MODELING THE EFFECTS OF SUBSISTENCE LIVELIHOODS ON MAMMALIAN OCCUPANCY AND UNDERSTANDING THE IMPORTANCE OF VALUES HELD BY MISKITO FOREST USERS FOR CARNIVORE CONSERVATION IN WORKING FORESTS

By

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ABSTRACT

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A detailed abstract with results is included at the beginning of each chapter as they are intended for separate publication. In chapter one, I modeled the impacts of coastal residents practicing forest-based subsistence livelihoods on an assemblage of 15 Neotropical terrestrial mammals. I hypothesized that as hunting and farming pressure increased, occupancy would decrease due to increasing human pressures on the forest. I placed camera traps at 80 unique sites near small communities in 2010, 2012 and 2014 to gather detection-nondetection data and analyzed it with single-season occupancy models using a Bayesian hierarchical framework. I organized species into three distinct groups based on their sensitivity to human disturbance (low, moderate or high). The results suggested that while the impact of subsistence livelihoods on occupancy may have been low, the effect of an advancing cattle-ranching frontier may have been very high. Our inability to directly model the impacts of the agriculture frontier warrants further investigation and immediate action to prevent further decline in mammalian occupancy.

In Chapter two, I investigated the knowledge held by Miskito forest-users and their attitudes about conflict and conservation of six Neotropical carnivores. In July 2014, I interviewed 50 villagers to 1) assess their ability to identify carnivore species when presented with photos and a size reference, 2) ascertain the level of livestock and pet depredation over the five years that coincided with the long-term camera trapping study, and 3) determine community attitudes about conflict and conservation for each of the six carnivore species. The high degree of carnivore knowledge, low instances of depredation, and low perceptions of conflict indicate that participants would likely be open to conservation initiatives aimed at preserving carnivores in this region.

This thesis is dedicated to Dennis and Susan Phillips for their unconditional love, support and encouragement, and to the communities of the Southern Caribbean Autonomous Region in Nicaragua who gave me a new perspective on life, and a second home.

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INTRODUCTION

We are advancing into a new chapter of the Anthropocene, one characterized by rapid defaunation at the hands of human activities (Ceballos et al., 2015). Although protected areas (PAs) have helped us reach minimum biodiversity targets set by the Convention on Biological Diversity (Chape et al., 2005), species are disappearing faster than western scientists can describe them and the buffer zones around these PAs are under eminent threat (DeFries et al., 2010; Lewis et al., 2016). Long-term conservation efforts often fall short due to incompatibility with the needs and livelihoods of humans occupying areas within and around PAs (Ferraro et al., 2011; Hayes, 2006). Guidance from the failures of "fortress conservation" must be used to inform future practices. In the past decade, many researchers have highlighted the need to incorporate the people who rely on these vulnerable ecosystems into conservation efforts (DeFries et al., 2010; Dickman, 2010; Rands et al., 2010). These coupled human and natural systems (CHANS) both within and outside of protected areas dominate the remote regions of the planet and serve as the critical reservoirs of biodiversity (Brooks et al., 2002; DeFries et al., 2005). Conservation programs that acknowledge and promote sustainable practices within these CHANS are the new standard. In remote regions like Nicaragua's Caribbean coast, the nexus of isolation, poverty, and biodiversity present a system that requires investigation to achieve conservation goals.

Nicaragua's remote Caribbean coast is a critical reservoir of biodiversity along the Mesoamerican biological corridor. In 1987, the Caribbean coast was divided into two, large, autonomously governed regions: The Northern Caribbean Autonomous Region (RACN) and the Southern Caribbean Autonomous Region (RACS). Complex relationships between people and wildlife dominate this region. The RACS of Nicaragua is home to a variety of threatened forest ecosystems, including lowland tropical rainforest, mangrove and palm swamps, palm savannah, and seasonally flooded forests. The forests are tightly coupled to the livelihoods of the indigenous, Afro-Nicaraguan, and mestizo colonists that inhabit the coastal region. The small villages of indigenous Ulwa, Miskito, and Rama, as well as Afro-Nicaraguan

Kriol and Garifuna peoples rely on these “working forests” for small-scale farming, hunting, gathering, and fishing for survival. Some villages generate communal income in addition to individual subsistence. The Miskito community of Kahkabila manages their forest for sustainable harvest of hardwoods and the Garifuna village of Orinoco depends in part on cultural tourism for their local economy. Altogether, these communities manage their lands and practice their livelihoods differently, with some villages relying almost entirely on fishing and others devoting more resources to farming. In contrast, mestizo colonists have migrated from the west coast in search of forest to convert into cattle pasture. Residents of indigenous and Afro-Nicaraguan communities have been in conflict with mestizo colonists over land use and rights for many years. In 2003, Nicaragua Law 445 recognized the rights of indigenous and Afro-Nicaraguan peoples to their lands, and guaranteed a process for formal land titling and regulation for each community The indigenous and Afro-Nicaraguan peoples residing in coastal communities have the exclusive rights to land and are prohibited by law from selling it to mestizo colonists. Despite federally recognized land titles, colonists continue to advance their frontier of deforestation into indigenous and Afro-Nicaraguan lands.

Deforestation is not the only threat that follows the cattle-ranching frontier. Once colonists find a forested region, many of them begin to hunt terrestrial mammals for survival, even those that federally protected. The Secretary of Natural Resources of the Autonomous Regional Council (SERENA) and the Ministry of the Environment and Natural Resources (MARENA) are charged with enforcing policies on natural resource use; however, illegal exploitation of natural resources in this region is seldom penalized. When regulations are enforced, it is often carried out in conjunction with the navy and usually limited to marine infractions. Terrestrial hunting laws in Nicaragua ban the harvest of most terrestrial mammal species year round (Vedas Nacionales, 2016). Game species such as agouti, paca, armadillo, white tailed deer, and both species of peccary, have seasonal hunting regulations that ban harvest from the 1st of January to the 30th of June (Vedas Nacionales, 2016). Due to the lack of regulatory infrastructure, most statutes regarding the harvest of terrestrial animals are determined and enforced at the community level of government rather than at the federal level, and carried out by voluntary police. Community leaders in the village of Kahkabila indicated that many communities adopt the same terrestrial harvest bans and regulations as the federal government, although there are exceptions for the retaliation after crop and livestock destruction. The chapters within this thesis aimed to illustrate the complex interplays between people and wildlife in the Southern Caribbean Autonomous Region of Nicaragua.

In chapter one, I sampled and modeled the impacts of coastal residents practicing forest-based subsistence livelihoods on an assemblage of 15 Neotropical terrestrial mammals. I hypothesized that as hunting and farming pressure increased, occupancy would decrease due to increasing human pressures on the forest. I placed camera traps at 80 unique sites near small communities in 2010, 2012 and 2014 to gather detection-nondetection data and analyzed it with single-season occupancy models using a Bayesian hierarchical framework. Due to low detections of rare target species, I organized species into three distinct groups based on their sensitivity to human disturbance (low, moderate or high). In 2010 and 2014, occupancy of low-sensitivity species (agouti, paca, armadillo, coati, white-tailed deer) was affected by distance from road (–), distance from coastline (+), and the interaction between livelihood and distance from community (+). Moderate-sensitivity species (ocelot, margay, jaguarundi, tayra, collared peccary) were only affected by gathering (+) in 2012 and distance from road and coastline (+) in 2014. High-sensitivity species (jaguar, puma, tapir, white-lipped peccary, red brocket deer) were affected by distance from road (+) in 2010 and distance from fresh water (– 2010, + 2014). An increase in farming pressure likely provided food and edge habitat to support generalist herbivores in the low-sensitivity group, preventing their rapid decline and supporting meso-carnivores within the moderate-sensitivity group with prey. High-sensitivity species persisted at low occupancy throughout the study, but responded negatively to riparian development. These results suggest that while the impact of subsistence livelihoods on occupancy was likely low, the effect of an advancing cattle-ranching frontier may have been very high. Our inability to directly model the impacts of the agriculture frontier warrants further investigation and immediate action to prevent further decline in mammalian occupancy.

In Chapter two, I investigated the knowledge held by Miskito forest-users and their attitudes about conflict and conservation of six Neotropical carnivores. In July 2014, I interviewed 50 villagers to 1) assess their ability to identify carnivore species when presented with photos and a size reference, 2) ascertain the level of livestock and pet depredation over the five years that coincided with the long-term camera trapping study, and 3) determine community attitudes about conflict and conservation for each of the six carnivore species. Through the identification interviews, I found that larger carnivores, (jaguars and pumas), were the most accurately identified of the six species. Seventy percent of participants accurately identified ocelots but misclassified the physically similar margays over 70% of the time. Unexpectedly, subjects distinguished jaguarundi as a separate species from the physically similar tayra, although less than 10% of participants could identify jaguarundi correctly. During the second phase, I found that depredation on livestock from 2009 to 2014 was extremely low. Participants reported the highest depredation for dogs, which go in to the forest, rather than for cows, which stay in the community. During the conservation and conflict phase, I found that while most participants perceived competition between themselves and carnivores over wild game, participants did not consider it as conflict. Furthermore, most participants would only persecute a carnivore in response to depredation of livestock, and not in any other scenario. folks were more or less willing to conserve cats is dep could be mitigated. The high degree of carnivore knowledge, low instances of depredation, and low perceptions of conflict indicate that participants would likely be open to conservation initiatives aimed at preserving carnivores in this region.

The goal of my research was to help indigenous communities and other remote populations balance their needs with the long-term health of threatened species and ecosystems by providing insights into the occupancy and conservation of terrestrial mammals in their shared landscapes. Each chapter is written for independent publication with coauthors, and thus, I use we instead of I throughout the text.

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CHAPTER 1

Mammals persist near communities practicing subsistence livelihoods in southeastern Nicaragua

ABSTRACT

In tropical regions, reliance on protected areas to conserve wildlife has come under increased criticism. Remote communities on the southeastern coast of Nicaragua are shifting from predominantly fisheries-based livelihoods to forest-based—creating challenges for conservation of terrestrial mammals. We hypothesized that as hunting and farming pressure increased, occupancy would decrease due to increasing human pressures on the forest. We expected large-bodied mammals to experience the greatest decrease in occupancy, followed by meso-carnivores and, ultimately, generalist prey species. We placed cameras in lowland rainforest adjacent to nine small villages to capture images of terrestrial mammals at 80 unique sites in 2010, 2012 and 2014. We analyzed detection/non-detection data using single-season occupancy models with disturbance, livelihood, and interaction covariates. In 2010 and 2014, occupancy of low-sensitivity species (agouti, paca, armadillo, coati, white-tailed deer) was affected by distance from road (-), distance from coastline (+), and the interaction between livelihood and distance from community (+). Moderate-sensitivity species (ocelot, margay, jaguarundi, tayra, collared peccary) were only affected by gathering (+) and distance from road and coastline (+). High-sensitivity species (jaguar, puma, tapir, white-lipped peccary, red brocket deer) were affected by distance from road (+) and distance from fresh water (- 2010, + 2014). These effects may be closely related to the increasing human presence on the coast. The increase in farming likely provided food and edge habitat to support generalist herbivores in the low-sensitivity group, preventing rapid decline and supporting meso-carnivores within the moderate-sensitivity group. High-sensitivity species persisting at low occupancy throughout the study, but responded negatively to riparian development. These results indicate that while the impact of subsistence livelihoods on occupancy may be low, the effect of an advancing cattle-ranching frontier may be very high and warrants immediate action to prevent further decline in mammalian occupancy.

INTRODUCTION

In tropical regions, the reliance on protected areas to conserve wildlife has come under increased criticism (Liu et al., 2001). The importance of integrative approaches to conservation (e.g. management of human-wildlife social-ecological systems) is gaining recognition (Liu et al., 2007), but our knowledge of how to manage these areas is limited. Much of the literature on Neotropical wildlife, and in particular mammal communities, comes from studies conducted within protected areas, rather than forests that are actively used by humans for survival (Ferraro et al., 2011). While valuable, studies focusing on the conservation of mammalian communities within reserves have limited applicability when managers want to create or preserve corridors that exist within a dynamic human landscape (Porter-Bolland et al., 2012). Rapidly changing resource levels drive local users to shift their activities and practice multiple livelihoods, often resulting in multifaceted threats to wildlife and creating challenges for conservation initiatives (Arts et al., 2012). These working forests—defined as forests outside of protected areas which are actively used for subsistence resource extraction—are the reality for most Neotropical mammals (Zarin et al., 2005). We know little about the impacts of human activities on wildlife in these working forests, which has created a major need for this type of research.

Remote communities on the southeast coast of Nicaragua are shifting from predominantly fisheries-based livelihoods to forest-based farming, hunting, and gathering (Stevens, 2014). As local users shift their practices to more intensively use working forests, there may be substantial implications for the distribution of mammals and the approaches needed for their conservation. Nicaragua's reputation for having one of the largest remaining contiguous tracts of forest in Central America is quickly changing. Recent assessments of global forest loss have highlighted Nicaragua as an epicenter of extreme deforestation (Hansen et al., 2013). Despite being the largest country in the region, Nicaragua has the lowest population in Central America due to civil conflict that lasted decades (Stevens et al., 2011). Nicaragua's remote east coast comprises two autonomous regions that are governed by the Afro-

Caribbean and indigenous groups that reside there. The forests that dominate these regions form a segment of the Mesoamerican wildlife corridor, which connects well-protected reserves in Honduras to those in Costa Rica. The corridor is vital to maintaining genetic flow between these parks and throughout Central and South America. This corridor is shrinking rapidly in the face of an agricultural frontier that is encroaching on Afro-Caribbean and indigenous territories. Despite the fact that these regions tout multiple reserves on maps, they are woefully unprotected. Zeller et al. (2011) highlighted this region as critical to maintaining the integrity of this corridor, especially for wide-ranging mammals such as jaguars and tapirs.

Within this shrinking landscape, a relatively intact assemblage of Neotropical mammals persists (Jordan and Hulse, 2011). The assemblage we focus on in this study consists of six carnivores and their prey. Some of these species, such as jaguars (*Panthera onca*) and tapirs (*Tapirus bairdii*), are of international conservation concern (Table 1.3). Many of the generalist herbivores and omnivores in this assemblage are important game species for subsistence hunting, such as agouti (*Dasyprocta punctata*), paca (*Cuniculus paca*), armadillo (*Dasypus novemcinctus*), coati (Nasua narica) and white-tailed deer. Game species like collared peccaries (*Pecari tejacu*), white-lipped peccaries (*Tayassu pecari*) and red brocket deer (*Mazama americana*) are becoming rare because they require more space or less disturbed habitat. While deforestation is widely recognized as the primary cause of biodiversity decline in this region and worldwide (Brooks et al., 2002; Foley et al., 2005; Turner, 2016), causes of decline in developing regions are especially multifaceted. Although these species may persist within working forests, their occupancy is likely to be negatively impacted by many anthropogenic pressures. Identifying the other drivers of the decline for these species is paramount to maintaining their populations in these human-dominated landscapes.

Members of coastal communities in and around Pearl Lagoon have long endured isolation from economic markets and federal infrastructure as a means of income (Stevens, 2014). During this study, only one unpaved road constructed in 2007 connected the west and east coast. Rather than provide an opportunity for coastal residents to sell their farming products, cheap goods from the west flooded the local market (Kramer et al., 2009). Residents report rates of unemployment and underemployment in the autonomous regions at over 80% (Jamieson, 1998; pers. comms: Oskar Theodore-Schwartz, Lauterio Tomas Fox, 2012, Kahkabila, Nicaragua). This leads most coastal residents to practice multiple subsistence and artisanal livelihoods to secure food and minimize risk. Residents most commonly practice fishing, farming, hunting, gathering, and timber harvest. The effects of these livelihoods on neighboring wildlife depend largely on their scale, the number of practitioners, and how far these activities radiate into the forest.

In this study we aimed to model the effects of human disturbance on the occupancy of 15 mammalian species within a single-season occupancy framework (Royle and Kéry 2007). We divided species into three groups based on a combination of morphological traits, ecological needs, and reported sensitivity to human activities (See methods; Table 1.3). We hypothesized that as hunting and farming pressure increased, occupancy would decrease due to increasing human pressures on the forest. We expected large-bodied mammals to experience the greatest decrease in occupancy, followed by meso-carnivores and, ultimately, generalist prey species. Table 1.2 summarizes the predicted effects of each disturbance and habitat covariate in the model.

METHODS

Data collection

We collected camera-trap images of terrestrial forest species from 2009 – 2014 in the Southern Caribbean Autonomous Region of Nicaragua (Fig. 1.1). This analysis used data from the 2010, 2012, and 2014 camera seasons (May – November) because they are the most complete seasons. We placed cameras near nine communities north of Bluefields, Nicaragua. The camera sites ranged over 70 km from the northernmost town of Kara on the Rio Grande de Matagalpa to the southernmost cameras a few km south of Pearl Lagoon (Fig. 1.2). We selected data with a two-year interval between camera seasons to allow time for significant development in the human landscape. The camera network was designed by Jordan and is described in detail in Jordan (2015). Based on the accessibility of the land during initial placement, we established between two and eight camera sites in the forest adjacent to each of the nine communities. The study area was divided into a 4 km^2 grid and a random number generator was used to determine camera placement at specific cells within the grid (Jordan, 2015). We maintained a 2 km buffer between cameras to provide some degree of sampling independence. This minimum distance was chosen in accordance with the small home ranges of common species such as agoutis and pacas (Aliaga-Rossel et al., 2008; Beck-king et al., 2017). Because the felids and other large mammals in our study have large home ranges (Rabinowitz and Nottingham, 1986; Foerster and Vaughan, 2017), camera grid design was not able to independently sample the home range of individuals. We collected data at the same sites from year to year except for when local deforestation or burning had occurred since the previous field season. In such cases, we replaced damaged cameras and relocated the site within 400 m of the previous site to sample from the same local community of wildlife. We used Model 119455C and 119435C motion-triggered Bushnell Trophy Cams™ for the duration of the study. We aimed for to maintain cameras at a single site for at least 57 days between mid-May and early November.

Image processing

The raw camera images required processing before they could be used for analysis. We used the *Renamer* software to rename all image files based on the date and time stamp contained in their meta-data (Version 4.1; www.den4b.com/products/renamer). For each camera station, within each year, the species of animal within each photo was manually identified. To aid in species identification, we referred to *The Mammals of Costa Rica* (Wainwright, 2007) and *A Guide to the Birds of Costa Rica* (Stiles and Skutch, 1989). We organized photos within each trapping year at the site level by separating species detections into distinct folders. If a camera detected the same species consecutively, we considered detections independent (not from the same individual animal) if a minimum of five hours had passed (Jordan, 2015). Thus, we did not include multiple detections of the same species at a single camera site within a five-hour period in the dataset. We processed photos depicting multiple individuals of one species the same as single-individual photos because of limitations in the processing package. To manage detections and conduct all further analyses, we used the R programming software (Version 3.3.2; https://www.R-project.org/). We used the *camtrapR* package to generate detection histories for each species at each camera site within each year (Version 0.99.8; https://CRAN.R-project.org/package=camtrapR). To reflect the average cycling period of large mammals within their home ranges, we chose a 10-day sampling period for the detection histories (Jordan, 2015). The detection histories reported detection, nondetection, and "no data" values for each species at each camera site.

Anticipating low detections of rare target species, we combined the detection histories of 15 species into three species groups based on their sensitivity to human disturbance (Table 1.3). The low-sensitivity group included the agouti (*Dasyprocta punctata*), lowland paca (*Cuniculus paca*), white-tailed deer (*Odocoileus virginianus*), white-nosed coati (*Nasua narica*) and nine-banded armadillo (*Dasypus novemcinctus*). The moderate-sensitivity group included the ocelot (*Leopardus pardalis)*, margay (*Leopardus weidii*), jaguarundi (*Puma yagouaroundi*), tayra (*Eira Barbara*) and collared peccary (*Pecari tajacu*). Lastly, the high-sensitivity group included the jaguar (*Panthera onca*), puma (*Puma concolor*), tapir (*Tapirus bairdii*), red brocket deer (*Mazama americana*) and the white-lipped peccary (*Tayassu pecari*).

Data analysis

Models, terminology, and notation are derived from Kéry and Schaub (2012). In order to estimate the impacts of livelihoods and disturbance on these mammal communities, we analyzed the image data using single-season occupancy models with covariates. Single-season occupancy models are state space models that consist of an ecological and observation process characterized spatially over time. The ecological process describes the latent or true state of occupancy for each species, and the observation process model helps estimate this latent state by accounting for imperfect detection. True occupancy (z_i) is Bernoulli distributed with probability (ψ_i). Observed occupancy ($y_{i,j}$) at site i, and sampling occasion j, given true occupancy at site i (z_i), is Bernoulli distributed with probability ($z_{i,}p_{i,j}$), where $p_{i,j}$ represents the probability of detection. In summary, the ecological process is defined by:

$$\mathrm{z}_i \sim Bernoulli(\psi_i)$$

, and the observation process is defined by:

$$y_{i,j}|z_i \sim Bernoulli(z_i p_{i,j})$$

There are several critical assumptions for a single-season occupancy model. System closure and the omission of false positive identification cannot be violated (Kéry and Schaub 2012). A camera site must be treated as a closed system over the sampling period (j) (MacKenzie et al., 2006). The 10-day period in which sampling takes place is a short enough time to assume a system remains closed. Required model assumptions also prohibit false positive identification of animals in photos during the processing phase (Kéry and Schaub 2012). This assumption is a particular concern for identification of the margay, ocelot, jaguarundi and tayra. With only minor differences in size, and a wide variation in pelage there is a strong resemblance between ocelots and margays. Jaguarundis also strongly resemble tayras, which are nearly the same size and also uniform in color. To distinguish between these species, we examined differences in facial musculature and stance. In order to mitigate the risk of false positive identifications, we reviewed all carnivore detections as a research team.

We fitted each model with site-level disturbance and community-level livelihood covariates to explain the patterns in occupancy experienced by a given sensitivity group. Each model included four standardized distance covariates, one of three livelihood covariates, and an interaction effect. Because the surveys took place over both dry and wet periods of the year—and species like jaguars and tapir tend to congregate around water—distance from fresh water was used as a habitat covariate. In addition to determining livelihood types and their scale in nine coastal communities, we also generated site-level covariates that represented different means of forest access for people. The 2009 road to Pearl Lagoon provided unprecedented access to impoverished mestizo migrants in search of forest to burn and convert to cattle pasture. Because we were unable to directly measure the extent of the agricultural frontier, we used the distance from camera site to road as a proxy for this disturbance. Eight of the nine communities we included in the study rely on boats for nearly all transportation. Thus in most areas, the coastline represents important point of access for natural resource users and we also included distance from camera site to coastline as a disturbance covariate. In all, covariates (with abbreviations) included: distance from road to camera (distRoad), distance from coastline to camera (distCoast), distance from camera to community (distComm), distance from fresh water to camera (distFW), number of hunters (hunt), farmers (farm), or gatherers (gath) in the nearest community, and an interaction effect between distance from community and a given livelihood.

The covariate data were generated during socioeconomic surveys conducted in the coastal communities within each camera trapping season by Dr. Kramer and his collaborators at the University of the Autonomous Regions of the Nicaraguan Caribbean Coast (Kramer et al. 2017). Data for each livelihood (hunting, gathering and farming) were provided as a proportion of total interviewees, which we then applied to census data for each community to estimate the total number of people participating in any given livelihood (Beer and Vanegas, 2007, Casillas et al. 2010). Due to a limited number of values for these community-level covariates, we converted all values to a "high" or "low" categorical variable. We classified all values above the group mean for each livelihood as "high" pressure, while we classified values below the mean as "low" pressure. Because most interviewees practiced multiple livelihoods, we fitted each livelihood practice in a separate model.

We fit the following candidate models for each sensitivity group, within each year:

Hunting model: $logit(y_{i,j}) = \alpha + \beta_d * distComm_i + \beta_h * hunt_i + \beta_d * \beta_h * interaction_i + \beta_c * distCoast_i + \beta_r * distRoad_i + \beta_{fw} * distFW_i$

Gathering model: $logit(y_{i,j}) = \alpha + \beta_d * distComm_i + \beta_g * gath_i + \beta_d * \beta_g * interaction_i + \beta_c * distCoast_i + \beta_r * distRoad_i + \beta_{fw} * distFW_i$

Farming model: $logit(y_{i,j}) = \alpha + \beta_d * distComm_i + \beta_f * farm_i + \beta_d * \beta_f * interaction_i + \beta_c * distCoast_i + \beta_r * distRoad_i + \beta_{fw} * distFW_i$

RESULTS

Of the 80 potential camera sites in the network, we retrieved functioning cameras from 67 sites in 2010, 52 sites in 2012, and 50 sites in 2014. Cameras were operational for 12,012 total trap nights and the average camera was operational for ≈ 71 days (Table 1.1). Cameras detected all 15 target species in each year with the exception of red brocket deer in 2012. The number of detections for all but four species was within one standard deviation of the mean number of detections for their species sensitivity group (Table 1.3). Only puma, jaguarundi, tayra and agouti fell within two standard deviations the mean. This was expected for puma, tayra and agouti, as each species is likely the most common within their respective sensitivity groups. The low jaguarundi detections aligned more closely with the high-sensitivity group, but this species is notoriously difficult to detect (Holbrook et al., 2013), and the literature suggests that they adapt well to disturbed habitat (Giordano, 2016).

The number of occupied sites and total detections declined over the four-year period for both the low and moderate species sensitivity groups (Figs. 1.4a, 1.4b). The low-sensitivity group experienced a steep decline in the number of occupied sites between 2010 and 2012 (62 to 45), but remained relatively stable at the new low between 2012 and 2014 (45 to 47). The number of occupied sites and total detections for the moderate-sensitivity group declined over the entire four-year period, eventually reaching the same state as the high-sensitivity group (31 to 16). The high-sensitivity group was consistently detected at very few sites throughout the study (12 ± 2).

We fit three candidate livelihood models (hunting, gathering, farming) to three species sensitivity groups within each year, for a total of 27 single-season occupancy models. Fourteen of these models yielded estimates of significant covariate effects (Table 1.5). Covariate estimate effects were significant if their 95% credibility intervals did not overlap zero. All models converged with a criterion of $\hat{R} < 1.10$. We calculated deviance information criteria (DIC) for the purposes of comparing the three livelihood models within a given year and sensitivity group. DIC values were only reported for models with significant covariate effects (Tables 1.4a – 1.4d).

Low-sensitivity species group

All three livelihoods models yielded significant covariate effect estimates during 2010 and 2014 (Table 1.5). Increasing distance from the road negatively impacted occupancy rates of this species group (Fig. 1.5a), while increasing the distance from coastline had a positive effect (Fig. 1.5b). During 2010, the interaction effects between livelihood (hunting, gathering, farming) and distance from community in each model were also significant predictors of occupancy. Because hunting, gathering, and farming were practiced at the same level (all low or all high pressure) for all but one community, the three models yielded nearly identical covariate effects estimates. We plotted occupancy probability against distance from community under curves of high and low livelihood covariate pressures (Fig. 1.5c). Under high pressure, occupancy is highest for low sensitivity species closest to the community and drops with increasing distance. Under low pressure, occupancy is slightly lower closer to the community, but remains high (> 0.85) regardless of distance. In 2014, only the main effects of hunting, gathering, and farming positively influenced occupancy.

Moderate-sensitivity species group

The gathering models in 2012 and 2014 were the only two models that yielded significant covariate effect estimates for this species sensitivity group. In the 2012 model, the main effect of gathering positively influenced occupancy probability. In 2014, increasing distance from both the road and the coastline yielded a positive effect on occupancy probability (Figs. 1.6a, 1.6b).

High-sensitivity species group

The livelihood covariates did not have a significant effect on occupancy for the high-sensitivity species. In 2010, increasing distance from road positively influenced occupancy probability (Fig. 1.7a) and increasing distance from fresh water negatively influenced occupancy (Fig. 1.7b). In 2014, increasing distance from fresh water had the opposite effect, and instead, positively influenced occupancy (Fig. 1.7c). There were no significant covariate effects estimates for high-sensitivity species in 2012.

DISCUSSION

There was an overall decline in occupancy of mammals during the study period. Except for the high-sensitivity species, which we detected at consistently few sites throughout the study, detections of both the low-sensitivity and moderate-sensitivity species declined in this human-occupied landscape. This study lends evidence to a growing body of literature pointing to the possibility of a faunal collapse in the very near future in a key region of the Mesoamerican Wildlife Corridor. Herein, we discuss the results first by sensitivity group and then over the broader scale of the study. We address requirements for future research in this region and suggestions for preventing the collapse of this important working forest.

Low-sensitivity species group

As expected, the five prey species that made up the low-sensitivity group (agouti, paca, armadillo, white-tailed deer, and coati), persisted at the highest rates of occupancy within close proximity to coastal communities ($\Psi \approx 0.92 – 0.98$). The most notable changes for the low-sensitivity group were the sharp decline in the number of occupied sites between 2010 and 2012 (Fig. 1.4a). In 2010, occupancy was higher further from the coast, but lower further from the Pearl Lagoon road. It is possible that proximity to the road was also associated with a higher likelihood of encountering edge habitat, which most species in this group prefer (Aliaga-Rossel et al., 2008; Beck-king et al., 2017). The interaction effect between distance from community and livelihood pressure was also significant for each model in 2010 (Fig. 1.5c). All two-level categorical livelihood covariate values were the same level (i.e. all low or all high within a single community) with the exception of one community where they differed. This meant that the hunting, gathering, and farming models yielded the same covariate estimates and thus the same interaction effect. Under low livelihood pressure, occupancy is lower closer to the community ($\Psi \approx 0.88$) and higher further from the community ($\Psi \approx 0.99$). Under high livelihood pressure, occupancy is highest closer to the community and declines rapidly as distance from the community increases ($\Psi \approx 0.99$ to $\Psi \approx 0.20$). The most logical explanation for this result for the hunting model would be that high hunting pressure only occurs when animals are present in high numbers closer to community—hunting is a response to occupancy rather than occupancy levels a response to hunting pressure. For the gathering model, forest gathering and occupancy rates are interrelated in that people only make a large gathering effort if forage is in excess, the same forage that the herbivores in this group feed on. In contrast, high farming pressure means an increased number of crops on farms located in the forest that these herbivores can exploit. In sum, occupancy changes hunting pressure, occupancy and gathering pressure are interrelated, and farming pressure increases occupancy by creating more food.

Another possible driver of increased occupancy near communities is that the eastward-advancing agricultural frontier is narrowing the remaining forest and forcing mammals eastward to occupy areas closer to the communities (Fig. 1.3). In 2014, the main effect of livelihood was the only significant effect. For hunting, gathering, and farming, occupancy was higher with the "high" livelihood level. This aligns well with the estimated effects in 2010, suggesting that the low sensitivity species group persists well in close proximity to communities practicing subsistence livelihoods.

Moderate-sensitivity species group

Occupancy of the moderate-sensitivity group, which included ocelots, margays, jaguarundis, tayras, and collared peccaries, was not well explained by the covariates in these models (Table 1.5). The gathering models in 2012 and 2014 were the only models that yielded significant covariate effects. For this group, high levels of gathering pressure were associated with higher occupancy ($\Psi \leq 0.89$). Because four of the five species in this group are carnivores that feed on species in the low-sensitivity group, it is likely that more gatherers in a community in a given year are associated with more available forage for both people and herbivores. Furthermore, the last species in the moderate group is the collared peccary, an herbivorous species that travels in herds and requires a lot of forage, which could corroborate this association. Thus, these results also align well with the results for the low-sensitivity group in 2014.

High-sensitivity species group

While detections of high-sensitivity species (jaguars, pumas, tapirs, red-brocket deer, and white-lipped peccaries) were very low (less than 18% of sites), they remained relatively stable over the four-year period (Fig. 1.4b). A sister study from 2010 – 2014 to the south of our camera network in a reserve with less human influence detected these species much more frequently and estimated occupancy probability of these species as high as 0.80 (Jordan et al., 2016). This suggests the high-sensitivity species in our study area already existed below their recent historical rates of occupancy and that the events driving their decline took place prior to 2010. It is possible that the extreme colonization of the Wawashang Reserve near the north of our study area has disrupted the corridor between population strongholds for these species to the north of Karawala and to the south in Indo Maiz (Fig. 1.3). One interesting result that further illustrates this decline is the change in significant covariate effects between 2010 and 2014 (Figs. 1.7b, 1.7c). In 2010, occupancy was higher further from roads and closer to fresh water (rivers) as we expected. This result aligns well with previous literature that cites low tolerance to human activity such as roads, and a tendency to congregate around fresh water sources for most members of this group (Terwilliger, 1978; Mayer and Wetzel, 1987; Crawshaw and Quigley, 1991). However, in 2014 the effect of the road disappears, and we see a reverse effect of lower occupancy closer to rivers. The rivers that these species relied upon in 2010 were also the "highways" for agricultural expansion in 2012 and 2014, destroying riparian habitat in many areas and, we suspect, driving this shift away from rivers. During our fieldwork, the research team noted a dramatic increase in riparian settlements by mestizo cattle ranchers between 2010 and 2014. Essentially, these rivers are now functioning like roads would in the terrestrial landscape, and providing pervasive access to humans who clear large patches of forests and hunt all species opportunistically.

When examining the covariate estimates by year rather than by sensitivity group, 2012 had the fewest models with significant covariate effects. While this season had fewer operational cameras than 2010 or 2014, detections remained robust within each species group (Table 1.3, Fig. 1.4b). This suggests that processes other than the covariates in the model influenced the occupancy of terrestrial mammals during this year. One potential explanation is that the trapping in 2012 took place during a La Niña climatic oscillation, a phenomenon that often results in extreme deviance from typical temperature and precipitation conditions (Trenberth and Hurrell, 1994). Because the trapping season started in mid-May in 2012, which is right before the start of the rainy season, a delay in rain or a rapid influx of rain could have influenced normal patterns in occupancy.

Perhaps the greatest threat to the wellbeing of both the coastal human settlements and terrestrial mammal communities is the aforementioned agricultural frontier. The degree of disturbance caused by migrant farmers from the west coast is much greater than from coastal farmers (Williams, 2015). This can be primarily attributed to differences in land use. Mestizo farmers burn very large patches of forest to prepare pasture for cattle grazing, as compared to coastal farmers who typically burn small patches for growing crops for personal consumption. Due to their longstanding history farming lowland rainforest soils, coastal residents know that cattle pastures can only be productive for a few years before depleting the soil entirely and choose to graze their small herds within the bounds of the community itself. Because pasture has to continue expanding to sustain a herd of cows over many years, the fragments of forests between mestizo farms also grow smaller and smaller. Losing the mosaic of forest between what used to be only small, dispersed, subsistence farms, has an extreme impact on connectivity for the entire region. Because of the importance of the agricultural frontier as a driver, the most important “next step” for subsequent analyses will be generating a covariate that accurately depicts the extent of the mestizo agricultural frontier throughout the region. In the two years of sampling between 2012 and 2014 alone, settlements in and around Wawashang Reserve have increased substantially (pers comms Miguel Ruiz Galeano, director Kahka Creek Rainforest Reserve within the Wawashang). New georeferenced layers of forest loss data from 2014 were recently made available (Hansen et al., 2013). In future analyses, we will use these layers to generate this missing covariate, and more holistically model the occupancy of the terrestrial mammal community.

Conceivably, the most important take-home message for this study is that traditional livelihoods practiced in the forests surrounding small coastal villages are having a very low impact on the mammal communities residing within their working forests. These results suggest that there is hope for spatial compatibility between coastal inhabitants and these mammals in the future if deforestation from the agricultural frontier can be halted. Coastal communities are so tightly linked to their working forests that further deforestation could also threaten them directly. It is the expressed interest of some communities in our study area to preserve traditional ways of life and maintain a functional forest from which they can continue to sustain themselves on (Kahkabila, Karawala and Orinoco residents, personal communications). Through focus groups, some community leaders have also indicated a desire to preserve their forests for tourism initiatives, a fate which is out of their hands under current enforcement practices (Andrea Allen, personal communication). Some communities have started to take enforcement into their own hands and evict people from illegal settlements on their land titles, but do not have the resources to monitor the whole forest regularly.

The corridor function of this coastal region is extremely threatened by the advancing agricultural frontier and possibly already disrupted by the heavy deforestation of the Wawashang Reserve. The Mesoamerican biological corridor is weakened by this and other threats. Federal development of the autonomous regions and the effect of climate change also present future challenges to maintaining connectivity for terrestrial mammals along the Atlantic coast. In 2016, the Indio Maiz reserve to the south of our study area was hit by a category 2 hurricane that caused massive deforestation. This reserve functions as a reservoir for the populations we studied to the north and a global reservoir for other rare and endangered species. As these storm events increase in frequency with climate change, their effects coupled with rapid deforestation may push mammal communities past their point of resilience. This reserve is also threatened by the potential development of a massive interoceanic canal that would create an impenetrable wall to nearly all terrestrial mammal species (Jordan et al., 2016).

With the Southern Caribbean Autonomous Region under multiple threats to deforestation and traditional ways of life, it is imperative that managers implement the immediate protection needed from illegal settlements and encourage sustained locally generated management of these complex landscapes. Empowering indigenous and Afro-Caribbean communities with the resources to enforce their land titles is the most important step we can take to preserve these working forests for both people and animals. The most successful conservation initiatives are those in which conservation goals are well aligned with sustainable sources of income or subsistence for stakeholders. Such de-colonial approaches to conservation issues show great promise for implementation in working forests like these in which there is scientific evidence for coexistence.

APPENDICES

APPENDIX I: Tables

Table 1.1: Summary of trap nights by year

Year	Total	Mean	Min	Max
2010	4,764	71.10	10	132
2012	3,733	71.79	26	131
2014	3,515	70.30	5	128
All years	12,012	71.50	5	132

All units are in days/nights.

Table 1.2: Predicted covariate effects on occupancy rates by sensitivity group

Covariate	High	Moderate	Low
distance from community	+	+	+
hunting pressure	–	–	–
gathering pressure			+
farming pressure	–	–	+
distance * hunting pressure	–	–	–
distance * gathering pressure			+
distance * farming pressure	–	–	–
distance from road	+	+	+
distance from coast	+	+	+
distance from fresh water	–		

High, moderate and low described the three species sensitivity groups. Positive effects on occupancy are represented with a "+" and negative effects on occupancy are represented with a "–". A missing symbol indicates a prediction of "no effect". Distance from community is abbreviated as "distance" for the interaction covariates.

Table 1.3: Number of detections and conservation status for each species within each high, moderate and low sensitivity group

High			Moderate			Low		
Species	*cons. status*	*detections*	*Species*	*cons. status*	*detections*	*Species*	*cons. status*	*detections*
Jaguar	NT	4	Ocelot	LC	19	Agouti*	LC	150
Puma*	LC	7	Margay	NT	5	Armadillo	LC	56
Tapir	EN	3	Jaguarundi*	LC	4	Coati	LC	61
Red-brocket deer	DD	3	Collared peccary	LC	16	Paca	LC	91
White-lipped peccary	VU	3	Tayra*	LC	26	White-tailed deer	LC	137
	total	20		*total*	70		*total*	495
	mean	4		*mean*	14		*mean*	99
	standard deviation	1.7		*standard deviation*	9.4		*standard deviation*	43

*Detections are from the 2010 trapping season. An * indicates a species with a value that is two standard deviations from the group mean. All other species were detected within one standard deviation from the group mean. Cons. status = IUCN global conservation status. EN = endangered, VU = vulnerable, NT = near threatened, LC = least concern, and DD = data deficient.*

Table 1.4a: DIC comparison of 2010 high-sensitivity models

Model	Deviance	pD	DIC	ΔDIC
Hunting	145	28.4	173	0
Gathering	145	28.4	173	0
Farming	147	27.5	174	1

Table 1.4b: DIC comparison of 2014 low-sensitivity models

Model	Deviance	pD	DIC	ΔDIC
Hunting	462	13.8	476	0
Gathering	462	13.8	476	0
Farming	464	19.9	484	8

Table 1.4c: DIC comparison of 2014 moderate-sensitivity models

Model	Deviance	pD	DIC	ΔDIC
Hunting	159	19.2	170	0
Gathering	151	14.3	173	3
Farming	161	18.8	180	10

Table 1.4d: DIC comparison of 2014 high-sensitivity models

Model	Deviance	pD	DIC	ΔDIC
Hunting	170	8.27	178	0
Gathering	171	12.7	184	6
Farming	171	15	186	8

We provide DIC for occupancy models of species sensitivity groups within years which yielded two or more models with significant covariate effects. All models had the same number of parameters. The results of all models with significant covariate effects were interpreted in the discussion regardless of DIC.

Table 1.5: Covariate estimates for each livelihood model, for each sensitivity group within each year.

	inter	comm	hunt	comm* hunt	road	coast	fw	inter	comm	gath	comm* gath	road	coast	fw	inter	comm	farm	comm* farm	road	coast	fw
2010																					
high	3.37	5.6	0.46	-0.25	**7.29**	-0.74	**-6.6**	3.37	5.6	0.50	-0.25	**7.29**	-0.74	**-6.6**	0.79	4.76	2.97	0.88	6.8	-0.82	**-6.86**
mod	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
low	**7.55**	5.73	-0.8	**-4.45**	**-2.38**	**3.11**	2.74	**7.55**	5.74	-0.8	**-4.45**	**-2.38**	**3.11**	2.74	**7.51**	5.72	-0.78	**-4.44**	**-2.38**	**3.11**	2.74
2012																					
high	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
mod	.	.	.	.	.	.	.	4.75	-2.27	**6.87**	0.46	-0.7	0.25	-1.85		.	.	.	.	.	.
low	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2014																					
high	1.02	-3.79	5.84	-5.86	4.7	-1.71	**6.24**	3.93	-3.6	4.2	-5.3	4.63	-3.02	**4.94**	-0.2	-1.55	5.68	-4.72	3.93	-1.23	**5.72**
mod	.	.	.	.	.	.	.	4.85	-7.25	1.1	4.36	**5.57**	**6.32**	0.47	.	.	.	.	.	.	.
low	5.75	0.37	**6.58**	0.4	1.079	-0.78	1.44	5.75	0.73	**6.67**	0.04	-0.07	-0.32	1.31	5.71	-0.59	**6.23**	0.41	-2.35	1.09	1.91

A ***bold*** *value indicates a significant covariate effect. A "." indicates an insignificant covariate effect (95% CRI overlapped zero). Inter = intercept, comm = distance from community to camera, hunt = high or low hunting pressure, gath = high or low gathering pressure, farm = high or low farming pressure, road = distance from road to camera, coast = distance from coast to camera, and fw = distance from fresh water to camera. In the 2010 trapping season, the covariate values for hunting, gathering, and farming in each model were all at the same level (all low or all high) for all but one community. Thus, models yielded nearly identical covariate coefficient estimates.*

APPENDIX II: Figures

Figure 1.1: Study area within Nicaragua: The Southern Caribbean Coast Autonomous Region (R.A.C.S.) is primarily composed of lowland tropical rainforest, palm savannah, palm swamp and mangrove swamps. The municipality and country shape files for ArcGIS were publicly available on www.mapcruzin.com

Figure 1.2: Camera sites, communities, and covariate features: Distance covariates were generated at the site level and measured using the nearest feature. The freshwater, coastline, and road shape files for ArcGIS were publicly available on www.mapcruzin.com.

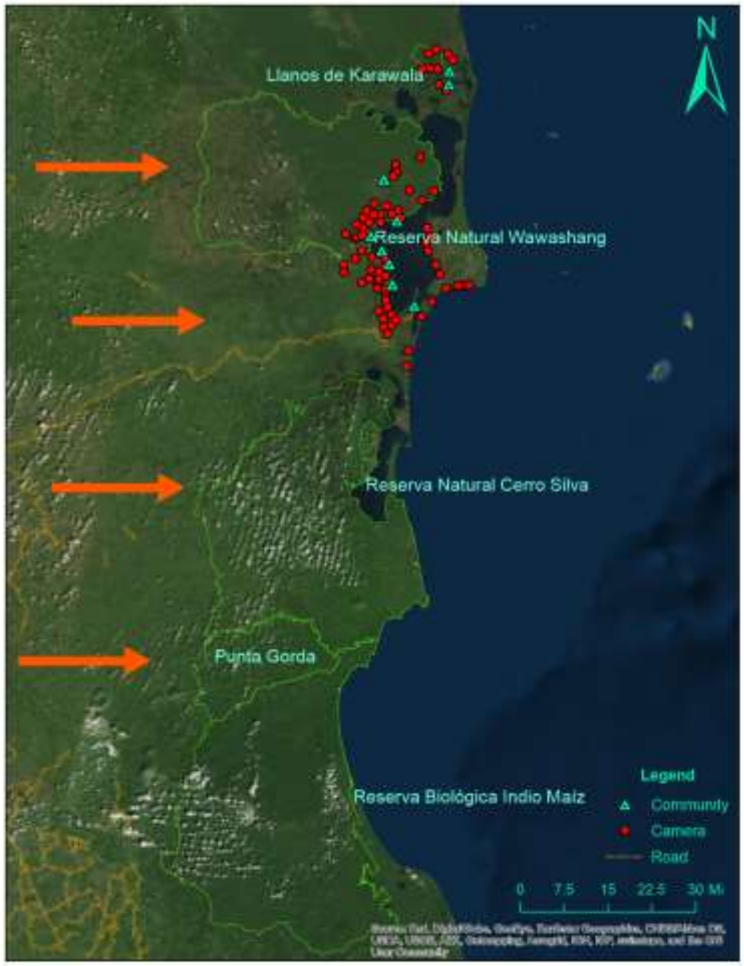

Figure 1.3: Reserves in the R.A.C.S. and the direction of the advancing agricultural frontier: Orange arrows represent the direction of the advancing agricultural frontier. Wawashang Reserve has experienced the greatest and most rapid deforestation of any reserve in the R.A.C.S. Indio Maiz Reserve remained the most intact throughout the study period, but has since been damaged by a category 2 hurricane. All three southernmost reserves would be severely damaged by the construction of the proposed interoceanic canal. The reserve shape files for ArcGIS were publicly available on www.mapcruzin.com.

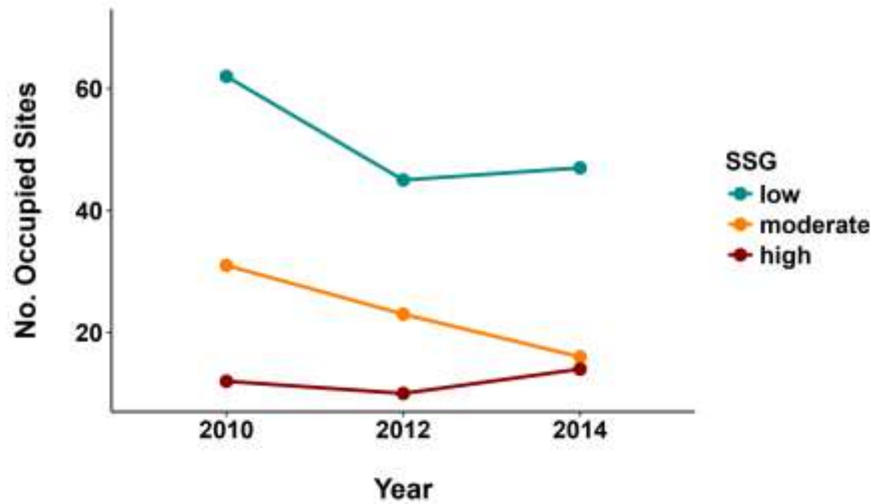

Figure 1.4a: Number of sites occupied by each species sensitivity group (SSG) in each year

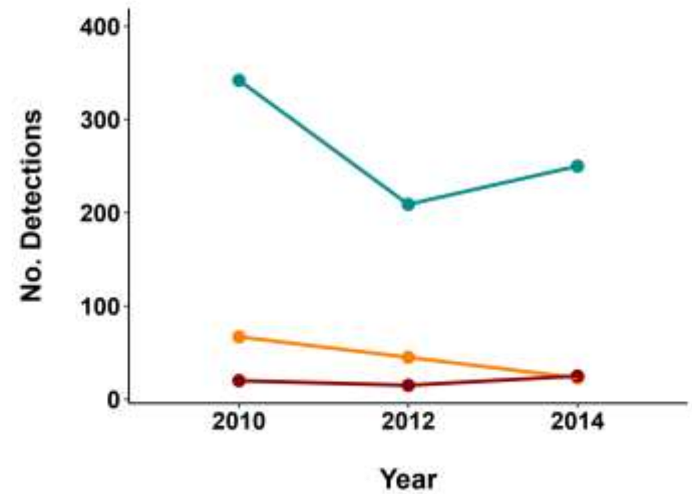

Figure 1.4b: Number of detections for each species group (SSG) in each year

Low-sensitivity species were detected less frequently and at fewer sites after the 2010 trapping season. The number of detections and sites occupied by moderate-sensitivity species declined dramatically throughout the study. High-sensitivity species were consistently detected at few sites throughout the study, with only one detection per site being normal.

Low-sensitivity Species Models

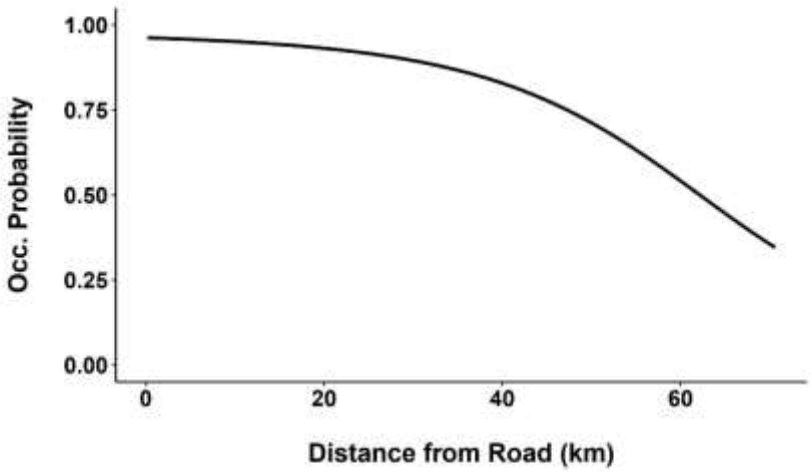

Figure 1.5a: Significant distance from road covariate effect in 2010 Occupancy probability decreases as distance from the road increases.

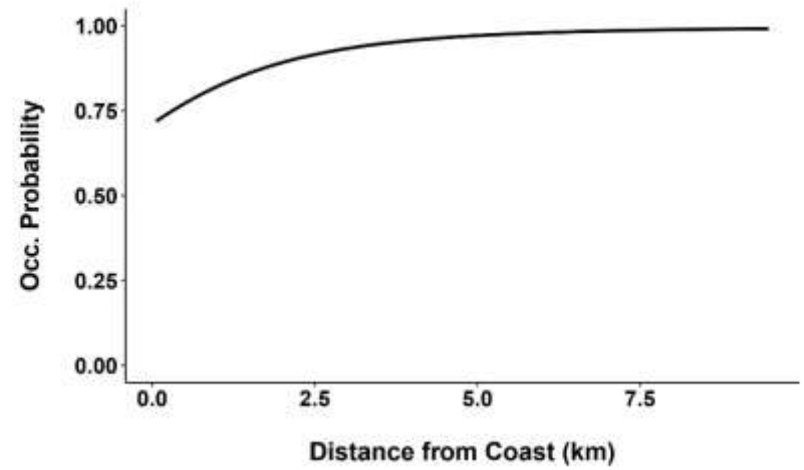

Figure 1.5b: Significant distance from coast covariate effect in 2010 Occupancy probability increases as distance from the coast increases.

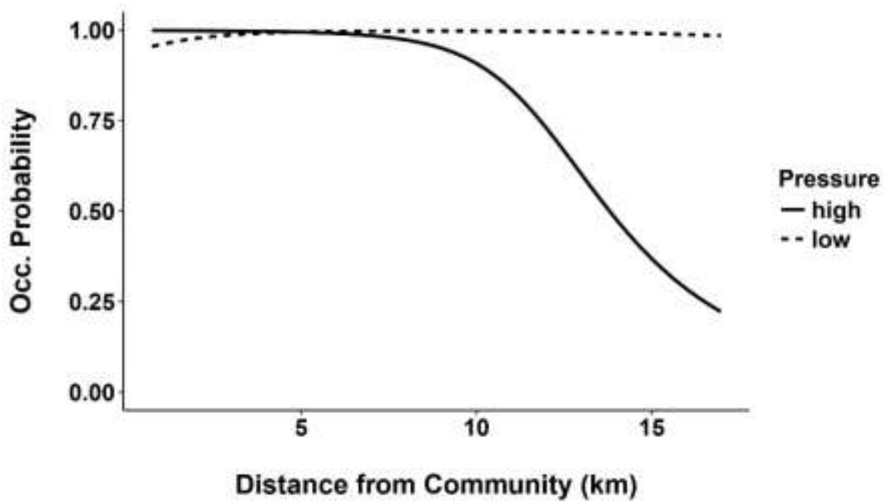

Figure 1.5c: Significant interaction between distance from community and livelihood: Livelihood is a two-level categorical covariate with "high" or "low" pressure. This graph depicts the significant interaction effect in all three livelihood models (hunting, gathering and farming) because these models yielded nearly identical estimates.

Moderate-sensitivity Species Models

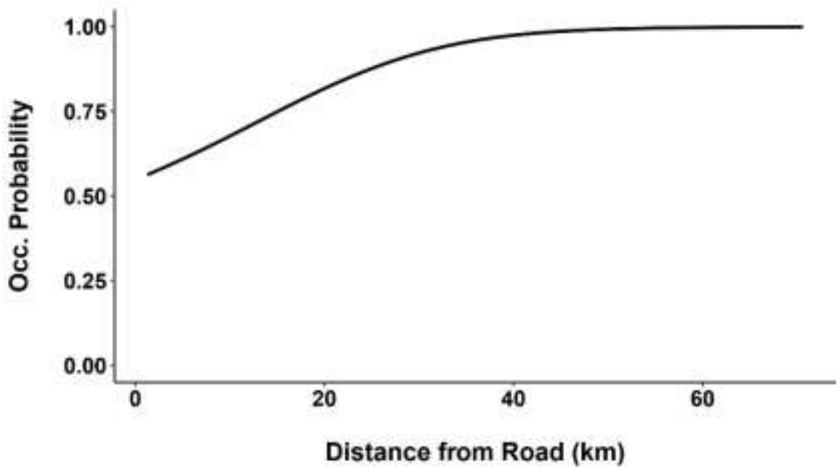

Figure 1.6a: Significant distance from road covariate effect in 2014
Occupancy probability increases as distance from road increases.

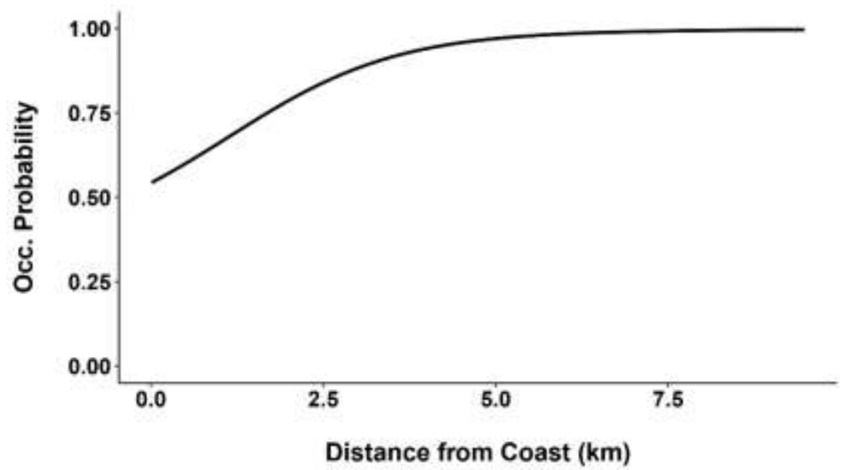

Figure 1.6b: Significant distance from coast covariate effect in 2014
Occupancy probability increases as distance from coast increases.

High-sensitivity Species Models

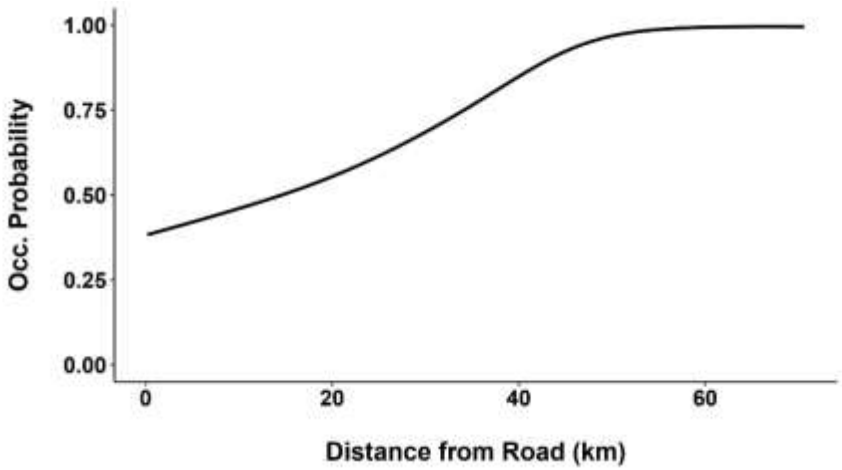

Figure 1.7a: Significant distance from road covariate effect in 2010
Occupancy probability increases as distance from road increases.

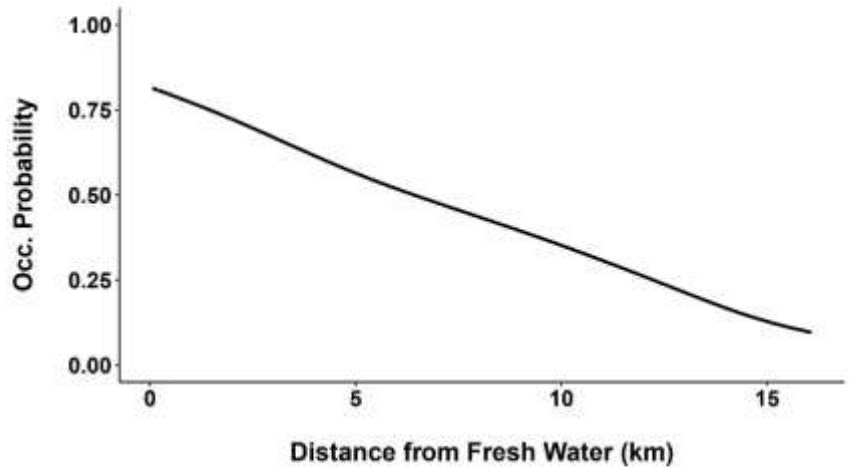

Figure 1.7b: Significant distance from fresh water effect in 2010
Occupancy probability decreases as distance from fresh water increases.

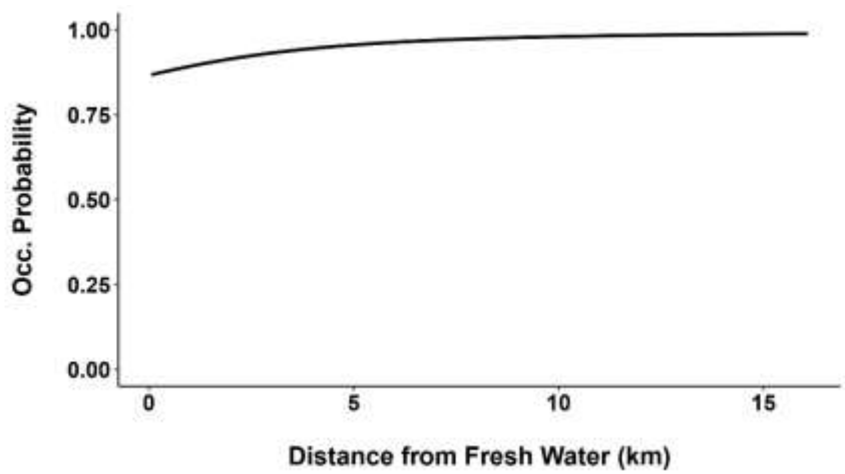

Figure 1.7c: Significant distance from fresh water covariate effect in 2014
Occupancy probability increases as distance from fresh water increases.

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CHAPTER 2

The importance of knowledge and values of Miskito indigenous forest-users for the conservation of a Neotropical carnivore assemblage in Nicaragua

ABSTRACT

The majority of global forests and biodiversity exists outside of protected areas. Working forests form an important area of study in the conservation literature. In working forests, understanding the roles and perceptions of local people is becoming recognized as paramount to successful conservation outcomes. I conducted 50 interviews in July 2014 in the Miskito community of Kahkabila, Nicaragua. The interviews focused on local knowledge and perceptions of six carnivores; jaguars, pumas, ocelots, margays, jaguarundis and tayras. My three primary objectives were to: 1) assess the ability of forest users to identify target species when presented with photos and a size reference, 2) ascertain the level of depredation on domestic animals over the past five years that coincide with a long-term camera trapping study, and 3) determine community perceptions of conflict and conservation for each of the six target species. Participants could identify the larger carnivores well (jaguar, puma, ocelot; mean >70%), but correct identification of smaller species was much less common (margay, jaguarundi, and tayra; mean < 25%). There were very few reports of depredation in the five years leading up to the interviews, and thus, 62% of participants indicated a lack of fear for their livestock and domestic animals. In addition, more than 80% of participants reported that jaguars, pumas, and ocelots were in severe decline due to hunting and deforestation. Approximately 65% of participants reported that they would only resort to lethal control of carnivores after depredation. Less than 10% of participants reported that they would persecute carnivores without provocation, and ≈28% indicated no desire to kill carnivores even if depredation had occurred. A commendable carnivore knowledge base and largely pro-conservation values indicate good potential for coexistences between carnivores and forest-users in Kahkabila’s working forests.

INTRODUCTION

Conservation efforts beyond the borders of protected areas have garnered increased attention as the exploration of coupled human and natural systems has emerged as a discipline (An, 2012; Liu et al., 2016). In working forests, understanding the roles and perceptions of local people is becoming more and more recognized as paramount to successful conservation outcomes (Dickman, 2010; Ferraro et al., 2011; Gardner et al., 2009). Traditional and local ecological knowledge provide unique insights and long-term data about wildlife, ecosystems, and their management on a time scale that western science rarely affords academia (Charnley et al., 2007; Gadgil et al., 2003). Recent research highlights the importance of including local knowledge, values, and livelihoods in the process of conservation planning (Ferraro et al., 2011). With species now going extinct at an estimated 100 times above the background rate (Ceballos et al., 2015), effective conservation planning has never been more important.

In Nicaragua, deforestation and illegal colonization threaten several high priority species, including several species of carnivores (Jordan and Hulse, 2011; Jordan et al., 2016;). This investigation focuses on five felids and one mustelid: jaguars *(Panthera onca)* pumas *(Puma concolor)*, ocelots *(Leopardus pardalis)*, margays *(Leopardus weidii)*, jaguarundis *(Puma yagouarundi)* and tayras *(Eira Barbara).* Felids are the primary predator assemblage in Nicaragua, responsible for the majority of top-down control within trophic webs (Rabinowitz and Nottingham, 1986). These iconic species are the sole focus of conservation and research efforts by nongovernmental organizations such as Panthera, and there is more funding available to protect them than there is for most terrestrial mammals. Conserving carnivores however presents additional challenges, as they are among the first species to disappear due to land use change and are typically the most directly persecuted by local natural resource users (Estes et al., 2011; Purvis et al., 2000). As coastal residents have shifted their livelihoods from sea-based to land-based practices (Stevens et al., 2014), small-scale farming in the adjacent forests has increased in recent years. This increase in edge habitat benefits the herbivores that act as prey to smaller carnivores (Beck-king et al., 2017), but the increase in fragmentation tends to drive larger carnivores out of the area (Rabinowitz, 1986; Olsoy et al., 2016). Furthermore, persecution in response to depredation presents unique challenges in this assemblage due to morphological similarities between species. Persecution of rare species in response to depredation by less rare species can contribute to further decline, highlighting the need to formally evaluate the ability of forest users to distinguish between these carnivores. Understanding these conflicts between humans and carnivores is critical in remote areas where poverty and underemployment are rampant because the factors that influence successful conservation are so highly nuanced.

My goal was to use interviews to provide insights that will help indigenous communities and other remote populations balance their needs with the long-term health of threatened species and ecosystems. The interviews focused on three primary objectives: 1) assess the ability of forest users to identify target species when presented with photos and a size reference, 2) ascertain the level of depredation on domestic animals over the past five years that coincide with a long-term camera trapping study, and 3) determine community perceptions of conflict and conservation for each of the six target species. These three objectives led to the following hypotheses:

I hypothesized that time spent in the forest would positively correlate with the percentage of correct identifications because hunting, farming, and gathering in the forest increased their chances of encountering these species. Furthermore, I expected participants to identify jaguars and pumas with the highest degree of accuracy due to their notoriety as predators of domestic animals and presence within folklore. Due to physical similarities between two pairs of predators (margay and ocelot; tayra and jaguarundi), I also predicted that these pairs would have the highest percentage of false or missing identifications.

For the depredation interviews, I hypothesized that the level of depredation on domestic animals by larger predators (jaguar, puma) would decrease due to habitat loss caused by an increase in landscape fragmentation and agriculture over the past five years. I also expected depredation by smaller predators to decrease over the five-year period but for a contrasting reason—an increase in the availability of natural prey species due to an increase in small-scale agriculture. Thus, I predict that respondents will report lower incidence of depredation in the last five years by both large and small predators.

For the final interviews on carnivore conflict and conservation, I hypothesized that participants would perceive conflict with the four smaller predatory species less frequently and perceive more conflict with the larger carnivore species, because the larger species present the greatest potential for loss of property. For the same reason, I expected a higher degree of willingness to conserve the smaller carnivore species over the larger species. I expected the responses of most interviewees to indicate conditional support of carnivore conservation due to the potential for increased conflict if carnivores made a rebound.

Research site

This research took place in the remote village of Kahkabila, Nicaragua, located in the Pearl Lagoon Basin of the Southern Caribbean Autonomous Region (RACS). The village was founded in the 1700's (Jamieson, 2011) and is home to ≈ 700 people of Miskito Indigenous or mixed Miskito-Kriol descent (pers. comms: Oskar Theodore-Schwartz). The Miskito form the largest indigenous group in Nicaragua. Kahkabila is the largest of only five Miskito villages in the RACS, compared to more than 50 in the Northern Caribbean Autonomous Region. The current, federally-recognized land title of Kahkabila is smaller than its historic area prior to the civil war from 1979 – 1990 (Jamieson, 2011). During the war most residents fled the coast to find sanctuary from conflict and returned in late 1980's. While Kahkabila received access to electric power in 2010, it can only be traveled to by boat. Kahkabila's isolation heavily influences its access to the regional economy, and thus, reinforces the reliance of its residents on natural resources for survival. Government initiatives to create infrastructure for alternative income in the autonomous regions are lacking and citizens in all villages experience high rates of unemployment and underemployment (Jamieson, 1998; pers. comms: Oskar Theodore-Schwartz, Lauterio Tomas Fox, 2012, Kahkabila, Nicaragua). Thus, subsistence and self-employed lifestyles that depend on natural resources dominate the coastal landscape (Stevens et al., 2014; Jordan, 2015), but these livelihoods are also under threat. Indigenous lands managed by these villages for natural resource use are facing increasing encroachment by mestizo migrants from the west coast (Stevens et al 2011). Without government support, it is very difficult for these small villages to secure their terrestrial resources from the affront of deforestation (pers. comms: Oskar Theodore-Schwartz, Lauterio Tomas Fox, 2012, Kahkabila, Nicaragua). This terrestrial encroachment from the west places additional pressure on coastal forest-use, and already depleted fisheries (Stevens et al., 2014). With increasing pressure on all of their livelihoods, it is important to evaluate the interactions between residents and species of conservation interest.

METHODS

Data collection

I carried out 50 interviews in July, 2014. The interview was divided into three sessions: 1) species identification, 2) depredation assessment and 3) species conflict and conservation. This study was granted exempt status by the Michigan State University Institutional Review Board on July 21, 2014 (Approval #: x14-721e). Each interview lasted approximately 60 – 90 minutes.

I selected subjects by reviewing suggestions made by Oskar Theodore-Cooper, a community leader from Kahkabila whom acted as translator and liaison to the research team. A lack of access to community census data at the time made random selection of subjects impossible. Subjects needed to meet three eligibility criteria for selection: 1) be 18 years of age or older, 2) work in the forest directly through a staple livelihood such as farming, timber harvest, hunting, or gathering and 3) be a resident of Kahkabila since 2010 or prior. I attempted to interview an equal number of male and female participants. Interviewees remained anonymous to all parties except the research team. All responses were coded with alternate identifiers that could not be linked back to the individuals. Furthermore, no information prompted by the interviews informed activities punishable by law. Any information willingly provided that addressed or acknowledged criminal activities was not recorded in the responses.

Several steps were taken to minimize risk from participation to the interviewees. With input from community members, I determined that answering the questions was in no way harmful or damaging to the subject's reputation. All interviews were conducted in private residences to further ensure privacy of responses and to reduce response bias from the presence of peers during the interview. Data was recorded by the interviewer on paper, and later transcribed on to a field computer. Alternate identifiers were designated at the time of transcription. In the interests of cultural and socioeconomic sensitivity, I used a verbal consent script in place of a written document (Appendix III). A verbal script was used to obtain informed consent because not all residents are able to read and write. To further practice cultural sensitivity, interviews were conducted in a local Kriol dialect, and I accepted responses to animal IDs in any of six coastal languages (Appendix IV).

The first step in the procedure was to obtain informed consent by reading the verbal consent script to the interviewee. Interviews began with a brief demographics inquiry about age, years of forest experience, livelihood activities, and possession of domestic animals (Appendix V). This was followed by the start of the first session: "Species Identification". In this session the interviewee is asked to name the species depicted in each of 23 photos presented in a random order. All five felids (jaguar, puma, ocelot, margay, jaguarundi) and one mustelid (tayra) were included in the photos (Appendix VI). Photos exhibited animals in night and day settings, near and far distances, and static and in-motion poses. This allowed for participants to have multiple opportunities to identify a single species. Interviewees were provided with a visual size reference with each photo based on comparisons to an average domestic dog or cat (Appendix IV). If any of the six species were not identified during session one, questions about those species were omitted from all subsequent sessions. Participants were only informed about unidentified species from session one if they asked the interviewer directly. I adopted this practice in an effort to limit the community conversation about the interviews while they were still ongoing.

The second session: "Depredation Assessment" started by asking the interviewee questions about the types of predators that prey on different domestic animals, which included livestock and pets (Appendix VII). Participants were then asked to recall accounts of depredation on domestic animals in the community since 2009. This time frame coincided with the camera trapping efforts detailed in chapter one, as I also aimed to link depredation frequency to the occupancy of each felid species. Participants were able to report any species they believed was responsible for depredation, but species other than the six focal predators were not included in the data analysis.

The third session: "perceptions of conflict and conservation" began with a brief assessment of participant knowledge on each species and how they came to know about it (Appendix VIII). The interviewee was then asked about their perceptions of specific risks or value they may assign to the species. Several prompts addressed how the interviewee would perceive or react to a variety of negative conflicts or competition with each species. The series of prompts was repeated for each of the six predator species which were correctly identified in session one. Interviews concluded by thanking the individual for their participation and offering them a printed copy of their favorite photo from the first session.

Data analysis

Identification responses for each image were categorized as: *correct, incorrect, partially correct,* or *no data*. A response was *correct* if all names for a given image matched the list of accepted names in Appendix IV. *Incorrect* was defined as responding with “I don’t know” or having no responses match the list of accepted names. *Partially correct* was defined as listing “class of tiger” or “class of cat” instead of a species-specific response. Responses containing conflicting but at least one matching name were also considered *partially correct.* The *no data* category was used when an interviewee said the image was too dark or difficult to make out. “Tiger Cat” was considered partially correct for Margay and Jaguarundi images due to its use as a general term, but considered correct for ocelot images as that is their only name in Kriol. The percent correct, incorrect, partially correct, and no data were calculated for each species to report overall findings.

Initially, I aimed to compare data from the domestic animal depredation assessments to data from the camera trapping surveys. Participants reported many instances of depredation prior to 2009, likely reflecting a higher occupancy of carnivores during that time. However, depredation was reported so infrequently for the 2009 to 2014 period that a robust statistical analysis was not possible. In place of this analysis, I summarized the community-wide depredation reports and examined whether or not farmers felt their animals were safe from depredation.

Conflict and conservation data was summarized by reporting perceptions of decline, danger, awareness of laws, and pelt-based income for each species in a series of tables. This summary was followed by an analysis of two, multi-phase questions that aimed to gauge a subject's willingness to conserve carnivores. In the first, interviewees were asked if they would seek revenge against a predator for killing their animals (retaliatory killing). This question was followed up by asking if they would kill a predator if they saw it at a safe distance in the forest (proactive or eradication killing). Individuals who answered "yes" to both questions (YY) were considered to be proponents for eradication of these predators. Individuals who answered "yes" to the first question, but "no" to the second (YN), were categorized as being "conditional" proponents for conservation. Lastly, interviewees who answered "no" to both questions (NN) were considered to be unconditional proponents for conservation of the given species. The final question addressed perceptions of food competition and conflict over wild game. Interviewees were asked if they thought they shared a food source with the predatory species (food competition) and if that was a problem (conflict). I summarized responses in the same categories as the first question: YY = pro-eradication, YN = conditional pro-conservation, and NN = unconditional pro-conservation.

RESULTS AND DISCUSSION

I conducted 50 complete interviews of forest users in the Miskito community of Kahkabila, Nicaragua. Participants represented individuals from approximately half of all households. The ratio of male to female participants was skewed (4:1), reflecting the tendencies for forest work to be male-dominated (Evans et al., 2016). Subjects covered a wide range of ages (18 – 70), and similarly, a wide range of years spent working in the forest (1 – 49). All but four subjects identified themselves as being of purely Miskito descent. Two of the remaining four subjects identified as Miskito-Kriol, while the other two identified as solely Mestizo or Kriol. All but 14 subjects were born in Kahkabila and all but one subject still works within the community forest. 41 participants owned their own farms, and all but one of these farms were located within the forest. 80% of interviewees owned livestock or pets. Subjects who owned domestic animals were four times more likely to keep them in the community rather than keep them out to the farm in the forest (Table 2). The “goat” and “cat” categories were removed from the depredation assessments because only one subject owned each species, and there were reportedly few people in the community who did. Time spent working in the forest was not correlated with the number of correct responses ($R = -0.03$).

Session 1: Identification

Jaguars and pumas are the largest and most distinct of Nicaraguan carnivores. 100% of interviewees were able to correctly identify at least one jaguar photo. Pumas were the second most recognizable, with 82% of subjects able to identify them in at least one photo (Fig. 2.1). As large, charismatic species that range throughout the country, residents are exposed to information and visuals on these species from a young age. People are also more likely to remember or report conflict between these large predators and domestic animals because the animals they kill are more valuable (Sillero-Subiri and Laurenson, 2001). Pumas are likely less recognizable than jaguars because they are absent from or uncommon in the Kahkabila forest. There is also strong evidence of pumas avoiding areas with jaguars (Foster et al., 2010), making it even more unlikely for Kahkabila residents to encounter one in the forest.

Ocelots are likely the most common species of felid in Nicaragua. Most subjects were able to correctly identify ocelots at least once (70%), but 20% of subjects incorrectly classified them as jaguars (Fig. 2.2). This was not expected, as a size reference was provided with each photo and all interviewees were informed that images depicted adult animals. Like jaguars, ocelots were also detected at the Kahkabila camera sites during the trapping study. As expected, margays were misclassified as ocelots more frequently than they were correctly identified (74% vs. 16%; Fig. 2.2). 74% of subjects classified margays as ocelots, usually referring to them as “tiger cat”. When asked if there was more than one type of tiger cat, these respondents replied no. Respondents who replied yes and further explained the image as depicting a smaller species of tiger cat were considered to have made a correct ID. Despite their obvious difference in size (11 – 16 kg vs 3 – 9 kg; Murray and Gardner, 1997), distinguishing between ocelots and margays at a distance is difficult due to their similar pelage. Similar to the avoidance behaviors observed between pumas and jaguars, margays tend to avoid areas with ocelots (Oliveira et al., 2010). Margays also make active use of the canopy rather than the ground (Di Bitetti et al., 2010), further reducing its potential for encounters with humans.

Jaguarundi and tayra display remarkable similarities in morphology and circadian activity (Giordano, 2016). As expected, correct identifications of jaguarundi were low (18%), while 56% of subjects correctly identified tayra (Fig. 2.3). However, misclassification of jaguarundi as tayra was lower than expected, indicating that villagers recognize this species as separate from the tayra. Most subjects classified the jaguarundi as an “unknown cat”, meaning that they recognized it was not a tayra but did not know what it was. Both jaguarundi and tayra are diurnal but jaguarundi are notoriously elusive (Giordano, 2016). The higher percentage of correct IDs of tayra can likely be attributed to their increased interactions with people during crop destruction (Amador-Alcalá et al., 2013). While 56% is more than half, I expected far more forest users to be able to correctly identify tayra. They are the most common carnivore in this assemblage, and many subjects reported memorable conflict with this species on their personal farms, citing their propensity to steal plantains and sugar cane. Instead, 42% of interviewees classified them as otters, raccoons, or other forest mammals. One explanation may be the recent, steep decline in detections of this species over the four-year camera study (see Chapter 1, unpublished data). It is possible that the recent decline in this species has reduced conflict to the point at which it is not being reported widely in the community.

Session 2: Depredation

Depredation was rare between 2009 and 2014. Most subjects reported zero instances of depredation on domestic animals by carnivores, regardless of the domestic animal species (Table 3). Subjects reported 82 instances of depredation on individual animals in total, but did not attribute all of these attacks to the six species of carnivores we investigated. Many participants noted that fowl (chickens and ducks) were more likely to be eaten by opossums or raccoons than by ocelots. And while one participant reported a loss of 30 hogs by a puma, most participants stated that this event occurred 15 years prior. Attacks on dogs were the most likely to be reported, with 50% of participants reporting attacks in the last 5 years. Dogs are more likely to be attacked than other domestic species because hunters bring them into the forest where they are much more likely to come in contact with predators. Cows were the next most likely to be attacked. Even though most cows are kept in the community, participants noted that cows often wandered into the forest looking for food where they were more vulnerable to depredation. Unexpectedly, 62% of livestock and pet owners (averaged across species) reported that they were not fearful for the safety of their animals. The recent decline in meso-predators and steady, low occupancy of large predators observed during the camera study may explain this attitude. Another explanation may be the trend in keeping domestic animals in the community near their homes where conflict with predators is less likely (Table 2). Without prompting, several participants also indicated a willingness to implement carnivore deterrents as opposed to lethal methods of control.

Session 3: Perceptions of conflict and conservation

The third session of the interview aimed to gauge the willingness of participants to conserve carnivores in their working forests. The number of subjects interviewed about each species for the third session ranged from 11 to 50, depending on species. Over 80% of participants reported that jaguars, pumas and ocelots were currently in decline or had declined sharply in the last five years (Table 4). Detections during the four-year accompanying camera study suggested that nearly all species of carnivores were in decline or had recently declined in this region (see Chapter 1, unpublished data). Even the once ubiquitous tayra was reported to be in decline by 47% of participants. When pressed further to reveal the causes of carnivore decline, four primary drivers emerged. The most commonly reported causes of decline were 1) hunting by unspecified parties, 2) hunting by mestizo migrants, 3) deforestation by mestizo migrants and 4) deforestation by unspecified parties (Table 4). This was unexpected as the fur trade was banned in the 70's and federal laws prohibit hunting any of the carnivores in the study (Vedas Nacionales, 2016). When asked if one could still sell carnivore pelts for profit, up to 42% of subjects replied yes (Table 5). Participants were largely unaware of federal hunting bans (≈ 38%) and community hunting bans (≈ 55%) on carnivores. This lends evidence to the argument that these laws are rarely, if ever, enforced in these remote regions (Jordan, 2015; Koerner et al., 2016). These drivers of carnivore decline highlight the need for institutions to support coastal communities in their efforts to secure their land title from the rapidly advancing agricultural frontier.

When questioned about food competition and conflict with carnivores, the most common response was for subjects to perceive competition but to not see it as conflict (Fig. 2.4). Most subjects explained that wild game was the natural prey of these carnivores, and that they needed to eat. Most also cited that they would rather have predators eating wild game than domestic animals. The most commonly cited conflict was between humans and tayras over crop and chicken loss (30%; Fig. 2.4). A surprising number of subjects did not see themselves as being in competition for food with carnivores (≈ 25%). It is possible that these participants in particular own more animals than others, thus reducing their reliance on wild game for protein. This attitude is known to be more common as societies reduce their reliance on natural resources for survival (Seoraj-Pillai and Pillay, 2016).

Responses to questions about killing carnivores in retaliation to depredation versus at a safe distance in the forest indicated that most subjects would be conditional proponents for carnivore conservation (Fig. 2.5). Proponents of eradication, participants who said they would kill the carnivore in both situations, were the least common participants (≤ 10%). The highest number of pro-eradication responses were assigned to the jaguar. This is likely because jaguars are historically notorious for killing high-value livestock such as cows (Rabinowitz, 1986), and they are still widely thought of as man-killers (pers. comms: Oskar Theodore-Schwartz, Lauterio Tomas Fox, 2012, Kahkabila, Nicaragua). These subjects felt that retaliatory killing was necessary to prevent future loss of property, but did not see persecution outside of this situation as warranted. This suggests that future conservation efforts should take into account a target occupancy to mitigate conflict or employ an active strategy such as fencing to prevent increased conflict (Packer et al., 2013). Responses indicating support of unconditional conservation were much higher than expected (12 – 44%; Fig. 2.5). It is possible that support is so high because carnivore occupancy has declined so steeply in recent years, minimizing conflict to the point at which livestock and pet loss is very rare. Many of these subjects identified the need to preserve carnivores in the forest so their children would be able to see it. These subjects were also driven by a desire to bring tourists to their village, and also stated that tourists are attracted to areas with charismatic carnivores, even if they are almost impossible to see during short stays.

CONCLUSIONS

Formal assessments of local knowledge and perceptions of conflict and conservation conflict interactions are uncommon, and can greatly improve the longevity and success of conservation programs. Participants demonstrated a depth of local ecological knowledge about carnivores and their environment that was passed down from grandparent or parent to child and was more complex than we could capture in the analysis. In Kahkabila, most forest-users possess the knowledge to distinguish between endangered and vulnerable species, thus negating the concern for persecution of the wrong species in response to domestic animal depredation. If conservation efforts by the community should succeed in increasing the abundance of carnivores in the forest, this skill will be important as instances of depredation become more common. Despite historically high rates of depredation, most domestic animal owners do not currently fear for their animals. The most reports of depredation were of dogs and cows that were in the forest at the time of the attack. Depredation on livestock, poultry and dogs within the village was virtually non-existent from 2009 – 2014. More than half of all participants reported that all six carnivores in the assemblage were in decline due to anthropogenic pressures. Most subjects attribute this decline to illegal hunting and deforestation, especially by migrant cattle ranchers from the western half of Nicaragua. Participants' reports of carnivore decline also corroborated the trends observed in the concurrent camera trapping study (see Chapter 1, unpublished data). Awareness of both federal and local hunting bans is low in this community, likely due to a general lack of enforcement of natural resource policy. In light of potential attacks on domestic animals and perceived competition for wild game, the vast majority of participants were classified as conditional or unconditional proponents for conservation (Figs. 2.5, 2.6). Pro-eradication sentiments were rare in the face of support for a "complete", functioning ecosystem with tourism potential.

A commendable carnivore knowledge base and pro-conservation values indicate great potential for coexistences between carnivores and forest-users in Kahkabila's working forests. However, the persistence of indigenous lands and the carnivores within them are not under the sole control of the interviewed forest-users. Securing land tenure and enforcing coastal boundaries from migrants will be critical to maintaining these forests and carnivores in the future. Government intervention is needed on the ground to protect land titles designated to indigenous villages throughout the Southern Caribbean Autonomous Region. Since the conclusion of data collection in 2014, a small group of forest-users in Kahkabila have organized themselves to patrol their forest monthly in an attempt to prevent further colonization and deforestation. The information garnered from this study will be reformatted for distribution to community leaders for use as baseline data to strengthen their arguments for conservation and ultimately inform conservation planning for the community of Kahkabila.

APPENDICES

APPENDIX I: Tables

Table 2.1: Summary of carnivore taxonomy, ecology and conservation status

Common Name	Latin Name	Family	Mass (kg)	Prey	Cons. Natl.	Cons. Global
Jaguar	*Panthera onca*	Felidae	42 – 57	deer, peccary	EN	NT
Puma	*Puma concolor*	Felidae	25 – 45	peccary, paca	VU	LC
Ocelot	*Leopardus pardalis*	Felidae	8.5 – 16	paca, agouti	VU	LC
Margay	*Leopardus weidii*	Felidae	2.9 – 3.9	rodents, birds	VU	NT
Jaguarundi	*Puma yagouarondi*	Felidae	4.5 – 9	agouti, rodents	LC	LC
Tayra	*Eira barbara*	Mustelidae	3 – 6	rodents,	LC	LC

Cons. Natl. = conservation status in Nicaragua, Cons. Global = IUCN conservation status. EN = endangered, VU = vulnerable, NT = near threatened, LC = least concern. All mass and prey information was obtained from University of Michigan's "Animal Diversity Web" website.

Table 2.2: Summary of livestock ownership and keeping practices

Animal	Owners	Town	Farm
Cow	40%	60%	40%
Horse	20%	43%	57%
Fowl	73%	90%	10%
Hog	10%	50%	50%
Dog	50%	100%	0%

Percent of owners = percent of livestock owners who own the given species of livestock, Town = percent of those owners who keep this species in the town, Farm = percent of those owners who keep these species in farms in the forest.

Table 2.3: Summary of community-wide depredation on domestic animals from 2009 – 2014

Animal	Subjects	Min	Max	Mean	Mode
Cow	46%	0	5	2.8	4
Horse	6%	0	3	1.7	2
Fowl	18%	0	30	9.6	10
Hog	26%	0	30	2.7	2
Dog	60%	0	14	3.7	2

Subjects = % of subjects who reported depredation on the given domestic animal, Min = the minimum number of depredation instances reported by participants, Max = the maximum number of depredation instances reported by participants, Mean = the mean number of non-zero depredation reports, Mode = the most commonly reported non-zero number of depredation reports.

Table 2.4: Summary of carnivore decline and causes by species

Species	Subjects	Decline	Cause 1	Cause 2	Cause 3	Cause 4
Jaguar	50	88%	HU	HS	DS	DU
Puma	46	87%	DU	DS	HS	HU
Ocelot	42	81%	HU	DS	DU	HS
Margay	11	55%	HU	HS		
Jaguarundi	12	67%	HU	DS		
Tayra	30	47%	DS	HS	HU	

Subjects = number of subjects who were interviewed about that species, Decline = % of subjects who reported that the species was in decline, Cause 1 – 4 = causes for decline in order of most to least reported, HU = unspecified hunting, HS = hunting by Spaniards, DS = deforestation by Spaniards, DU = unspecified deforestation. Spaniard is the coastal term for Mestizo people.

Table 2.5: Summary of threat perception, law recognition, and pelt income

Species	Subjects	Danger	Fed. law	Comm. law	Income
Jaguar	50	92%	52%	58%	42%
Puma	46	57%	50%	54%	30%
Ocelot	42	14%	52%	60%	38%
Margay	11	0%	36%	55%	27%
Jaguarundi	12	8%	16%	67%	16%
Tayra	30	33%	27%	37%	7%

Subjects = number of subjects who were interviewed about that species, Danger = percent of subjects who perceived the animal as dangerous, Fed. law = percent of subjects who were aware of the federal ban on hunting of that species, Comm. law = percent of subjects who were aware of the community ban on hunting of that species. Income = percent of subjects who reported that the fur of this species could still be sold

APPENDIX II: Figures

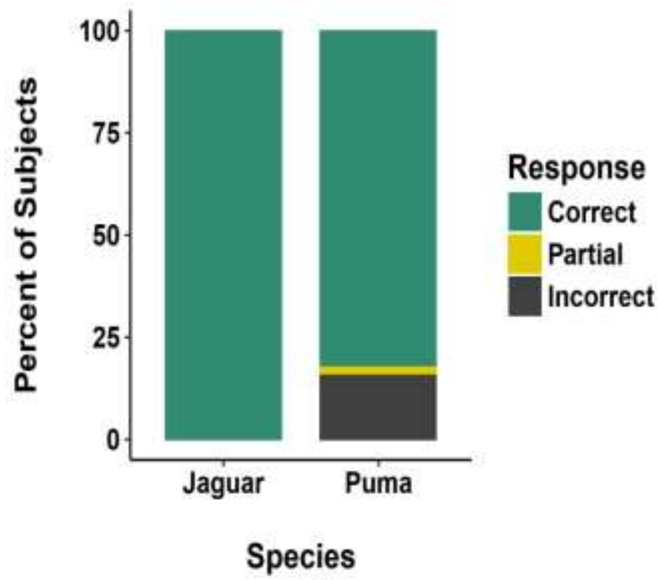

Figure 2.1: Jaguar and puma identification: Correct = all names provided in response to a photo matched the list in Appendix III, Partial = some names were correct, or a general term was used, Incorrect = no names were correct. Both species had a high percentage of correct responses (≥ 85%) due to their large size, reputation for killing livestock, and uniqueness.

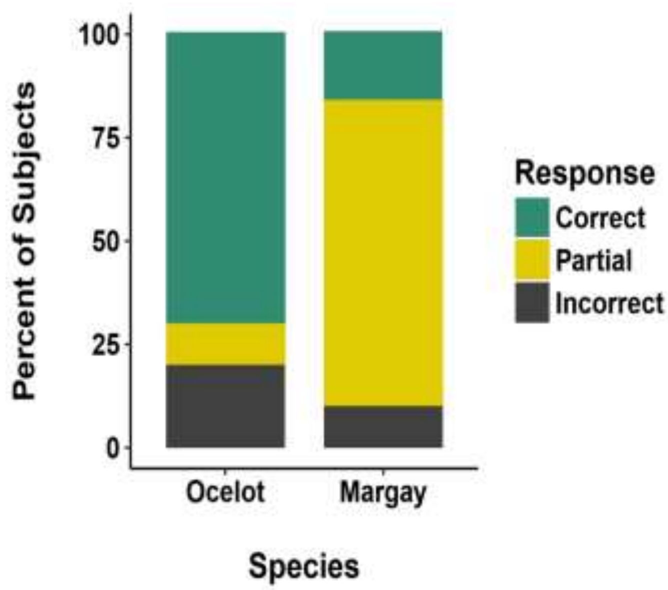

Figure 2.2: Ocelot and margay identification: Correct = all names provided in response to a photo matched the list in Appendix III, Partial = some names were correct, or a general term was used, Incorrect = no names were correct. Margays were mistaken for ocelots more frequently than they were correctly identified and ocelots were most frequently misclassified as jaguars.

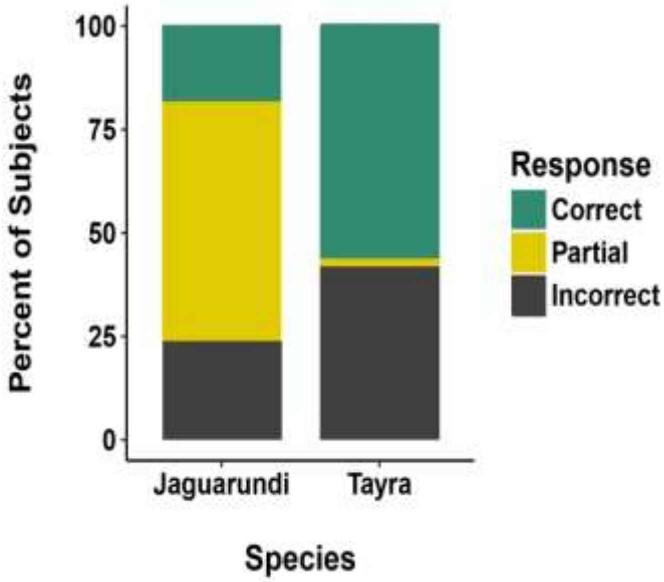

Figure 2.3: Jaguarundi and tayra identification: Correct = all names provided in response to a photo matched the list in Appendix III, Partial = some names were correct, or a general term was used, Incorrect = no names were correct. Very few people could identify the jaguarundi (18%), but they were infrequently misclassified as the tayra (< 10%).

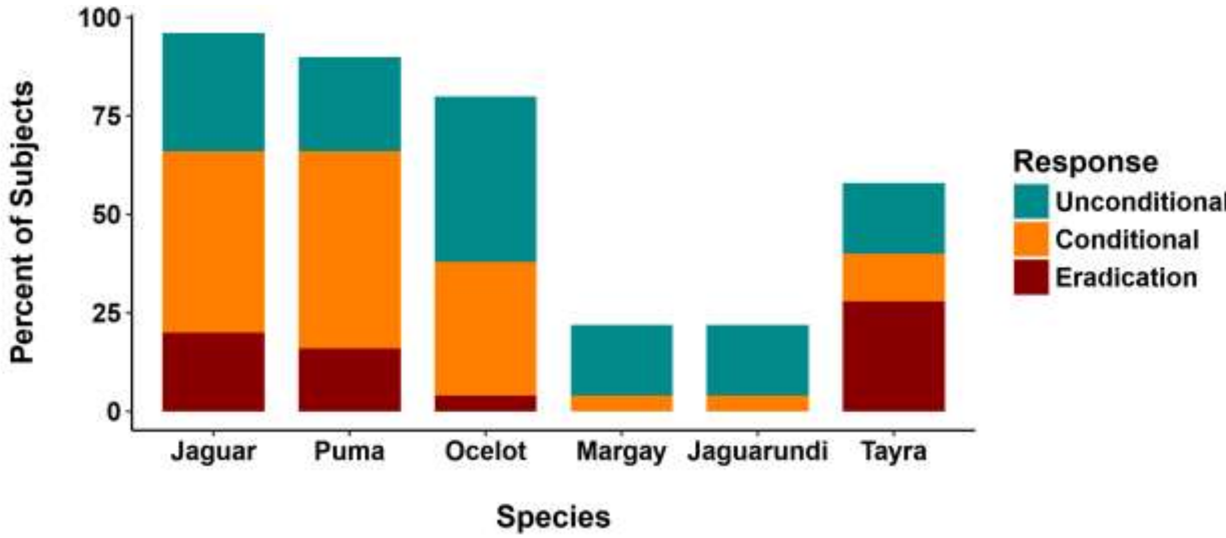

Figure 2.4: Perceptions of food competition and conflict: Unconditional = percent of participants with unconditional pro-conservation responses, Conditional = percent of participants with conditional pro-conservation responses, and Eradication = percent of participants with pro-eradication responses. Here, participants who correctly identified the species in session one answered questions in session 3; therefore, bars do not sum to 100%. The vast majority of participants acknowledged competition between humans and carnivores over wild game (Conditional and Eradication responses), but did not perceive it as a source of conflict (Conditional and Unconditional responses).

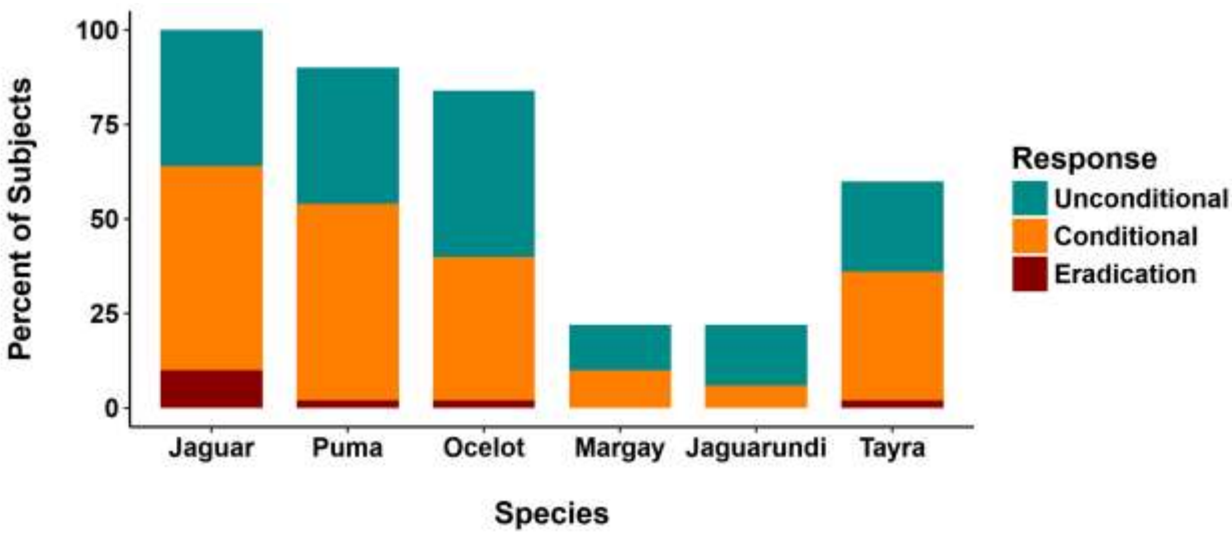

Figure 2.5: Attitudes about retaliatory persecution and eradication: Unconditional = percent of participants with unconditional pro-conservation responses, Conditional = percent of participants with conditional pro-conservation responses, and Eradication = percent of participants with pro-eradication responses. Here, participants who correctly identified the species in session one answered questions in session 3; therefore, bars do not sum to 100%. The percentage of participants who would persecute a carnivore in response to depredation was lower than expected (Unconditional responses). Eradication responses were no greater than 10% and largely applied only to the jaguar, a known predator of valuable livestock.

APPENDIX III: Consent script

Verbal Consent Script

Species Identification and Perceptions of Human-Wildlife Conflict for Six Nicaraguan Predators

Dis interview try to get information for research about some animals in Kahkabila bush.

Dis information will help we learn how people and animals are making a life close to each other in Kahkabila.

De interview will take 45 minutes to one hours of your time.

During dis time we will ask you question about animal names, animal behaviors and animal conflict.

We no think dere is any risk for answer question with us. Dere are also no benefits except for feel good that you help make the research.

If you have any question after the research complete, you can contact me (Lauren Phillips) at 505 5755 2676.

Your participation is voluntary and you can quit question at any time. Dere is no penalty or negative impact for quitting the questions.

Your answers to questions will not have your name to them. No one will know what answers are for you except me and my team.

Participant #: _____

Signature of Witness to Verbal Consent:______________________ Date: ________

APPENDIX IV: Accepted names and size references

Accepted names and size references for species identification interviews

Table 2.6: Common species names accepted as correct answers during interview phase I

Latin	English	Kriol	Miskito	Español
Panthera onca	Jaguar	Tiger, spotted tiger, speckled tiger, brimble tiger, leopard tiger	Limi bulni, limi siksa	Tigre, tigre real, tigre americano, otorongo, yaguar, yaguarete
Puma concolor	Puma, cougar, mountain lion, panther, catamount	Red tiger, deer tiger, brown tiger, lion	Limi pauni	León, león americano, león bayo, león colorado, león de montaña, mitzli, onza bermeja
Leopardus pardalis	Ocelot	Tiger cat, big tiger cat, kitty tiger	Kruhbu, limi kruhbu, unta punska	Oceolote, manigordo, gato onza, tigrillo
Leopardus wiedii	Margay, tree ocelot	Little tiger cat, peludo, liki kitty tiger, pus tiger	Kruhbu sirpi, unta punska sirpi	Tigrillo, manigordo largo, gato montés, caucel, gato pintado
Herpailurus yagouaroundi	Jaguarundi, eyra cat	Next tiger cat, next kitty tiger, black tiger cat, little black tiger oonki	Puns siksa, limi wayata, next kruhbu sirpi, kruhbu yahba, oonki	Yaguarundi, leoncillo, león brenero, gato moro, gato colorado
Eira barbara	Tayra	Bushdog	Arari	Tolomuco

No names were provided in Rama, Garifuna, or Ulwa. Names not retrieved from personal communications with community leaders were obtained from the IUCN Red List profiles for each species at www.IUCNredlist.org.

Table 2.7: Size references provided to interviewees during interview phase I

Species	**Size description in Kriol**
Panthera onca	much bigger than dog
Puma concolor	bigger than dog
Leopardus pardalis	bigger than pus, size of average dog
Leopardus wiedii	small like pus, long
Herpailurus yagouaroundi	liki bigger than pus
Eira barbara	liki bigger than pus

APPENDIX V: Demographic questions

Demographic Data

How you named? ________________________

How many years you have? ____________________

You are Miskito?   Y   N   P

You were born to Kahkabila?   Y   N

Do you work in de bush?   Y   N

How many years you have in the bush? _____

Do you have farm?   Y   N

Is de farm in de bush?   Y   N

What animals you have?   Cow   Horse   Fowl   Pelibuey   Hog

APPENDIX VI: Identification photos

Photos used for species identification interviews

Figure 2.6: Jaguar photos used during interview phase I

Figure 2.7: Puma photos used during interview phase I

Figure 2.8: Ocelot photos used during interview phase I

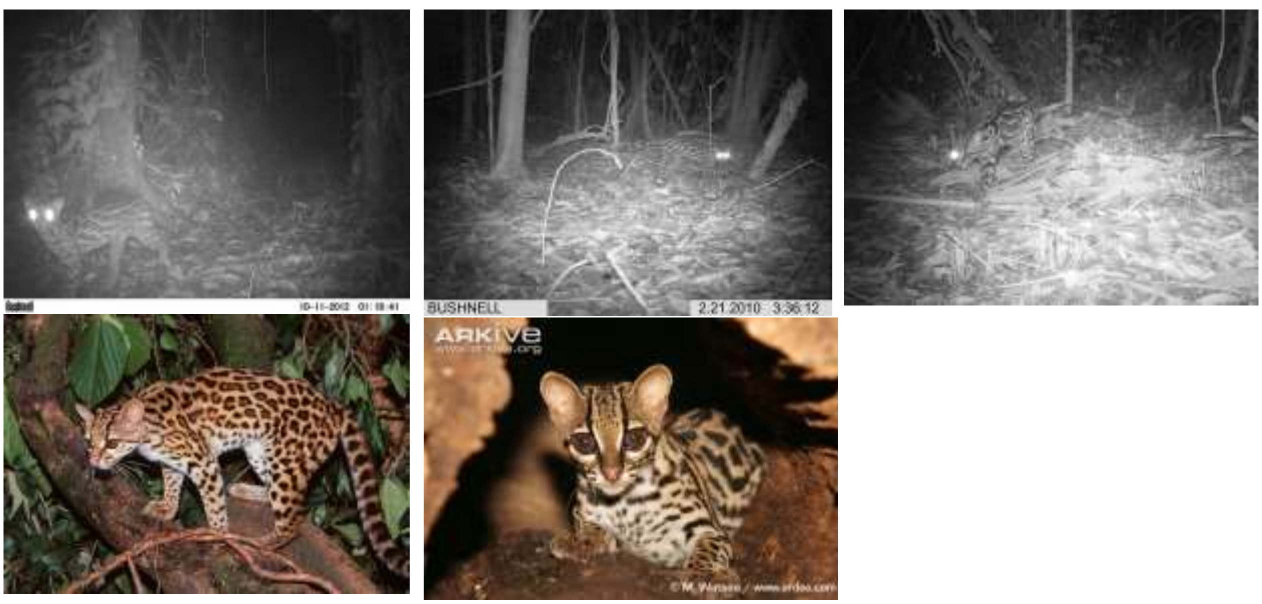

Figure 2.9: Margay photos used during interview phase I

Figure 2.10: Jaguarundi photos used during interview phase I

Figure 2.11: Tayra photos used during interview phase I

APPENDIX VII: Depredation questions

Livestock depredation assessments

Does dis animal eat/kill…

	Jaguar	Puma	Ocelot	Margay	Jaguarundi	Tayra
Eat Cow						
Eat Horse						
Hog						
Fowl						
Pelibuey						
Dog/Pus						

How many times in last year…

	Jaguar	Puma	Ocelot	Margay	Jaguarundi	Tayra
Eat Cow						
Eat Horse						
Hog						
Fowl						
Pelibuey						
Dog/Pus						

How many times in last five years…

	Jaguar	Puma	Ocelot	Margay	Jaguarundi	Tayra
Eat Cow						
Eat Horse						
Hog						
Fowl						
Pelibuey						
Dog/Pus						

APPENDIX VIII: Conservation and conflict questions

Perceptions of conflict and conservation values

Questions were repeated for each species identified by the participant in part. The example below is for the jaguar.

Tiger – Jaguar – Limi bulni – *Panthera onca*

1. Do dis animal live in Kahkabila bush? Y N How you know so?
2. Is dere same number of dis animal as first time? Y N Why?
3. Does dis animal have next name? Y N
4. What do dis animal eat?
5. Do you eat de same food as dis animal? Y N How do you see that?
6. Does dis animal eat or kill next cat? Y N
7. Is dis animal dangerous? Y N Why?
8. Who teach you about dis animal?
9. If dis animal kill animal that is for you, would you kill it? Y N Why?
10. If you see dis animal in de bush, would you kill it? Y N Why?
11. Do people get money for sell part of dis animal? Y N What part?
12. Is dere law in Nicargua for no hunt dis animal? Y N What penalty is dere?
13. Is dere law in community for no hunt dis animal? Y N What penalty is dere?

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CONCLUSIONS

The goal of my research was to help indigenous communities and other remote populations balance their needs with the long-term health of threatened species and ecosystems by providing insights into the occupancy and conservation of terrestrial mammals in their shared landscapes. My research adds evidence to a growing body of literature examining coupled human and natural systems in remote, impoverished, and biodiverse regions.

In Chapter 1, I sought to model the impacts of subsistence livelihoods practiced by indigenous and Afro-Nicaraguan peoples on the occupancy of terrestrial mammals in the working forests surrounding nine villages. My results indicated that the low-sensitivity species (agouti, paca, armadillo, coati and white-tailed deer) maintained a high occupancy probability near coastal communities (> 0.75) and an even higher probability within their immediate (8 km) forests (> .90). Low-sensitivity species also exhibited high occupancy near the road to Pearl lagoon, likely benefitting from the increase in edge habitat and crops for forage. Due to low detections, the models I fitted for the moderate- and high-sensitivity species over-estimated occupancy values. However, the trends across the range of covariates still add evidence to my arguments. The number of camera sites occupied by the moderate-sensitivity species (ocelot, margay, jaguarundi, tayra and collared peccary) declined by ≈ 50% over the four-year study period. Occupancy probability closer to the road was very low for the moderate-sensitivity group, indicating very low tolerance to human disturbance of this nature despite the obvious benefits to their prey and food sources. High-sensitivity species (jaguar, puma, tapir, red brocket deer and white-lipped peccary) were detected at fewer than 10% of camera sites throughout the study period. This is well below their historic occupancy in this region, and adds evidence to the argument that they have low tolerance human disturbance. Trends in the occupancy probability of high-sensitivity species illustrated a dramatic shift in land use around fresh water over time. In 2010, these species had the highest occupancy probability near fresh water, and that occupancy declined dramatically as distance from the water increased. This is supported by evidence that suggests many of the species in this group prefer or require habitat immediately near fresh water. In 2014 however, after colonists and coastal inhabitants developed farms on riparian zones, this trend reversed and I observed lower occupancy of high-sensitivity species near fresh water. These expected but alarming trends demonstrate an urgent need to explore conservation practices for preventing faunal collapse in this biodiverse region. Due to limitations in measuring the presence and pervasiveness of the cattle-ranching frontier directly, I was only able to model the impacts of one half of the human landscape that is directly impacting the occupancy of terrestrial mammals in the region. The continued persistence of these mammals depends on the ability of coastal communities to enforce their land titles and prevent the continued deforestation of their working forests by mestizo colonists. Many of the trends in occupancy I reported in chapter 1 were corroborated by reports from the interviews I conducted in chapter 2.

In Chapter 2, I focused my attention on six species of carnivores from the camera trapping investigation that I felt were the among the most vulnerable to deforestation and conflict with humans. These interviews explored these topics on Jaguars and pumas from the high-sensitivity species group and ocelots, margays, jaguarundis and tayras from the moderate-sensitivity group. I used interviews to explore the knowledge and attitudes towards conservation of these animals held by Miskito forest users. I found that forest users in the community of Kahkabila demonstrated an impressive knowledge about carnivores and an unexpected willingness to conserve them. With multiple species of carnivores sharing their working forests, it was important to establish a baseline for their knowledge of these carnivores. The identification interviews revealed that forest users knew the largest or most common carnivores (jaguar, puma, ocelot, tayra) very well, but small, rare species such as margay and jaguarundi were poorly known. Participants surprised me with their ability to distinguish between tayra and jaguarundi, despite not being familiar with jaguarundis as a species. In the depredation assessment, I was unable to estimate a total number of depredation events, but determined by speaking with participants that depredation from 2009 to 2014 was very rare. Low depredation likely influenced the fact that most participants reported they did not fear for the safety of their livestock. Reports of low depredation in recent years lend further evidence to my low or declining occupancy results in Chapter 1. Most participants also reported that all six carnivore species have declined in recent years, adding further evidence to these results. When asked about competition of wild game, most participants recognized that they shared a food source with these carnivores. However, most participants did not perceive this competition as a source of conflict, an important pro-conservation attitude. Although most participants said they would persecute a carnivore in response to depredation of livestock, many of them expressed interest in methods for mitigating depredation in the first place. Furthermore, less than 5% of participants said they would kill a carnivore without provocation, indicating very high support for the continued persistence of these animals in the working forests. Residents in Kahkabila recognize the decline in carnivores and show a high degree of potential for effective, collaborative, conservation planning.

Together, the individual studies within my thesis shed light onto the complex story of terrestrial mammals persisting at the confluence of land conflict between coastal communities and mestizo colonists. Despite declines in terrestrial mammal occupancy and the willingness of certain communities to conserve them, successful conservation initiatives may still be out of reach. Deforestation, hunting, and illegal settlement by mestizo colonists has an enormous influence on this landscape, and will continue to negatively impact both terrestrial mammals and the indigenous and Afro-Nicaraguan communities. The mestizo colonists are among the poorest people in the country, and with few options for survival, they are unlikely to cease deforestation without direct intervention from the federal government. Some villages have taken action to remove colonists from their land. The village of Kahkabila peacefully evicted several families from their forest in 2015. A few committed community members have also donated their time to patrol the forest to prevent new families from settling. While Kahkabila has experienced some success protecting their land, other indigenous communities in the autonomous regions have been met with extreme violence after attempting to evict colonists. In all, coastal communities require assistance to enforce the boundaries of their land titles and colonists need better alternatives to illegal cattle ranching for survival.

As the forests surrounding and connecting protected areas become more fragmented, global conservation initiatives will not be able to rely solely on protected areas to preserve biodiversity. Working forests like those on the Caribbean coast of Nicaragua dominate remote regions which hold the highest concentrations of rare and threatened species. Empowering communities with the resources they need to protect their lands and continue their subsistence livelihoods is the most important step we can take to preserve working forests for both people and animals.