STATUS AND THREATS TO PERSISTENCE OF THE CHACOAN PECCARY (*Catagonus wagneri*) IN THE DEFENSORES DEL CHACO NATIONAL PARK, PARAGUAY

by

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ABSTRACT

S. S. Saldivar Bellassai. Status and Threats to Persistence of the Chacoan Peccary (*Catagonus wagneri*) in the Defensores del Chaco National Park - Paraguay, 116 pages, 10 tables, 7 figures, 13 appendices, 2014.

Habitat loss and overexploitation threaten Chacoan peccary (*Catagonus wagneri*), a forest-dependent species endemic to the Dry Chaco ecoregion. I used interviews to assess the sustainability of peccary harvest, quantified deforestation and road development rates using remote sensing techniques, and assessed factors influencing Chacoan peccary distribution using camera-traps and site occupancy models. Hunters preferred Chacoan peccary but the opportunistic offtake, lack of market hunting, and limited access indicate sustainability of current harvest levels. Deforestation and road development has increased at an exponential rate since 1985 without slowing. Chacoan peccary were attracted to roads, which put them at greater harvest risk compared to the other peccary species. Chacoan peccary seem secure at present, but habitat loss and increasing road access is an emergent threat to be monitored. I provide a baseline assessment and methodology for tracking changes in Chacoan peccary status and threats.

Keywords: Interviews, Harvest Sustainability, Subsistence Hunting, Occupancy, Modeling, Competition, Roads, Deforestation, LANDSAT

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INTRODUCTION

First described as a fossil record and thought extinct until 1971, the Chacoan peccary (*Catagonus wagneri*) is today an endangered mammal endemic to the Dry Chaco ecoregion in South America whose persistence is considered to be threatened by habitat loss (deforestation) and over-harvesting (Altrichter et al., 2008). The Paraguayan Chaco has sustained high deforestation rates and pressure for development for cattle ranching, and is therefore a focus of conservation action. Paraguay is also the core of Chacoan peccary range, containing the largest portion of the species range, and is thus strategic for their conservation. This project aimed to provide crucial information on the species vulnerability to human harvest, rates of habitat loss due to forest clearing, and factors affecting their vulnerability to harvest relative to the sympatric white lipped (*Tayassu pecari*) and collared peccary (*Pecari tajacu*).

Chacoan peccaries are an important source of protein for local communities, but whether harvest is sustainable is in question. Chacoan peccary abundance has been negatively correlated with high road density, probably due to increased access for hunting (Altrichter and Boaglio, 2004). Moreover, they are usually seen on roads (Sowls, 1997), and do not run away when encountered by people – behavior that may make Chacoan peccary more vulnerable to harvest in contrast to the seemingly more wary white lipped and collared peccary. Given the importance of the Chacoan peccary for the human population and the endangered status of the species, it is essential to examine harvest pressure in order to determine its sustainability. Chapter 1 documents hunting practices and harvest rates around the Defensores del Chaco National Park in northwestern Paraguay. The other major threat to persistence of Chacoan peccary is loss of their forest habitat. Chapter 2 quantifies the rate of forest clearing, and assocatiated road development, from 1986 to 2011.

Lastly, Chapter 3 aimed to provide an assessment of the distribution, relative abundance, and habitat use of the three sympatric peccary species. Competition for resources and space between the three tayassuids (New World pigs) has not been studied; although researchers have suggested seasonal avoidance due to scent secreted from the dorsal gland, which would allow sympatry by having scent marked home ranges (Mayer and Wetzel, 1986). But Chacoan peccary also may be competitively excluded from forest-interior areas by the more common and aggressive peccary species, which may force them into less suitable cleared habitats such as timber clearcuts and roadside habitats (where they are vulnerable to human harvest). I investigated peccary avoidance of roads and each other using camera traps and occupancy models.

There are few studies on Chacoan peccaries, and this thesis differs from others in that it will provide key aspects of this species habitat use that will facilitate management actions in the region. Better knowledge of the forces structuring Chacoan peccary distribution and abundance may be the difference between their persistence and extinction in the area, because there are no other studies on the species in this region where deforestation rates are increasing at an alarming rate.

This thesis was structured as three independent chapters formatted to the specifications of the journal *Biological Conservation*.

CHAPTER 1: Hunting practices and the sustainability of peccary in the Paraguayan Dry Chaco

Abstract

Overexploitation is an oft-cited driver of species extinction throughout the Neotropics where hunting for subsistence is common and largely unregulated. Balancing traditional practices and the needs of local people with protection of rare or declining species poses a complicated conservation challenge. This challenge may be particularly intractable for species like the endangered Chacoan peccary (*Catagonus wagneri*), whose "tame" behavior may increase their vulnerability to harvest in comparison to sympatric white-lipped (*Tayassu pecari*) and collared peccaries (*Pecari tajacu*). I interviewed ~46% of the resident hunters (n=34) around Defensores del Chaco National Park to ascertain motivations and species preferences, quantify hunting effort and total harvest levels, and assess hunting sustainability in the region. Hunting motivations varied, and Chacoan peccary were preferred, but offtake was largely opportunistic due to the lack of market forces and limited storage capacity. Harvest rates ranged from 0.02-0.03 peccaries/year/km^2, an intensity expected to be sustainable given population densities >0.05 peccaries/km^2 (for Chacoan and collared peccary) or 0.1 white lipped peccaries/km^2 under a deterministic sustainable yield model. Although peccary densities were unknown, densities above these target levels have been observed elsewhere in the Dry Chaco ecoregion. Nevertheless, the Chaco is undergoing large-scale and rapid deforestation, with a rapid growth in the road network, which may drive declines in species abundance and increase the risk of overharvest in the near future. The public's perception of Chacoan peccary abundance and population trend differs from professional opinion, likely owing to frequent encounters on roads, and potentially undermining any attempt to reduce harvest on Chacoan peccary in the future through voluntary means.

1. Introduction

The most pervasive drivers of species declines and extinction around the world include habitat loss and fragmentation, overexploitation, and invasive species (Hoffmann et al., 2010; Vié et al., 2009). Overexploitation remains of particular concern in tropical forests where subsistence hunting is both common and largely unregulated and where hunting impacts on populations may be exacerbated due to rapid deforestation (Alvard et al., 1997; Bodmer et al., 1997; Fa et al., 2002; Hill et al., 1997, 2003; Novaro et al., 2000; Peres and Nascimento, 2006; Robinson and Bennett, 2000). At a country-wide level, harvest sustainability has been positively correlated with indexes of public health, education, and economic well-being, likely reflecting the technical and socio-political capacity of a government to manage wildlife resources (Weinbaum et al., 2013). Yet harvest sustainability is likely to be spatially heterogeneous within a given country, and for geographically restricted species more regional assessments will be needed to effectively gauge species status and identify appropriate conservation action (Robinson and Bennett, 2000).

The Dry Chaco (a Quechua word for "hunting land") is the second largest ecoregion in Latin America, hosting the largest continuous neotropical dry forest (Eva et al., 2004) which spans portions of Bolivia, Paraguay, and Argentina (Olson et al., 2001). The Dry Chaco ecoregion is unique in hosting three sympatric peccary species – Chacoan peccary (*Catagonus wagneri*), white-lipped peccary (*Tayassu tajacu*), and collared peccary (*Pecari tajacu*). Peccaries are considered ecosystem engineers due to their influence on plant communities, are important prey items for top predators like jaguar (*Panthera onca*) and puma (*Puma concolor*), and also are highly valued for meat by subsistence hunters. The Chacoan peccary, or tagua to local people, is endemic to the Dry Chaco. In contrast to the other species, Chacoan peccary do not immediately flee when encountered by humans, a behavior that may predispose them to a higher risk of harvest (Taber et al., 1993). For example, in Paraguay, the Chacoan peccary is the rarest of the three species and yet one of the most commonly harvested animals (Altrichter and Boaglio, 2004; Neris et al., 2010). Given their endemic and endangered status, overharvest of Chacoan peccary is of concern in the Dry Chaco.

Diverse approaches have been employed to assess the sustainability of harvest in the Neotropics, from empirical assessments of population trends over time (Hill et al., 2003; Larivière et al., 2000) or comparisons of hunted and unhunted populations (Hurtado-Gonzales and Bodmer, 2004; Robinson and Redford, 1994), to various models based on the hypothesized sustainable yield of a population (Bodmer, 1994; Bodmer et al., 1994; Robinson and Bodmer, 1999; Combreau et al., 2001; Hill et al., 2003; Lofroth and Ott, 2007; Milner-Gulland and Rowcliffe, 2007). Models can be employed when there is minimal field data available, a situation common in remote areas of the Neotropics and true of the Paraguayan Dry Chaco. A simple and commonly used approach is the unified stock assessment model (Robinson and Bodmer, 1999; Robinson and Redford, 1991), $P = (0.5D) \times (Y \times g)$, where annual production (P) is a function of the number of offspring per female (Y), the number of gestations per year (g), and population density (D; assuming a balanced sex ratio). Under this model, harvest is considered sustainable when offtake (or harvest rate) is ≤40% of P. This approach has been criticized for assuming a simple linear decline in productivity with density (logistic population growth), for not accounting for other sources of annual mortality, for lacking the biological realism of age-dependent productivity and mortality, and not being precautionary enough due to exclusion of variation within the parameters (Weinbaum et al., 2013). As a result, harvest levels much lower than 40% of P may be unsustainable. Nevertheless, this approach is appealing because it integrates biological and social information in the harvest assessment, provides a standard assessment comparable to other studies across the tropics, and heuristically explores thresholds for achieving sustainability.

Another common limitation to assessing harvest sustainability is quantifying harvest levels, especially in regions where harvest is unregulated and therefore largely untracked. Interviews are commonly used to ascertain hunting motivations, practices, and offtake. Although the illegality of hunting may call the veracity of interview data into question, subsistence hunting in the Neotropics is pervasive, considered socially acceptable, and is generally conducted without legal consequences due to respect of traditional practices and food security implications (Sowls, 1997). Focal interviews have provided crucial information on the relative abundance of species and harvest intensity on a national level in Paraguay (Neris et al., 2002), the Atlantic forest (Hill and Padwe, 2000), and even for the Argentinian Chaco (Altrichter, 2005) – providing a template for this assessment of the Paraguayan Dry Chaco. Moreover, understanding the drivers of harvest and traditional practices provides crucial insight for devising effective plans for species conservation that also meet the needs of local people.

Herein, I quantify human hunting practices as potential threats to the persistence of Chacoan peccary in and around Defensores del Chaco National Park (DCNP) – a reserve area of particular interest because of its large size (7,146.17 km^2), and by extension its ability to maintain animals having large space requirements, as well as its strategic location in a remote, well-preserved area. I asked residents of the area about their harvest preferences, effort, and success to quantify total harvest rates, and used the unified stock assessment model to evaluate the sustainability of current harvest levels under alternative peccary densities. Ultimately, I provide a quantitative and qualitative baseline on wildlife harvest in the area that is inexpensive to repeat, and provides an efficient means of tracking threats to the persistence of Chacoan peccary over time.

2. Materials and Methods

The DCNP is located in a remote area of the Paraguayan Dry Chaco in the Alto Paraguay Department near the Bolivian border (20°10'12"S 60°18'5"W). The predominant vegetation type is thorny xerophytic forest receiving an annual precipitation of 700-800 mm per year (Red de Inversiones y Exportaciones, 2009). Annual temperature ranges from -2°C to 44°C and precipitation varies from 500 to 1,000 mm/year. Seasonality occurs due to precipitation regimes having dry winters and rainy summers (Adamoli et al., 1990). Soils are generally loam or clay loams (Buol, 2007). The area is documented to support 65 species of large and medium sized mammals (Direccion de Parques Nacionales y Vida Silvestre, 1999), of which the three peccary species, brown brocket deer (*Mazama gouzoubira*), tapir (*Tapirus terrestris*), jaguar and mountain lion make up the focal set of species for my interviews.

The study area was defined by a 140-km radius circle centered on the DCNP (Figure 1.1). Based on heterogeneity in human settlement and access, I divided the region into quadrats (NE, SE, SW, and NW) for summarizing harvest patterns. Homes in this region are small wooden or material houses with tin or thatched roofs that lack electricity, running water, and telephone lines or cell reception. Few roads in the region are paved (none within the study area), and dirt roads are rarely maintained providing limited road access during the rainy season (Dec-May). The primary economic drivers in the region are cattle ranching and agriculture. There are also several military installations with temporary staff. There are no commercial centers, schools, or hospitals in the study area. Local travel is by vehicle, horse, or foot and most communication is conducted by radio.

2.1 Human patterns of wildlife harvest

Data on human motivations, methods, and successes with hunting were gathered by structured interviews (Vaske, 2008) conducted in person by S. Saldivar Bellassai in July 2013. I initially recruited participants through a list of families provided by the park ranger in the areas surrounding the National Park within Paraguay (not in adjacent Bolivia). Subsequent interviewees were recruited by snowball sampling (Vaske, 2008), by which the people first contacted would direct us to other people living in the same area to increase our sample size and extend our sampling extend to reduce any potential bias. A standard set of 24 multiple choice and 16 open-ended questions were asked of all interviewees (Syracuse University IRB #13-121). In addition to the three peccary species, interviewees were asked specifically about their experiences hunting brown brocket deer and tapir along with the two main predators in the region – mountain lion and jaguar. I attempted to ascertain certainty in species identification, by asking interviewees to identify species from photos. However, images lacked the key characteristics people use to differentiate among peccary species (relative body size, group size and behavior), and so I ultimately included all responses regardless of an individuals' ability to differentiate species by photo.

Questions were categorized within five major areas (Appendix 1). One set of questions focused on the relative abundance of each species – asking how often they see them, when was the last time they saw each species (encounter rates, modified from Hill et al., 1997), where they see them, and which they perceive to be more common. A second set of questions asked specifically about whether the interviewee hunted, and if so, for how long and how often. A third set of questions focused on the economics of hunting, asking what people do with the animals harvested (e.g, used personally for food, sold for meat or fur), how much income might be gained, how much might be invested in hunting gear, and how important hunting is to the family’s income. The fourth set of questions targeted how much effort individuals extended on hunting (e.g, how many days, how many hours each day, how far in travel), how they hunt (from vehicles, while walking trails, with firearms or traps), what species hunters are targeting, the degree to which they select for specific species, and how they respond to encounters with different species. And a final set of questions focused on the interviewee’s perception of the status of different species (becoming more or less common than 5 years ago).

After interviews were completed, responses to open-ended questions were categorized to enable numerical summaries. For responses summarized as percentages, values were calculated using the number of interviewees who answered a given question (which varied from 3-34, the total number of respondents is reported only when less than 34). To evaluate whether hunter’s preferred species based on body size, I correlated body size to rank order species preferences using the Spearman’s rank correlation coefficient. For this analysis, I used 19 kg for brown brocket deer (Anderson, 1997), 18 kg for collared and white lipped peccary (Lorini Rodríguez, 2006), 35 kg for Chacoan peccary (Nowak, 1999; Taber et al., 1993), 150 kg for tapir (Ayala, 2000), 77 kg for mountain lion (Parera, 2002), and 100 kg for jaguar (Parera, 2002). To ascertain relative abundance of the 7 focal species, I asked about the last time each interviewee encountered each species and calculated the number of days passing, on average, since the last encounter between interviewees and each focal species by quadrat (NW, NE, SW, SE). I calculated catchment area in each quadrat, i.e. the huntable area, as a circle centered on the surveyed village (or ranch) having a radius equal to the average distance traveled during individual hunting forays (modified from Naranjo et al., 2004).

2.2 Assessment of hunting sustainability for peccaries

Using the unified stock assessment model I considered $g = 1$ for all three peccary species (Noss, 2000) with $Y = 1.95$ for collared, 1.77 for white lipped (Noss et al., 2003), and 1.70 for Chacoan peccary (Taber et al., 1993). Species density, D, was unknown and thus iteratively entered in increments of 0.1 from 0.0 to 2.0 peccaries/km^2 to identify the values of D over which hunting would be considered sustainable while holding everything else constant. For each focal species, I calculated the offtake or harvest rate, H, as the total number of individuals harvested / year / km^2 as $H = (K/3 * N)$ / A (modified from Altrichter, 2005) where $K = (E / e)$ and E = the encounter rate (average number of encounters with the focal species / year), e = effort (average number of hunting forays / year), N = the number of hunters in the area, and A is the total area (in km^2). For e, I ran two scenarios, the reported hunting rate and a second one increasing the reported rate by 300% owing to possible under-reporting given the illegality of hunting in the region. I divided the Kill rate (K) by three expecting that only one in three hunting trials would result in a harvest (Noss et al., 2004); however, I also tested the effect of assuming each encounter to result in a harvest (K/1) as an alternative scenario. I set N equivalent to the total human population density in the Department of Boquerón (Direccion General de Estadistica, Encuestas y Censos, 2004) the more densely populated of the two departments in the area. This yielded a gross over estimate of N because both population density in the study region was considerably lower than this estimate of N and because typically only one member of each household (or the men) hunt. I also increased N by 250% to illustrate potential increases in future populations in this region. Thus, baseline estimates (Scenario A) assumed a human population density of 0.4 people/km^2, 34.4 hunting forays/person/year, and a 33.3% hunting success rate. Scenario B increased hunting success rate to 100%, and Scenario C increased human population density to 1 person/km^2, while holding everything else at their baseline values.

2.3 Perception by conservation specialists

Conservation professionals that have recent publications or presentations on wildlife in the region were asked for their opinions regarding wildlife encounters and their perceptions of hunting in the region.

2.4 Species relative abundance

To corroborate perceptions of species abundance as identified by focal interviews, I also deployed 27 sensor-triggered camera traps with infrared night vision (Bushnell TrophyCams) along the boundary and up to 3 km into the interior of the DCNP. Cameras were spaced >3 km apart to ensure independence and were deployed from 5 Jul to 6 Nov 2013, coinciding with the dry season. Photos were identified to species and two indices of species abundance were derived. Catch-per-unit effort was calculated as the number of detections of a given species divided by total trapping effort (O'Brien et al., 2003), where effort was the number of days camera traps were functional. Latency to first detection was calculated as the number of camera trap nights occurring prior to the first detection of each species (Foresman and Pearson, 1998).

3. Results

3.1 Human patterns of wildlife harvest

A total of 34 interviews of study area residents were completed. Although this is a small sample size, according to the park ranger (S. Gonzalez, pers. comm.) there were a total of 74 families living in the area surveyed that fulfilled the requirements for the interview (living in the area for more than 5 years); meaning roughly ~46% of the target families were surveyed. There were two different segments to this population: settlers who owned their land and lived there with their families year-round, and temporary residents who worked on the cattle ranches. Only 38.2% of interviewees owned a cattle ranch (n=13), 29.4% worked at someone else's ranch (n=10), 26.4% were contractors working on ranch buildings or fences (n=9), 17.6% worked in agriculture (n=6), and 8.8% worked in commerce (n=3). No spatial patterns in occupations were identified (see Appendices 3-8). The majority of interviewees lived in the area ≥20 years (47.0%), with 32.0% being resident for <10 years.

Given that interviewees worked mostly outdoors, the great majority (85.0%) indicated that they commonly saw wildlife. When asked to identify black and white photographs of the three peccary species (the only species that could be confused of the 7 focal species), the majority (59.0%) identified them correctly. Of the people who incorrectly identified one or more peccary species, most (57.1%) correctly identified the Chacoan peccary.

Upwards of 87.5% of interviewees said they hunted at least once in their lifetime (n=32). Most of the interviewees (66.7%, n=29) indicated that they did not hunt regularly, and did not see themselves as hunters (meaning they do not hunt for a living), whereas 33.3% stated they commonly hunted (although not for a living). All of interviewees stated they hunted for subsistence, 14.8% said they hunt to protect their crop from herbivores, and 3.7% reported hunting to protect their family (n=27). When asked how many times a week or month did they go hunting, most people (91.2%) did not answer the question and instead commented that they did not hunt routinely but rather only when they needed to due to the unavailability of meat for purchase, when they were out of supplies, or by chance. Every interviewee reported that bush meat was not sold in the area (n=28), so hunting did not provide them income, nor did it save them money because they could not buy bush meat otherwise. Their expenses for hunting were very low because they owned firearms for protection and only needed to buy ammunition (~$35 US Dollars per box).

When they hunted, the majority reported trips lasting <6 hours at a time (1-3 hr: 46.4%; 3-6 hr: 32.2%; n=28) with ~25% of the population hunting for up to a full day (7-10 hr: 7.1%; 1 full day: 14.3%). Contractors reported the lowest hunting frequency (12 days/yr on average; n=9), probably due to ranch owner prohibitions against hunting on their land. People in commerce (n=3) and agriculture (n=6) reported higher hunting occasions per year (48 days/yr). Moreover, interviewees indicated that they hunted alone, or in parties consisting solely of the men in the house that were old enough to hunt. They either walked (40.7%, n=30), used motorcycles or vehicles (48.2%), or rode horses (14.8%) to look for animals. And they used firearms solely (no trapping, n=30). Elderly interviewees indicated that there used to be professional hunters in the region that used traps until the market for furs was regulated.

In this part of the world, the seasons were mostly dictated by precipitation regimes (dry season: Jun-Nov; rainy season: Dec-May), and interviewees were divided on what season provided the best hunting (46.7% rainy, 53.3% dry). Of the 30 interviewees who answered the question, some commented that in the dry season one could easily find animals near water bodies, indicating a differential vulnerability of species to harvest during the dry season.

In terms of encounter rates, the brown brocket deer was the most abundant species with an average score of 35.0 days (0.3-64.9, n=31) since last encounter, followed by the collared and Chacoan peccary with 50.0 (15.1-86.2, n=30) and 54 days (16.2-92.1, n=29), respectively, then tapir at 93 days (46.4-138.7, n=26), and white-lipped peccary at 111.0 days (52.9-170.7, n=21). Mountain lion and jaguar were considerably less common with an average score of 175.0 (105.6-

246.2, n=27) and 182.0 days (117.4 – 247.1, n=23), respectively. Several people indicated that they had not seen the white-lipped peccary (20.6%) in their area, while others indicated peccary occurrence to be patchy, with white-lipped peccaries found only near water bodies and Chacoan peccaries in uplands with sandy soil. People reported encountering white lipped and collared peccary, brown brocket deer, and tapir more often in the eastern portions of the study area, and encounters with Chacoan peccaries were most common in the NW quadrat. Cattle ranchers and goat ranchers encountered the 5 focal herbivore species 12-20 times more often than other vocations, whereas all occupations seemed equally likely to encounter the 2 carnivore species.

On average, interviewees hunted 2.9 times a month (SD: 1.5, n=7) for an average of 10 hours at a time (15.9, n=28). The other interviewees commented that they could not say they hunted once a month (the most sparse option offered) because they perceived their irregular pattern to be less common than once a month. Across the quadrats, hunting effort ranged 0-2 days/month and averaged 5.0-11.7 hours/day (Table 1.1). People in the western two quadrats hunted more often (NW=16.0 and SW=24.0 days/year on average, n_{NW} =12, n_{SW}= 1) than in the east (NE=0.0 and SE=1.5 days/year on average, n_{NE}=5, n_{SE}=16). The great majority of the hunters (82.0%) stated that they hunted along trails or roads (n=28). Moreover, according to the interviewees, the best places for hunting were near water bodies, or tajamares (artificial ponds), as well as along trails or roads. Sixty nine percent of respondents indicated they travelled up to 6 km during their hunting forays for an average distance of 6.7 km (n=27, 50% 1-3 km category, 19% 3-6 km category). Villages and cattle ranches (n=7) were estimated to have an average of 142.3 km^2 of catchment area (6.7 km diameter; Table 1.2).

All 7 of the focal species were hunted, but with different frequencies be it for subsistence (ungulates), cattle or crop protection (carnivores and herbivores), or sport (usually the only reason tapir were hunted). Members of the Order Artiodactyla (deer and peccary) were the most hunted overall (pooled 79.9%). In rank order of prevalence, hunters equally sought brown brocket deer and collared peccary (18.8% each) followed closely by Chacoan peccary (18.1%) and white-lipped peccary (16.7%). The next most hunted species were mountain lion (11.8%) and jaguar (8.3%). Tapir (7.6%) were rarely hunted except by sport-hunters seeking trophy animals (i.e., hunters not resident within the study area). Perceptions of trends in the focal species populations over the past five years were mixed, but with the majority perceiving stable or increasing populations (Figure 1.2A). Other species hunted by interviewees included snakes (*Bothrops* spp. or jarara, *Crotalus* spp. or mboi chini), pigeons (Columbiforms), Chaco Chachalaca (*Ortalis canicollis*), and foxes (*Lycalopex gymnocercus* and *Cerdocyon thous*).

Interviewees indicated that they preferred the taste of some species over others, or preferred to hunt species that were more easily encountered. Jaguar and tapir were not found palatable to people. Species preferences by people in descending order were: brown brocket deer (38.5% of responses), Chacoan peccary (28.2%), white lipped peccary (12.8%), collared peccary (10.3%), and mountain lion (2.6%; n=32). This rank order of preference showed a negative but non-significant correlation with body mass (r = –0.69, P = 0.09). In contrast, a strong positive correlation existed between hunter preference and how common a species was perceived to be (r = 0.81, P = 0.03). However, despite collared and Chacoan peccary being perceived as essentially equivalent in terms of relative abundance, Chacoan peccary was more preferred. The two carnivore species were considered neither abundant nor preferred, yet a moderate number of hunters indicated carnivores as hunting targets (32.4% of respondents; Figure 1.3A).

Although people had different motivations for hunting and clear species preferences, rather than being selective hunters indicated that they would harvest the first animal encountered during a hunting foray (96.0% of respondents, n=25). Moreover, all hunters that responded to this question (n=22) indicated that they would kill only one animal when encountering a group, and typically only one animal would be killed per hunting foray. Two reasons were given for single animal harvests – lack of refrigeration units (leading to rapid meat spoilage) and hunting with firearms (the noise scaring away the other animals). Regarding a hunter encountering a group of animals including an adult female accompanied by young, 69.6% of interviewees said that they would hunt the mother (mainly due to their inability to distinguish males from females at a distance), 21.7% would not hunt either of them, and 8.7% said that they would hunt both (as an exception to hunting only one animal, because the litter usually does not flee once the mother is down, and are easy to carry).

3.2 Assessment of hunting sustainability

Model parameters remained constant across the range of peccary densities considered, as a result offtake, calculated as a percent of productivity, declined precipitously with increasing peccary density (Figure 1.4). Due to their relative rarity, white lipped peccary offtake was lower than the other species. The conservative baseline scenario, indicated sustainable harvest for all three peccaries across the range of densities considered (Figure 1.4A). Increasing human population density or hunting success led to unsustainable harvest for low density peccary populations (0.05-0.23 animals/km^2; Figure 1.4 B, C). An inflection point, below which populations become increasingly more vulnerable to overharvest, occurred at ~0.5 peccaries per km^2.

3.3 Perception by conservation specialists

Eleven conservation professionals, who had visited the region for an average of 13.5 years,.gave opinions on trends in wildlife populations in the region, Similar to residents, conservation professionals encountered deer and collared peccaries most often and jaguar least often (similar to residents). In contrast to residents, they perceived Chacoan peccary to be less common than tapir.

Conservation professionals perceived the most important reason for hunting in the Dry Chaco to be for subsistence, although they considered sport hunting to be almost as important. Professionals indicated that harvested species are sold within the ecoregion – a difference in perspective from local residents that may be due to the larger geographic scope considered by conservation professionals. Regarding perceptions of population trends in the last 5 years, conservation professionals were consistent in their opinion that jaguar and white lipped peccaries have declined but were inconsistent regarding whether mountain lion, tapir, Chacoan peccary, and collared peccary were decreasing or maintaining their numbers (Figure 1.2B). Even so, more professionals perceived the 7 focal species to be declining than did the residents.

3.4 Camera trap estimations of relative abundance

A total of 3,378 camera days were recorded. Cameras captured photos of 18 identifiable mammal species (see Appendix 13) as well as several bird and lizard species. Chacoan and collared peccary were both detected, but white lipped peccary was not detected. The catch-per-unit-effort index ranked the large mammals in declining order of abundance as brown brocket deer (*Mazama gouazoubira*), tapir (*Tapirus terrestris*), collared peccary, Chacoan peccary, puma (*Puma concolor*), and jaguar (*Panthera onca*). Latency to detection ranked species slightly differently, but agreed with deer being most abundant, peccaries of intermediate abundance, and large predators rare (Table 1.4).

4. Discussion

Subsistence hunting was common in the area surrounding the DCNP in Paraguay with all 7 focal mammals in this study being hunted despite 2 of these species being listed by the IUCN as endangered (Chacoan peccary) or vulnerable (white lipped peccary) to extinction. Hunting without a permit in this region is illegal, but the trip and expense of acquiring a permit is beyond the reach of most residents, and enforcement of hunting regulations is lacking. Moreover, interviews revealed no commercial source of meat in the region, including no sales of bush meat, and so all residents interviewed hunted to some degree.

Although hunters indicated species preferences, and favored Chacoan peccary over the other peccary species, their actual take of animals appeared to be opportunistic. Kills were based on encounter rates and typically only 1 animal was killed per hunting foray owing to a lack of refrigeration units for storage. The primary motivation for hunting was to acquire protein for immediate family needs, without being driven by the commercialization of bushmeat that has proven detrimental to wildlife populations elsewhere in the tropics (Bodmer and Puertas, 2000; Hart, 2000). Although conservation professionals indicated that commercial markets do exist within the larger region, local residents around the DCNP indicated a lack of access for either buying or selling bushmeat. As a result, subsistence hunters sought to efficiently acquire meat for their table rather than selectively pursue species that carried a higher market price. For this reason, harvest rates in this region appeared to be driven primarily by differential encounter rates among species which provides a self-correcting feedback where total harvest will vary as a function of animal density.

Species encounter rates, as reported by hunters, generally reflected the expected relative abundance of each species as determined by camera surveys as well as the opinion of conservation professionals – but with the notable exception of the endangered Chacoan peccary. Hunters reported Chacoan peccary as the second most encountered species after the widespread and abundant brown brocket deer, and equally as common as collared peccary. In contrast, camera traps indicated Chacoan peccary to be considerably less abundant than deer and half as abundant as collared peccary. Moreover, conservation professionals considered collared peccary to be common but Chacoan peccary to be uncommon throughout the region. This apparent mismatch in perception of Chacoan peccary abundance may be due to their being more likely to use areas along roads than the other peccary species (see Chapter 3), or perhaps due to their being less wary than other species of approaching humans (Mayer and Wetzel, 1986). The higher than expected encounter rate between hunters and Chacoan peccary in this region raises concern over the sustainability of their harvest, especially as the network of roads has been increasing at an exponential rate (see Chapter 2) and overharvest is considered to be a primary threat to their persistence.

Using a simple stock assessment model, and assuming a higher than actual number of hunters in the region, current harvest rates in the region appeared to be sustainable for all three peccary species under current subsistence hunting practices. My model indicated a critical threshold for peccary density, in the range of 0.05-0.08 animals/km^2, below which present harvest practices might become unsustainable. However, I assumed all parameters to remain constant across the range of peccary densities considered, without allowing harvest to decline as species encounter rates decline. I considered that important because of the relationship between Chacoan peccary and roads (see Chapter 3), which seems to inflate encounter rates beyond that expected due to density alone. Although data on actual peccary densities around the DCNP is lacking, for similar environments in Argentina and Bolivia densities have been reported to be as low as 0.16 Chacoan peccaries/km^2, 0.33 white lipped peccaries/km^2, and 0.62 collared peccaries/km^2 (Altrichter, 2005; Ayala and Noss, 1999; Noss, 1999) – above the critical thresholds identified by my application of the unified stock assessment model. Increasing the human population to 1 hunter/km^2 (to represent future population growth), or assuming every encounter with a peccary resulted in a kill, raised the density threshold for sustainability to 0.12-0.22 peccaries/km^2 – a range that could be of concern for the relatively rare Chacoan peccary. However, elsewhere in Paraguay Chacoan peccary densities have been reported at 0.43 animals/km^2 (Taber et al., 1993) and 9.24 animals/km^2 (Mayer and Brandt, 1982), although the latter estimate is considered to be artificially high due to the reliability of water from surrounding farms in central Paraguay.

Although harvest rates appeared to be sustainable at present for Chacoan and white lipped peccary, this assessment was based on a grossly simplified and deterministic population recruitment model and so should be interpreted with caution. In addition to the risk of the increasing road network in the region, rapid habitat loss from deforestation (see Chapter 2) may reduce local peccary numbers, concentrate animals into fewer habitat patches, and concentrate hunting activities in such a way as to increase the risk of overharvesting in the very near future (Cardillo, 2005; Peres, 2001). Moreover, there were two military forts in the region whose personnel were not unavailable for interviews. Therefore, there are some pressures on wildlife resources have not been taken into account by my assessment. Hunting pressure is expected to grow along with economic growth in the region, with expanded cattle operations already being observed (Caldas et al., 2013) and an exponentially increasing rate of forest lost underway (see Chapter 2. So the grossly overabundant human population ran in my scenarios may too soon be achieved, and the unaccounted for pressures on wildlife perhaps already threatening the sustainability of subsistence hunting in the region.

Despite a lack of enforcement, the Wildlife Law passed in 1992 that prohibited hunting countrywide, combined with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) were cited by interviewees as reasons for the disappearance of professional trapping in my study region. Since then, subsistence and recreational hunting have gained in importance as drivers of species harvest. Although protected areas have been created to protect the resource, and current hunting patterns tend to favor sustainability, hunting remains a potential threat whose influence on Chacoan and white lipped peccary should be tracked over time (Flesher et al., 2013).

Should conservation action desire to reduce harvest on Chacoan peccary, the needs and traditional practices of local people should be considered – perhaps providing an alternative source of protein or compensating people for foregoing Chacoan peccary when hunting. My interviews indicated that people in this area were generally able to distinguish Chacoan peccary from the other two species, providing an opportunity for targeted education to encourage a voluntary reduction in harvest of this potentially sensitive species. However, the perception that Chacoan peccary are locally abundant, be it real or artificial due to their use of roads and lack of wariness of people, may cause resistance to warnings about the sustainability of harvest and indicate a need for better communication among conservation professionals and the public relying on wildlife resources for their livelihood in this region.

5. Conclusions and recommendations

Hunting practices by local rural inhabitants of the Chaco were described and characterized, regarding it as sustainable under current conditions but highlighting some areas of concern for the future. Tracking harvest patterns over time will be important given the expectation of human population growth in the region, rapid development of roads and loss of forest habitat that may increase encounter rates between hunters and the endangered Chacoan peccary, and the potential for commercial markets to become established and alter hunting pressures. Efforts to evaluate the density and productivity of the Chacoan and white lipped peccary in the Paraguayan Dry Chaco are warranted. Finally, perceptions of local people in the area differ from wildlife experts regarding the status of species, communication channels should be improved so that informed actions can be made from all sectors, and to increase support for conservation activities.

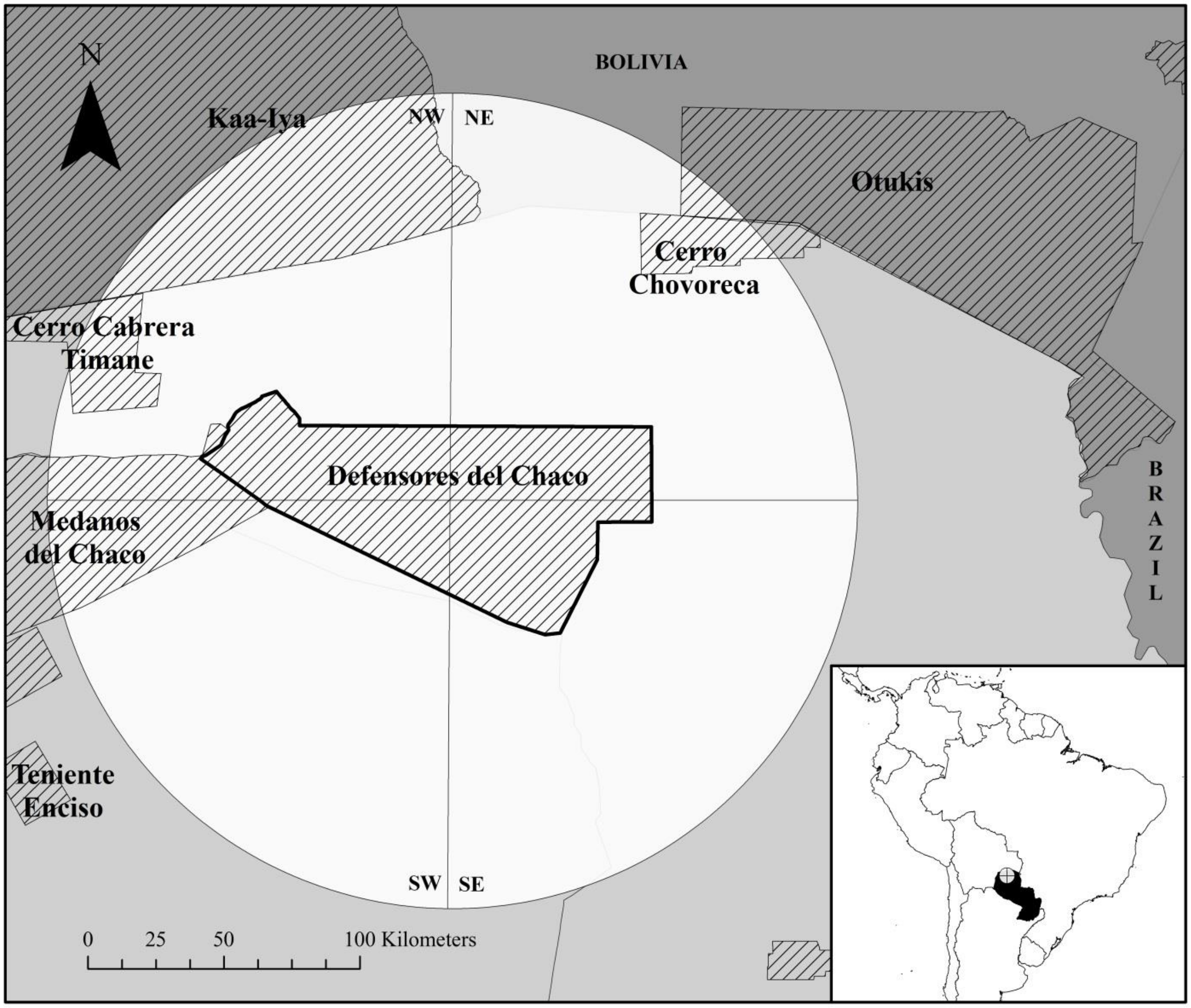
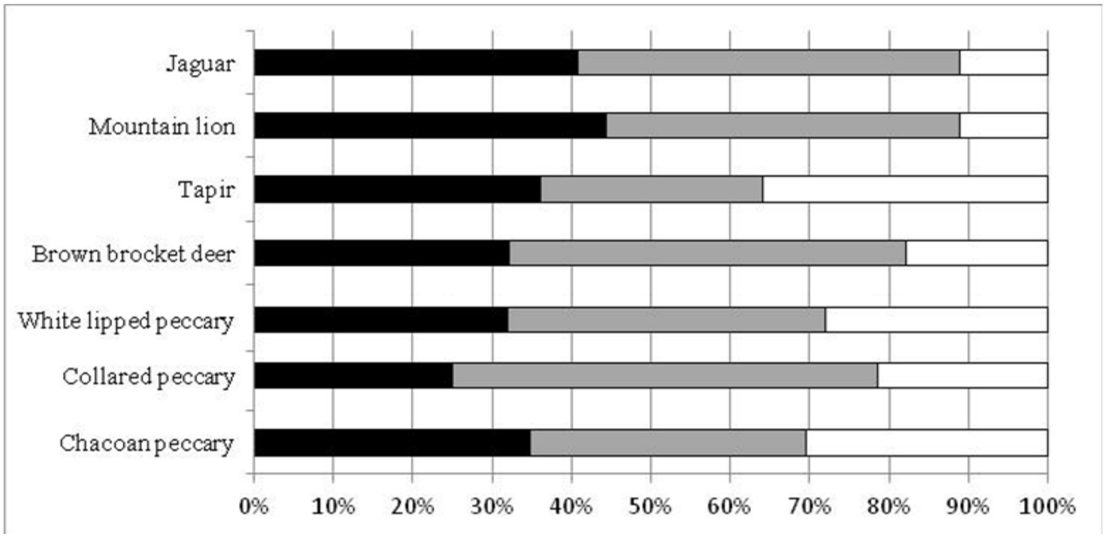


Figure 1.1. Study area centered on the Defensores del Chaco National Park in northern Paraguay. Protected areas are shown (striped polygons with names labeled) as well as adjacent countries (dark gray).

A



B

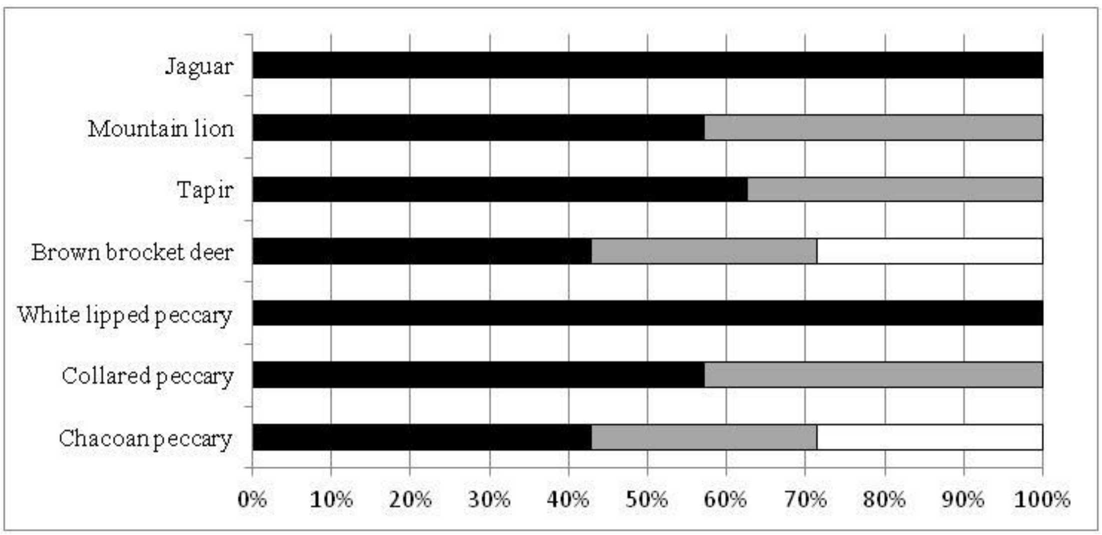
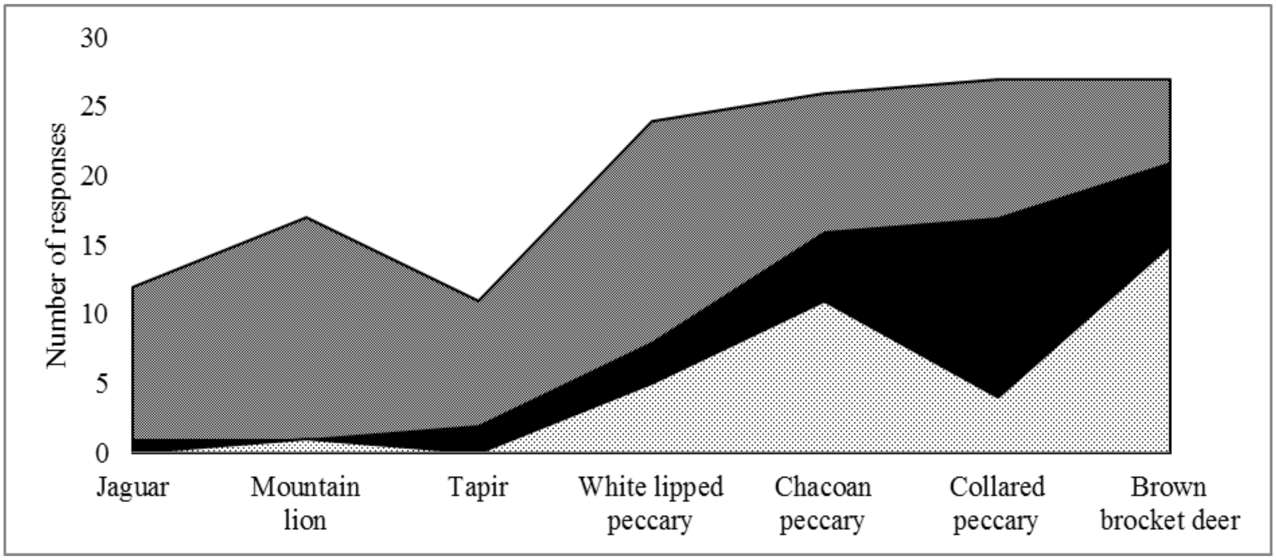


Figure 1.2. Perception for wildlife abundance changes in the last 5 years by local people in the study area (A) and conservation specialists (B) of the Defensores del Chaco National Park in 2013. Perception of decrease (black) is greater in conservation specialists, whereas local people have unclear patterns of perception, population increase is marked white and equal population abundances are marked in gray.

A



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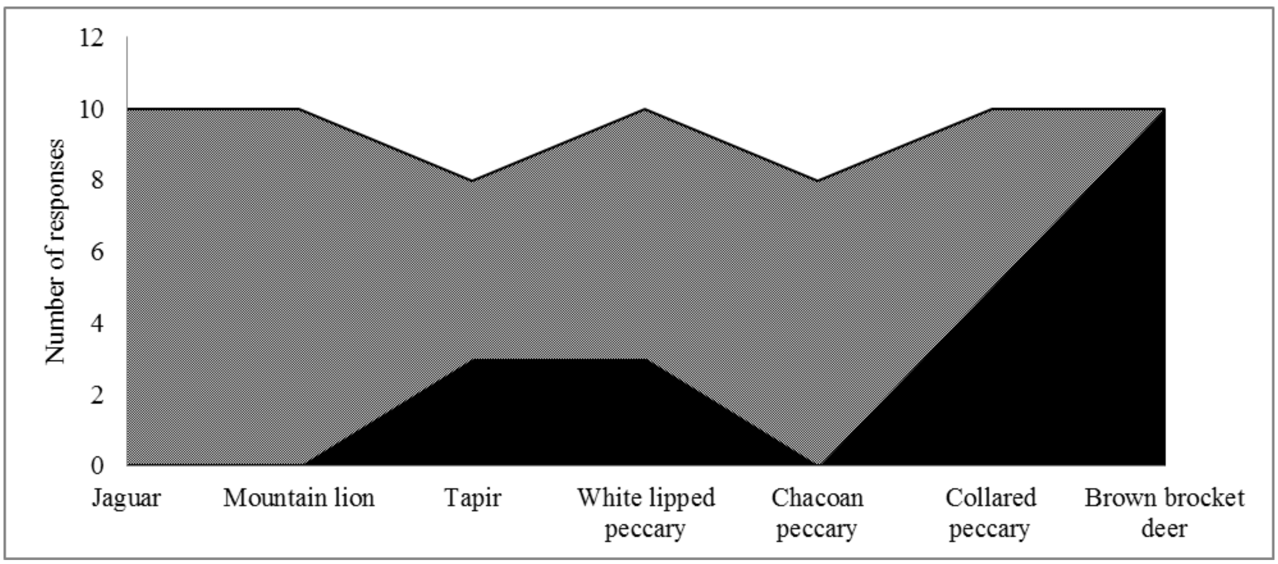

Figure 1.3. Comparison of residents (A) and conservation professionals (B) regarding their perceived abundance of local species (black), whether or not they harvested (gray), and whether or not a species was preferred by hunters (light gray) at the Defensores del Chaco National Park in 2013.

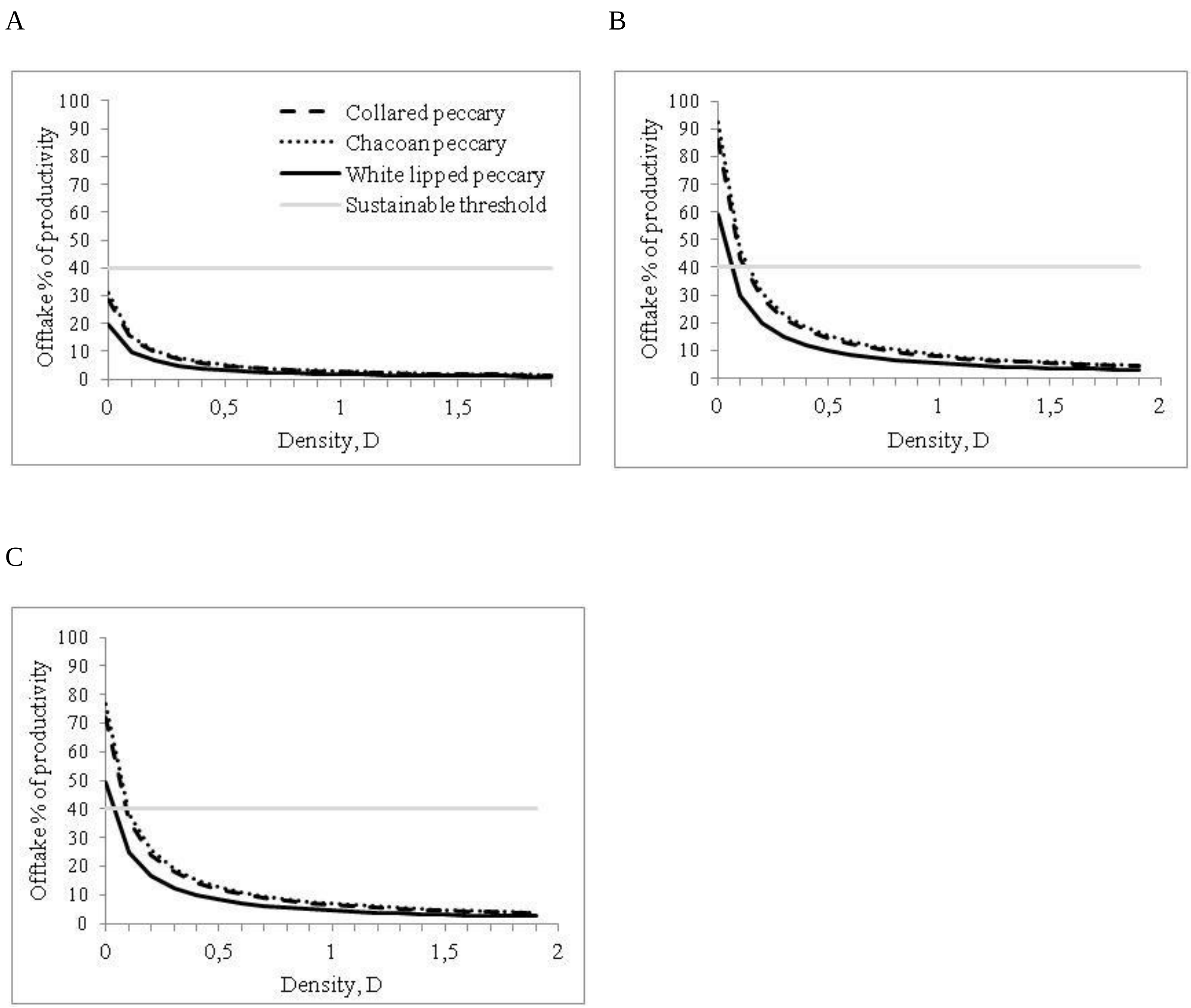

Figure 1.4. Deterministic predictions of offtake as a percent of productivity given a plausible range of peccary density. Baseline estimates of the Defensores del Chaco National Park in 2013 (A) assume a human population density of 0.4 people/km^2, 34.4 hunting forays/person/year, and a 33.3% hunting success rate. The effect of increasing hunting success to 100% (B) and increasing human population density to 1 person/km^2 (C), while holding everything else at their baseline values is also shown.

Table 1.1. Average number of hunting forays per month and time spent per foray summarized by region. Values represent the mean across respondents, with standard deviations and the number of respondents respectively, given in parenthesis.

Area	Hunting forays / month	Hours hunted per foray	Number of residents	Maximum Encounter per year (Brown brocket deer)
Pooled average	2.9 (1.5)	10 (16.1)	18,056	10.5
SE	1.0 (0.0;n=2)	8.93 (16.0; n=16)	4,514	6.9 (n=16)
SW	2.0 (0.0;n=1)	5.0 (0.0;n=1)	4,514	52.1(n=1)
NW	4.0 (0.0;n=4)	10.06 (15.5;n=8)	4,514	36.8 (n=10)
NE	--	19.5 (24.9;n=3)	4,514	50.7 (n=4)

Table 1.2. The average distance traveled during hunting forays as reported by interviewees, which were used to estimate individual catchment areas as well as the cumulative area hunted per region. Values represent the mean across respondents, with standard deviations and the number of respondents respectively, given in parenthesis.

Area	Distance traveled per foray (km)	Estimated catchment area by hunter (km^2)	Cumulative catchment area across all hunters (km^2)
Pooled average	6.7 (6.8)	142.3 (145.8)	3,992.3 (4,263.4)
SE (n=15)	5.5 (5.83)	95.0 (106.9)	1,425.5 (1,603.9)
SW (n=1)	5.0 (0.0)	78.5 (0.0)	78.54 (0.0)
NW (n=8)	7.9 (7.5)	197.9 (175.4)	1,583.5 (1,402.8)
NE (n=2)	12.0 (14.1)	452.4 (628.3)	904.8 (1,256.6)

Table 1.3. Harvest rates (peccaries/km^2/year) for peccaries in the area surrounding Defensores del Chaco National Park in 2013, according to estimated hunting success (encounters/forays/year), catchment area in km^2, and estimated human population of (0.04 people/km^2). Scenario A: current conditions in the study, B. 100% success harvest rate, C. human density of 1 person/k m^2. See methods for calculation of K and H.

	Species	Kill rate (K)	Harvest rate (H)	Peccary density at which fixed harvest becomes unsustainable
A	Collared	0.07	0.028	0.07
	Chacoan	0.07	0.026	0.08
	White lipped	0.04	0.017	0.05
B	Collared	0.21	0.084	0.22
	Chacoan	0.20	0.078	0.23
	White lipped	0.13	0.052	0.15
C	Collared	0.07	0.070	0.18
	Chacoan	0.07	0.065	0.19
	White lipped	0.04	0.044	0.12

Table 1.4. Relative abundance index with camera traps and latency to detection comparisons in July-November 2013 among large mammals in the Defensores del Chaco National Park.

Relative abundance index (detections/camera-days)*100		**Latency (days to first detection)**	
15.69	*Mazama gouazoubira*	0	*Mazama gouazoubira*
1.51	*Tapirus terrestris*	6	*Pecari tajacu*
1.10	*Pecari tajacu*	6	*Catagonus wagneri*
0.68	*Catagonus wagneri*	9	*Tapirus terrestres*
0.24	*Puma concolor*	21	*Puma concolor*
0.12	*Panthera onca*	42	*Panthera onca*
NA	*Tayassu pecari*	>3378	*Tayassu pecari*

CHAPTER 2: Rates of deforestation and road development around Defensores del Chaco National Park, Paraguay.

Abstract

Habitat loss (through deforestation) and overharvest (facilitated by roads) represent key threats to the persistence of the Chacoan peccary (*Catagonus wagneri*), a species endemic to the Dry Chaco ecoregion in northern Paraguay. Using remotely sensed images, I quantified the rate of deforestation and road development in and around Defensores del Chaco National Park (DCNP), Paraguay. From 1985-2011 a total of 7,137 km^2 (15.8%) of the forest was permanently converted to other land uses, most commonly cattle ranching. The cumulative amount of forest loss was roughly equivalent in size to 690 Chacoan peccary home ranges. The forest clearing rate increased exponentially from 25 km^2 (or <0.1 peccary home ranges) to 867 km^2 (or 0.8 peccary home ranges) per year. Deforestation typically followed road development, and the road network also grew at an exponential rate. With the exception of expansion of administrative areas, no forest clearings or new roads occurred inside DCNP boundaries, indicating protected areas are effectively maintaining intact forests in this region. However, deforestation and road development rates did not indicate a slowing trend over the 25 years of this study, and are expected to continue their exponential increase into the future as long as there is land availability, making protected parks ever more important for maintaining forest-dependent wildlife in the Dry Chaco region.

1. Introduction

The most pervasive drivers of declines in and extinction of species around the world are habitat loss and fragmentation, overexploitation, and invasive species including diseases (Hoffmann et al., 2010). All of these threats to species persistence are consequences of human activity. For forest-dependent species, 2.3 million km^2 of forest habitat was lost globally from 2000-2012

(Hansen et al., 2013). Nearly half of the tropical rainforest lost over this period occurred in South America. Drivers of deforestation in tropical countries include agricultural expansion, cattle ranching, and infrastructure expansion; with the underlying causes being economic (e.g. market growth and commercialization, urbanization and industrialization, price increases, comparative cost advantages), political and institutional (e.g. formal policies on economic development, credits; policy climate such as corruption, mismanagement; and property rights), and technological (e.g. agro-technical change such as intensification versus extensification, applications in the wood sector, agricultural production factors; Geist and Lambin, 2002).

Within South America, tropical dry forest has sustained among the highest rates of tropical forest loss (Altrichter et al., 2008; Hansen et al., 2013) – with Argentina, Paraguay and Bolivia leading the statistics. In fact, Paraguay ranks 11th world-wide in total area of forest loss, and 2nd (after Malaysia) in terms of percentage of forest lost (Hansen et al., 2013). Although large-scale assessments of land use change exists for the Gran Chaco ecoregion as a whole (spanning Bolivia, Brazil, Argentina and Paraguay; Asociación Guyra Paraguay, 2014; Caldas et al., 2013), as well as for the country of Paraguay (Huang et al., 2009), land management decisions are made on finer spatial resolutions. Regional assessments of forest loss within Paraguay, at a scale useful to land managers, are lacking.

Importantly, the Gran Chaco ecoregion is home to the endemic and endangered Chacoan peccary (*Catagonus wagneri*) – a species whose persistence is threatened by habitat loss (through deforestation) and overharvest (facilitated by roads). Chacoan peccary are considered endangered at both the global and local level (Secretaria del Ambiente, 2006; Altrichter et al., 2008). Northern Paraguay, in and around Defensores del Chaco National Park (DCNP), is considered important for persistence of the Chacoan peccary because the region encompasses the core and largest portion of Chacoan peccary range. The region is strategic for Chacoan peccary conservation as the only part of the country where protected areas are large enough to sustain species having large area requirements.

Herein, I quantified the rate of deforestation and road development within and around the DCNP, and framed the amount of forest loss in terms of the number of Chacoan peccary home ranges an equivalent area of forest might support. This analysis provides key information for species conservation planning in the region and highlights the urgent need for action for forest conservation in the region.

2. Materials and Methods

The study site was demarcated as a 140-km radius circle centered on the DCNP (20°10'12"S 60°18'5"W), located in a remote area of the Paraguayan Dry Chaco ecoregion in the Alto Paraguay Department near the Bolivian border. The predominant vegetation type was thorny xerophytic forest receiving an annual precipitation of 700-800 mm per year (Red de Inversiones y Exportaciones, 2009). The park is known to host 65 mammal species including Chacoan peccary, white-lipped peccary (*Tayassu pecari*), collared peccary (*Pecari tajacu*), brown brocket deer (*Mazama gouzoubira*) and tapir (*Tapirus terrestris*; Direccion de Parques Nacionales y Vida Silvestre, 1999) – all forest-dependent species.

To quantify forest loss and road development, LANDSAT TM satellite images (Path 228-229, Row 73-75) were obtained through the Instituto Nacional de Pesquizas Espaciais online catalog (INPE, 2014; http://www.dgi.inpe.br/CDSR/) every 5 years from 1985-2011 (more recent images were unavailable). Images were selected to contain < 25% cloud cover, and were acquired within any month of the year. Within a year, images were mosaicked and clipped to the study area. Band 5 was interpreted visually for forest clearings and roads, which were digitized at a resolution of 1:64K to polygon and line shapefiles, respectively, by S. Saldivar Bellassai. Deforestation was calculated as the total amount of forest area cleared / 5 years and road creation as linear km of road added / 5 years. To assess spatial patterns in land use change, I calculated the mean distance to protected area for each forest clearing by year using the Near tool in ArcMap 10 (ESRI, Redlands, CA).

3. Results

Cleared forest increased 5.6-fold from 123.86 km^2 in 1986 (Figure 2.1A) to 7136.54 km^2 in 2011 (Figure 2.1B). The rate of forest clearing increased exponentially over this time period (Figure 2.2A). Transforming the data to a log-scale and fitting linear models yielded log(cleared area in km^2) = -2389.90 + 315.33 log(year) ($R^2 = 0.98$, $p < 0.01$). All forest clearings occurred outside DCNP boundaries, except one conducted for infrastructure improvements within the park. Individual forest clearings also increased in size over this period from an average of 1.1 (1.7 SD) km^2 in 1986 to 11.9 (23.0 SD) km^2 in 2011 (Table 2.1). The rate of change in clearing size, like total forest harvest, was also exponential with log(clearing size) = -583.7 + 177.0 log(year) ($R^2 = 0.96$, $p < 0.01$). The accompanying increase in the variance of clearing size (Table 2.1) reflected the wider array of recent drivers of forest clearing, with a push towards large ranching operations and away from small family farms.

There was no change over time in the mean distance of clearings to the park boundary (Table 2.1). However, clearings were concentrated along the eastern and southern boundaries of the DCNP because the Medanos del Chaco National Park was located along the western boundary. North of the park remains well preserved despite its lack of protected park status, probably due to more difficult access and drier environments.

Road development tended to precede forest clearing. I documented a baseline road network in 1986 that totaled 2,149 km and primarily connected villages and military forts in the region (Figure 2.1C). The total linear extent of the road network increased 313% through 2011 to a total of 13,005 km with many of the recently developed roads extending into large clearcut areas ($\bar{x}$ = 11.9 km^2, 23.0 SD) rather than serving as connections among communities. The rate of increase in the road network, like that of forest clearing, was also exponential with log(road length in km) = -847.88 + 112.71 log(year) (R^2 = 0.99, $p < 0.01$; Figure 2.2). Based on the coefficients of the fitted models, the rate of forest clearing was nearly 2.8 times greater than the rate of road development (Figure 2.2B) in this region.

4. Discussion

Deforestation of the Dry Chaco in and around the DCNP increased at an exponential rate between 1986 to 2011, showing no indication that the rate of forest loss was slowing. Hansen et al., 2013 and others have called attention to the alarming rate of global forest loss with countries like Malaysia, Cambodia, Cote d'Ivoire, Tanzania, Argentina, and Paraguay leading the records in terms of percentage of overall forest loss. In 2009, Huang et al. evaluated forest loss across Paraguay and concluded that protected areas were effective in maintaining their forest cover – which I also observed in this study. However, Huang et al. (2009) indicated that all areas outside of protected areas in the Atlantic Forest had been cleared, which may be the future for the areas surrounding the DCNP, although they concluded that deforestation rates in the Chaco ecoregion at that time were considered "moderate." In response to these assessments, tracking of forest loss and landuse change by Guyra Paraguay has increased both in terms of frequency and extent.

Large-bodied animals like Chacoan peccary, having large area requirements, are particularly threatened by habitat loss (Altrichter et al., 2008; Black, P. and Vogliotti, A., 2008; Caso, A. et al., 2008a, 2008b; Gongora, et al., 2011; Keuroghlian, A. et al., 2013; Naveda, A. et al., 2008). Taking the average size of Chacoan peccary home ranges to be 1000 km^2 (Taber et al., 1993), and assuming no overlap among peccary home ranges, the total amount of forest loss documented in this study was equivalent to the loss of at least 690 Chacoan peccary home ranges. Growth in the road network also occurred at an exponential rate over the period of my study. Road construction is a disturbance that affects wildlife by causing direct loss of habitat, alteration of adjacent habitat, road-kills, impediments to movement, habitat fragmentation, and increasing opportunity for hunting (Sowls, 1997; Robinson and Bennett, 2000; Forman et al., 2003). Species demonstrate differential vulnerability to such disturbance: either by being attracted to roads (for food, nesting, living space, or facility of movement) and increasing their vulnerability to being harvested, or decreasing their movements due to road avoidance and exacerbating the habitat potential lost due to roads presence (Forman et al., 2003). Chacoan peccary are attracted to roads (see Chapter 3) and are more likely to be encountered by hunters along roads (see Chapter 1) – indicating the very real potential for increasing road networks to increase harvest rates and decrease their potential for persistence in the region long-term.

Caldas et al. (2013) indicated that land use changes in the Chaco ecoregion were driven by cattle ranching as opposed to soy bean agriculture which drives landuse change elsewhere in Paraguay, which is consistent with my observations that the size of forest clearings has increased to accommodate the growing cattle operations in the region. Disease epidemics and competition with livestock may pose additional threats to Chacoan peccary as a result of expanded cattle operations over time (Altrichter et al., 2008; Black, P. and Vogliotti, A., 2008; Caso, A. et al., 2008a, 2008b; Gongora, et al., 2011; Keuroghlian, A. et al., 2013; Naveda, A. et al., 2008).

More likely, cattle operations may and dense road networks may act as barriers to connectivity of core habitats like those provided by protected areas in the region. The DCNP, Chovoreca National Park, Medanos del Chaco National Park collectively provide 13,988 km^2 of protected forest habitat in the region in addition to the 44,470 km^2 of protected areas established in neighboring Bolivia. Maintaining effective connectivity among these protected areas will become increasingly important in light of the continued exponential rate of forest loss and road development in the region.

These changes are particularly notable given that habitat loss (from deforestation) and overharvest (facilitated by roads) are the leading concerns for the persistence of the endangered Chacoan peccary in this region.

Conservation actions might include road impact mitigations such as underpasses, minimizing road adjacent clearings, invasive species management and road patrolling to decrease hunting pressure – which are expensive and difficult to implement. Better advance planning to stem forest loss and maintain functional connectivity is desirable.

5. Conclusions and recommendations

Although the area surrounding the DCNP has experienced rapid forest loss, park boundaries remained secure with forests inside the park exhibiting no significant change over the course of this study. Continued loss of forest habitat outside of the park combined with ever-increasing road access for hunters in the area, indicates that the park will increasingly become an important reservoir for wildlife resources in the region. In light of my assessment of hunting practices (see Chapter 1), the rate of road increase is of conservation concern especially for Chacoan peccary who commonly use areas near roads (see Chapter 3) and do not flee from approaching humans. Although harvest levels seem sustainable at present (see Chapter 1), the rapid rate of habitat loss and road development may alter the impact of hunting on animal populations – and these changes are happening fast.

Forest loss should be monitored closely in the area through satellite imagery at relatively low costs for developing countries. Buffer zones with limited development around park boundaries would help to increase the effective conservation benefit of protected areas. Given the rapid rates of land use change, assessments of peccary harvest patterns along with forest conversion and road development assessment should occur again, within perhaps 5 year-intervals, to track potential changes in their populations and increasing risks of overharvest in the region.

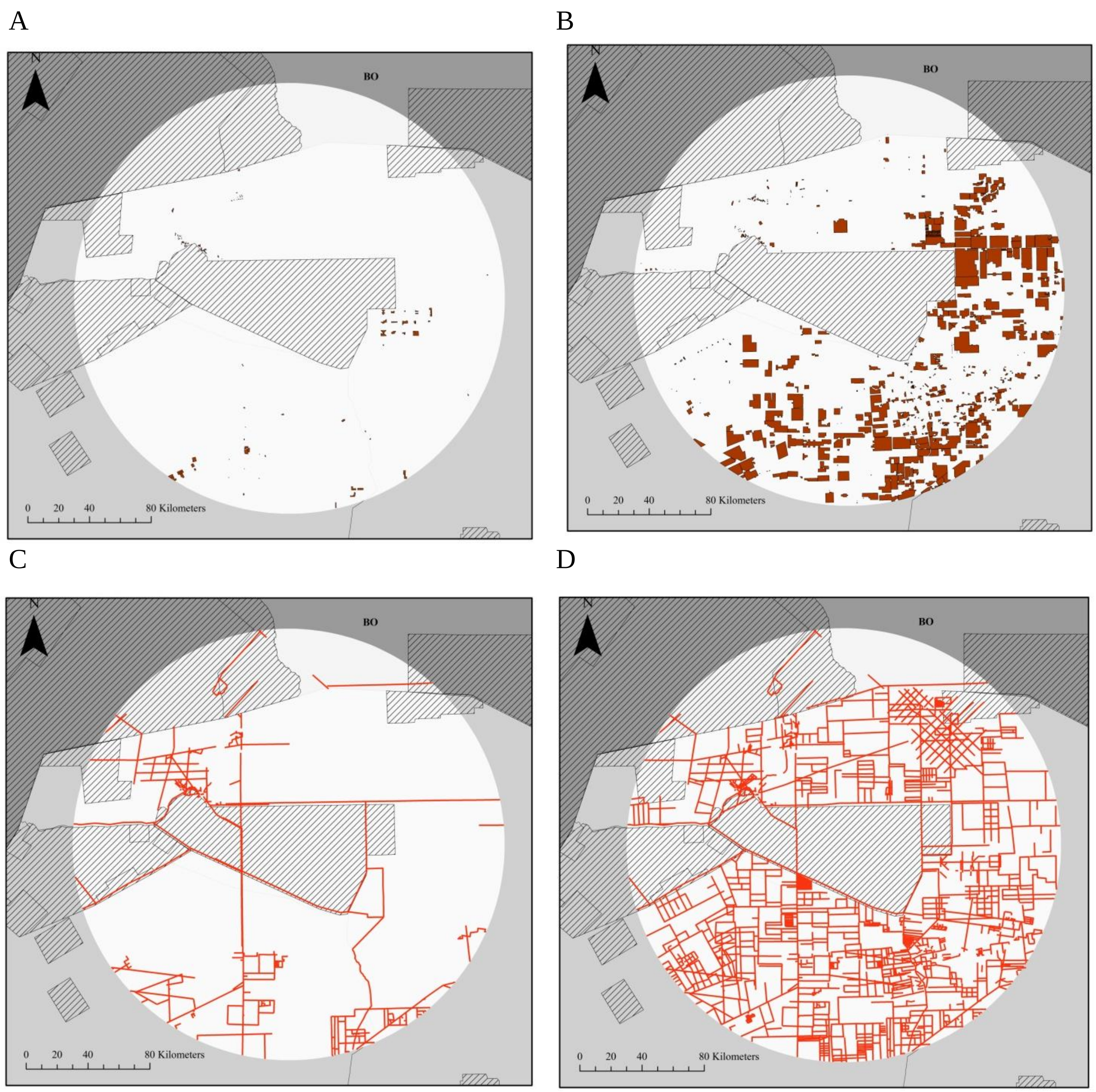

Figure 2.1. Changes in forest clearings (top panels) and road development (bottom) from 1986 (left panels) to 2011 (right panels).

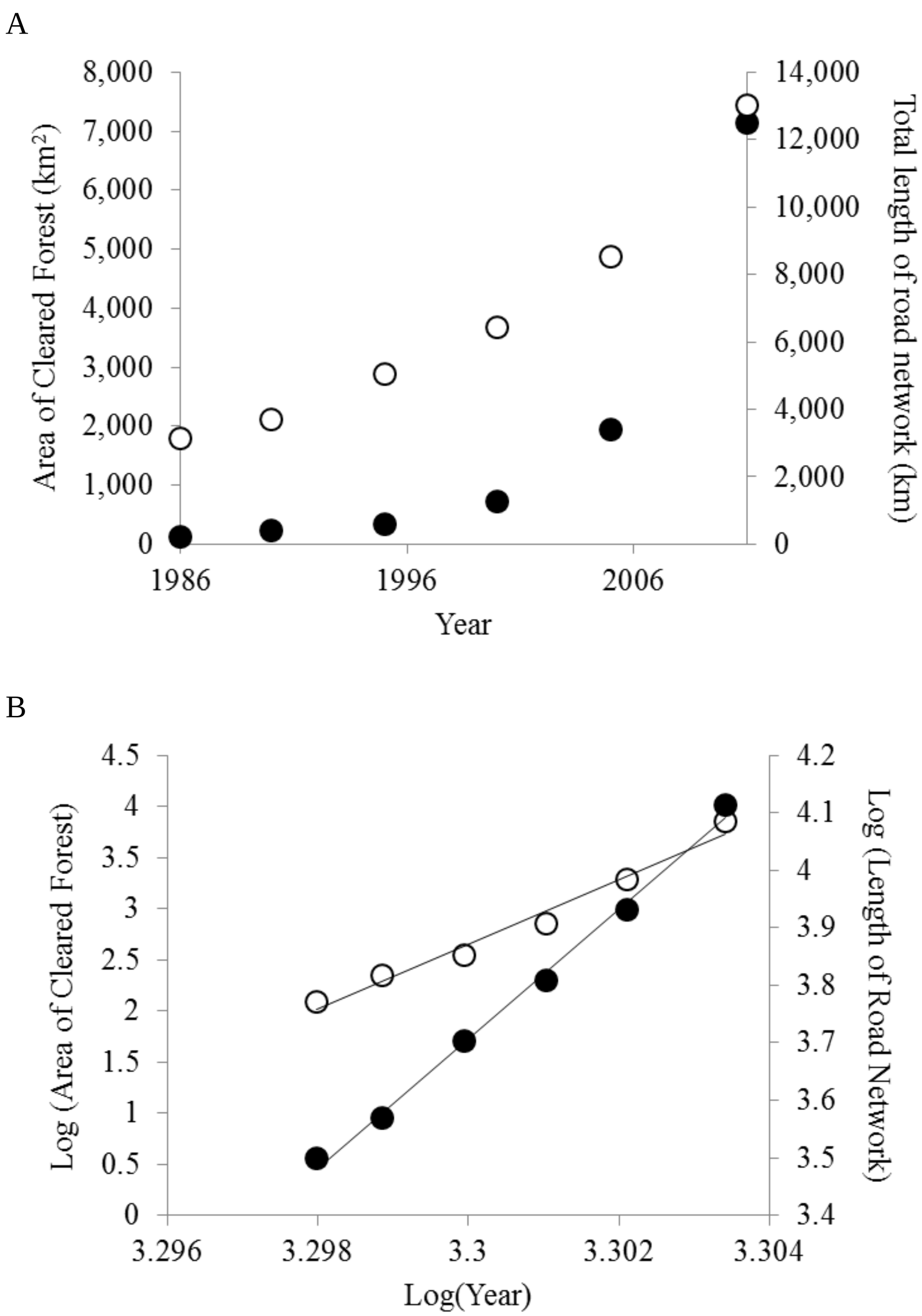

Figure 2.2. Total amount of cleared forest (filled symbols) and length of road network (open symbols) (A) within and around Defensores del Chaco National Park, Paraguay, documented using Landsat TM imagery from 1986-2011. The same data plotted on a log scale with fitted lines to estimate the rate of change (B).

Table 2.1. Change in forest clearings and roads from 1986-2011, in 5 year-intervals, within and around the Defensores del Chaco National Park, Paraguay.

	Year					
	1986	**1990**	**1995**	**2000**	**2005**	**2011**
Number of forest clearings	109	121	173	232	352	599
Total area cleared (km^2)	123.9	225.3	351.0	721.0	1,937.3	7,136.5
Deforestation rate (km^2/5 years)	--	25.4	25.2	74.0	243.3	866.5
Percent of total forest loss	0.3	0.5	0.8	1.6	4.3	15.8
Mean size (km^2; with SD)	1.1 (1.7)	1.9 (3.7)	2.0 (5.1)	3.1 (7.2)	5.5 (13.0)	11.9 (23.0)
Mean distance to any protected park (km^2; with SD)	27.7 (27.8)	34.6 (25.8)	29.9 (26.1)	30.9 (25.3)	34.4 (24.0)	34.8 (23.5)
Mean distance to DCNP (km^2; with SD)	34.9 (33.8)	46.0 (30.2)	35.2 (29.8)	34.7 (29.1)	38.0 (27.0)	41.4 (25.1)
Total length of road network (km)	3,149.0	3700.7	5,060.7	6,427.8	8,531.3	13,004.8
Road development rate (km/5 years)	--	137.9	272.0	273.4	420.7	745.6

Table 2.2. Minimum and maximum home ranges in km^2 and estimated home ranges lost due to forest conversion in the study area neighboring the Defensores del Chaco National Park, Paraguay.

Species	Home	Number of Lost Home Ranges					
	ranges	1986-1990	1990-1995	1995-2000	2000-2005	2005-2011	Total
Catagonus	10.15[g]	10.0	12.4	36.4	119.8	512.2	690.9
wagneri	15.51[g]	6.5	8.1	23.9	78.4	335.2	452.1
Tayassu	13[e]	7.8	9.7	28.5	93.6	399.9	539.4
pecari	123.5[f]	0.8	1.0	3.0	9.8	42.1	56.8
Pecari	3[c]	33.8	41.9	123.3	405.5	1733.1	2337.6
tajacu	6.9[d]	14.7	18.2	53.6	176.3	753.5	1016.3
Mazama	1.2[h]	84.5	104.8	308.3	1013.6	4332.7	5843.9
gouazoubira	1.5[h]	67.6	83.8	246.6	810.9	3466.1	4675.1
Tapirus	1.06[b]	95.7	118.6	349.0	1147.5	4904.9	6615.7
terrestris	39.14[a]	2.6	3.2	9.5	31.1	132.8	179.2
Puma	25[i,j]	4.1	5.0	14.8	48.7	208.0	280.5
concolor	51[k]	2.0	2.5	7.3	23.9	101.9	137.5
Panthera	11[l]	9.2	11.4	33.6	110.6	472.7	637.5
onca	1290[m]	0.1	0.1	0.3	0.9	4.0	5.4

[a]Da Silva and Rodriguez, 1997 [b]Tobler, 2008 [c]Miserendino, 2002 [d]Taber et al., 1994 [e]Ayala et al., 2006 [f]Taber et al., 1994 [g]Taber et al., 1993 [h]Pinder and Leeuwenberg, 1997 [i]Cuellar et al., 2005 [j]Romero-Muñoz, 2008 [k]Maffei et al., 2004 [l]Rumiz et al., 20033 [m]McBride Jr., 2006**.**

CHAPTER 3: Effects of competition and roads on site occupancy by peccaries: a case study in the Defensores del Chaco National Park, Paraguay

Abstract

The Paraguayan Dry Chaco is a unique setting to test competition and road effects on peccary distribution because the area harbors three sympatric species: Chacoan peccary (*Catagonus wagneri*), collared peccary (*Pecari tajacu*), and white lipped peccary (*Tayassu pecari*). My objective was to document the use of use of intact forest (low risk of harvest) and roadways (high risk of harvest), along with the effect of competition on the use of space by the endangered Chacoan peccary. I used camera traps to detect species occurrence and an occupancy framework to model peccary space use in the Defensores del Chaco National Park, Paraguay. Collared and chacoan peccary were detected, but white lipped peccary was not. Overall, the probability of site occupancy by Chacoan peccary was low compared to collared peccary (ψ= 0.37-0.46 and 0.62-0.67, respectively). Some evidence for competitive displacement of Chacoan peccary by collared peccary was indicated. Moreover, Chacoan peccary selectively occupied areas near roads, with no evidence that they were competitively displaced into such areas by collared peccary. Chacoan peccary use of roadside areas increases their vulnerability to harvest, with the mechanism driving their use of roads being revealed by this study as attraction to some unknown resource rather than competitive displacement into suboptimal habitats by an aggressive competitor.

1. Introduction

Roads play an inordinately large role as a driver of landscape change and, by extension, of the functioning of ecosystems and the persistence of species dependent upon those systems (Coffin, 2007). Throughout the world, increases in road density have been correlated with declines in species diversity and abundance (Fahrig and Rytwinski, 2009). Roads are a source of habitat loss (Forman et al., 2003; Ortega and Capen, 1999), barriers to animal movement (Burnett, 1992; May and Norton, 1996; Rondinini and Doncaster, 2002), and mortality (Forman and Alexander, 1998), although some species are known to benefit from roadside habitats (Bellamy et al., 2000). For large mammals, roads are an important source of mortality both directly through collisions with vehicles and indirectly through encounters with hunters (Laurance et al., 2006; Robinson and Bennett, 2000; Sowls, 1997), yet roads also may be an attractant due to increased food availability (vegetative forage for herbivores, road kill for carnivores), nutrients (e.g., road salt), or movement efficiency. As such, roads may set ecological traps (Schlaepfer et al., 2002), which may become especially problematic given the rapid pace of road development around the world.

Although a large volume of literature documents the negative effects of roads on wildlife populations (see Forman et al., 2003), comparatively little is known about the behavioral mechanisms driving animal responses to roads in rare species. The fundamental decision animals make as they move through a landscape is to select or avoid a given location they encounter based on local environmental conditions, with whether the location contains requisite resources and is sufficiently safe being criteria by which resource selection decisions are made. Models of animal movement, resource selection, and site occupancy, especially for large mammals, typically include the proximity or density of roads as a variable (Grosman et al., 2011; Jaeger et al., 2005; Kasworm and Manley, 1990; Laurance et al., 2006; Rost and Bailey, 1979; Whittington et al., 2005) – enabling animals to vary their resource selection patterns as a function of road context. But a species relationship with its habitat is also subject to vary with the density of conspecifics as well as the presence or density of competitors or predators, variables that are far more difficult to quantify than vegetative cover and other site covariates and, as a result, are often excluded from resource selection studies. Species-interaction occupancy models are a recent analytical development that provide a means of quantifying how the presence of a second species (competitor or predator) might influence the space use decisions of the target species (MacKenzie et al., 2004).

I used occupancy modeling to investigate how roads influenced the distribution of sympatric peccary species in the Dry Chaco ecoregion of northern Paraguay, specifically seeking to understand the behavioral mechanisms influencing use of areas near roads by the endangered Chacoan peccary (*Catagonus wagneri*). The Dry Chaco is the only region where Chacoan peccary coexist with collared (*Pecari tajacu*) and white lipped peccary (*Tayassu pecari*). Persistence of the Chacoan peccary is considered threatened by habitat loss (forest conversion, see Chapter 2) and overhunting (see Chapter 1). Although generally considered to be less common than the other peccary species, Chacoan peccary are more commonly seen along roads and as a result are the most harvested peccary species in the region (see Chapter 1). Several possible mechanisms may explain why Chacoan peccary are commonly seen along roads – they may selectively use road-adjacent areas due to the resources they provide, they may use road-adjacent areas at random whereas the other peccary species avoid roads which would give a false impression of road selection by Chacoan peccary, or they may avoid roadside areas except in the presence of one of the more aggressive species which would indicate competitive exclusion of Chacoan peccary into suboptimal roadside habitats. Understanding the drivers of road use by Chacoan peccary is crucial for identifying management actions to mediate the potential impacts of road-driven harvest on persistence of this endangered species.

2. Materials and Methods

Peccary site occupancy was studied within the Defensores del Chaco National Park (DCNP; 20°10'12"S 60°18'5"W), located in a remote area of the Paraguayan Dry Chaco in the Alto Paraguay Department near the Bolivian border (Figure 1.1). The predominant vegetation type of the park was thorny xerophytic forest (86% of the study area), with overstory species being *Schinopsis lorentzii*, *Chorisia insignis,* and *Aspidosperma quebracho-blanco*, and a shrub layer including *Ruprechtia triflora, Capparis retusa, Acacia praecox, Acacia polyphylla, Ximenia americana,* and *Capparis salicifolia* (Taber et al., 1993). The understory was dominated by Cactaceae, Bromeliae or Gramineae. Less common vegetation types included floodplain forest (4.46%), xerofitic-cerrado (4.41%), cerrado (1.25%), shrub sand dunes (0.24%), and forest clearings (2.58%). Soils in the region included Eutric Regosol-Haplic Luvisol (Rge-LVh; 76.62), Haplic Luvisol.Eutric Gleysol/Haplic Luvisol-Eutric Cambisol (LVh-Gle/LVh-CMe; 13.51%), Eutric Leptosol (LPe; 6.00%), Eutric Cambisol (CMe 2.5%), Chromic Cambisol/Stagni-chromic Cambisol (CMx-CMjx; 0.48%), and Haplic Arenosol (ARh; 0.13%). The area received 700-800 mm of precipitation per year (Red de Inversiones y Exportaciones, 2009) with a distinct dry (May-Oct) and rainy (Nov to Apr) season.

Peccary use of the landscape was determined using sensor-triggered camera traps with infrared night vision (Bushnell TrophyCams). To determine peccary use of areas near roads, a set of 14 cameras were placed within 50 m of the roads encircling the DNCP, with cameras placed for a field-of-view parallel to the road, and spaced at ~20 km intervals along the road to sample the heterogeneity of the region (Figure 3.1). To document use of areas away from roads, 14 additional cameras were placed 500- 4,615 m distant from roads. Plots away from roads were not placed along trails, rather the camera field-of-view was cleared with a machete to maintain a consistent visible area across cameras within the otherwise dense understory. Plots near and away from roads were separated by ≥ 3 km to ensure independence. Cameras collected data in a closed season from 5 Jul to 6 Nov 2013, coinciding with the dry season. For analysis, alternative "capture" windows were considered for detections within 5, 10, 15, and 20-day pooled intervals to increase the detection rate for analysis and potentially reduce parameter bias (Brodie and Giordano, 2012) .

The probability of detecting a species given that it occupied a site (p) and the probability of site occupancy (ψ) were estimated using program PRESENCE 6.4 (Hines, 1996). Single-season single-species models were created independently for each peccary species to test the effect of road proximity and other site covariates on each species detectability and occupancy patterns. A two species interaction model was estimated to evaluate the potential competitive displacement of Chacoan peccary by the more aggressive peccary species. The species interaction parameterization uses encounter histories from two different species to estimate an independent p_i and ψ_i, where i = species A or B, as well as the probability of co-detection (φ) and probability of co-occurrence (ϕ; see Appendix 12 for full parameter description). I observed no instances with more than one peccary species being detected in a single photo during this study, but pooling time periods over daily or longer intervals created artificial co-detections. For this reason, I did not derive a co-detection parameter (φ). Of particular interest was whether models indicated differences in site occupancy by Chacoan peccary in the presence versus absence of a second peccary species, whether Chacoan peccary use of roadside areas was influenced by the presence of a second peccary species, and, ultimately, ϕ, the species interaction factor, which was derived as $\phi = \psi_{AB}/\psi_A \times \psi_B$.

Site covariates thought to influence peccary use of space were quantified on the ground within a 2.5-m radius of each camera as well as for the larger surrounding area using available remote sensing data (Kruck, 1998). At the plot level I recorded the presence or absence of plant species important to Chacoan peccary (See Appendix 9 for list of forage species) as well as the total percent ground cover of these species using ocular estimation by a single observer. Polygon layers provided by the Paraguayan government (1:250K resolution; Project Sistema Ambiental Chaco 2006) were used to identify the vegetation cover type (5 classes) and soil type (5 classes) of each site (see Appendix 10 for cover class descriptions). Given the importance of water in this arid region, the distance to the nearest permanent water source (river or artificial ponds/tajamares) from each camera trap was also recorded using the landcover data and field-collected coordinates for watering holes.

Candidate single species models included p as either constant across sites, affected by individual camera performance (camera number entered as a covariate), or affected by the proximity of water due to concentrated animal activity near water sources. Candidate models further incorporated ψ as influenced by either road proximity (near versus far), park zone (west versus east; with the eastern zone receiving 100 mm more precipitation annually), or proportional coverage of vegetation cover and soil types within three buffers around each site. Buffers represented daily movement distances for Chacoan peccary (0.24 km radius; Taber et al., 1993), annual home ranges (2.05 km radius; Taber et al., 1993), and twice the annual home range (4.10 km radius; see covariate descriptions in Appendix 11). Candidate models were compared using Akaike's Information Criterion with an adjustment for small sample size bias (AIC_c). Where overdispersion was indicated ($\hat{c} > 2$), QAICc was used (Burnham and Anderson, 2002). Candidate models for the two species interaction models included: (1) Null: Chacoan peccary occupancy was the same for sites where the second peccary species was present or absent $\psi_{BA} = \psi_{Ba}$, (2) Competition: Chacoan peccary occupancy was lower in areas where a second peccary species was present $\psi_{BA} < \psi_{Ba}$, (3) Competitive displacement towards roads: Chacoan peccary occupancy of a site with respect to road proximity was greater in the presence of a second peccary species $\psi_{BA} < \psi_{Ba}$ and $\psi_{BA\,on\,road} > \psi_{BA\,off\,road}$. Measures of model adequacy, specifically $\hat{c}$ and χ^2 goodness-of-fit (MacKenzie and Bailey, 2004) , were used to compare alternative pooling windows (5, 10, 15, and 20-day periods). Moreover, plausible candidate models were required to successfully converge and to produce meaningful parameter estimates (i.e., estimates that were not fixed at either 0 or 1 or having confidence intervals spanning 0-1).

3. Results

Our total effort was 3,378 camera days (camera 4 was removed due to malfunctions yielding a total of 13 plots away from roads). Cameras captured photos of 18 identifiable species of mammal (see Appendix 13) as well as several bird and lizard species. Chacoan and collared peccary were both detected, white lipped peccary was not. Single species models for Chacoan peccary indicated road proximity as an important covariate – with roads included in the top model for 3 of the 4 different sampling intervals including at the 20-day pooling interval where $\hat{c}$ indicated the best model fits (Table 3.2). In contrast, vegetation, soil and water were each included in only a single top model. Site covariates were more influential on Chacoan peccary than collared peccary, with null models being selected for 3 of the 4 pooling intervals for collared peccary (Table 3.3). An effect of roads and vegetation was indicated at the 5-day pooling interval for collared peccary, but the high associated $\hat{c}$ values indicate poor model fit. Null models indicated that the probability of site occupancy by Chacoan peccary was 29-45% lower than collared peccary (Table 3.4). In contrast, the probability of detecting either species was similar, ranging 0.7-0.23 across the different sampling intervals. Across the entire season I had a 67-85% chance of observing either Chacoan or collared peccary, indicating an adequate survey design. The highest ranked covariate models indicated an attraction to roads by Chacoan peccaries, along with an attraction to areas near water and avoidance of the Haplic Luvisol soil type (Table 3.4). Species interaction models indicated some support for competition between Chacoan and collared peccary (Table 3.5), with models including competition accounting for 21-27% of the AIC model weight, and with a ϕ of ≥ 0.67. Chacoan peccary occupancy was estimated to be 37-53% lower in the presence of collared peccary but high associated variance precluded detecting statistically significant differences. The presence of collared peccary did not appear to influence use of roads by Chacoan peccary ($\Delta AIC_c > 2.2$; Table 3.5).

4. Discussion

Chacoan and collared peccary were detected within the DCNP, whereas white lipped peccary were not. With 27 cameras deployed for 154 days, the length of the camera trap effort yielded a sufficiently high probability of detecting either Chacoan or collared peccary (67-86%) and detected species considered in this area to be even more rare than white lipped peccary. White lipped peccary are considered vulnerable by the IUCN, and have been reported recently in the region by residents and conservation professionals (see Chapter 1). My inability to detect white lipped peccary may be due to a combination of low abundance, high dependence on water sources in this area yielding a particularly patchy distribution (Sowls, 1997), and possibly a narrower tolerance for disturbances leading to avoidance of areas near roads or camera sites (Altrichter, 2005). However, the fact that rare and elusive species were detected in this study (e.g. mountain lion, tapir) indicated white lipped peccary to be considerably more rare than expected in this region.

Not surprisingly, collared peccaries occupied a larger portion of the available study area and were relatively more abundant than the endemic Chacoan peccary. Site covariates did not appear to influence the probability of site occupancy by collared peccary, which are known to inhabit a wide range of habitat types, temperature, rainfall, and elevation (Gongora, et al., 2011). Although I expected all peccary species to be associated with water in this study, I found no support for water (as measured herein) being an important predictor of space use by collared peccary. Likewise, site covariates failed to explain differential site occupancy of collared peccaries in the Pantanal (Oliveira-Santos et al., 2011). Similarly, in the Paraguayan Humid Chaco collared peccary space use covaried only with average annual temperature and year (Mujica Cameroni, 2013). Collared peccary did not avoid roads in this study, and therefore I can reject the hypothesis that their avoidance of roads gives the false impression of selection of roads by Chacoan peccary. Moreover, encounter rates with collared peccary on roads may well reflect their abundance across the landscape (see Chapter 1).

Given the wide-spread distribution and relatively high abundance of collared peccary, combined with their tendency to move in large groups and act aggressively towards interlopers (Sowls, 1997), I expected collared peccary presence in the landscape to be an important predictor of Chacoan peccary use of space. Competition is expected when two related species occupy a similar niche, occur in the same area at the same time, and utilize shared resources (Vaughan, 1985), which is the case with two tayassuids studied here. Competitive exclusion into suboptimal habitats was hypothesized as a mechanism for the apparent selective use of roadside habitats by Chacoan peccary. Chacoan peccary were less likely to occupy areas where collared peccary also occurred, and they did selectively use areas near roads. However, Chacoan peccary use of areas near and far from roads appeared to be the same with and without the presence of collared peccary. Multi-species models are parameter rich, and require a high data burden to achieve precision, so the failure to detect an effect of collared peccary on road use by Chacoan peccary may simply be an issue of statistical power. But my observations, if real, have important implications for management actions aimed to reduce the higher levels of mortality risk Chacoan peccary face by using roadside habitats. For instance, reducing collared peccary density may have a positive overall effect on Chacoan peccary abundance due to competitive release, but is not expected to reduce their attraction to roads. Chacoan peccary attraction to roads is more likely due to the co-occurrence of a limited resource such as mineral rich muds exposed by bulldozers during road maintenance (Sowls, 1997) or more efficient movement corridors. Finer scale investigations of limiting resources and what attractive elements roads may provide to Chacoan peccary will be important to identify effective conservation actions, such as potentially providing mineral licks off-road.

Chacoan peccary attraction to roads is of concern because roads increase their encounter rates with hunters in the region (see Chapter 1). Hunters prefer Chacoan peccary, and their offtake of species is directly proportional to encounter rates, which in the case of Chacoan peccary seems to be driven by road-based encounters rather than animal density per se (see Chapter 1). Hunters almost exclusively use roads and trails during hunting forays rather than machete their way through the thorny understory (see Chapter 1). When encountered on roads Chacoan peccary, in contrast to the other peccary species, do not flee but instead demonstrate curiosity towards humans (Taber and Oliver, 1993). The combination of attraction to roads and failure to flee has led to the endangered Chacoan peccary becoming one of the most harvested species in the region (Neris et al., 2010; see Chapter 1). Creation of new roads to support broad-scale timber harvest as well as expanded cattle ranching is progressing at an alarming rate (see Chapter 2), creating even more opportunity for harvest. Protected areas have successfully maintained intact interior forest without road effects (citation; Chapter 2), but outside of protected areas forests are being rapidly converted to other land uses (citation; Chapter 2). Chacoan peccary abundance has been negatively correlated with road density in the Argentinian Chaco (Altrichter and Boaglio, 2004), and as the road network grows and loss of their forest habitat progresses protected areas like the DCNP will become increasingly important habitat reservoirs for Chacoan peccary.

5. Conclusion and recommendations

Collared and Chacoan peccary populations appeared robust within the DCNP, whereas white lipped peccary were more scarce than expected. Chacoan peccary attraction to roadside habitats put them at increased risk of harvest, and is a conservation concern in light of the rapidly growing road network in the region. An important finding was that Chacoan peccary are apparently not competitively displaced into roadside habitat by the more aggressive collared peccary, indicating Chacoan peccary attraction to roads is a function of some resource they seek. Finer scale investigations into the resources roads provide to Chacoan peccary – food, minerals, travel corridors – will be helpful to identify potential management actions.

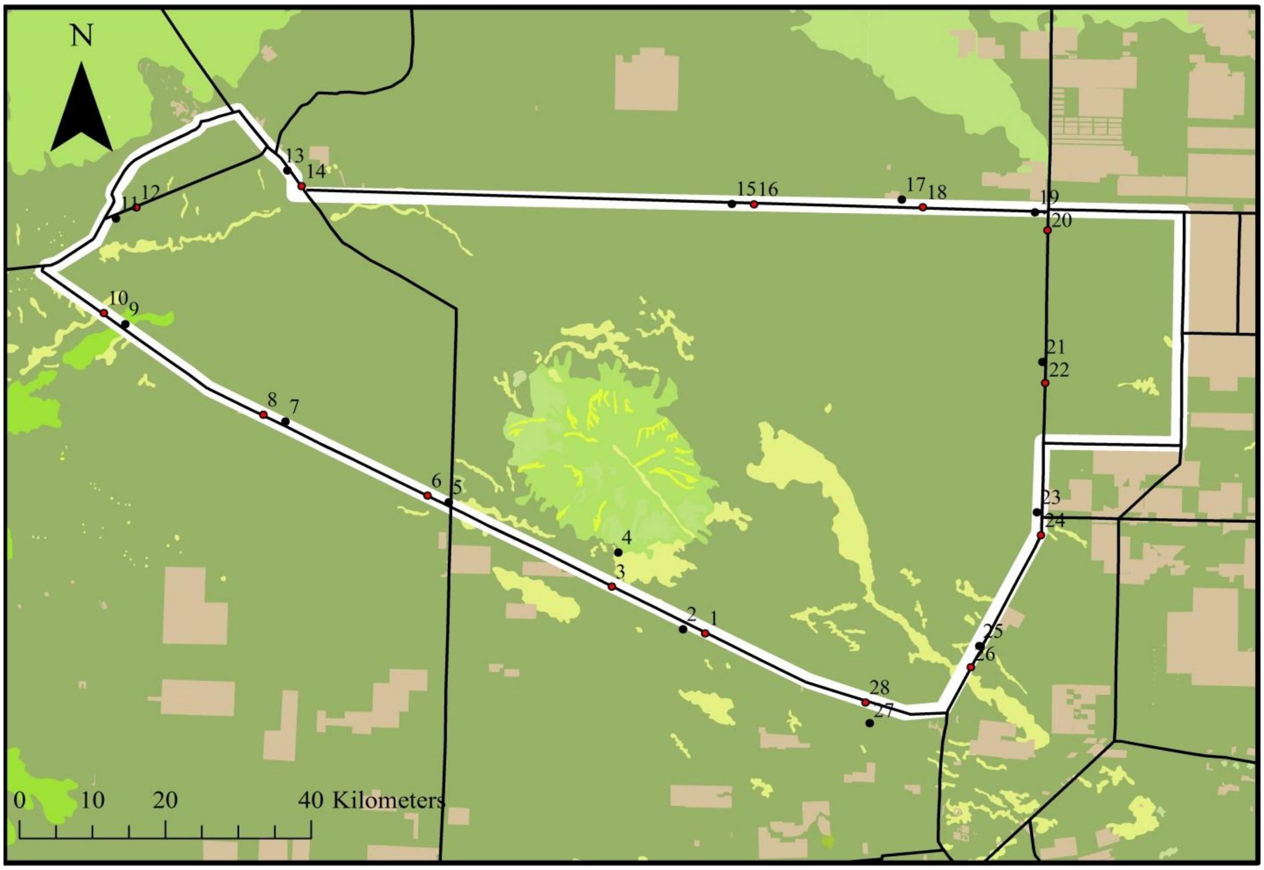

Figure 3.1. Camera trap placement at the Defensores del Chaco National Park in July-November 2013. Sites marked in red (on road) and in black (off road). Park boundary is displayed in a white thick line, and road network in black lines. Vegetation types are displayed in different tones of green and cleared production areas are in beige.

Table 3.1. Single-season single-species occupancy models for Chacoan peccary in the DCNP, June-Nov 2013. Candidate models included effects of either road proximity (R), water accessibility (W), vegetation type (V) and soil type (S), or up to two covariates in combination, on the probability of site occupancy (ψ) and camera trap function (C) or water accessibility (W) on the probability of detection (p). Indicated for each model is the difference in QAICc, shrinkage parameter for most complicated models (**ĉ**), significance level for a χ2 goodness-of-fit test, and whether meaningful estimates were acquired for all parameters (Y=yes, N=no). Model selection was conducted within a given temporal interval only for models producing meaningful covariates.

Model		5-day window				10-day window				15-day window				20-day window			
Ψ	*p*	$\Delta QAIC_c$	$\hat{c}$	*P*	M	$\Delta QAIC_c$	$\hat{c}$	*P*	M	$\Delta QAIC_c$	$\hat{c}$	*P*	M	$\Delta QAIC_c$	$\hat{c}$	*P*	M
--	--	6.1		0.02	Y	7.1		0.02	Y	11.7		0.08	Y	3.6		0.06	Y
--	C	9.2		0.03	Y	10.6		0.01	Y	4.4		0.04	Y	19.7		0.14	Y
R	--	16.8		0.02	Y	7.3		0.02	Y	13.8		0.07	Y	**0.0**		**0.04**	**Y**
V	--	6.1		0.02	Y				N				N				N
S	--				N	6.2		0.02	Y				N				N
W	--	6.0		0.02	Y	11.8		0.03	Y	13.9		0.08	Y	9.4		0.07	Y
W	C	**1.4**		**0.02**	**Y**				N	**0.0**	**2.8**	**0.03**	**Y**	20.1	1.6	0.13	Y
WF	--	14.3		0.02	Y	14.0		0.03	Y				N				N
RV	--	10.3		0.01	Y				N				N				N
RS	--				N	**0.0**		**0.01**	**Y**				N				N
RW	--				N	6.9		0.02	Y	14.9	2.0	0.08	Y	**1.1**	**2.7**	**0.04**	**Y**
R	C	4.1		0.01	Y	10.2		0.01	Y	2.1	2.6	0.03	Y	12.5	1.9	0.08	Y
RV	C	**0.0**	**15.2**	**0.01**	**Y**				N				N				N
RW	C				N	6.7	7.4	0.01	Y				N				N

Table 3.2. Single-season single-species occupancy models for Collared peccary in the DCNP, June-Nov 2013. Candidate models included effects of either road proximity (R), water accessibility (W), vegetation type (V) and soil type (S), or up to two covariates in combination, on the probability of site occupancy (ψ) and camera trap function (C) or water accessibility (W) on the probability of detection (p). Indicated for each model is the difference in AICc (or QAICc when **ĉ**>2), shrinkage parameter for most complicated models (**ĉ**), significance level for a $\chi 2$ goodness-of-fit test, and whether meaningful estimates were acquired for all parameters (Y=yes, N=no). Model selection was conducted within a given temporal interval only for models producing meaningful covariates.

Model		5-day window				10-day window				15-day window				20-day window			
Ψ	*p*	ΔQAIC$_c$	$\hat{c}$	*P*	M	ΔQAIC$_c$	$\hat{c}$	*P*	M	ΔQAIC$_c$	$\hat{c}$	*P*	M	ΔAIC$_c$	$\hat{c}$	*P*	M
--	--	220.3		0.04	Y	**0.0**		**0.02**	**Y**	**0.0**		**0.07**	**Y**	**0.0**		**0.43**	**Y**
--	C				N	6.1		0.02	Y								
R	--				N	4.2		0.01	Y	6.2		0.08	Y	**1.5**		**0.42**	**Y**
V	--	31.9		0.04	Y				N				N				N
S	--	39.6		0.03	Y				N				N				N
W	--	28.5		0.04	Y	2.5		0.02	Y	13.1		0.08	Y	**1.3**		**0.44**	**Y**
RV	--	**0.0**	**5.6**	**0.04**	**Y**				N				N				N
RW	--	60.2	2.3	0.04	Y	**1.8**	**8.3**	**0.02**	**Y**	14.3	1.9	0.08	Y	3.4	0.4	0.72	Y
R	C									6.2	2.1	0.08	Y				N

Table 3.3. Estimates from the highest-ranked, single-species occupancy models for Chacoan and collared peccary. The estimated probabilities of site occupancy (Ψ), probability of detection within a single interval ($\hat{\mathbf{p}}$), and probability of detection across the survey period (p*) are shown for the null model excluding covariate effects. Estimated covariate effects (Beta coefficients) for the highest ranked AICc model are also given with standard errors in parentheses. CMx-CMjx=Chromic Cambisol – Stagni-chromic Cambisol.

	5-day interval		10-day interval		15-day interval		20-day interval	
Variable	Chacoan	Collared	Chacoan	Collared	Chacoan	Collared	Chacoan	Collared
Null model								
Ψ	0.37	0.67	0.39	0.62	0.41	0.64	0.46	0.65
	(0.12)	(0.14)	(0.13)	(0.13)	(0.14)	(0.14)	(0.18)	(0.15)
$\hat{p}$	0.07	0.07	0.13	0.14	0.17	0.18	0.17	0.23
	(0.02)	(0.02)	(0.04)	(0.03)	(0.06)	(0.05)	(0.07)	(0.06)
*p**	0.85	0.84	0.8	0.84	0.77	0.8	0.67	0.79
Beta coefficients for detection probability								
Camera	0.92	--	--	--	1.22	--	--	--
	(0.62)				-0.77			
Beta coefficients for occupancy probability								
Road prox.	1.72	0.63	1.18	--	--	--	0.86	--
	(1.35)	(1.22)	(1.13)				(1.15)	
Water prox.	--	--	--	--	–0.04	--	--	--
					(0.08)			
Soils								
CMx-CMjx	--	--	–2.03	--	--	--	--	--
			(0.35)					
Vegetation								
Clearings	84.71	--	--	--	--	--	--	--
	(73.22)							
Forage species	--	0.09	--	--	--	--	--	--
		(1.66)						

Table 3.4. Species interaction models testing for competitive displacement of Chacoan peccary (species B) by collared peccary (species A) in addition to the effects of roads on Chacoan peccary. No competitive effect occurs when $\boldsymbol{\psi_{BA}} = \boldsymbol{\psi_{Ba}}$, with competitive displacement indicated where $\boldsymbol{\psi_{BA}} < \boldsymbol{\psi_{Ba}}$ (see methods). The effect of road proximity (near vs. far) was tested for $\boldsymbol{\psi_{BA}}$ (Chacoan peccary occupancy in the presence of collared peccary). Models are given for 5-, 10-, and 20-day intervals, for which single species models indicated a potential effect of roads on Chacoan peccary site occupancy. Differences in AICc, AIC model weight (ωi), and estimated occupancy parameters and coefficient values (with standard errors in parentheses) are given, and bolded where model selection uncertainty exists (ΔAICc < 2). The probability of co-occurrence and probability of detection are also reported for each time interval.

5-day interval					10-day interval					20-day interval				
ΔAIC_c	ω_i	ψ_{BA}	ψ_{Ba}	ψ_{BA} Road effect	ΔAIC_c	ω_i	ψ_{BA}	ψ_{Ba}	ψ_{BA} Road effect	ΔAIC_c	ω_i	ψ_{BA}	ψ_{Ba}	ψ_{BA} Road effect
No competition ($\psi_{BA} = \psi_{Ba}$)														
0.0	**0.50**	**0.37 (0.11)**	**0.37 (0.11)**		**0.0**	**0.55**	**0.38 (0.12)**	**0.38 (0.12)**		**0.0**	**0.55**	**0.41 (0.13)**	**0.41 (0.13)**	
2.2	0.16	0.29 (0.15)	0.29 (0.15)	0.45 (0.16)	2.2	0.18	0.29 (0.15)	0.29 (0.15)	0.46 (0.17)	2.22	0.18	0.32 (0.17)	0.32 (0.17)	0.50 (0.19)
Competition ($\psi_{BA} \neq \psi_{Ba}$)														
1.3	**0.27**	**0.25 (0.13)**	**0.62 (0.26)**		**1.9**	**0.21**	**0.28 (0.14)**	**0.56 (0.25)**		**1.9**	**0.21**	**0.30 (0.16)**	**0.65 (0.34)**	
3.5	0.07	0.25 (0.13)	0.62 (0.27)	0.86 (0.39)	4.7	0.06	0.21 (0.19)	0.57 (0.25)	0.33 (0.20)	4.7	0.06	0.22 (0.20)	0.67 (0.29)	0.37 (0.22)
Probability of co-occurrence (ϕ)														
		0.67					0.73					0.73		
Probability of detection (pA=pB=rA=rBA=rBa)														
		0.07 (0.01)					0.13 (0.03)					0.21 (0.05)		

CONCLUSIONS

Herein I provided an assessment of peccary populations as well as two potential threats to their persistence (hunting and deforestation) within the vicinity of the Defensores del Chaco National Park in Paraguay – the first such assessment in this region. I would highlight as worrisome the fact that white lipped peccary harvest rates were lower than the other two peccary species, and that they were not detected by camera traps, suggesting their status in the area is of greater conservation concern than previously thought.

Although Chacoan peccary seemed fairly abundant, and current harvest levels seemed fairly low, increasing loss of forest adjacent to the park combined with increasing road networks indicate that conditions are changing rapidly in this region, which could tip the balance towards species decline in the near future. Chacoan peccary were at elevated risk of harvest compared to other peccary species due to their selective use of roads and the exclusive use of roads by people when hunting. Reported encounter rates between hunters and wildlife in the region reflected the expected rank order of species in terms of their abundance with the notable exception of Chacoan peccary due to their attraction to roads. This poses a conservation conundrum because people resident in the region perceive Chacoan peccary to be as or more abundant than the other peccary species, which is not the case. This mismatched perception of species abundance may make voluntary reduction of the take of Chacoan peccary, which were preferred by hunters, unlikely. I recommend gaining deeper insight into why Chacoan peccary are attracted to roads as a means of identifying what actions might be taken to reduce that attraction – such as potentially providing mineral licks off road.

I observed some support for competitive exclusion of Chacoan peccary by collared peccary, indicating that both populations should be monitored to detect if management actions of collared peccary populations are necessary to maintain healthy Chacoan peccary populations. Importantly, my results indicate that reduction of collared peccary density might increase space use (and potentially density) of Chacoan peccary, but would not be expected to reduce their use of areas near roads.

Finally, Chacoan peccary are forest-dependent species. A deforestation rate of 866.53 km^2 per year in the areas surrounding the DCNP, with the rate of forest loss increasing at an exponential rate without showing signs of slowing, is worrisome. Protected parks have effectively maintained their interior forests while the forests around them continue to decline. As such, protected areas will become increasing important habitat reservoirs for Chacoan peccary in the future, and ensuring connectively among these protected areas will become important. Policies and actions to manage deforestation rates and growth of roads networks in a manner that maintains large tracts of well- connected forest habitat would most certainly be beneficial to the persistence of Chacoan peccary in this region.

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APPENDICES

Appendix 1. Questionnaire used in July 2013 in the areas surrounding the Defensores del Chaco National Park approved by Syracuse University IRB number 13-121.

QUESTIONNAIRE

1. How long have you been living in the area? *Write the number of years (e.g. 24 years)*

__________years

2. What do you do for a living? *Check all that apply.*

- ☐ Merchant
- ☐ Cattle rancher
- ☐ Cattle ranch keeper
- ☐ Agriculturist
- ☐ Contractor
- ☐ Other: _______________

3. What animals are these? *Show animal pictures and check all that apply.*

Identified correctly:

☐ Chacoan peccary

☐ Collared peccary

☐ White lipped peccary

4. Do you usually see wild animals? *Check one box.*

☐ Yes
☐ No

5. What species do you see? *Check all that apply.*

Chacoan peccary	☐
White lipped peccary	☐
Collared peccary	☐
Brown brocket deer	☐
Tapir	☐
Mountain Lion	☐
Jaguar	☐

Other:____

6. When did you last see each species? *Check one box or provide exact time, add more species if cited.*

	Last Week	**Last month**	**Last year**	**More than a year**	**Exact time**
Chacoan peccary	☐	☐	☐	☐	____________
White lipped peccary	☐	☐	☐	☐	____________
Collared peccary	☐	☐	☐	☐	____________
Brown brocket deer	☐	☐	☐	☐	____________
Tapir	☐	☐	☐	☐	____________
Mountain Lion	☐	☐	☐	☐	____________
Jaguar	☐	☐	☐	☐	____________
Other:__________	☐	☐	☐	☐	____________
Other:__________	☐	☐	☐	☐	____________
Other:__________	☐	☐	☐	☐	____________
Other:__________	☐	☐	☐	☐	____________

7. Which ones are common to see? *Check all that apply, add more species if cited.*

Chacoan peccary	☐
White lipped peccary	☐

Collared peccary	☐
Brown brocket deer	☐
Tapir	☐
Mountain Lion	☐
Jaguar	☐
Other:____________	☐
Other:____________	☐
Other:____________	☐
Other:____________	☐

8. How often do you see each species? *Check one.*

	Never	**1-5 times/yr**	**More than 5 times/yr**
Chacoan peccary	☐	☐	☐
White lipped peccary	☐	☐	☐
Collared peccary	☐	☐	☐
Brown brocket deer	☐	☐	☐
Tapir	☐	☐	☐
Mountain Lion	☐	☐	☐
Jaguar	☐	☐	☐
Other:_______	☐	☐	☐
Other:_______	☐	☐	☐
Other:_______	☐	☐	☐
Other:_______	☐	☐	☐

9. Where do you see them? *Write responses.*

	Locations
Chacoan peccary	____________________
White lipped peccary	____________________
Collared peccary	____________________
Brown brocket deer	____________________
Tapir	____________________
Mountain Lion	____________________
Jaguar	____________________
Other:____________	____________________
Other:____________	____________________
Other:____________	____________________
Other:____________	____________________

From here on, I will make questions about what people do in general. Please do not give any specific names.

10. Do people here hunt? *Check one.*

- ☐ Yes
- ☐ No

11. Have you ever hunted? *Check one.*

- ☐ Yes
- ☐ No

12. How long have you been hunting? *Check one.*

__________years

13. Do you hunt regularly? *Check one.*

- ☐ Yes
- ☐ No

14. Why do you hunt? *Check all that apply.*

- ☐ To sell
- ☐ To eat
- ☐ To have something to do
- ☐ To protect my family
- ☐ To protect my crops

15. Is bush meat sold? *Check one.*

- ☐ Yes
- ☐ No

16. What part do people sell? *Check all that apply.*

- ☐ Fur
- ☐ Meat
- ☐ Other. Explain:____

17. How much do people earn from what they sell? *Check one.*

- ☐ 0 – 100.000 Gs
- ☐ 100.001 – 1.000.000 Gs
- ☐ more than 1.000.000 Gs

18. How much do save due to hunting? *Check one.*

- ☐ 0 – 100.000 Gs
- ☐ 100.001 – 1.000.000 Gs
- ☐ more than 1.000.000 Gs

19. How much do people spend on hunting gear? *Check one.*

- ☐ 0 – 100.000 Gs
- ☐ 100.001 – 1.000.000 Gs
- ☐ more than 1.000.000 Gs

20. On average, how many times a week do people go hunting? *Check one.*

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

21. On average, how many times a month do people go hunting? *Check one.*

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Other: ______________

22. How many kilometers do you generally travel each hunting occasion? *Check one.*

- ☐ 1-3 km
- ☐ 3-6 km
- ☐ 6-9 km
- ☐ 9-12 km

- ☐ 12-15 km
- ☐ 15-18 km
- ☐ 18-21 km
- ☐ more

23. How much time do you spend each hunting occasion? *Write.*

- ☐ 1-3 hours
- ☐ 3-6 hours
- ☐ 6-9 hours
- ☐ 9-12 hours
- ☐ 12-15 hours
- ☐ 15-18 hours
- ☐ 18-21 hours
- ☐ more

24. What type of vehicle do you use for transport (when hunting)? *Check one.*

- ☐ Truck
- ☐ Car
- ☐ Motorcycle
- ☐ Bicycle
- ☐ Walk
- ☐ Horse

25. Do people hunt on trails or roads? *Check all that apply.*

- ☐ Trails
- ☐ Roads
- ☐ Forest
- ☐ Other:_________

26. Do people generally hunt with a fire arm or with traps? *Check all that apply.*

- ☐ Fire arm
- ☐ Trap

27. What kind of traps? *Write.*

____traps

28. What animals do people hunt? *Check all that apply.*

Chacoan peccary	☐
White lipped peccary	☐

Collared peccary	☐
Brown brocket deer	☐
Tapir	☐
Mountain Lion	☐
Jaguar	☐
Other:____________	☐
Other:____________	☐
Other:____________	☐
Other:____________	☐

29. What do you people if they encounter a group of animals? *Check one.*

☐ All group is hunted
☐ Only one animal is hunted

30. Do people select animals to hunt or do they hunt what they encounter first? *Check one.*

☐ Select
☐ Hunt what they encounter first

31. If yes, according to what features/characteristics? *Write.*

____

32. If people encounter females with litter, what do they do? *Check one.*

☐ Hunt the mother
☐ Hunt the litter
☐ Hunt both
☐ Hunt neither

33. What is people's favorite animal to hunt? *Check all that apply.*

		Why?
Chacoan peccary	☐	___________________________________
White lipped peccary	☐	___________________________________
Collared peccary	☐	___________________________________
Brown brocket deer	☐	___________________________________
Tapir	☐	___________________________________
Mountain Lion	☐	___________________________________
Jaguar	☐	___________________________________
Other:____________	☐	___________________________________

Other:___________	☐	______________________________
Other:___________	☐	______________________________
Other:___________	☐	______________________________

34. Is there a best time of the year to hunt? When? *Check one.*

☐ Dry season
☐ Wet season

35. Is there a best place to hunt? Where? *Write.*

____

36. What parts of the animals are useful? *Write answer.*

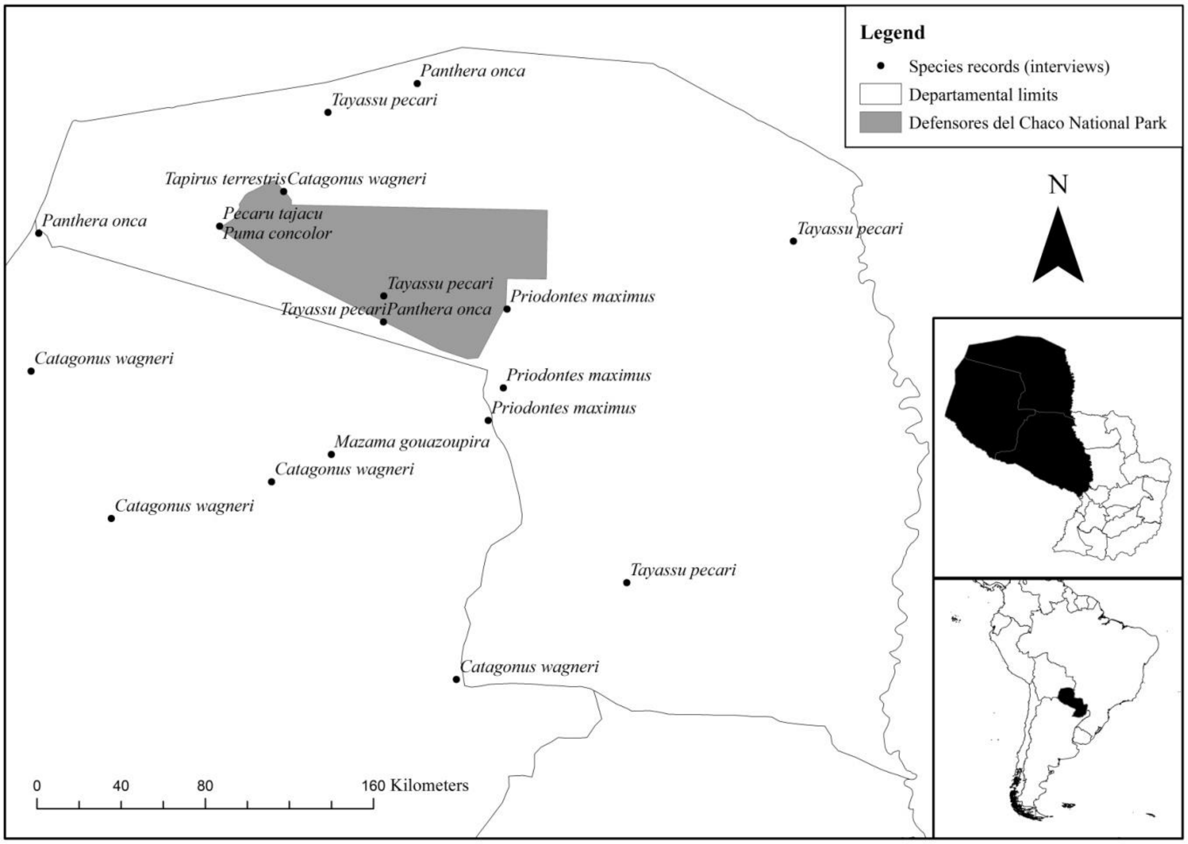
	Parts
Chacoan peccary	____
White lipped peccary	____
Collared peccary	____
Brown brocket deer	____
Tapir	____
Mountain Lion	____
Jaguar	____
Other:___________	____
Other:___________	____
Other:___________	____
Other:___________	____

37. Do you think there are more or less animals now than 5 years ago? *Check one.*

	More	**Equal amount**	**Less**
Chacoan peccary	☐	☐	☐
White lipped peccary	☐	☐	☐
Collared peccary	☐	☐	☐
Brown brocket deer	☐	☐	☐

Tapir	☐	☐	☐
Mountain Lion	☐	☐	☐
Jaguar	☐	☐	☐
Other:____________	☐	☐	☐
Other:____________	☐	☐	☐
Other:____________	☐	☐	☐
Other:____________	☐	☐	☐

Appendix 2. Species records provided by local people in structured interviews around the Defensores del Chaco National Park, Paraguay in July 2013. Locations are geo-referenced to the nearest point according to reported sightings.



Appendix 3. Average number of days since last encounter with each species of large mammals as resported by interviewees. Standard deviations are reported in parenthesis, pooled for all intervieweesand per quadrat (SE: Southeast, SW: Southwest, NW: Northwest, NE: Northeast) around the study area, Defensores del Chaco National Park, Paraguay in 2013.

Encounter days	n/a	Pooled average	SE (n=16)	SW (n=1)	NW(n=12)	NE (n=5)
Percent of deforested areas			29.86	37.36	11.57	21.21
Brown brocket deer	3	35 (91.8)	53	7	10	7
Collared peccary	4	51 (97.6)	72	7	23	9
Chacoan peccary	5	54 (104.2)	67	47	10	67
White lipped peccary	13	81 (137.7)	112	47	34	20
Tapir	8	83 (120.0)	77	47	61	78
Mountain Lion	7	164 (186.4)	230	47	75	25
Jaguar	11	176 (151.7)	261	303	42	25

Appendix 4. Average number of days since last encounter with each species of large mammals as reported by interviewees per occupation around the study area Defensores del Chaco National Park, Paraguay in 2013.

Encounter days	Commerce (n=3)	Agriculturist (n=6)	Cattle rancher/goat rancher (n=9)	Cattle ranches keeper (n=10)	Contractor/barb wire (n=7)
Brown brocket deer	4.7	4.7	94.2	7.8	7.0
Collared peccary	10.0	6.2	117.2	24.8	33.3
Chacoan peccary	15.3	14.0	94.1	48.8	21.9
White lipped peccary	2.3	64.8	140.4	23.5	64.6
Tapir	7.7	22.2	169.8	55.2	24.3
Mountain Lion	202.	132.7	173.3	64.0	207.1
Jaguar	101.0	95.7	173.4	58.4	307.7

Appendix 5. Yearly encounters (days since last encounter/365) pooled for all interviewees in the study area (pooled average) and per quadrats (SE: Southeast, SW: Southwest, NW: Northwest, NE: Northeast) around the study area Defensores del Chaco National Park, Paraguay in 2013.

	Number of yearly encounters				
Species	Pooled average	SE (n=16)	SW (n=1)	NW (n=12)	NE (n=5)
Brown brocket deer	10	7	52	37	51
Collared peccary	7	5	52	16	40
Chacoan peccary	7	5	8	37	5
White lipped peccary	5	3	8	11	18
Tapir	4	5	8	6	5
Mountain Lion	2	2	8	5	15
Jaguar	2	1	1	9	15

Appendix 6. Average distance traveled to hunt per occupation and pooled for all interviewees around the study area Defensores del Chaco National Park, Paraguay in 2013.

Occupation	Distance in km
Commerce	7.17
Agriculturist	4.42
Cattle rancher/goat rancher	3.73
Cattle ranches keeper	4.35
Contractor/barb wire	4.33
Pooled average	6.73

Appendix 7. Number of encounters with wildlife per year and hunting occasions per year pooled for all interviewees in the study area and per quadrats (SE: Southeast, SW: Southwest, NW: Northwest, NE: Northeast) around the study area Defensores del Chaco National Park, Paraguay in 2013.

Times per year	Pooled average	SE (n=16)	SW (n=1)	NW (n=12)	NE (n=5)
Hunting	34.3	1.5	24	16	0
Brown brocket deer	10.5	6.9	52.1	36.8	50.7
Collared peccary	7.2	5.1	52.1	16.2	39.7
Chacoan peccary	6.7	5.4	7.8	37.1	5.5
White lipped peccary	4.5	3.3	7.8	10.7	17.9
Tapir	4.4	4.7	7.8	5.9	4.7
Mountain Lion	2.2	1.6	7.8	4.9	14.6
Jaguar	2.1	1.4	1.2	8.7	14.6

Appendix 8. Number of encounters with wildlife per year and hunting occasions according to occupation around the study area Defensores del Chaco National Park, Paraguay in 2013.

Times per year	Commerce (n=3)	Agriculturist (n=6)	Cattle rancher/goat rancher (n=13)	Cattle ranches keeper (n=10)	Contractor/barb wire (n=9)
Hunting	48	48	36	24	12
Brown brocket deer	78.2	78.2	3.9	46.8	52.1
Collared peccary	36.5	59.2	3.1	14.7	101
Chacoan peccary	23.8	26.1	3.9	7.5	16.7
White lipped peccary	156.4	5.6	2.6	15.5	5.7
Tapir	47.6	16.5	2.2	6.6	15
Mountain Lion	1.8	2.8	2.1	5.7	1.8
Jaguar	3.6	3.8	2.1	6.3	1.2

Appendix 9. List of species part of the Chacoan peccary diet (Mayer and Brandt, 1982).

Family	***Species***
Cactaceae	*Cleisticactus baumanii*
Cactaceae	*Opuntia discolor*
Cactaceae	*Opuntia canina*
Cactaceae	*Opuntia sp.*
Cactaceae	*Stetsonia coryne*
Cactaceae	*Quiabentia verticilata*
Cactaceae	*Cereus validus*
Fabaceae	*Acacia aroma*
Bromeliaceae	*Bromelia sp.*

Appendix 10. Cover class description for the Defensores del Chaco National Park polygons shapefiles provided by the Paraguayan government (Secretariat of the Environment) according to the Project Sistema Ambiental Chaco, 2006.

Classes Vegetation	**Description**
Use	Areas cleared for human activities
MSD Shruby Sandy Dunes	Discontinuous vegetation formed mainly by shrubs and few isolated trees not higher than 5 meters, no noticeable stratification, developed on sandy soil. Understory with Cactaceae and Euphorbiaceae. Woody species: *Aspidorperma piryfolium, Schinopsis balansae, Jacaranda mimosifolia, Acacia aroma, Pterogyne nitens and Schinopsis cornuta.*
BI Floodplain forest	Similar to the xerophytic forest but in areas with non-permeable soil, with less species diversity and different dominant species more tolerant of water and more Graminae species. Dominant species are *Calycophyllum multiflorum, Salix humboldtiana, Tessaria integrifolia, T. dodonaefolia, Copernicia alba, Tabebuia nodosa, Prosopis nigra, P. ruscifolia, P. alba* and *Geoffroea decorticans*.
BX Xerofitic forest	Dense low forest with more than two strata. Tree species: *Pisonia sapallo, Anadenanthera colubrine, Anadenanthera peregrine, Aspidospera quebracho-blanco, Schinopsis heterophylla, Amburana caerensis, Cochlospermun tetraporum, Athyana weinmannifolia, Tabebuia impetiginosa. Understory with Capparis retusa, Ruprechtia triflora, Quiabentia planzii, Ximena americana, Schinus fasciculata, Acacia praecox, Mimosa velloziana*, and herbaceous *Dicliptera tweediana, Physalis sp., Jatropha grossidentata, Croton sp., Dickya sp. Bromelia hyeronimi*, etc.
CRR Cerrado	More open formation, isolated patches of shrubs and trees within a grassland matrix of Graminae like *Elionurus spp*. and *Schizachyrium sp*. Abundant species are *Tabebuia aurea, Tabebuia spp. Cordia trichotoma, Pseudobombax sp. Luehea sp. Trema micrantha, Astronium fraxinifolium, Banisteriopsis sp. Cochlospermum regium, Acacia praecos, Bauhinia sp*. Herbaceous species are *Lantana camara, Justicia spp. Physalis sp. Turnera krapovijasii*, etc.

Soil	
CMx-CMjx Chromic Cambisol – Stagni-chromic Cambisol	Weak horizon differentiation, medium and fine textured materials derived from primary rocks, colors red and mottles of oxides.
CMe Eutric Cambisol	pH ≥ 5.5, weak horizon differentiation, medium and fine textured materials derived from primary rocks
LVh-Gle/LVh-CMe Haplic Luvisol-Eutric Gleysol/Haplic Luvisol-Eutric Cambisol	Mixed characteristics. Very weakly developed and unconsolidated materials, mixed mineralogy, high nutrients and good drainage. Soil with bad drainage, acid; usually containing water in the profile.
Rge-Lvh Eutric Regosol-Haplic Luvisol	Mixed characteristics. Very weakly developed and unconsolidated materials, mixed mineralogy, high nutrients and good drainage. Acid.
ARh Haplic Arenosol	Soil of less than 40 percent of gravels or coarse fragments in all layers within 100 cm to a petroplinthic, plinthic or salic horizon.

(Kruck, 1998)(Jahn et al., 2006)

Appendix 11. List of variables, definitions, and method of measurement of the covariates for occupancy estimation and modeling of peccary occupancy in the Defensores del Chaco National Park, Paraguay.

Variable	**Explanation**	**Measured**
Proportion of cover type (Shruby Sandy Dunes, Floodplain forest, Xerofitic forest, Clearings, Cerrado)	Continuous: proportion of each vegetation type in the three different spatial scales computed as area of vegetation type divided by the circular area.	GIS
Proportion of soil type (LVh-Gle/LVh-Cme, CMe, RGe-LVh, CMx-CMjx, ARh)	Continuous: proportion of each soil type in the three different spatial scales computed as area of soil type divided by the circular area.	GIS
Percent of forage species	Continuous: visual examination of percent of ground covered by species cited to be in the Chacoan peccary diet, divided by 100.	On site
Water proximity	Continuous: distance to nearest georeferenced water source (km)	GIS, on site
Road proximity	Binary: 1 if within 50 m of the road, else 0.	On site

Appendix 12. List of names of parameters, definitions and parameterizations used for occupancy estimation and modeling (MacKenzie et al., 2004).

Parameter	Definition	Occupancy Framework
ψ	Probability of site occupancy	Single species-single season
p	Probability of detection at the site	Single species-single season
ψ_A	Probability of site occupancy by species A	Species Interaction
ψ_{BA}	probability that the area is occupied by species B, given species A is present	Species Interaction
ψ_{Ba}	probability that area is occupied by species B, given species A is not present	Species Interaction
ψ_B	Probability of site occupancy by species B. Derived $\psi B = \psi A \times \psi BA + (1 - \psi A) \times \psi Ba$	Species Interaction
ϕ	Species co-occurrence SIF, species interaction factor $\phi = \psi BA / \psi A \times \psi B$	Species Interaction
p_A	Probability of detection of species A at the site given that species B is not present	Species Interaction
p_B	Probability of detection of species B at the site given that species A is not present	Species Interaction
r_A	Probability of detection of species A at the site given that both species are present	Species Interaction
r_{BA}	probability of detecting species B, given both are present, and species A was detected	Species Interaction
r_{Ba}	probability of detecting species B, given both are present, and species A was not detected	Species Interaction

Appendix 13. List of mammals species detected by camera traps from July-November 2013 in the Defensores del Chaco National Park by this study.

Order	**Family**	**Scientific name**	**Common name**
Pilosa	Myrmecophagidae	*Myrmecophaga tridactyla*	Giant anteater
Artiodactyla	Tayassuidae	*Catagonus wagneri*	Chacoan peccary
		Pecari tajacu	Collared peccary
	Cervidae	*Mazama gouzoubira*	Brown brocket deer
Perissodactyla	Tapiridae	*Tapirus terrestris*	Tapir
Carnivora	Felidae	*Puma concolor*	Mountain Lion
		Panthera onca	Jaguar
		Leopardus pardalis	Ocelot
		Puma yagouaroundi	Yaguaroundi
	Mustelidae	*Eira barbara*	Tayra
	Procyonidae	*Nasua nasua*	Coati
		Procyon cancrivorus	Raccoon
	Canidae	*Cerdocyon thous*	Crab eating foxes
		Lycalopex gymnocercus	Pampas foxes
Lagomorpha	Leporidae	*Sylvilagus brasiliensis*	Tapiti
Rodentia	Dasyproctidae	*Dasyprocta azarae*	Agouti
	Caviidae	*Dolichotis salinicola*	Chacoan mara

CURRICULUM VITAE

SILVIA SOLEDAD SALDIVAR BELLASSAI

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EDUCATION

State University of New York - College of Environmental Science and Forestry Expected graduation June 2014
Master of Science: **Fish and Wildlife Biology and Management**;
Fulbright Scholar (Cumulative GPA: 4.0 – 4 scale)

National University of Asuncion - College of Exact and Natural Sciences Completed in 2011
Graduate Program in Research Methodology

National University of Asuncion - College of Exact and Natural Sciences Graduated in 2010
Bachelor of Science – Biology (GPA: 4.36 – 5 scale)

PROFESSIONAL AND RESEARCH EXPERIENCE

Masters Candidate 2012
State University of New York - College of Environmental Science and Forestry Syracuse, NY

- Project "Persistence of Peccaries in the Paraguayan Dry Chaco"
- Led research proposals development and implementation
- Conducted field research using camera traps and interviews with local people
- Analyzed data using occupancy and social survey methods

Junior Researcher and Wildlife Technician 2010 – 2012
Ministry of the Environment, Paraguayan Government Asuncion, Paraguay

- Conducted analysis on hunting of herbivores in the Chaco, the conservation impact of national parks in herbivore conservation, and the conservation status and priorities of big and medium sized mammals in Paraguay
- Analyzed mountain lion skulls from Latin America and their size change over the last century
- Created a bat database and proposed Bat Conservation Areas with the Bat Conservation Program
- Organized and presented public workshops on the importance of wildlife conservation
- Collected fish measurements to report on illegal fishing

Assistant Field Technician 2007 - 2009
Corrientes Biological Station – Argentine Museum of Natural Sciences Corrientes, Argentina

- Assisted in doctoral dissertation project and master thesis project on primates behavior studies
- Conducted behavioral observations and census counts of howler monkeys
- Set permanent vegetation parcels

Intern Curator of the Vertebrate Collection (Mammal section) 2009 – 2010
National Museum of Natural History of Paraguay San Lorenzo, Paraguay

- Maintained the collection free from fungal and bacterial infections
- Catalogued new specimen

Animal Care Assistant 2006 – 2008
Breeding Unit - Zoo and Botanical Garden of Asuncion Asuncion, Paraguay

- Cleaned animals enclosure and maintained security features
- Provided dietary and environmental enrichment
- Led fundraising activities to improve facilities

TEACHING AND OUTREACH EXPERIENCE

Teaching Assistant of Applied Wildlife Science Spring 2013
State University of New York - College of Environmental Science and Forestry Syracuse, NY

- Assisted students with software analysis and interpretation of results using programs MARK, DISTANCE, PRESENCE, ArcGIS, Microsoft Excel and Microsoft Word.
- Provided student mentoring and grading support

President of the Organizing Committee August 2012
First Mammalogy Meeting in Paraguay - Bat Conservation Program in Paraguay Asuncion, Paraguay

- Addressed partners and donors to get materials, equipment, venue and presentations for conference
- Organized and coordinated committee meetings and tasks

Coordinator and Facilitator 2007 2012
Arapacha, Strengthening Teams Asuncion, Paraguay

- Created and coordinated the Environmental Education Program
- Trained staff for the Environmental Education Program
- Facilitated outdoor activities with adults, teenagers and children: team work and communication strengthening

English Teacher
Paraguayan-American Cultural Center (San Lorenzo, Paraguay) 2008 – 2012
Santa Elena School (Asuncion, Paraguay) 2008 –2009

- Prepared and executed engaging curriculum for adults, teenagers and young children; graded exams

Facilitator 2008 – 2009
Multidisciplinary Support Organization for Parents and Students (OMAPA) Asuncion, Paraguay

- Facilitated workshops for school teachers in the "Water, source of life" program, engaging school teachers in simple experiments to raise awareness about water scarcity and importance for health and ecosystem conservation (to be repeated at their classrooms)

PUBLICATIONS & PRESENTATIONS

Publications

Berganza, M. L., Gómez, G., Chamorro, D. Berganza, R., Ovelar, M., Cogliolo, S. **Saldívar, S.** 2012. Water, Life Resource: Scientific Practices and Experiments. Students' Guide and Teachers' Guide for 3rd, 4th, 5th and 6th Grade. Paraguay.

Oral Presentations

Saldivar, S. & V. Martinez. 2013. Analysis SUMIN of Large and medium sized mammals in Paraguay. First Mammal Meeting in Paraguay, Asuncion, Paraguay.

Martinez, V. & **S. Saldivar.** 2013. Areas of Importance for Bat Conservation. First Mammal Meeting in Paraguay, Asuncion, Paraguay.

Neris, N., **S. Saldívar,** P. Pérez, & K. Colmán. 2010. Chronological comparison of the age structure of populations of the three peccaries in the Paraguayan Chaco. Argentine Mammalogy Days XXIII. SAREM, Bahía Blanca, Argentina.

Poster Presentations

Saldivar, S., R. Owen, & R. Casal. 2013. Survival rates and abundance of two mice species in the Paraguayan Atlantic Forest. First Mammal Meeting in Paraguay, Asuncion, Paraguay.

Saldívar, S. & V. Martínez. 2012. Chronological comparison of the Skull size of *Puma concolor* and its effects on management. First International Congress of Fauna Management in Latin America and the Amazon, Salta, Argentina.

Martínez, V. **S. Saldívar**. 2012. Assessment of Large Herbivores Conservation in Protected Areas in Paraguay through the use of GIS tools. Fifth International Congress of Fauna Management in Latin America and the Amazon, Salta, Argentina.

Saldívar, S., V. Martínez, N. Neris, P. Pérez, & K. Colmán. 2011. Age structure of *Puma concolor* as a result of illegal hunting in the Paraguayan Dry Chaco. Mammalogy Congress in Bolivia V. ABIMA, La Paz, Bolivia.

Neris, N., **S. Saldívar,** P. Pérez, & K. Colmán. 2010. Subsistence hunting and poaching in populations of herbivores of the Paraguayan Dry Chaco – Secretariat of the Environment. Argentine Mammalogy Days XXIII. SAREM, Bahía Blanca, Argentina.

GRANTS AND AWARDS

2012-4 Fulbright Scholar: State university of New York – College of Environmental Science and Forestry
2013 Graduate Student Travel Grant for I Mammal Meeting in Paraguay Conference
2013 Sequoia Zoo Conservation Fund ($1,000USD)
2013 Mohammed bin Zayed Conservation Fund ($4,000USD)
2013 National Council for Science and Technology – Paraguayan Government ($3,000USD)

SKILLS, ABILITIES & MEMBERSHIPS

- Languages: Spanish, English, Portuguese
- Data entry, management and analysis: Microsoft Office - Windows, DISTANCE, PRESENCE, MARK, R, SPSS.
- GIS software packages: Arc GIS 10, Quantum GIS, Diva GIS
- **SOCIETY MEMBERSHIPS** Argentine Society for the Study of Mammals (Since 2010) Bat Conservation Program in Paraguay (Since 2012) Society of Paraguayan Mammalogy (Since 2013)

COURSES AND CONFERENCES

2012 International Conference of Wildlife Management in the Amazon and Latin America
UNAS – Salta, Argentina

2012 Course Basics of the Community based Monitoring
Dr. Wendy Townsend, Noel Kempff Mercado Museum – Salta, Argentina

2011 Restoration Ecology Course
Moises Bertoni Foundation – Asuncion Paraguay

2011 Conference Blue Planet – Environmental Education in Water
WET Project – Bozeman, Montana, USA

2011 Paraguayan Days of Herpetology
Paraguayan Association of Hepetology (APAH) – Asuncion, Paraguay

2011 Course in Collection, Conservation Plans and Monitoring Amphibians and Reptiles
Paraguayan Association of Hepetology (APAH) and WCS Bolivia – Asuncion, Paraguay

2011 Conservation and Wildlife Management Methods Workshop
Guyra Paraguay Association, NGO S.P.E.C.I.E.S. – Asuncion, Paraguay

2011 Course in Ecology and Behaviour of Neotropical Primates
Guyra Paraguay Association, Yacyreta Binational Dam – Ayolas, Paraguay

2011 Course in Assesment of Bolivian Mammals
ABIMA Bolivian Association of Mammal Investigators –La Paz, Bolivia

2011 V Mammalogy Conference in Bolivia
ABIMA Bolivian Association of Mammal Investigators –La Paz, Bolivia

2010 Mini Course Application of Thin Layer Chromatography (TLC) to identify species mammals via fecal bile acid pattern
SAREM – Argentine Society for the Study of Mammals - Bahía Blanca, Argentina

2010 Argentine Mammalogy Days XXIII
SAREM – Argentine Society for the Study of Mammals - Bahía Blanca, Argentina

2010 Paraguayan Congress of Environment and Sustainable Development I
Moisés Bertoni Foundation – Asunción, Paraguay

2009 Mini Course "Biodiversity" – MSc. Andrea Weiler
Paraguayan Association of Biology Students
College of Exact and Natural Sciences - National University of Asuncion

2009 IMC 10 – International Mammalogy Congress
CONICET, National Council of Science and Technology – SAREM, Argentine Society for the Study of Mammals – Mendoza, Argentina

2008 Brazilian Conference of Zoology XXVII
Brazilian Society of Zoology – Federal University of Paraná

2007 Projects Planning Seminar
Junior Chamber International - College of Exact and Natural Sciences

2007 Course in Neotropical Reptiles
Laboratory of Zoology - College of Exact and Natural Sciences

2007 EINAVI - International Meeting of Tourism, Recreation and Experiential Education
Arapacha, strengthening teams

2006 Biology Students Forum II
Paraguayan Association of Biology Students - San Bernardino, Paraguay

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