheet explaining my project and the uses of any data that I might generate (see above). In my earlier (2001-5) research, conducted independently, I was careful to provide verbal information to all participants (this is key to my conservation aims), but did not provide a written information sheet.
Q9. I have considered the implications of my project on my informants. The only information which could conceivably compromise a participant's wellbeing is if participants reveal that they have hunted or killed monkeys in the past. Hunting for personal consumption is legal. I will take particular care to thoroughly anonymise such information in any reports, and if I cannot do so, I will not include it.

* Covert surveillance means observing research subjects from a position of concealment unbeknownst to the observed. This can be physically e.g. behind a barrier or screen, or it can mean that in the process of participant observation, the fact that observation is being conducted is not disclosed at appropriate opportunities, nor is informed consent in principle sought after.

11. Please add any other additional information that is relevant to your project

The study design has been refined in collaboration with my supervisors.

12. Please answer the following questions only if you selected 'NO' in question 1

		YES	NO	

12a	**Does your project involve non-human primates?**		**NO**	
12b	**Have you sent an application for Life Sciences approval?**			If NO, please do so
12c	**Has your application been approved by Life Sciences?**			If NO, the committee must wait until Life Sciences approval has been given
12d	**Have you attached or enclosed your Life Sciences approval?**			If NO, please attach or enclose

Declaration

I have read:

1. I have read the Code of practice of the relevant professional association (e.g. ASA), and the University Policy on Ethical Approval and believe that my project complies fully with the precepts of those documents.

2. Please state the professional organisation whose code of practice you are following:

3. I confirm that my project will adhere to The Durham University Principles for Data Protection. http://www.dur.ac.uk/data.protection/dp_principles/

I will not deviate from the methodology or reporting strategy without further permission from the Department's Ethics Subcommittee (electronic signatures accepted)

Applicant's Signature .... Date 16/1/2016

Primary Supervisor Name (if applicable)……Jo Setchell

Primary Supervisor Signature (if applicable)  Date 24 Jan 2016

Please ensure that you send <u>a completed electronic version of this form</u> to <u>Jennifer.legg@durham.ac.uk</u> (Modern Apprentice, Research & Finance) by the appropriate deadline

Appendix 4

REPUBLICA DE PANAMA	MINISTERIO DE AMBIENTE Apartado C, Zona 0843, Balboa, Ancón, Panamá	PERMISO CIENTÍFICO SCIENTIFIC PERMIT No. SE/A-12-16 VALIDO HASTA: 01-01-2017 VALID UNTIL
		FAUNA / FLORA / HONGOS / BACTERIAS / OTROS ORGANISMOS FAUNA
INVESTIGADOR RESPONSABLE MAIN RESEARCHER PEDRO MÉNDEZ CARVAJAL	IDENTIFICATION I.D. 8-515-1279-PAN	COLECTA COLLECT MARCADO MARKING OBSERVACION OBSERVATION OTROS OTHERS ESPECIAL
ASISTENTE (S) ASSISTANT (S) Elvia Miranda Luz Loría Amores Emilio Espino Glenis De León Bonarge Rodríguez	IDENTIFICATION I.D. 4-742-2182 4-740-1353 7-704-378 7-704-2491 8-245-576	
INSTITUCION QUE RESPALDA LA INVESTIGACION INSTITUTE SUPPORTING THE RESEARCH Fundación Pro-Conservación de los Primates Panameños (FCPP)		