THE DYNAMICS OF WILDLIFE AND ENVIRONMENTAL KNOWLEDGE IN A BIOCULTURALLY DIVERSE COUPLED NATURAL AND HUMAN SYSTEM IN THE CARIBBEAN REGION OF NICARAGUA

By

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ABSTRACT

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Many of the most biodiverse locations on earth consist of landscapes inhabited by human societies with subsistence economies that depend on the harvest of the same resources researchers want to protect and study. In such contexts, especially when the rights to resource use are protected by law, it is essential for researchers, conservationists and practitioners to carefully consider and engage local peoples to ensure the success and efficiency of their work and to help protect the wellbeing of all stakeholders. My study site, the Caribbean Coast of Nicaragua, is very similar to this. I designed my initial research to explore: 1) methods to justly and effectively involve local and indigenous people in ecological research, and 2) the importance of local and indigenous people to such research. I then followed this up by integrating the results into broader research looking at trends in traditional environmental knowledge loss/retention and neotropical mammal occupancy in the context of rapid land-use change and globalization.

There is an extensive literature on traditional environmental knowledge and neotropical mammals. Yet there is a dearth of publications on these topics on the context of Caribbean Coast, Nicaragua. Additionally, few research efforts have looked explicitly at the interface between the two broad topics. This dissertation builds on the literature by: 1) providing case studies concerning both traditional environmental knowledge and neotropical mammals from a region that is under-represented in academic publications, and 2) describes research that explicitly considers the process of involving local peoples into ecological research.

In Chapter 1, I test a social science method for understanding traditional environmental knowledge and discuss how the results can be integrated into ecological research. In Chapter 2, I worked with locals to apply their knowledge of Baird's tapirs to a large monitoring program in a way that permitted me to compare the efficiency of multiple Baird's tapir sampling techniques, including some that integrated traditional knowledge and one that did not. In Chapters 3 and 4 I report on broader research looking at general trends in traditional environmental knowledge loss/retention and neotropical mammal occupancy over time.

I found that mental model interviews are a fairly easy, but effective means for ecologists to understand how local peoples consider the ecosystems they live in, to learn how to communicate with locals about their environment, and to learn how to best integrate locals into Western science fieldwork. In addition, I found that local environmental knowledge can affect the efficiency of ecological sampling, which underscores the importance of understanding the process of local involvement in wildlife research and integrating local knowledge in a systematic way. Research on traditional environmental knowledge and wildlife occupancy reveal a landscape that remains rich in biocultural diversity, but faces threats and possible declines in wildlife and traditional knowledge in the near future. Larger species who are more sensitive to habitat change such as Baird's tapirs, jaguars, and white-lipped are particularly at risk.

This research contributes to the field of ecology by underscoring the importance of justly and effectively including local stakeholders in research. My hope is that many of the lessons I learned and the results I obtained can be applied in the coming years to help conserve biocultural diversity in the Caribbean Coast of Nicaragua.

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To work efficiently in locations with poor infrastructure for science and research, like Nicaragua, researchers and conservationists must establish large, comprehensive networks in many different sectors of society. Due to this, many individuals and organizations in Nicaragua and internationally supported me in one way or another during my path toward a PhD.

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PREFACE

Each chapter is prepared as a separate stand-alone manuscript to be submitted for publication. For this reason, there is some repetition between chapters in the study site description and methods. Chapter 1 was published in 2013 as a co-authored work:

Jordan, C. A., G. R. Urquhart, and D. B. Kramer. 2013. On Using Mental Model Interviews to Improve Camera Trapping: Adapting Research to Costeño Environmental Knowledge. *Conservation and Society*. 11(2): 159-175.

It is modified slightly here to match the required dissertation formatting. In Chapter Three, I included many tables that will not appear in publications so that the reader has access to the complete results.

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KEY TO ABBREVIATIONS

LEK – Local Environmental Knowledge

TEK – Traditional Environmental Knowledge

WSK – Western Scientific Knowledge

RACCS – South Caribbean Coast Autonomous Region

MSU – Michigan State University

URACCAN – Universidad de la Regiones Autónomas de la Costa Caribe Nicaragüense

IUCN – International Union for Conservation of Nature

TS – Maximum Total Survey Effort

AIC – Akaike's Information Criterion

SE – Standard Error

VITEK - Vitality Index of Traditional Environmental Knowledge

RG – Intergenerational Rate of Retention

RC – Cumulative Rate of Retention

CA – Annual Rate of Change

ANOVA – Analysis of Variance

HSD – Honest Significant Difference

TOM- Trips Outside of Community per Month

DPL – Distance to Pearl Lagoon

DTC – Distance to Nearest Community

DIVERSITY – Tree Diversity

CANOPY – Mean Canopy Height

FOREST – Percent of Sampling Site Classified as Forested

BIOMASSC – Total Terrestrial Biomass Harvested by Nearest Community Scaled by Distance of Camera to Community

HUNTC – Proportion of the Nearest Community that Considers Themselves Hunters Scaled by the Distance of Camera to that Community

BIOMASSPL – Total Terrestrial Biomass Harvested by Nearest Community Scaled by Distance of Camera to Pearl Lagoon Town Road

HUNTPL – Proportion of the Nearest Community that Considers Themselves Hunters Scaled by the Distance of Camera to Pearl Lagoon Town Road

BIOMASSM – Total Terrestrial Biomass Harvested by Nearest Community Scaled by Distance of Camera to Nearest Market of Significant Size

HUNTM – Proportion of the Nearest Community that Considers Themselves Hunters Scaled by the Distance of Camera to Nearest Market of Significant Size

DIC – Deviance Information Criterion

CRI – Credible Interval

T – Treatment

C – Control

INTRODUCTION

While Nicaragua is not large, at approximately 130,000 square kilometers the entire country is smaller than the Brazilian Pantanal, it still has several unstudied locations along its Caribbean Coast so infrequently visited by humans that there are no machete scars on trees, no hunting roads, and an awe-inspiring, spiritual aura one only finds in the wilderness. Yet each year these remarkable places shrink as a cattle ranching frontier and large projects surge from West to East with the tacit approval of a central government that sits on their hands for fear of losing the support of the "Pueblo." On a fairly regular basis environmental news websites and science journals publish stories and articles detailing the plight of the world's last wild places as large infrastructure projects and agricultural frontiers eat away at forests, savannas, oceans, and other natural habitats. While these stories are important and help shape our lifestyle choices and influence us to donate money or effort, it is much different to live the devastation.

I was familiar with the literature on road construction and the environmental toll it can take (i.e. Laurance et al. 2006), so I was certainly not expecting promising trends for my study species. However I was less familiar with the fascinating larger chaos of the Caribbean Coast Nicaraguan context. Forest loss in Nicaragua concerns many things, including the contested autonomy of indigenous peoples; government corruption at the national, regional, and local levels; land trafficking; extreme poverty; subsistence farming and hunting; market hunting; the lingering anger and attitudes from living through a Civil War; drug trafficking; the constant threat of mega-infrastructure projects; hurricanes; and many, many other things. It is a complex, endlessly interesting context that truly defines the term Coupled Natural and Human System. Yet it is also a context that results in over 75,000 hectares of forest loss per year, which is not sustainable for a country roughly the size of Alabama (Hansen et al. 2013).

To function efficiently within Nicaragua requires one to establish connections with as many different stakeholders as possible. It requires one to learn to live amongst corruption and disorganization; to learn to pressure different people and organizations at the proper moments and in the proper ways to convince them to act without closing any doors in the future. My advisors' encouragement to implement not just wildlife research using camera trap, track and sign, and transect surveys allowed me to include extensive research on indigenous knowledge, attitudes, and ways of life. My research on the cultural, political and social aspects of local forests, in turn, gave me the insight to truly learn how to function successfully within the apparent chaos surrounding me. It also helped me to understand that the extensive forest destruction in Nicaragua, which lost over 822,000 hectares of forest from 2000-2012, was not a symbol of economic progress and development, but was instead directly increasing the vulnerability of some of the poorest, most vulnerable communities in the country (Hansen et al. 2013).

Thus, after several years of living with locals, researching the complexities of forest cover change, and witnessing camera trap site after camera trap site burned to the ground to make room for more Pacific coast cattle ranchers that neither benefit Caribbean Coast peoples or economies in the long-term, my objectives shifted. Along with colleagues from MSU and Caribbean Coast Nicaragua, we began making plans to help conserve what is left of coastal forests. Then we used my dissertation research as a launching pad and began working to build a wildlife and forest conservation initiative that uses the endangered Baird's tapir as an umbrella species. Since 2012, we have continued and expanded the research described in this dissertation to include a tapir GPS collaring project, extensive hunting research (Jordan et al. 2014), and forest mapping with drones. Yet we have also used the data we have collected to organize tapir conservation committees, approve territorial level tapir hunting bans, hold tapir conservation forums, found a tapir rescue and rehabilitation center, bring international attention to the plight of Nicaraguan tapirs and their forested habitats, and are now working with donors and big NGOs to expand our programs. Moving from my dissertation research to applied conservation was a relatively seamless transition that underscores the philosophy and, frankly, logic behind the concept of fieldwork as commitment (Stevens 2001). It also convinced me of the importance of multi- and inter-disciplinary research, not simply for understanding my research context, but also for understanding my potential for a larger, more applied role within my study context. Without the comprehensive knowledge of Caribbean Coast people and how they view and use the forest, designing conservation strategies and reaching locals and politicians with our message would have been much more of a struggle. This is not to say conservation has been easy, it never is in such a complex landscape, and we have a long way to go for our work to be considered successful, but my multidisciplinary fieldwork prepared me to hit the ground running.

This shift from research in the strict sense to applied conservation may not seem attractive to some scientists. Certainly in an ideal world, we would also simply research the world's wild places and not have to worry about any larger political, cultural, or economic forces destroying them and the species within them. However, wildlife biologists and ecologists are some of the best-suited individuals to truly make a difference in conservation, especially given the fact that our work so often includes the human dimensions of wildlife conservation and research. If we are well equipped to work in conservation, is it ethical to simply monitor species and ecosystems into extinction? Should we not feel obligated to help avoid biodiversity loss? Ecological monitoring programs are at their core systems to help us manage and protect wildlife, and I believe we must begin to use them for this purpose more effectively (Lindenmayer et al. 2013).

So in the end, after five and a half years working toward my PhD, this dissertation is less a final chapter of my experience and more of a summary of the experience that lead me into full time work as an applied conservationist. I believe the multidisciplinary of the research will make it clear how my understanding of the Caribbean Coasts, its people, and its ecosystems was hugely benefited by both the ecological research and the social science based research. It should also communicate how compiling this information helped in my professional development and why I believe that social science methodologies are essential for wildlife biologists working in Coupled Natural and Human Systems like the Caribbean Coast of Nicaragua.

In **Chapter One**, which assesses the effects of integrating local environmental knowledge into wildlife sampling, I found that including local's knowledge of Baird's tapir ecology into sampling for tapirs increases efficiency substantially. This chapter serves as something of a primer to understanding the intimate knowledge Caribbean Coast Nicaragua locals have of their forests as well as the potential for integrating that knowledge into wildlife research and conservation.

In **Chapter Two**, which was published in Culture & Society in 2013, I described how I used mental model interviews to improve my understanding of local environmental knowledge and how I engage that knowledge in my research with camera traps. This chapter continues where the prior chapter left off in the sense that it strengthens the connection between the natural and human components of Caribbean Coast Nicaragua in my research, and explains my process for understanding how to engage both in my fieldwork.

In **Chapter Three**, I describe our use of the VITEK methodology to assess the loss and retention of Traditional Forest Knowledge in two Caribbean Coast indigenous communities, Kahkabila and Karawala, and one migrant community, Pueblo Nuevo. The chapter elucidates some important patterns and processes of local environmental knowledge transmission and underscores a key difference between indigenous communities and migrant communities: the former have a shared body of knowledge about local forest plants and animals and thus a shared cultural value for these species, whereas the latter does not. This is an important piece of information that can help when designing strategies for conservation and environmental education initiatives.

Chapter Four describes three years of data from camera traps for an assemblage of medium and large mammals and how we attempted to integrate data from socioeconomic surveys into occupancy models. One of our objectives with this paper was to use occupancy models in a way that informed us about local process of development and shifts in local resource extractive behaviors. Our results suggest that rare species declined significantly in those areas of the coast with higher levels of development and invasion by Pacific coast cattle ranchers in a period of just three years (2010-2012). This indicates that more active forest management and conservation will be required to ensure these lands retain their function as wildlife corridors in coming years.

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CHAPTER ONE

ON USING MENTAL MODEL INTERVIEW TO IMPROVE CAMERA TRAPPING: ADAPTING RESEARCH TO COSTEÑO ENVIRONMENTAL KNOWLEDGE

Abstract

In many regions it is necessary to apply traditional or local environmental knowledge in biological research projects based in Western scientific knowledge. In such endeavors, it is important for researchers and often locals that the integration of the two knowledge systems occurs in a manner that produces reports that meet the expectations of government agencies, NGOs, and grant agencies. Yet, it is also critical for the research and knowledge system integration to benefit locals by reinforcing their autonomy, skills, education, and culture as they desire. Scholars acknowledge that every knowledge system is created through a unique combination of social processes and is therefore unique. Thus there is no universal list of best–practices that will attain these two goals. To discover the best–practices for a particular project, it is necessary to treat the project as unique and to develop the relationship between the two knowledge systems and related research methodologies based on personal experience. One means of achieving this is to use social science research techniques in conjunction with the project's biological sampling methods. This paper outlines how I used mental model interviews to attempt to achieve these two goals in the context of my camera-trapping project in Nicaragua that integrates traditional environmental knowledge.

Introduction

The last remote regions of the globe are quickly becoming connected to and influenced by global forces. These regions, which also tend to be some of the most biodiverse areas, are experiencing rapid increases in development with the potential to substantially alter local and global ecosystems (Kramer et al. 2009). For development to be sustainable, ecological research in and monitoring of these areas to understand how recent changes and connections affect biodiversity are essential (Kramer et al. 2009).

In such remote regions, infrastructure for Western scientific research is often scarce and Western scientists are typically few and far between. Rather, there are typically many local, often indigenous, peoples who possess extensive environmental knowledge generated through a lifetime of subsistence activities. Therefore Western scientists who wish or are asked to undertake ecological research or monitoring in these contexts often look to these local experts to hire as assistants, field technicians and collaborators (Luzar et al. 2011). In so doing, these scientists include what is often termed local environmental knowledge (LEK) or, in the case of indigenous peoples, traditional environmental knowledge (TEK) into their research process. This relationship is sometimes governed by local or national laws and regulations (i.e. GNWT 2005).

Pairing bodies of LEK or TEK with bodies of Western scientific knowledge (WSK) in the same project is not typically a straightforward endeavor. There can be cultural differences in processes such as knowledge generation, transmission and retention that can, for instance, make certain practices or concepts seem essential and valid to Western scientists, yet unnecessary or irrelevant to local peoples and vice versa. At the same time, it is essential for Western scientists and global conservation that the knowledge of local assistants is included in research in a manner that results in papers, grant applications, and reports that are intelligible to scientists, and conservation and grant agencies. If this goal is to be achieved, the bodies of TEK or LEK that are paired with WSK, similar to the case with citizen science in the United States, have to be included into projects in a way that does not completely undermine the controls and rigid research designs of WSK required by international conservation and government agencies and institutions. This is also becoming increasingly essential for the indigenous peoples in the remote region explored in this study, the South Caribbean Coast Autonomous Region (RACCS). Indeed, as global conservation dialogues from NGOs, government agencies, and international resource extraction companies addressing global warming, sustainable development, payments for environmental services, and ecotourism increasingly penetrate the RACCS, the interest of its communities' members in obtaining conservation or resource management grants is growing. Additionally, this means that their interaction with these organizations regarding resource management and resource–use regulations is on the rise. National and international researchers as well as local government and community members therefore perceive as increasingly important the capacitation of local peoples to participate in related environmental policy discussions and decision–making processes. Indeed, as global forces and dialogues are thrust upon them by governments and NGOs, it is perceived as critical that locals have the capacity to ensure their continued autonomy and land–use rights. This would require locals be trained to communicate their environmental knowledge, including ideas and beliefs about their ecosystems, such that it is represented truly but also articulated in a manner appropriate for national and international forums, which are often governed by WSK (Ellis 2005).

At the same time, even in projects without primary objectives that are directly related to TEK or LEK, it is impolitic to simply appropriate the LEK or TEK that meets the requirements of WSK, integrate it into research to ensure the production of scientific reports and conference material intelligible to Western scientists, and call it a day (Ellis 2005, Shackeroff & Campbell 2007). Indeed, this often results in the subjugation of the local peoples and the discounting of important components of their knowledge, including "myths, practices, values, beliefs, and other contextual knowledge" (Ellis 2005: 6). Due to this, when incorporating local knowledge into ecological research, it is equally important for Western researchers to consider issues of local capacitation and empowerment; local autonomy, in particular the rights of local peoples to direct their own environmental education pathway; and cultural survival and conservation. Without doing so, Western researchers may force assimilation into a world of Western values and beliefs onto local peoples (Agrawal 1995).

To assist researchers in simultaneously attaining these two goals: scholarly publication on the one hand and support of local autonomy with regards to LEK or TEK on the other, many scholars have published articles, papers, and reviews to inform practitioners of general practices and philosophies for using LEK or TEK and WSK systems in complementary ways that enhance data collection, ensure local cultural survival or both (Berkes 2008, Calamia 1999, Ellis 2005, Gagnon & Berteaux 2009, Stevens 1997). At the same time, it is often acknowledged that there are no overarching best practices for this type of bicultural project (See Moller et al. 2009, Stephenson & Moller 2009 and related forum). Indeed, most agree that the best–practices for effectively and respectfully engaging with and jointly applying LEK or TEK alongside WSK in an appropriate manner will be specific to the context of the research. This is due to the fact that there exists no general, rigid divide between LEK, TEK and WSK (Agrawal 1995). Each person and community has accumulated his/her/their L/TEK system in and adapted that system to a unique, changing landscape. Likewise, each different Western researcher and/or conservationist has developed his/her WSK system through a unique educational process inspired by a unique set of objectives. It follows logically that the best practices for a research project that jointly applies two of these unique knowledge systems, as well as the results of that collaboration, will also be unique. Huntington (1998) argues that for biological and ecological researchers who wish to fairly combine two knowledge systems in data collection, one means to determine these context–specific best practices is to use techniques based in social science to inform the biological science aspects of the project.

This paper supports Huntington's (1998) argument by reporting on my efforts to use results from mental model interviews of TEK to inform an on–going camera–trap study that has a data–collection methodology that integrates both TEK and WSK. It briefly outlines how an analysis of the interview results largely in the context of a framework proposed by Gagnon & Berteaux (2009) provided me with information about the nature of the TEK of my local assistants that I subsequently used to increase the efficiency and rigor of the camera trap research by maintaining the type of ecological sampling mandated by WSK. It also describes how the same interview results helped shape my efforts to use the research project to capacitate locals in WSK wildlife monitoring skills and data analysis, and to reinforce autonomy of local TEK transmission. Shortcomings and ideas for project expansion are briefly discussed.

Study Site

The 27,000 km2 RACCS comprises more than 20% of Nicaragua, the largest country in Central American. Yet with approximately 400,000 people, it holds less than 7% of its population. The RACCS was historically unconnected to the Pacific side of the country and its predominantly Mestizo culture, a culture characterized by its mix of Nicaraguan and Spanish descent and traditions, including the capacity to speak only Spanish. This resulted in the conservation of indigenous and traditional cultures that are greatly distinct from Mestizo culture. The small communities dotting the coast are of five main ethnicities: the Rama, Sumu, and Miskito indigenous peoples, the Garifuna with roots in Honduras and Caribbean Islands, and the Nicaraguan Kriol. They are sometimes referred to jointly as Costeños. Together these groups speak six languages: Miskito, Kriol English, Spanish, Ulwa, Rama, and Garifuna. The latter three are the most uncommon and rarely heard. Individual Costeños are generally proficient in between 2–4 languages. Isolation from the Pacific coast did not just entail cultural remoteness during this time. Indeed, the areas around Managua comprise this nation's economic hub, thus the RACCS was also economically and politically isolated for many years. National and international companies essentially only visited the RACCS to exploit the abundant natural resources for their own gain. Aside from some basic education initiatives, government entities never frequented the coast. It was, and in many locations remains, a remote region of extreme poverty with minimal development throughout much of history (Christie et al. 2000, Jamieson 1999).

Despite its historic isolation, the region and its people are becoming increasingly connected to the Pacific coast. An agricultural frontier has been moving from west to east across Nicaragua, meaning that a growing number of RACCS communities are Mestizo. From roughly the 1950s through the 1970s these Mestizo communities came to the coast intermittently as a result of government programs (Jamieson 2011), nowadays they come in greater numbers seeking land for farms and cattle pasture; economic opportunities they cannot find in the more densely populated western side of the country. While indigenous agriculture is traditionally of the swidden horticulture variety and incorporates large patches of forest into landscape level land–use, Mestizo practices are considered much less sustainable and include clearing forests entirely to raise cattle or sell land. Mestizo colonization and development cause a high degree of animosity and conflict between indigenous coastal residents and Mestizo migrants because, according to the Autonomy Statute of 1987, the Constitution drafted in 1995, the Demarcation Law 445 approved in 2002, and local tradition coastal communities have legal, communal tenure over the land under Mestizo settlement (Goett 2004).

A distinct type of connection between the RACCS and the Pacific coast was established in 2007 when a road was completed to the small town of Pearl Lagoon, effectively linking it to the markets of the river port city of El Rama and thereby Managua (Schmitt & Kramer 2009). Since then, local economies have started to shift away from the traditional focus on subsistence activities and Mestizo culture appears to be making stronger inroads and holding greater influence as an increasing number of Mestizos bring their businesses to the RACCS. In addition to this, government agencies and environmental NGOs have an increased presence throughout the region. This has included a rise in environmental education workshops and environmental regulatory action. Meetings regarding resource policy and regulations held with Costeño community members are often acrimonious, and local complaints of inadequate representation of their desires and customs are common. Thus, there appears to be a need for greater capacitation of RACCS locals in order for them to engage with all of these groups on a more level playing field and to include their traditions and beliefs as fundamental components of the processes of connection and development.

While the road has affected many of the coast's previously remote coastal communities, its influence is certainly not uniform. For instance, there is no road network in the RACCS, so most communities outside of Pearl Lagoon must travel by water to reach the new markets. The cost of making this trip is often prohibitive. This obstacle appears to buffer the effects of the new road; those communities at greater distances from Pearl Lagoon appear to be changing at a less rapid rate (Schmitt & Kramer 2009).

However there has been considerable change and development is likely to continue, including substantial land cover change to the region's expansive lowland tropical rainforests, mangrove forests, and seasonally flooded swamp forests due to increased Mestizo cultural and physical predominance. Indeed, in similar cases in other regions of the globe, new roads have resulted in extensive deforestation and cultural assimilation (Laurance et al. 2009). As Mestizo culture makes more inroads, Costeño traditional resource use practices are expected to decline further, especially if the only higher education opportunities for youths continue to mandate that they leave their homes to attend Spanish language schools in nearby cities. A larger research group with which I am affiliated initiated a 5 year interdisciplinary research project in this context in 2008. Research efforts include broad socioeconomic surveys, analyses of social networks, interviews on local politics, and ecological monitoring; all components of the project were discussed with local community governments and adjusted to comply with their requirements and desires. Subsequent to this, formal agreements were reached and research initiated. The principle investigators periodically travel to all communities to discuss research results, the progress of the project, and collect the feedback and the suggestions of community members. All community members are invited to these meetings and a majority attend. The project is a collaborative effort by researchers from Michigan State University (MSU) with between 2–20 years of experience in the region, and highly experienced Nicaraguan researchers from la Universidad de la Regiones Autónomas de la Costa Caribe Nicaragüense (URACCAN), a Nicaraguan located in Bluefields, the capital city of the RACCS. The combination of community government input in conjunction with input from URACCAN and MSU researchers with knowledge of communities and extensive experience living and working in the region ensured to a large extent that our methodologies were locally pertinent and desirable. The project has several goals, including the generation of the type of information needed to help guide local development such that local cultures and environments are conserved without inhibiting economic and educational growth, and the production of scientific reports and articles to further our personal careers and make contributions to international conservation. It is important to note that I am not affiliated with conservation NGOs or government agencies and are gathering data primarily as a means of increasing understanding of the connection of remote communities in the scientific community and in the RACCS. Although I may provide assistance if asked, the purpose of my research was to provide information that communities currently lack, not participate actively in decision making processes.

As one component of this larger project, a camera trap monitoring program was initiated in May 2009 to evaluate the relationship between terrestrial wildlife occurrence and local development. In this work, I hire indigenous and Kriol locals to work as my forest guides as they are some of the few ecological experts in a rural area of a country with universally poor infrastructure for science. I rely on their knowledge of the local forests in two primary ways. First, their spatial and environmental knowledge is critical to my navigating the landscape safely. Second, I collaborate closely with guides and discuss their knowledge of local flora and fauna to select locations for camera placement that will produce photos of the highest diversity of animals possible. To ensure that the incorporation of TEK was of benefit to camera trapping and as fair as possible to locals I endeavored to collect sufficient data to gain a basic understanding of the TEK being shared with us. To this end, mental model interviews were conducted in nine Costeño communities, here listed as they are locally known, either in Kriol, Miskito, or Rama: Haulover, Kahkabila, Brown Bank, Orinoco, Corn River, Bankukuk, Monkey Point, Kara, and Karawala. Spanish translations of community names may be found on some maps, but even Mestizo people in the RACCS rarely refer to these communities in Spanish. The population size and ethnicity of communities vary (**Table 1.1**), but the majority of adults in each site engage in subsistence fishing and farming activities to earn their livelihoods. The same is not necessarily true for the youngest generations, who are much more likely to leave home for work or school, or to solely engage in commercial fishing. No Mestizo individuals were interviewed as Mestizo settlements are located more inland along the agricultural frontier. This in no way discounts their environmental knowledge but rather reflects the geographic scope of the collaborative research effort of MSU and URACCAN, which is situated in coastal communities. Indeed, despite this, efforts have since been made to include Mestizos in research and outreach efforts.

Methods

Mental Model Interview Process

The lead author carried out mental model interviews (n=34) in 9 different RACCS communities to explore the structure and composition of the local forest knowledge most likely to be shared during my camera trap work with local guides. Interviewees were selected using a variant of the *peer review* technique described by Davis & Wagner (2003). Key community members including local government leaders and persons previously employed as forest guides were individually asked to free–list other men and women that they considered experts in knowledge about the forest. The men and women mentioned most frequently were subsequently interviewed. Interviews were conducted primarily in English and/or Spanish but also frequently included portions in Miskito and Kriol. Each interview was digitally recorded for analysis with the interviewee's permission. While it is not recommended to use more powerful community members as gatekeepers, it was necessary in most communities. Community members were generally unwilling to 'name names' without first consulting their leaders. Throughout the interview process I followed the protocol approved by MSU's Social Science Institutional Review Board, and thus gave each interviewee a description of the interview, its affiliation with the larger MSU/URACCAN project, and the general goals of both, and then informed him/her of his/her right to refuse to participate before the interview process began. Interviewees were not compensated for participation.

Granger Morgan *et al*. (2002) suggest that the mental model interviewer use an expert model to guide the mental model interview process. An expert model is a carefully researched map of all of the knowledge about the interview topic that an expert in said topic would be expected to hold. These maps typically are visualizations (Similar in style to **Figure 1.2**) that describe all of the information domains related to the main topic, tangentially related ideas and concepts, and how all of this interacts to form the expert's understanding of the topic. The map is subsequently used as a source of prompts throughout the interview. The objective of a mental model interview is to get the interviewee discussing the chosen topic without exerting significant influence over his/her comments. This allows the researcher to subsequently use interview comments to build a similar map of the interviewee's understanding of the interview topic. Interviewee maps are typically drawn and directly compared to the expert model to assess any gaps in the layperson's understanding[1].

However, I decided that creating an expert model of indigenous knowledge was unwise. For instance, the power hierarchy common to many Western scientist–TEK holder relationships often results in a tendency for Western scientists to assign characteristics to TEK systems based on incorrect assumptions and prior academic publications; this can lead to misunderstandings and even cultural or physical harm to TEK holders (Shackeroff & Campbell 2007, Davis & Ruddle 2010). I considered that the risk of doing this, even unintentionally, in the context of the

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[1] It should be clarified that the topics discussed in Morgan *et al*. (2002) are unrelated to issues of indigeneity or natural resource management. The authors address topics such as the public's misconceptions of radon gas, thus their use of the word expert, much disparaged in TEK research and ecosystem management, should not be viewed in a negative light.

creation of an expert model of TEK was too high. Further, I wanted to ensure that I avoided making assumptions regarding species classification during interviews, as differences between WSK and TEK classification systems have been previously recorded in the literature and are generally considered significant to understanding traditional knowledge and how it might differ from WSK and important to respect to avoid cultural insensitivity (i.e. Hunn 1982). Thus I decided to use what I termed a 'researcher's framework' as my guide. This framework simply outlined broad knowledge domains and subcategories I hypothesized would be pertinent. Under each domain I wrote lists of follow–up questions (See below). After a thorough review of the TEK literature, I based my framework on Zent & Maffi's (2008) cosmopolitan TEK domain list, which they created as a general foundation for studies of TEK loss and retention. Zent (2010) defines these knowledge domains as 'delimited fields of meaning and action that appear to be identifiable in a wide number of biocultural situations throughout the world' (2). I altered the original list to more directly apply to forested ecosystems and to address additional research questions regarding RACCS political and cultural ecological knowledge. Appendix B contains the final list of knowledge domains used for the researcher's framework.

The interview process had two main stages. In stage one, I prompted the interviewee to discuss forests, but did so with as little leading as possible to ensure I was not influencing responses. For instance, the opening prompt was: 'What I'd like to ask you to do is to just talk to me about what you know about the forest: that is, tell me all the different things you know and how you use that knowledge.' As was necessary to keep the interviewee engaged and discussing pertinent topics, this initial prompt was reinforced by several equally inexplicit planned phrases, such as: 'Anything else? It doesn't matter if you think it is right or wrong; just tell me what comes to your mind about the forest.' Throughout this stage, the 'researcher's framework' was used for taking notes. When and if an interviewee mentioned a domain in the framework, it was marked with a check and planned follow–up questions corresponding to that domain were asked to explore the breadth of knowledge associated with it. For example, if an interviewee enumerated several different tree species, I asked, ‘Can you tell me more about how you tell the different classes of trees apart?’

At some point, each interviewee ceased to mention new domains and stage two of the interview began in which the domains from the researcher’s framework that remained unexplored were more explicitly presented to the interviewee. This was still done with neutral language to avoid influencing responses. For instance, I often used statements such as, ‘Have you ever heard any one speak about rules for using the forest? Do you know anything about this?’ The data sheet was once again utilized in the same manner and follow–up questions asked when appropriate. I concluded each interview by asking the interviewee to describe any aspects of forest knowledge that he/she thought the interview process failed to touch on. From March–August 2010 this process was replicated with 34 individuals, between 2–8 members in each of the 9 communities, and lasted from 20 minutes to 1 hour per individual.

Focus Group Workshops

In June 2010 after completing the majority of interviews and a preliminary analysis, two multi–day focus group workshops were conducted in the community of Kahkabila. To organize the focus groups, the lead author held a community meeting in which all available adult community members participated (approximately 60) and were asked to select six men and six women considered local experts in forest knowledge. Over the next week three five–hour sessions were held with the men, and then three five–hour sessions were held with the women. The meetings consisted of three distinct stages, only two of which are pertinent here. In session one, participants were tasked with thinking about the forest and then listing the 40 trees, 40 herbs, 40 crops, and 100 animals they considered most important to know about. These limits were chosen based on the suggestions of Zent (2010), to make the task less daunting given the extremely high diversity of neotropical flora and fauna, and to ensure that participants ruminated on which species to include as most important to know about. Then in sessions two and three, each particular plant and animal species on their lists was individually re–visited, and participants were asked to share the knowledge they held about it. Participants described uses, physical plant and animal characteristics, stories, behaviors, and pertinent activities and interactions in rich detail. All information was recorded on poster board.

The focus group results pertinent to this paper included gender specific, thoroughly annotated lists of 40 trees, 40 herbs, 40 crops, and 100 animal species. Each group worked on documenting their knowledge of forest plants and animals for approximately 15 hours over three days. The extra time and ability to interact in a group led to greater attention being given to a number of ecological interactions, anecdotes, lore, and jokes that were infrequently mentioned in the much more rapid mental models interviews. I coded each group's set of data as if it had come from one additional mental model interview (See: A Note on Coding). The focus group approach elicits much more detailed data than does the mental model technique. I include the results in this analysis because I believe that they present a more accurate picture of the breadth of local TEK. Nonetheless, I did not weight them more heavily than a mental model interview so that the important nuances of the mental model interview results were not overshadowed. Although I assume basic environmental knowledge composition to be similar to some degree across communities due to the similarity of their subsistence resource extraction activities, this also prevents the data from being overly representative of the TEK most common in Kahkabila, if in fact it does differ markedly from that of other locations. In neither the mental model interviews nor the focus group workshops do I presume to have collected sufficient data to understand all of the complexities of TEK in the RACCS. Rather, it is important to underscore that I sought to and believe I have captured the TEK that my local assistants are most willing to share with outsiders such as me during fieldwork like my camera trapping project.

A Note on Coding

We conducted a preliminary analysis of the data and adjusted the knowledge domains and subcategories from the initial researcher's framework (Appendix B) to describe the forest ecosystem mainly in terms of forest plants and animals. More specifically, I used interview comments to first create a framework with plants on the one hand and animals on the other. Then I broke these down into subdomains. The plant subdomains included: Crops, Herbs, Trees, and Palms. The animal subdomains included Mammals, Insects, Birds, Reptiles and Amphibians, and Domestic Animals. Then I broke each subdomain into two categories of comments: Characteristic and Life History Information and Information about Use. Each of these comment categories, in turn, had subcategories; the former consisted of Morphology, Habitat Information, Planting Information, Harvest Information, The Organism's Diet, The Organism's Behaviour, Risks Associated with the Organism, Ways the Organism can be Harvested, Spiritual or Cultural Information, Political Information, and Other Information Related to Life History. The latter consisted of information on: Food Uses, Medicinal Uses, Uses as a Tool, Spiritual or Cultural Uses, Uses in Construction, Uses for Labour, Uses for Fuel, Commercial Uses, Uses in Craft or Ornament Making, Uses for Social Process, and Uses as an Indicator.

Although this rearrangement may make the local TEK corpus appear less complex in the figures below than is actually the case (for example, information on soil types is embedded within the habitat subcategory of plant and animal subdomains, rather than included as a separate domain), the strategy, as well as the construction of simple diagrams in general, helped me to more easily conceptualize and apply the interview results.

After modifying the researcher's framework, the interviews were reviewed a final time and the different statements within each one were coded to specify the domain, subdomain, category, and subcategory to which it corresponded. Interactions between subdomains described by interviewees were also noted. The subsidiary information associated with each species on the focus group lists was also reviewed and coded with the same methodology. Citations of *different* subcategories with reference to the same subdomain were coded as unique events (for instance, a description of the construction uses of 'maypole' trees in minute 3 of the interview and the medicinal uses of 'locas' trees in minute 7). However, many individual interviewees contributed two or more comments that were coded into the same subcategory within the same knowledge subdomain (for instance, by describing the construction uses of 'maypole' trees in minute 3 of the interview and the construction uses of 'mahogany' trees in minute 7). After coding all interviews, I decided not to differentiate between these interviews and those in which the same subcategory within the same subdomain was only touched upon a single time. In other words, for each interview, each subcategory in each subdomain was either given a 1 if it was mentioned or a 0 if not. This was done to avoid mistakenly interpreting gregariousness of one individual as an indicator of a component of the TEK most likely to be shared with me by Costeños. Thus, each subcategory within each subdomain has a maximum value of 36, the total number of interviews, while each subdomain has a higher maximum value that represents the sum of all its subcategory values. I differentiate between interviews (maximum value=36) and citations (highest maximum value=262) in the results and discussion to keep this distinction clear.

Cognitive Maps

Cognitive maps were created using CMAP tools, a free software created by the Institute for Human and Machine Cognition (IHMC 2010). I drafted an initial map that describes the interactions between subdomains that were described by interviewees. Then I created a set of more detailed, embedded maps describing each subdomain according to its subcategories. Together, these maps represent the aggregation of the data from all interviews; they are composite maps that describe the knowledge about local forest plants and animals that a typical Costeño is most willing to share with a Western researcher. In the particular context in which I work with many different local guides for the camera work, aggregate maps were deemed a potentially more helpful tool than over 30 sets of individual maps. Further, although interviewees were ethnically distinct and varied in age, the similarities in livelihood activities led to considerable homogeneity in responses, which offered additional support for my decision to build aggregate maps. Despite this, the diagrams should not be interpreted as a comprehensive depiction of TEK in the RACCS as TEK is much more complex, with nuances unexplored by my interviews that vary between communities and individuals for political, religious, and economic reasons.

Results

Interviews

Mental model interview comments provide a picture of the Costeño relations with and knowledge about the forest that are most likely to be shared with me during camera trapping research. In certain instances, some of which are noted below, the interview content agreed to a great extent with the content described in the literature available on RACCS natural history and the region's history of resource exploitation. I believe this supports my conclusion that interviewee responses reflect the TEK Costeños are most apt to share with us, and further contend that other outside forest ecosystem researchers would likely receive similar types of information throughout the course of collaborative research.

Tree knowledge (262 citations) was the most frequently cited knowledge subdomain in the mental model and focus group interviews. Multiple tree subcategories were mentioned in over 1/3 of interviews. Trees, for example, were commonly described as important for local subsistence activities, as lumber for building houses (31 interviews), as material for dugout canoes and tools such as harpoons and paddles (21 interviews), and as sources of firewood and charcoal (11 interviews). Locals also consider trees commercially valuable (11 interviews), which resonates with the historical literature on the coast: throughout much of the twentieth century, multiple foreign companies came to the region and extracted large quantities of precious woods, including mahogany (Swietenia macrophylla), Spanish cedar (Cedrela odorata), and Caribbean pine (Pinus caribaea) (Christie et al. 2000). Costeños were frequently employed by these companies (Christie et al. 2000).

Costeños also revealed a broad knowledge of tree ecology, including tree identification (21 interviews) and tree distribution across the landscape (22 interviews). Multiple interviewees described how the timber–boom years, in conjunction with the expansive deforestation caused by Hurricane Joan in 1988, have made both the most profitable and locally useful tree species quite rare. This has apparently focused local attention on aspects of tree natural history such as reforestation patterns and growth rates (21 interviews). It has also made these trees into political symbols. When it is one of the last few standing and threatened by the chainsaws of Mestizos encroaching onto local territory from the Pacific side of the country, a large mahogany tree is much more than simply a tree (13 interviews). Surprisingly, ecological interactions involving trees were infrequently mentioned except in the context of wild mammals eating from and gravitating toward fruit trees (22 interviews) and intercropping fruit and timber trees with other food plants in farm fields (6 interviews)

Mammal knowledge (256 citations) was the second most frequently cited subdomain. As in the case of trees, multiple mammal subcategories were described in numerous interviews. Most frequently mentioned was the contribution of mammal meat to the local diet (31 interviews). Mammals are also commercially important (19 interviews) given the active market for bush meat described by several interviewees. Knowledge of other mammal uses, however, was less frequently cited.

Given that Costeños described successfully hunting or capturing an animal and preventing animals from raiding crops (18 interviews) as vital to their livelihoods, again both in terms of household economy and subsistence; it is unsurprising that all interviewees revealed a broad knowledge of mammal characteristics and ecology. This knowledge includes behaviour (27 interviews); habitat preferences (28 interviews); seasonal activities (22 interviews) and species of seeds, fruits, crops, and herbs commonly eaten by game animals (32 interviews).

Ecological interactions involving mammals were extremely common; it was by far the most densely connected subdomain. The most frequently mentioned mammal interactions with other animals generally involved predation or competition. The most frequently mentioned mammal interactions with plants generally involved shelter or dietary information.

Herb knowledge (145 citations) is the third most frequently mentioned subdomain. The use of medicinal herbs (29 interviews) was described in interviews as important to the wellbeing to many of the Costeños. A variety of common ailments such as colds, headaches, general pain, and 'kidney' problems are treated with herbs that the general population knows well and often plants in home gardens (33 interviews, also Barrett 1994, Coe & Anderson 2005, Coe 2008). The economic value of herbs was less commonly cited (7 interviews) than the economic value of trees and mammals. Interviewee comments addressed this: So–called bush–doctors or sukias who are highly respected for their knowledge in combating serious illnesses, especially those caused by evil spirits, as well as for their ability to prescribe cures for illnesses through a type of controlled dreaming, are generally the only Costeños paid for herbal knowledge. Other local doctors who can cure people suffering from venomous snake bites are also sometimes paid. Yet both are very protective of their knowledge, sharing it with very few people. In this sense, they hold a monopoly over the herbal economy; the typical Costeño therefore does not ascribe economic importance to herbs.

Costeños hold substantial knowledge of common herb habitat (27 interviews) and reproduction (33 interviews). However, ecological knowledge of herbs was less commonly mentioned than ecological knowledge of trees and mammals. Aside from its food value for mammals, descriptions of ecological interactions involving herbs were uncommon.

As with the other frequently mentioned subdomains, crops were described in the context of their obviously important contribution to subsistence (33 interviews), however crops were less frequently described in terms of their commercial value (5 interviews). This agrees with analyses describing local markets; fish are more commonly sold than crops (Schmitt & Kramer 2009).

Despite the apparent lack of significant commercial value, interviewees revealed much information relating to crop ecology. Information on planting (33 interviews), harvesting (22 interviews), and suitable crop habitat (27 interviews) was common in interviews and described in great detail. Ecological interactions involving crops were not commonly discussed, except for crop–mammal interactions (20 interviews) and crop–insect interactions (5 interviews). In both cases the interactions predominantly described certain mammal and insect species as pests that can consume certain crops and ruin the harvest.

With the exception of birds (the food value of the great curassow (*Crax rubra*) and crested guan (*Penelope purpurascens*) was often mentioned (10 interviews)) there was a lack of salient patterns in interview comments about the other subdomains that limits a similar overview of the content. In general, they were also much less frequently discussed, as displayed in the cognitive maps below. This extends to comments about ecological interactions involving them, which, aside from those with mammals, were uncommon.

Cognitive Maps

The interaction map (**Figure 1.2**) displays the subdomains of knowledge considered in this study and the interactions between organisms mentioned by interviewees. The numbers superimposed on each interaction arrow represent the number of interviews in which an example of that interaction was explicitly described. For example, the 1 on the arrow connecting 'Domestic Animals' and 'Trees' indicates that an interaction between a domestic animal species and a tree species was described in only one interview. The numbers in parentheses within the subdomain nodes themselves refer to the number of interviews in which a within subdomain interaction was mentioned. For instance, the number 5 underneath 'Mammals' indicates that a wild mammal species was described as interacting with another wild mammal species in 5 different interviews. The values associated with interactions are herein referred to as 'tie–strength' and range from 0–22. Tie–strength values above 10 are in bold to highlight those most frequently mentioned. Within subdomain tie–strength values only ranged from 0–5. It is clear that 'Mammals' is the most densely connected subdomain.

The second set of maps is at a finer, within subdomain scale (**Figure 1.2**). Each describes one subdomain according to the different subcategories associated with it by interviewees. Each subdomain has between 11 ('Insects')–18 ('Trees') subcategories associated with it. The numbers within the different subcategory nodes indicate the number of interviews in which that subcategory was referenced in the context of the associated subdomain. These values range from 1 to 33. The numbers within the principle subdomain nodes indicate the cumulative number of citations that each received in interviews, irrespective of subcategory. These range from 'Insects' with only 37 citations to 'Trees' with 262. It is important to interpret these models as 'submaps' embedded within the previous interaction map.

Discussion

Interview Content

Gagnon & Berteaux (2009) reported on what they consider a general trend in research that aims to gather the data embedded within TEK systems. They posit that the 'level of the local community's interest in and contact with a given species influences the ease with which it is possible to gather traditional ecological knowledge' (Gagnon & Berteaux 2009: 6). In particular, they hypothesize that when a community 'has little interest in or contact with a given species, e.g., some cryptic insects, TEK is low and therefore cannot be gathered productively' (Gagnon & Berteaux 2009: 6). In contrast, they also hypothesize that 'when the community is highly interested in a species, issues surrounding this species can be locally strongly politically charged…and TEK can become difficult to acquire without bias' (Gagnon & Berteaux 2009: 6). They conclude that the most readily gathered, unbiased TEK, i.e. that TEK most likely to be discussed by indigenous people in interviews and collaborations, will be about species of high local interest that are often interacted with, but in no way contentious.

In general, my results confirm the pattern that increases in interest and contact with a species makes the TEK associated with it more readily discussed by locals. For instance, the four subdomains most commonly cited: trees, crops, herbs, and mammals, were frequently described in interviews in terms of how Costeños use species within them to make them directly beneficial to household economics and subsistence. In other words, the interviewees clearly have high interest and high rates of contact with these subdomains. This is underscored by the fact that interviewees revealed more detailed knowledge of them. For instance, these more frequently cited subdomains were also those with the highest mean tie strengths. Knowledge about these subdomains, which are locally perceived as highly important, are therefore most likely to emerge in the greatest detail in research collaborating with Costeño TEK of forests as they are the first that come to mind in interviews and fieldwork. It is also possible that locals consider that researchers share their view of these subdomains as highly important and therefore choose to share knowledge about them first and foremost.

In contrast to this, insects are not consumed or sold in the RACCS, and although they are important for pollination, this is unlikely to be an obvious process that many locals observe and interact with frequently. Herptiles and birds do have historical commercial value and there are certain forest–associated, rare species of both that contribute to local diets, but these are less commonly sold and eaten respectively in contemporary times, making a detailed ecological knowledge about them less critical for Costeños. The scarcity of these species likewise limits contact with them. In accordance with the Gagnon & Berteaux (2009) framework, as the evidence suggests that Costeños have lower interest and lower rates of direct, meaningful contact with these subdomains of less subsistence value, knowledge about them should be less likely to emerge in interviews and research collaborations between Western scientists and RACCS locals. Indeed, in my interviews, I received fewer, less detailed citations regarding this knowledge. It is important to underscore, however, that this in no way confirms the absence of this type of knowledge in the local TEK corpus. If researchers wanted to seek information about these subdomains, more direct interview techniques would be needed.

A similar pattern is also evident if ecosystem interactions are considered in and of themselves. For example, comments about mammal–crop/fruit tree interactions (35 interviews) were more frequent than mammal palm interactions (12 interviews) or mammal forest tree interactions (10 interviews). The mammal–plant interactions off farms were only described in the context of animal habitat use; however the mammal–plant interactions on farms were described in the context of threats posed by animals to crops, hunting, and animal habitat use. Again, the interviewees appear to have higher interest and higher rates of contact with the interaction of higher subsistence value, mammal–crop/fruit tree interactions, and this interaction emerged more frequently in interviews. Thus, I should expect knowledge about these interactions to emerge more frequently in my research collaborations that include Costeño TEK of forests.

Although my results generally support the Gagnon & Berteaux (2009) hypothesis, they also include additional nuances. For example, in the context of my results, infrequent citation of a domain may have an alternative explanation: the domain is not strongly associated with the forest. This likely explains the dearth of palm comments. For instance, multiple palm species are locally important for subsistence as roofs in these communities are commonly thatched with palm species. In certain communities, *Raphia taedigera* palm fruits are also consumed as a seasonal dietary supplement. Additionally, palms are widely considered commercially valuable in light of a market–oriented oil palm plantation near the majority of study communities, and an active market for *Acoeloraphe wrightii*, which is used to stake lobster traps. Thus, it would seem likely that interviewees would commonly describe their ecological knowledge of palms. Yet this was not the case. However, it was common for interviewees to describe palms as growing in 'swamps,' which were referred to in a way that made it seem as if locals classify swamps as a land–class distinct from forests. Perhaps palm knowledge would have been discussed more frequently in an interview on swamp environmental knowledge. This hypothesis is supported by the relatively high mean tie–strength of palms. This result does not serve to undermine the Gagnon & Berteaux (2009) argument, but rather as a cautionary note for researchers seeking to understand characteristics of a TEK system using results from interviews that only explore specific domains of local TEK.

On a similar note, and underscored by comments and results described in the previous two paragraphs, my results are not comprehensive enough to determine if TEK about the less frequently cited subdomains is "low" as the Gagnon & Berteaux (2009) framework suggests. This is in part because my results are only informative about knowledge of these subdomains in the context of forests. They say nothing about the broader knowledge of them. For instance, green turtles have been harvested for centuries in Miskito communities and the sharing of their meat a ritual that maintains social structure (Nietschmann 1973). Thus a more general interview about TEK that included marine ecosystems would have unquestionably included many references to reptiles. Furthermore, as the interviewees probably considered the information they shared to be of high importance to their communities, they likely assumed that it would be the information of greatest interest to me as well. This means that it could have been included to the exclusion of other information that they thought would have been of less interest to us. That my interview method was rather rapid makes this more likely. To truly make conclusions about *levels* of TEK about different organisms would require long–term ethnographic fieldwork or the creation of some type of aptitude test based on long–term observation and collaboration (i.e. Zent and Maffi 2008).

Finally, politically charged information did emerge in the interviews, and often included denigrating comments about *Mestizo* land–use practices and/or hunting philosophies. They were described as having a much more negative effect on forest resources than the practices typical of coastal communities. The Gagnon & Berteaux (2009) framework suggests that information provided in this context should be highly biased. I have no means of systematically comparing the impact of *Mestizo* and Costeño practices, but anecdotal evidence, including anecdotal evidence from unsystematic wildlife observations, gained from visiting farms of both groups supports interviewees' statements. Furthermore, analyses carried out on wildlife camera photos provide evidence of a strong negative effect of *Mestizo* farms on terrestrial mammal and bird activity (Jordan & Roe 2010). Nonetheless, it was more important for my fieldwork to understand that this type of comment would be frequently shared with me throughout my collaboration with locals than to test and judge its bias.

Application in Camera Trap Research

The general patterns revealed through this analysis assisted my camera trapping work. A brief description of some details of the camera trapping facilitates an explanation of how the interview results helped. Given that a large portion of the study area constitutes forests actively managed by Costeños, agricultural fields, or impenetrable swamp, I need to rely on guides to direct me toward forested areas that are at least plausibly accessible. Thus a sampling grid of 2 km^2 cells was overlain on maps of the local forested ecosystems surrounding each community and the centroid points of those cells were labeled and randomly numbered. In the field, the protocol is to walk as close to the lowest numbered centroid point that a guide considers accessible as possible. Then I ask him in clear terms to walk to the closest area, within the same 2 km^2 cell, where he believes the most different wildlife species will traffic. The guides choose the general location for the camera based on their knowledge of local wildlife, and then I select a precise location in the general vicinity that has a favorable structure and adequate light conditions for installing the device.

Initially, it was assumed that bringing a guide to a random centroid point before carrying out this process would ensure that I met my aim to install cameras at an ecologically diverse set of sites. For example, I assumed that the randomness would ensure that camera sites would be located at a variety of distances from agriculture and thereby enable me to build models to assess the impacts of local subsistence activities on wildlife. However it rapidly became evident that after I approached the centroid point, many guides actively searched for areas close to a farm, sometimes passing on more densely forested areas with fruiting trees and shrubs important for wildlife. Why, exactly, did this occur? First, it is a reflection of my poor diction; edge habitat *is* potentially where the most different species of wildlife will traffic. Second, it appears that the higher interest in and higher contact with wildlife–crop/fruit tree interactions (35+ interviews) than with wildlife–forest tree or wildlife–palm interactions (10 total interviews[2]) meant that my guides were more likely to consider the former interaction during camera placement than either of the latter two. In other words, it seems that guides had higher contact with the former interaction and were therefore perhaps more confident placing a camera near a farm with wildlife food resources than near a fruiting forest tree or palm at greater distance from the farm. As my interest was to sample various sites with various ecological characteristics in order to relate my measure of site diversity to different degrees of forest degradation and land–use, it took a slight adaptation of the protocol and additional explanation to attain a variety of edge and forest–core camera sites. Although I may have noticed and tried to address this problem without carrying out social science interviews, the results helped me to notice the problem rapidly before the issue undermined my goal of understanding landscape scale patterns in biodiversity and also helped to explain the bias. In this same vein, it helped me to avoid the danger of assuming that Costeños did not know about wildlife activity in the forest and thereby misrepresenting and underestimating their knowledge. Indeed, without an awareness of the nature of the knowledge they are most apt to share, I may have abandoned the initial protocol and sought to choose forest sites independent of Costeño input and then reported on this deficiency in the literature.

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[2] These numbers may confuse the reader as tree–mammal interactions (22) are greater than crop–mammal interactions (20), but many of the tree–animal interactions mentioned involved fruit trees planted on farms and in communities. Only 10 interviews referred to trees likely to only occur in more primary forest.

[3]It is important to note that researchers did not attend these meetings. Rather, they were held in the typical community meeting format, with local leaders presiding and offering an introduction to the meeting and other attendees given the opportunity to provide their input about the topics of discussion.

As I caught the problem early on, I do not have data to adequately compare diversity indices from cameras placed before the protocol change with cameras placed after. Returning to study communities now to test the benefit of making this change in my camera placement protocol by using the original protocol to place additional cameras within each site with other locals and then comparing diversity indices between the new and old cameras is cost and time prohibitive. Further, it may not work as most community members in each study community are now very familiar with the camera–trap research. However, the results of a different project offer indirect evidence that the difference in diversity would be substantial. During my initial camera placement, I placed approximately 104 cameras along the coast of the RACCS. Of these cameras, only four yielded photos of Baird's tapir (*Tapirus bairdii*), a species unknown by the International Union for Conservation of Nature (IUCN) to occur throughout much of the study area before my camera placement (IUCN 2011). After discussing tapirs with my local guides, I sought funding to initiate research focusing on their distribution in the RACCS. This project also has a camera trapping component and a similar camera placement protocol as the broader camera trapping effort. However, in each of my initial camera sites, the guide is asked to choose the place that he considers it is most likely that a *tapir* will pass, rather than the highest diversity of species. Although the project is on–going, of the first 56 cameras placed for tapirs, 14 cameras yielded tapirs. Even if the additional camera sites which have not yet been sampled with cameras for tapirs are removed from consideration, and account for imperfect detection, the tapir detection rate of 'tapir cameras' when a tapir is present (44%) is substantially higher than the tapir detection rate of 'regular cameras' (13%) (Presence v2.3 2012). Future, detailed publications on this project are forthcoming (Jordan *et al.* 2011). To us, this confirms my interview results that my Costeño assistants have a complex understanding of their ecosystem and understand which components are utilized by which organisms. Furthermore, it suggests that my change in protocol likely altered the results of the camera trapping and enabled a sampling design that yielded results that are more representative of the entire forest surrounding communities.

The details from the interview comments also helped in more basic ways: descriptions of key animal habitat, areas of primary forest and areas of intense resource exploitation were almost always spatially referenced and given with their local toponyms. This enlightened me to new potential areas for camera trap sampling and facilitated my arriving at those locations.

Details also allowed me to refine the covariates I originally hypothesized would significantly affect wildlife occupancy. For example, I now intend to separate seeds and fruits harvested for human consumption from those not harvested for human consumption into distinct covariates. This will in theory improve the fit of my models by better accounting for human disturbance, and in conjunction with harvest data allow me to better explore original hypotheses about the impacts of subsistence communities on wildlife.

Application in Building Rapport and Local Capacitation

Again, the interviews underscored the political significance of forest resources, particularly of mammals (11 interviews) and trees (13 interviews). Most political comments referred to the agricultural frontier and associated natural resource threats, outside attempts to regulate local resources, or a within community effort to protect community resources. Additionally, many interviewees described plants and animals as having 'spirit owners' (49 interviews). These supernatural beings, rather than representing benevolent regulators of natural resources, appear to symbolize selfishness and individualism, and a distrust of certain outsiders, who have previously entered community lands to engage in unfair dealings (Jamieson 2010). The Caribbean coast of Nicaragua has had a politically and economically tumultuous history during which many Costeños have suffered economic, cultural, and physical distress. Indeed, whether or not the environmental information supplied regarding politically and spiritually charged entities was biased, as Gagnon & Berteaux (2009) hypothesize, given that these political and spiritual topics were discussed in detail in greater than 1/3 of interviews, the interview results quickly led me to conclude that the project would benefit if I held whole–community meetings in each study community to clarify that the objectives of the camera work are unrelated to regulating resource extraction and that the researchers are unaffiliated with government resource agencies. Previously I had done this only with community leaders. To further ensure good will and a long–term trusting relationship, it was decided early on to also distribute all wildlife photos taken in and around each community to its members and to periodically seek feedback and suggestions for the project. my efforts to include whole communities in the work have fostered a sense of community pride in the project in many areas. This pride, in turn encourages community members to protect the cameras when I leave them in the field, which in general leads to fewer stolen or disturbed cameras and the collection of more data. In the community of Kara, for instance, a man from a different, nearby village stole a camera and tried to sell it in a third village. News of the sale reached Kara and one of my forest guides aggressively pursued the man; he was castigated for his actions and the camera was returned to us. He is currently wanted in Kara and has been sentenced to manual labor in absentia. Indeed, the actions inspired by the results of my interviews have helped the research team avoid many of the pitfalls of cultural relativism and for that I have clearly benefitted.

Local peoples have also benefitted more directly from my scientific research being more culturally sensitive and based in a basic understanding of the TEK they share with us. Indeed, my efforts to work fairly with local assistants have encouraged many of them to take ownership over the project to the extent that they have become comfortable with requesting more formal training in camera setup, programming, and installation. In the communities of Haulover, Kahkabila, Karawala and Orinoco, my assistants are now able to undertake this work independently. Furthermore, in Kahkabila and Pueblo Nuevo, assistants have requested and received cameras to monitor the activity of particular species (jaguars (*Panthera onca*) and collared peccaries (*Pecari tajacu*), respectively) of interest to community members. In Kahkabila, leaders hope to use the information to request money for jaguar conservation from NGOs active in the area. In Haulover, a local assistant plans to use the photos in a community meeting to discuss hunting regulations. Throughout the course of research, assistants from these same communities have also been trained in the use of GPS technologies. Indeed, it is clear that locals are becoming capacitated in the technology to a degree sufficient for them to use the data as a tool in their interactions with local authorities. In fact, I are currently working with Kahkabila locals to use camera trap results in grant applications for additional forest conservation and forest patrolling projects suggested in community meetings[3]. Similarly, in Monkey Point, territorial leaders asked me to draft a report describing camera trapping results for them to use in meetings concerning the construction of a deep–water port in the bay by their community (Jordan 2011). Without my initial efforts to work more closely with entire communities, which was informed by interview result analysis, these activities and phenomena would likely not have occurred as rapidly if at all. This also underscores the fact that WSK projects that apply TEK and the information such projects generate are inherently political, and that simple integration of TEK without actions and activities to keep indigenous peoples engaged in the project will yield less comprehensively beneficial results and limit researchers' capacity to attain the second objective presented in the 'Introduction.'

Interview results also provided material for a forest wildlife guide that has been distributed to communities as an educational tool for youth (Jordan & Urquhart 2011). Throughout interviews, interviewees lamented that the knowledge their children have of wildlife is declining. Most comments indicate that the primary reason for this trend is a decline in the forest activities undertaken by RACCS youth. Youths are reported to spend less time in the forest as their time in school both in and outside of their home community increases. While elder community members wish the TEK they hold was transmitted to their children, they also want their children to remain in school. Thus, after discussing the idea with locals, contributing a wildlife guide inclusive of both WSK and TEK for use in local schools and households was decreed desirable. The first edition was published with local input and distributed without charge in 2011 (Jordan & Urquhart 2011). It is important to note that myths, beliefs, values, and other types of contextual information not found in typical wildlife field guides *was* included in this publication after further local consultation. The first edition is in English, and versions in Kriol, Miskito, and Spanish are currently in the planning stages. Although the guide was created with my assistance, I believe it provides a novel way for locals to transmit their knowledge and therefore increases their options for autonomously guiding TEK related processes in their communities. Other collaborative TEK projects and workshops are currently in planning stages.

While it should not be assumed that local, independent analysis of species' presence and absence across the landscape has not occurred, perhaps the largest deficiency in the project thus far is that I have not used the rapport I have generated to involve local assistants in formal

Western scientific analysis of the photos or in publication of the results. This is a problem common to many projects that include both TEK and WSK (Ellis 2005). I intend to rectify this in coming years with those assistants most active in this project. Despite this, undergraduate students from two of the study communities who attend URACCAN have analyzed, interpreted and written about the camera data for a thesis project supervised by the lead author. The lead author and an URACCAN research collaborator born in the RACCS have also jointly published on camera trap findings in a national journal, an international newsletter and presented a similar paper at an international conference (Jordan et al. 2010, Jordan & Roe 2010, Jordan & Roe 2011). These efforts are clearly not a substitute for more formal analysis and publication with local assistants. Indeed, it has been shown that capacitating university educated locals is not an effective way to ensure capacity building and representation within rural communities (i.e. Ellis 2005). Nonetheless, these activities are a step in the right direction toward a more fully just relationship with local communities and assistants and have fostered a relationship that would permit such expansion of capacitation efforts. At such a time, the mental model interview results will be used to help guide the design of workshops and to help ensure that the format of data is applicable to locally important contexts.

Broader Conservation Potential

Lastly, much of the same information that has been helpful to research efforts has additional potential to inform practicing conservationists of how to create better partnerships with these RACCS communities. For instance, in the design of conservation initiatives or protected areas, it would be invaluable to know that the prevailing belief amongst Costeños is that their farmland is not categorically distinct from, but an important component of the forest. Attempts in the RACCS to forge a conservation partnership based on notions of sustainable use and a matrix–concept inclusive of swidden horticulture would be much more successful than one based solely on an exclusive protected area concept that included rigid regulations and fines. Similar beliefs and research showing the benefit of swidden agriculture from other regions are not uncommon in Latin America, but it is never wise to make assumptions in applied conservation, thus it is important to explore the issue in the particular context of a project. The mental model interview results provide the necessary evidence. Also, the political environment of this legally autonomous area that was made evident in many interviews dictates that a priority must be given to local consultation in any conservation initiative. In the RACCS, the judgments that the autonomous local peoples and their leaders make regarding a project instituted by an NGO or government agency are instrumental in determining its success or failure. First contact, first meetings, and equity in consultations would have to be much more carefully regulated than may be the case elsewhere.

The cultural information revealed in interviews could also be used more creatively. Understanding which species and areas are considered spiritually (48 citations) or politically (41 citations) important versus those that are considered risks to personal health or agricultural pests (51 citations) would allow for the proposal of more culturally sensitive and feasible regulations and help guide local collaboration and communication in this regard. It may make sense, for instance, to work with a suite of species popularized in local myths (i.e. Baird's tapirs, Central American agoutis (*Dasyprocta punctata*), mantled howler monkeys (*Alouatta palliata*)) in conservation discussions rather than those considered dangerous or mischievous (White–nosed coati (*Nasua narica*), tayra (*Eira barbara*)). These same ideas could also be applied in order to design more engaging environmental education initiatives inclusive of both WSK and TEK. The specific applications would largely depend on the objectives of the project; the social, cultural, and economic contexts; and the desire of Costeños (Shackeroff & Campbell 2007).

Conclusion

Recent trends in conservation biology suggest that collaborations and partnerships that apply two distinct knowledge systems in data–collection are likely to continue increasing. Such projects are often challenging when WSK is involved, as the work must meet the dual goals of producing scientific reports, articles, and papers; and respecting and including the disparate knowledge system in a just manner that respectfully supports its autonomy. The challenging nature is partly due to the fact that each different collaboration, as it is comprised of two unique knowledge systems, will have *context specific* best practices for justly working with the two systems and achieving these goals in the same project. Huntington (1998) argues that arriving at and implementing these best–practices for each project are greatly facilitated when WSK researchers couple their biological investigations with research techniques based in social science that access, document, and provide them an understanding of the other knowledge system.

This article provides support for Huntington's (1998). my analysis of mental model interviews concerning Costeño forest knowledge using a framework proposed by Gagnon & Berteaux (2009) clarified my understanding of the TEK my local assistants were sharing with me and has helped me tread a path toward attaining the two goals outlined above. In the context of the first goal, creating cognitive maps allowed me to consider the TEK of my local assistants with greater awareness, which enabled me to improve the sampling methodology of a camera trapping study of neotropical mammal occupancy that applies it. The results of the study have since resulted in publications, presentations, and additional grant applications (Jordan et al. 2010, Jordan & Roe 2010, Jordan 2011, Jordan & Roe 2011), generated potentially useful conservation suggestions and helped avoid undesirable cultural pitfalls of strictly filtering TEK into data (Shackeroff & Campbell 2007).

Additionally, my mental model interviews documented certain components of TEK of forests in an area that is rapidly changing due to the establishment of recent connections to external markets and multiple development initiatives. As Moller *et al*. (2009) argue, cultural diversity is under just as great a threat as biological diversity in these contexts and work to document TEK as a means of supporting TEK transmission can help prevent further losses. In these contexts, it is essential for locals to have the WSK and TEK resources necessary for them to autonomously choose in which conservation and resource–use conversations to engage, to communicate as equals with other parties involved in those conversations, and to choose the knowledge they and their families are exposed to most frequently. Indeed, *ex–situ* conservation of TEK is not sufficient for cultural conservation (Agrawal 1995). I believe that my written overviews of interview results, and especially the behaviors and activities stemming from them, including the capacitation of local assistants and publication of a wildlife guide that includes a variety of TEK not included in typical wildlife guides (Jordan & Urquhart 2011) have helped locals to take some of the steps required and/or provided resources to help achieve such autonomy. Further plans to use interview results to help design training and education workshops will advance this progress.

Although many biologists will likely argue that there is not sufficient time to add a social science component to their research, a practical understanding of the entire context in which research is carried out is often essential for a project to be efficient and fully attain its objectives. Therefore if a project includes the integration of two knowledge systems, such as TEK and

WSK, undertaking interviews for an hour each day before or after field work with the purpose of helping to attain that understanding is more than worth the effort. Working in conjunction with a trained social scientist and increasing sample size would, of course, yield even greater benefits and insights (Shackeroff & Campbell 2007). Indeed, my methodology and sample size are clearly incapable of yielding a comprehensive understanding of the TEK of Costeños. However, I believe that undertaking such interviews to the extent possible is better than nothing. The partial understanding of the TEK that Costeños are most likely to share with me that I gained through mapping mental model interviews was adequate to make my project more culturally sensitive and scientifically rigorous, and to support local autonomy with regards to TEK. Ecological studies and monitoring programs conceptually based in WSK that apply components of TEK systems have been and continue to be contentious and political, yet in many contexts it is the only format in which such efforts are feasible (Luzar *et al*. 2011). Applying research components based in social science to complement biological research can help scientists undertaking such projects to better understand their relationship and work with indigenous and other rural peoples. Even in projects with objectives that are ostensibly unrelated to TEK, such an understanding can help to increase the efficacy of the project as a whole, including improvements in scientific data collection and in community outreach and capacitation.

APPENDICES

APPENDIX A: TABLES AND FIGURES

Table 1.1 Summary of important community characteristics. PL=Pearl Lagoon.

Community	Ethnicity	Distance to PL (km)	Population
Haulover	Kriol	<5	~600
Kahkabila	Miskito	8.32	497
Brown Bank	Garifuna/Kriol	13.7	202
Orinoco	Garifuna/Kriol	23.9	1,010
Karawala	Ulwa	65.6	1,700
Kara	Ulwa	61.9	~200
Corn River	Rama/Kriol	120.0	~40
Monkey Point	Kriol	82.5	~60
Bangkukuk	Rama	85.0	~70

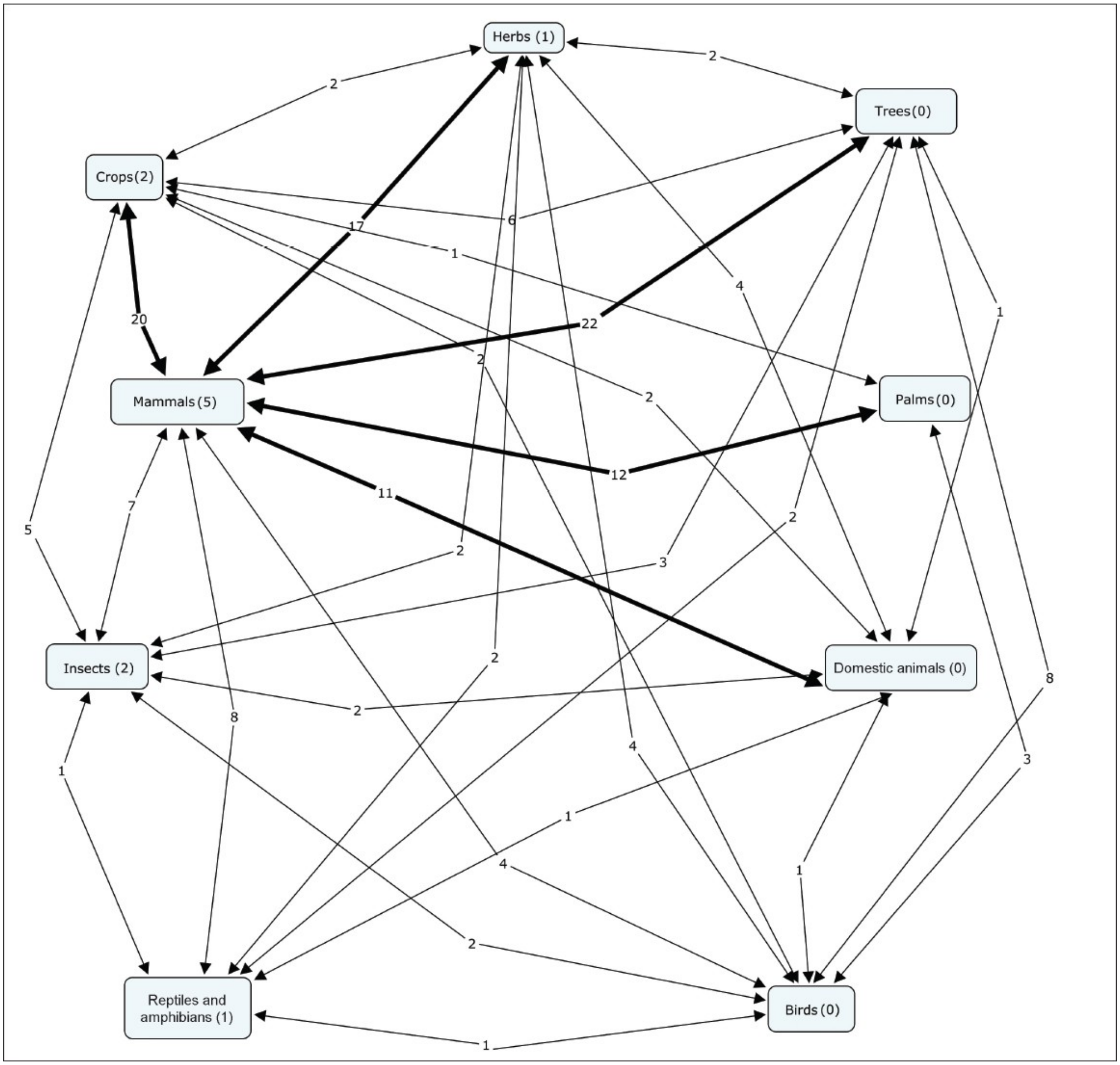

Figure 1.1: Cognitive Map 1 displays the different knowledge subdomains explored in this paper and the important interactions between them according to local peoples. Numbers superimposed on arrows indicate the number of interviews in which a particular interaction was described. Numbers within subdomain nodes refer to the number of interviews in which a species was described as interacting with another species from the same subdomain (i.e. a mammal species interacting with a different mammal species). These tie strengths range from 0–22.

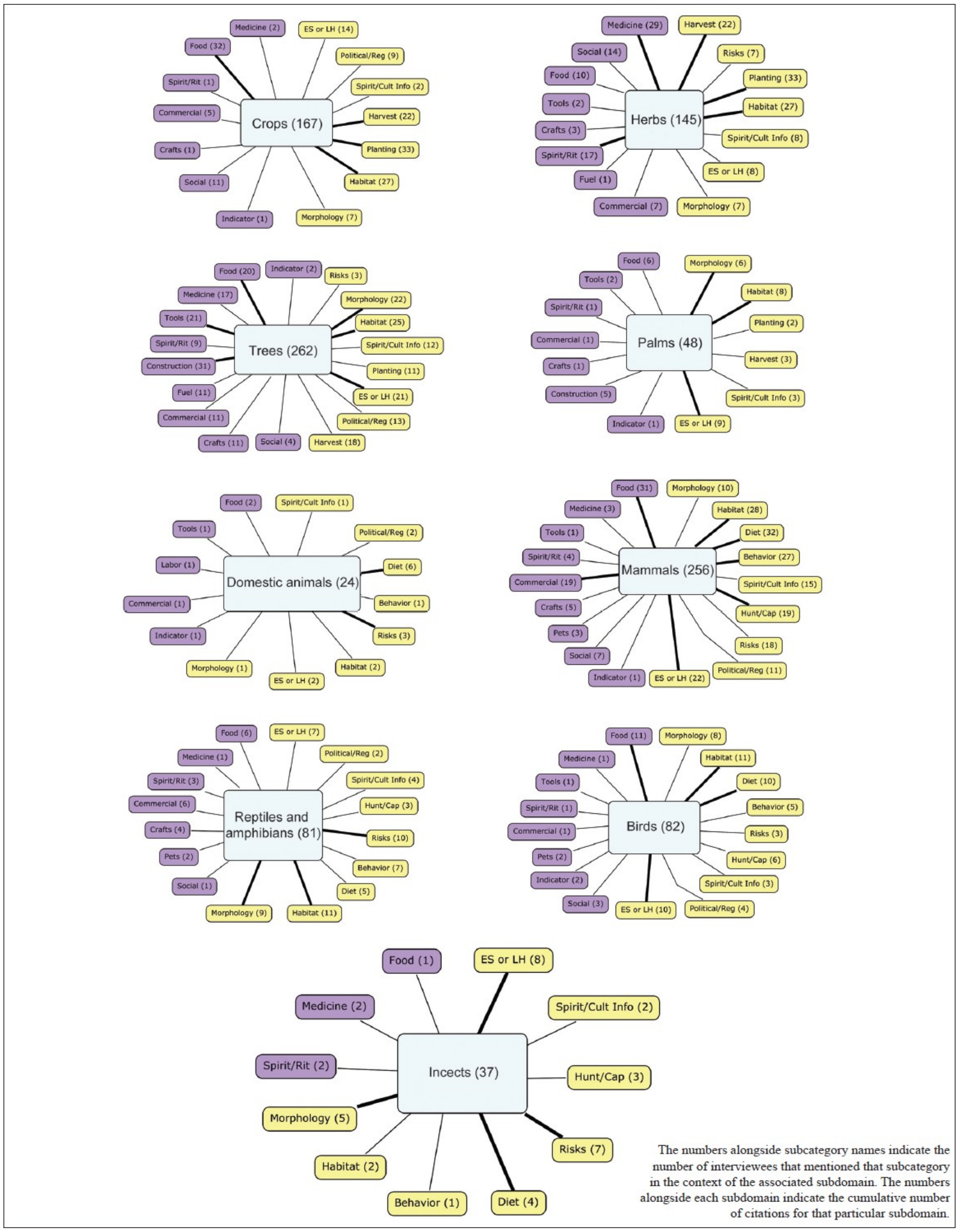

Figure 1.2. A series of submaps describing each subdomain according to the subcategories interviews associated with it. The numbers alongside subcategory names indicate the number of interviewees that mentioned that subcategory in the context of the associated subdomain. The numbers alongside each subdomain indicate the cumulative number of citations for that particular subdomain.

APPENDIX B: RESEARCHERS FRAMEWORK FOR MENTAL MODEL INTERVIEWS

1) Conceptual Knowledge

A) Empirical Plant Domain:

i) Taxonomic names and classifications,

ii) Use: edible, medicinal, construction, fuel, commercial, crafts/ornament

iii) Characteristics: morphology, life history

B) Empirical Animal Domain:

i) Taxonomic names and classifications

ii) Use: edible, medicinal, labour, commercial, ornamental/crafts

iii) Characteristics: morphology, life history

C) Empirical Ecosystem domain:

i) Plant and animal relationships: type of relationship, effect of relationship

ii) Biotopes/landscape units: names, characteristics, use

iii) Soils: names, characteristics, use

iv) Climate: elements, seasonal periods, seasonal activities

D) Metaphysical Ecosystem Domain:

i) Political: boundaries and tenure, rules and regulations

ii) Cultural: specific myths, taboos, social processes

iii) Spiritual knowledge: spirits, demons, religiosity

2) Practical Skills and Knowledge

A) Primary Resource Production or Procurement Domain: agriculture, herding, hunting, fishing, collection

B) Food Preparation or Processing Domain

C) Ethno medical Preparations and Applications Domain

D) Craft and Tool making Domain

E) Architecture and Construction Domain

F) Practical Metaphysical Knowledge

i) Political Processes

ii) Cultural Processes

iii) Processes of Spiritual Engagement

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CHAPTER TWO

ASSESSING THE IMPACT OF ENVIRONMENTAL KNOWLEDGE ON ECOLOGICAL SURVEYS

Abstract

Researchers sometimes use datasets from a single camera trapping initiative to analyze multiple species and species assemblages regardless of initial objectives. Others have published on the potential pitfalls of this practice. In this paper, I explore this issue through the lens of a project that integrated local environmental knowledge. Specifically, I test the hypotheses that the objective of sampling and thus the nature of the environmental knowledge elicited and applied in choosing the locations for camera traps, as well as the sampling methodology, influenced detection the results of my wildlife surveys. I applied three survey methods: 1) camera trap surveys informed by local knowledge of species richness, 2) camera trap surveys informed by local knowledge specific to Baird's tapirs, and 3) track surveys informed by local knowledge specific to Baird's tapirs. I used occupancy modeling to compare detection probabilities for Baird's tapirs among methods, assess potential future surveys by simulating datasets with various survey designs, and compare the efficiency of the two camera sampling designs at surveying species richness. Results confirmed my hypotheses. The top ranking occupancy model portrayed variability in detection probability for Baird's tapirs by survey method; the two tapir specific methods were most efficient at detecting tapirs. Simulations constrained by specified limits on total effort indicated that a tapir occupancy monitoring program relying on cameras placed to maximize species richness would not achieve the benchmark precision regardless of design, while several survey designs using solely the second survey method and numerous designs implementing exclusively the third survey method were predicted to meet the precision benchmark. Cameras placed with specific knowledge of species

richness performed marginally better at rapidly surveying the local terrestrial fauna community than cameras placed using tapir specific knowledge. my results reveal the impact that both integrating local environmental knowledge and choice of survey technique can have on research results. Particularly notable is that camera traps installed in locations chosen using local environmental knowledge specific to tapirs were nearly three times more likely to detect tapirs than those installed in locations chosen using local environmental knowledge to maximize species richness. This reveals the importance of specifying project objectives a priori and designing research specifically to achieve those objectives.

Introduction

With just one field visit to install camera traps and another to pick them up, researchers can: sample for several months within a discrete season; organize data into multiple, chronological sampling occasions; and collect data on a diversity of medium and large bodied terrestrial wildlife species (Rovero et al. 2014). Indeed, camera traps are efficient tools that produce datasets that offer considerable modeling flexibility and therefore the opportunity to use datasets from a single research initiative in the analysis of multiple species or species assemblages. For instance, camera trapping datasets from studies designed to assess tiger populations have also been used to assess tapir populations (Wong 2011). Similarly, camera datasets from projects designed to survey terrestrial biodiversity have been used to assess populations of specific, sometimes rare species (Tobler 2009). This is seen as an important advantage of camera traps, particularly in remote regions with limited access where very little is known about terrestrial wildlife and often nothing about rare and endangered species. However, several recent publications question this practice by suggesting that not all specific camera trap locations within a single sampling site are created equal (see, for example: Harmsen et al. 2010).

Different habitat elements, such as roads or important fruiting tree species, within a single sampling site attract different wildlife species at different rates. Thus within the same site, detection probability of a species may vary depending on precisely where the camera is installed (Harmsen et al. 2010). If the sampling protocol and data analyses do not or cannot allow researchers to detect and account for such variation, this could decrease the robustness of inferences.

Here I explore this issue by examining it through the lens of another phenomenon common to research initiatives in remote regions with little scientific infrastructure: the inclusion of local environmental knowledge in biological research. In remote research locations, including local peoples in fieldwork is and has historically been fairly common (McComb et al. 2010). This is due to several reasons. In certain contexts, especially in countries without research stations run by Western scientists and in projects with time intensive sampling protocols, it is too expensive or logistically impossible to hire Western scientists (Luzar et al. 2011). It can also be a matter of efficiency: recent studies have shown that locals perform more efficiently, and as well as or better than Western scientists in biodiversity assessments (Jensen et al. 2014). Finally, local peoples, particularly in the case of indigenous peoples, may hold traditional tenure over the land and natural resources and the rights to their use. Thus they also have rights to participate in or control ecological monitoring and natural resource management decisions within their territories.

In this paper, I assess the impact that integrating local environmental knowledge has on surveying for Baird's tapirs and species richness in Nicaragua. I also compare the efficiency of multiple survey techniques for Baird's tapirs at my field site. Specifically, I undertook two simultaneous occupancy research projects in the South Caribbean Coast Autonomous Region

(RACCS), Nicaragua on Baird's tapirs (*Tapirus bairdii*) and on terrestrial species richness in which I utilized multiple survey methods and techniques for collaborating with local people. My objectives were to: 1) estimate Baird's tapir occupancy in the RACCS, 2) assess the impact that local environmental knowledge can have on tapir detection probabilities and on biodiversity assessments, 3) Assess the efficiency of multiple survey techniques for detecting Baird's tapirs and 4) run data simulations to assess different designs for future tapir monitoring efforts. I had four primary hypotheses regarding these objectives: 1) Survey methods informed by tapir specific knowledge would have higher tapir detection probabilities than my method informed by non-tapir specific knowledge, 2) Camera trapping informed by knowledge of species richness would be more efficient at documenting terrestrial biodiversity than camera trapping informed by tapir-specific knowledge; 3) The use of survey methods integrating local tapir knowledge would allow for more flexibility in choice of efficient, powerful tapir monitoring protocol designs, and 4) Not integrating local tapir knowledge into surveying would result in highly biased datasets that would impede meaningful occupancy modeling and analysis for tapir specific occupancy models.

Study Site

From November 2010 through July 2011 I carried out this project in the forests surrounding thirteen small indigenous, afro-descendant, and Mestizo communities in the RACCS, Nicaragua. For various reasons, it is politically, logistically, and ethically necessary to include locals as assistants in research and monitoring in and around these communities. For instance, according to the Autonomy Statute of 1987, the Constitution drafted in 1995, the Demarcation Law 445 approved in 2002, and local tradition, these coastal communities, with the exception of Pueblo Nuevo, have legal, communal tenure over the land (Goett 2004).

Additionally, these communities utilize their communally managed forests to varying but similar degrees for subsistence horticulture and hunting, and have high cultural value for local plants and wildlife. Thus many locals possess a wealth of environmental knowledge accumulated both by personal experience and from its intergenerational transmission. Finally, Caribbean coast Nicaragua has no Western-funded and operated research station.

The RACCS landscape has high ecological diversity and includes large expanses of lowland neotropical rainforest, mangrove and seasonally flooded swamp forests, and economically and ecologically important lagoon, estuarine and marine ecosystems (Sollis 1989). The RACCS climate historically included a marked wet season from May to December during which 2,000-4,000 mm of rain fell and large expanses of the area's forests and communities flooded (Christie 2000). Precipitation in recent years has been less predictable. Mean annual temperature is 25.6°C to 27.7°C (Christie et al. 2000). I conducted wildlife surveys in lowland neotropical rainforest and swamp forests. Both habitat types, especially the former, are threatened by an advancing agricultural frontier. Swamp forests were located in patches embedded in lowland rainforest, yet the forest types share similar species and structural characteristics.

Methods

Tapir Surveys

We selected camera trapping sites by first overlaying each community forest with a 4 km2 lattice. Each 4 km2 cell was assigned a random number. Upon arrival in a community, local environmental experts were chosen using the peer review technique described by Davis and Wagner (2003) and subsequently hired as guides. I then began sampling by traveling to the lowest numbered cell in the community's forest. This cell was used as the first survey site. Of the cells contiguous to the first survey site, I also sampled the cell with the lowest random number. This cell was the second site. I almost always sampled two cells per day. I repeated the entire process on a daily basis until all cameras available for that community were deployed.

Initially, I decided on precise camera locations within 4 km2 cells by asking the local guide to pick the spot in the cell being surveyed where he believed the highest diversity of wildlife would pass. I allowed locals autonomy in their choice with the condition that there be a minimum of 2 km between cameras in adjacent cells. To a large extent this ensured that a structurally diverse set of both on and off-trail sites were selected, which is integral to camera trap studies aiming to collect unbiased data on whole species assemblages (Harmsen et al. 2010). Cameras were taken down and rotated to a new site using the same sampling protocol approximately every two months. I refer to the data collected with these cameras as species richness-targeted cameras as they drew on local knowledge of species richness rather than just tapirs. Species richness-targeted camera sampling was conducted over the course of the entire nine months of sampling.

When I returned after two months to review the first round of species richness-targeted cameras, I conducted the other two survey methods. First, upon arriving in the community I re-hired the previous local environmental expert who had helped to install the species richness-targeted cameras. Before heading to the camera sites, however, I instructed him that my goals for the day were to check each previously deployed camera and set an additional camera close to the original location. I explained that I wanted to install this additional camera within the same survey cells, but where it was most certain that a tapir would pass, rather than where the highest diversity of species would pass. I made sure it was clear that he was free to choose essentially the same location as the cell's species richness-targeted camera if he thought it was also the best option for tapirs. I generally installed this second camera on the way to check the previously deployed camera. Camera installation was completed within 56 of the sites sampled for species richness. These "tapir-specific" cameras were set at a minimum distance of 1.5 km from one another and left for a minimum of 70 days. After 70 days, installed cameras were taken down and re-installed in remaining sites with species richness targeted cameras that had not yet been sampled with this methodology. I refer to this second survey method as tapir-targeted cameras because it applied tapir specific knowledge. Tapir targeted camera sampling was conducted over the course of the entire aforementioned timespan except for the first two months

I also used field visits to have a trained field assistant carry out a series of habitat measurements using a standardized protocol at the species richness-targeted camera locations. The measurement process took between 40 minutes to one hour depending on the vegetation at the site (i.e. recently abandoned farms and young secondary forests with a high density of saplings and vines took longer to measure than open, primary forest with fewer, larger trees). During the duration of the habitat sampling, one of the principle investigators worked with the local guide to survey the site for tapir tracks and sign. Thus the duration of the track survey varied depending on the habitat. I assumed that habitats that limited mobility and made measuring habitat characteristics more difficult would also hinder surveying for tapir tracks, and that the increased sampling time in these locations relative to more easily navigable habitats would thereby help to standardize survey effort. In all cases, I applied the prior knowledge of tapir occurrence of the local expert to inform track and sign surveys. In all sites, the date, time, GPS location, type of sign, and distance from closest initial camera and closest other "tapir specific camera" were recorded. The presence/absence data I accumulated by looking for tracks and sign were utilized as the dataset for the third survey method in occupancy modeling. I refer to this method as tapir track surveys.

Occupancy Modeling

The analytical capability to easily account for imperfect detection and thus test for differences in detection probabilities between repeat surveys or distinct survey methods makes occupancy modeling well suited to testing the first hypothesis in this paper (MacKenzie et al. 2002). I constructed tapir detection histories using the data from the three survey methods to run single season occupancy models in program PRESENCE to estimate tapir occupancy and detection probabilities at each site (PRESENCE, version 2.3, http://www.mbr-pwrc.usgs.gov/software/presence.html, accessed 8 November 2011).

One of the most important assumptions of occupancy models is population closure throughout the duration of surveys (MacKenzie et al. 2002). Given the Baird's tapir's slow reproductive cycle, I can justify the assumption that the local population was closed throughout the entire sampling period. I conducted sampling over a period of nine months, which is substantially less than the approximately 400 day gestation period of Baird's tapirs (Brooks et al. 1997). Hunting of tapirs does occur throughout the study area, but less frequently than the hunting of more common species such as the lowland paca or white-tailed deer. my data indicate that an average of 0.26 tapirs are hunted per community per year (Jordan et al. 2014). From 2000-2011, my data indicate that approximately 3.3 tapirs were killed per year in the majority of the coastal RACCS. However, I have the spatial information from the tapir kill sites and am thus reasonably certain no tapirs were killed within or adjacent to my grid cells. The closure assumption also necessitates that animals either do not move in and out of sampling cells or that they do so randomly (MacKenzie et al. 2006). While I am unable to substantiate this with data, I assume that tapir movement in and out of cells is random. my sampling cells were selected randomly, thus the distribution and percentage of different cover types within these cells is likewise a random sample, effectively making any tapir movement in and out of cells due to habitat random as well. Given the assumed closure of the population, and that most of my surveys within the same site temporally overlapped with one another, my approach is similar to that described in MacKenzie et al. (2006) in which the surveyor uses spatial replication within the same site on the same day rather than temporal replication in order to achieve the repeat samples needed to generate the detection histories needed to estimate occupancy while accounting for imperfect detection. Thus, in my case, at each site, each survey method either contributed a one if it detected a tapir or a zero if it did not detect a tapir. The detection history, H1 = 0 0 1 would mean that in site 1, the first method (species richness-targeted cameras) failed to detect tapirs, the second method (tapir-targeted cameras) also failed to detect tapirs, but the third method (tapir track surveys) detected tapirs.

For the first model I held both occupancy and detection probabilities constant. In the second model I allowed detection probability, p, to vary by survey method. I made parameter estimates for each model using maximum likelihood estimation in Program PRESENCE (PRESENCE, version 2.3, http://www.mbr-pwrc.usgs.gov/software/presence.html, accessed 8 November 2011). I then used Akaike's Information Criterion (AIC) and model weights to compare the two models (Burnham and Anderson 2000).

Assessing Differences in Survey Methods

To understand the differences in survey methods I first calculated and plotted p*, the probability of detecting a tapir at least once in K number of surveys for i technique using pi, i survey technique's unique p value and the equation:

$$p_i = 1 - (1 - p_i)K$$

as described in MacKenzie and Royle (2005). I visually compared these results.

Subsequent to this I used program SODA to run data simulations to assess the sampling designs that would be necessary for occupancy estimates to achieve a certain level of precision if I were to use only one of my sampling methods in my tapir survey project (Guillera-Arroita et al. 2010). For each individual survey technique, I ran simulations to find the combinations of number of sites and number of replicate surveys that would achieve my desired precision based on the detection probability of that method in initial sampling efforts. Three pieces of information are needed for such simulations: 1) a target level of precision, 2) an estimate of maximum total survey effort than can be expended and 3) approximations for the two key parameters, occupancy and detection probability:

In the worked example in Guillera-Arroita et al. (2010) the authors considered their occupancy estimator unbiased if the simulations indicated it had a maximum standard error (SE) < 0.075. I also utilized this target level of precision to discriminate between acceptable and unacceptable survey designs. It should be noted, however, that given my higher approximation for occupancy probability in the simulations (see below) compared with that of 0.2 used in Guillera-Arroita et al. (2010), higher standard errors would likely be acceptable for managers and other scientists.

We determined the maximum total effort that could be expended on surveying throughout the course of one year. This was referred to as TS and is equal to the number of repeated surveys, K, multiplied by the total number of sites, S. I decided to estimate my total possible effort, TS, by using the camera traps as the limiting factor. I left the cameras out for slightly more than two months in all cases. Latency to tapir detection for camera traps that detected tapirs varied from 2-60 days, with a mean of 24.2 (see Results). If I consider that any given camera potentially must be left in a site for 60 days in order to adequately survey for tapirs, this means that a camera can be used in a maximum of 6 sampling occasions in one year. For occupancy modeling, it is necessary that the sampled population remains closed during sampling. It is reasonable to assume population closure in a tapir population for an entire year as tapirs reproduce approximately once per year in ideal conditions. I also decided to run simulations as if the population closure assumption only held for half a year rather than a full 12 months. This would result in a maximum of 3 iterations per camera per season. Cameras are cost prohibitive and cannot be purchased to sample all sites simultaneously if the number of sites, S, is high. This means that adding replicates limits the number of sites that can be sampled. In my calculations, I assumed that 50 cameras was the maximum for my study and that were sampling with one camera per site. This meant that the maximum total survey effort (TS) was equal to 150 when K=3 and 300 when K=6.

I used the parameter estimates generated by my best-fitting model as the approximations of Ψ and pi needed for simulations. Before I ran simulations, I also decided to make the minimum number of sites in simulations = 25. I did this because one of the primary objectives of my tapir monitoring work is to describe tapir habitat preference by including site-specific habitat information as occupancy covariates. For models to converge with even two covariates, it is necessary to have a fair amount of replicate sites. I considered 25 to be the absolute minimum with which I could build models to describe tapir habitat use, though I stated that my preference was for a higher number of sites. I then ran simulations in program SODA with 50,000 iterations for all combinations of K and S with $S \geq 25$ that resulted in a TS between 150 - 300 for each of the three different values of pi. In all simulations the assumed occupancy rate was identical. The standard error of the occupancy estimate (i.e. the root-mean square error from the simulation) was recorded after each simulation. This process resulted in three tables depicting the predicted standard error for all simulated combinations of K and S that resulted in a TS of between 150 - 300, each one unique to a specific survey method. These tables were used to assess which survey designs would be most likely to meet the goal I set for precision at the outset of modeling.

Species Richness

For this analysis I removed sites where tapir targeted cameras were installed in the same location as species richness targeted cameras. I did this because in these locations, locals typically suggested the location for the tapir-targeted camera after saying that tapirs were unlikely to be present in the site and they had no recent knowledge of tapirs occurring there, so their best guess for the location for the location where a tapir was most likely to pass was the location of the species richness-targeted camera. As this decision was not based specifically on tapir ecology within the site, I believe it makes most sense to remove them for this analysis. This allows for a clearer comparison between cameras specifically installed to detect tapirs and cameras specifically installed to detect the highest diversity of species. I also removed cameras that appeared to have a high degree of camera failure. These cameras will often detect species with a larger mass, such as tapirs but not smaller species.

For each of my camera trap based methods, I used the model by Dorazio et al. (2006) to conduct an analysis of species richness that accounts for imperfect detection. As this requires the repeated sampling to estimate detection probability, I used the first 60 days of data from each camera and treated each day as an individual sampling occasion, resulting in 60 sampling occasions per camera per site. I inflated the species list for each camera trapping survey method by using all species I have ever detected with camera traps using any methodology in my sampling in the RACCS from 2009-2014. For each camera trapping method, therefore, I produced a spreadsheet with a row for each species, a column for each site, and a number of detections (0-60) for each of those species at each site.

We specified the model in BUGS language and fit it in WinBUGS (Spiegelhalter et al. 2003) using the R2WinBUGS package in R (Sturtz et al. 2005). As in Rovero et al. (2014) I ran models with five Markov chains, with 55,000 iterations for each chain, a burn-in period of 5,000 iterations, and a thinning rate of 50, returning 5,000 samples from the posterior distributions. Species accumulation curves were plotted for a survey of 60 sites for each survey method.

Results

We sampled a total of 56 shared sites using the three techniques. The species richness-targeted cameras detected tapirs at five out of the 56 sites. The tapir-targeted cameras detected the species at 14 out of the 56 sites. The tapir track surveys detected tapirs at 31 out of 56 sites. Latency to detection with the motion sensor cameras varied from 2-60 days and had a mean of 24.2 days. All cameras were left in the field for at least 60 days, though not all functioned for a full 60 days. For analyses, I only used the first 60 days of data from each camera. A priori planned sampling occasions for cameras were approximately seven weeks; this figure was later converted to 60 days for initial modeling, the period of time that was required to collect my complete detection history.

The parameter estimates for the initial model with occupancy rate and detection probability held constant were $\Psi = 0.7175$ (+/- SE 0.1027) and $p = 0.416415$ (+/- SE 0.065680). The second model that allowed detection probability to vary by survey technique yielded $\Psi = 0.5887$ (+/- 0.0705) with unique detection probabilities for each survey method: 1) detection probability for species richness-targeted cameras, p1 = 0.151883 (+/- SE 0.062869); 2) detection probability for tapir-targeted cameras, p2 = 0.424669 (+/- SE 0.088000); 3) detection probability for tapir track surveys, p3 = 0.940340 (+/- SE 0.057736). The second model (AIC=163.66, AIC weight=1.00) was more highly ranked than the initial model (AIC=203.03, AIC weight = 0.00); its parameter estimates were therefore used for all subsequent analyses and simulations to explore potential future model designs.

The unique p* estimates for each technique differed widely (**Figure 2.1**). Species richness-targeted cameras reached a 99% probability of detecting a tapir given the species' presence after 27 sampling occasions. Tapir targeted cameras reached this benchmark after 11 sampling occasions. Track surveys reached a 99% probability of detecting a tapir given the species' presence after two sampling occasions. It is important to note that the time scale for one sampling occasion is not necessarily uniform across methods, though I contend they are at least comparable. In this analysis, the camera methods had a sampling occasion with a duration of 60 days, whereas for the track surveys the duration of sampling itself is only one day. Nonetheless for the results of two track surveys to be independent from one another, it would be necessary to wait until old tracks and sign disappeared and new tracks and sign that represented new tapir activity in the site were present. The entire process required for one sampling occasion would therefore be considerably longer. Personal observation suggests it can take approximately two months depending on the weather and the amount of rainfall that reaches the forest substrate, which is determined largely by percent canopy cover of the forest. Nonetheless, the average is likely considerably less than two months, perhaps more along the lines of two weeks.

Three sets of simulations, one for each of the three different survey designs, with TS between 150 and 300 were run in Program SODA using the approximations of occupancy and detection probability from the highest ranking model. Thus $\Psi = 0.5887$ for all simulations, p1 = 0.151883 for the first set of simulations, p2 = 0.424669 for the second set of simulations, and p3 = 0.940340 for the third set of simulations. The simulations generated estimates of the precision that the different combinations of K and S would attain for each of the three survey methods. I deemed any design that generated a predicted SE ≤ 0.075 acceptably likely to generate robust data suitable for occupancy modeling. No monitoring protocol designs that implement solely species richness-targeted cameras were predicted to attain the desired level of precision for tapir monitoring. Eleven designs that implement solely tapir-targeted cameras were predicted to have the desired level of precision. The majority of designs, 187, that implement solely tapir track surveys were predicted to have the precision desired (**Table 2.1**).

The distributions generated during simulations were also plotted as a visual aid in interpreting simulation results. As an example, the results for each different simulation group with S=71 and K=4 are displayed below (**Figure 2.2**).

The number of species predicted to be detected by each camera based survey method after 60 sites varied slightly, with the tapir targeted cameras predicted to detect a mean of 47.84 species, with a median of 47 species, a Q1 of 45 and a Q3 of 50. The species richness targeted cameras were predicted to detect a mean of 51.79 species, with a median of 50, a Q1 of 47 and a Q3 of 54. The species richness targeted camera accumulation curve (**Figure 2.3**) appears to reach asymptote while the tapir targeted camera species accumulation curve (**Figure 2.4**) appears to still be increasing, albeit slowly, at the 60 site mark. This indicates that the species richness-targeted cameras were in fact slightly more efficient at capturing species richness than the tapir-targeted cameras. Nonetheless, the Q1 value of the species richness targeted cameras was below the mean of the tapir targeted cameras, so the difference is not very large.

Discussion

The occupancy estimates from both candidate models, $\Psi = 0.7175$ (+/- SE 0.1027) and $\Psi = 0.5887$ (+/- 0.0705) were quite high. Given that the latter estimate, generated with the second candidate model, resulted from the best fitting model, I considered it likely to be the best estimate. It also had a smaller error and was more clearly within the realm of acceptable precision to practitioners and researchers, thus it was more likely to be acceptable as a foundation for management suggestions. The fact that I generated an estimate of tapir occupancy in these 56 sites in the RACCS is notable in that prior information on tapirs in the region was virtually nonexistent (Jordan and Urquhart 2013). In fact, the IUCN (2011) considered the tapir to be extirpated from the RACCS until my pilot data proved otherwise (Jordan et al. 2010).

It was not unexpected that the occupancy model that allowed detection to vary with sampling occasion was a better fit for the data than the model with detection probability held constant. Indeed, the presence/absence data from each sampling occasion was generated using a different method; species richness-targeted camera traps in the first, tapir-targeted camera traps in the second and tapir track surveys in the third. Perhaps more notable is that within the output from this second model, the detection probability estimates differed so greatly among the survey techniques. Track surveys informed by local tapir knowledge had the highest detection probability, and were over six times more likely to detect a tapir than my one method that was not informed by local tapir knowledge. This was likely a function of the type of knowledge used, but also due to the different efficiencies of the sampling techniques themselves. Nonetheless, in the case of the two types of camera trapping this second factor was eliminated and the primary disparity in methods was the nature of the local environmental knowledge used to inform the specific site of camera installation. Even in this case, camera trapping informed by local tapir knowledge were almost three times more likely to detect a tapir than camera trapping efforts uninformed by local tapir knowledge. This result supports my first hypothesis.

The significance of the difference in detection probabilities between the various techniques were made quite clear by p* calculations and data simulations. The p* calculations indicated that non-tapir targeted cameras would be certain to detect a tapir that is present at a particular site if sampling continued for roughly 1,650 days. This length of time far exceeds any reasonable length of time for which I could assume population closure. In contrast, the p* calculation for the tapir-specific cameras indicate that this survey method would be certain to detect a tapir that is present at a particular site if sampling continued for approximately 671 days. The population closure assumption is at least somewhat realistic over a two year period given that tapirs have a gestation period of about 13 months and that the offspring do not leave their mothers for one to two years. However in the context of the hunting and possible migration of tapirs in the RACCS, the assumption is tenuous at best. Finally, the p* calculation for the tapir knowledge informed track surveys indicate that this survey method would be certain to detect a tapir that is present at a particular site if sampling was carried out twice during a period of roughly 120 days (i.e. once every two months). Track surveys, rather than camera trapping, was quite clearly the most efficient method and therefore most effective if the goal of a study is to confirm with as little doubt as possible that tapirs are present or absent in a particular location.

The difference in efficiencies of the distinct survey methods was further underscored by data simulations. In particular, if a monitoring protocol were implemented for tapirs that was based solely on species richness-targeted cameras, there would not be any survey design that given my limits on total effort that would be likely to yield unbiased estimators given my target precision. This confirmed the first half of my second hypothesis and my third hypotheses and was significant in that it suggested that within my study area, camera trapping designs not specifically informed by local environmental knowledge about tapirs, would very likely lead to biased results. A second glance at the plotted distribution of this group's simulations (**Figure 2.3**) make this abundantly clear.

In the case of both of the methods informed by tapir specific knowledge, however, there were many different design options that would generate unbiased estimators. This increased flexibility is important in designing future sampling efforts as they will allow me to choose designs that will meet the goals of my broader tapir monitoring project and make most sense given my budget. For instance, if my goal is to choose a design that will allow me to detect changes in tapir occupancy over time, any of the designs predicted to have the required level of precision would meet this criterion. However, if my goal is to model tapir occupancy as a function of various site specific habitat characteristic covariates, the probability of accomplishing this is maximized by increasing the spread of covariate values, which, in turn, is accomplished by sampling a higher number and higher diversity of sites. Thus, from my survey designs that reach my specified precision benchmark, it would make the most sense to choose the design with the largest number of sites and fewest replications. In the case of a monitoring protocol implementing only tapir-targeted camera traps, this would mean a design with S=75 and K=4. In the case of a monitoring protocol implementing only tapir-knowledge informed track surveys, this would mean S=150 and K=2. Intermediate values of K and S could be used if these survey methods were combined. Such an approach would broaden analysis potential. For instance, it would allow the researchers to collect data with the precision offered by the track surveys, but also analyze the supplementary data provided by photographs of tapirs, including the ability to identify individuals, sex, and the presence of young.

The species richness targeted cameras were, in fact, more efficient at surveying the species richness in my study area, albeit marginally so. This offers some support for the second half of my second hypothesis. I hypothesize that the difference in efficiency not larger because the most common generalist species occur throughout the majority of a sampling site and will be detected regardless of the habitat elements in the immediate vicinity of the camera. For instance, both sets of cameras were highly efficient at detecting Central American agoutis (*Dasyprocta punctata*) and Common opossums (*Didelphis marsupialis*).

Together, these results offer new support for what prior studies have shown, that the selection of the specific location for camera trap installation can systematically bias detection probabilities for certain species and can perhaps even affect species richness estimates (Harmsen et al. 2010). This underscores the need to carefully design sampling protocols specifically to achieve the project's objectives. Depending on the research, this may mean implementing completely random camera installation (Wearn et al. 2013) or implementing camera installation to maximize detection probability for highly rare and elusive species. This means that if generating data on tapir presence is a key objective to a project, the sampling protocol applied ought to be designed specifically based on tapir ecology. If this is not possible, i.e. if tapir data must necessarily come from biodiversity survey datasets, pilot data should be generated using several different methods, some specifically targeting tapirs and others with more general targets to either ensure tapir data are not biased or to collect the data needed to account for the resulting bias (i.e. Nichols et al. 2008). Given that the difference between species richness estimates from my species richness targeted cameras and the tapir targeted cameras was relatively small, if it is only possible to implement one camera trap sampling protocol to conduct multiple analyses, my data indicate that it is preferable to design protocols to detect a specific target species and use those cameras to analyze species richness rather than vice versa.

This project likewise has implications in the context of research collaboration with local assistants and application of local knowledge of wildlife in conservation biology. First, it underscores the impact that local or traditional environmental knowledge can have on Western research projects. My data varied considerably depending on the nature of the knowledge I elicited from my local assistants. Thus if the processes of eliciting and applying local knowledge are not done using a standardized protocol, this could result in significant variation in research results that researchers are unable to account for. Similarly, if researchers are not experienced with local knowledge and language at a particular field site, it is unlikely that the process of eliciting and applying the most suitable information will occur seamlessly. This could, for example, reduce detection of a desired organism and lead to erroneous conclusions regarding its status in the study area. In such instances of low detection, if researchers later find evidence to refute that the species is scarce, it is possible that they would then be led to undervalue local environmental knowledge, which could strain relationships with locals. Research in which proper, understanding techniques are applied in interactions with locals are more likely to result in just results for all involved parties and in publications that contribute both to Western science and to cultural survival. The capacity to ask the right questions and apply them in the proper manner is greatly enhanced by conducting social science interviews or focus group sessions on the topic of interest as one component of pilot studies (Jordan et al. 2013).

An important point to mention is the differences in the sampling occasion length between the camera trap method and the track surveys. As described above, the mean effort of the track surveys in total days is likely less than the effort of the camera sampling in total days, which seems to make them less directly comparable. In the case of my research, the fact that it is the track surveys, which are by far the most efficient sampling technique for tapirs, that have a potentially shorter sampling occasion renders this difference less meaningful. Nonetheless, it is still important for the reader to consider this difference when interpreting results. In addition to this, it is important to stress that Baird's tapirs are a particularly ideal species for track surveys. Throughout the majority of their range, including Nicaragua, both the shape and large size of their tracks are unique; the former eliminates the possibility of misidentifying tracks and the latter ensures that tracks will remain visible for an extended period of time in the RACCS. For smaller species, or species with tracks that resemble the tracks of different species (i.e. in the case of jaguars (*Panthera onca*) and pumas (*Puma concolor*)), similar research and analyses using track surveys would be much more problematic. In addition, it is important to consider the effect that variable substrate can have on track surveys. In my study site, most substrates are quite soft and very effective at recording wildlife tracks. In other locations in the Baird's tapirs range, such as the drier forests of the central cordillera of Costa Rica, track surveys may not be efficient.

Conclusion

Our results support prior studies revealing the importance of carefully choosing the specific location for camera trap installation within a sampling site. Indeed, not all specific camera trap locations within a single site are created equal, and for certain species, two different locations within the same site can result in substantially different detection probabilities. my results suggest that specific camera location choice within sites can also have implications for species richness estimates. My results also show that including local environmental knowledge in Western scientific research can have a substantial impact on results. In both cases, the choice of camera installation location and the integration of local environmental knowledge in wildlife sampling, applying environmental information that is not specific to the species or species assemblage of interest may result in systematic bias. I recommend that researchers choose site selection methodology and design protocols for working with local assistants to specifically achieve the objectives of a particular study. When this is not possible, I recommend that data analyses include results from small pilot studies designed to collect the data needed to test for and account for bias in the primary research methods. In the context of projects integrating local environmental knowledge, I recommend that researchers implement social science methodologies or focus group sessions to ensure they truly understand local vernacular and are capable of tactfully, justly and compassionately involving local assistants; and respectfully integrating and reporting on local culture and knowledge.

This research reveals that track surveys are the most efficient sampling technique for Baird's tapirs in Nicaragua. However, the efficiency and feasibility of conducting track surveys varies greatly depending on the study species and the substrate of the study site; thus my conclusions related to the track survey data should not be extrapolated to other species or regions without caution. This caveat stresses one of the most important points made by the camera trapping results, that wildlife surveys must be designed for the specific context of the survey, including both the complexities of the study site and the project objectives.

APPENDIX

APPENDIX

Table 2.1 Results indicating which of the various designs are of acceptable precision (SE ≤ 0.075). The top row, K = number of replicate surveys. Each of the next three rows is associated with the detection probability from one of my survey methods. The left most column defines the detection probability and the other columns indicate the range of sites that could be sampled, given a particular K, to attain the minimum precision.

K	2	3	4	5	6	7	8	9	10	11	12
S for p=0.15											
S for p=0.42			71-75	56-60	50						
S for p=0.94	75-150	50-100	38-75	30-60	43-49	43					

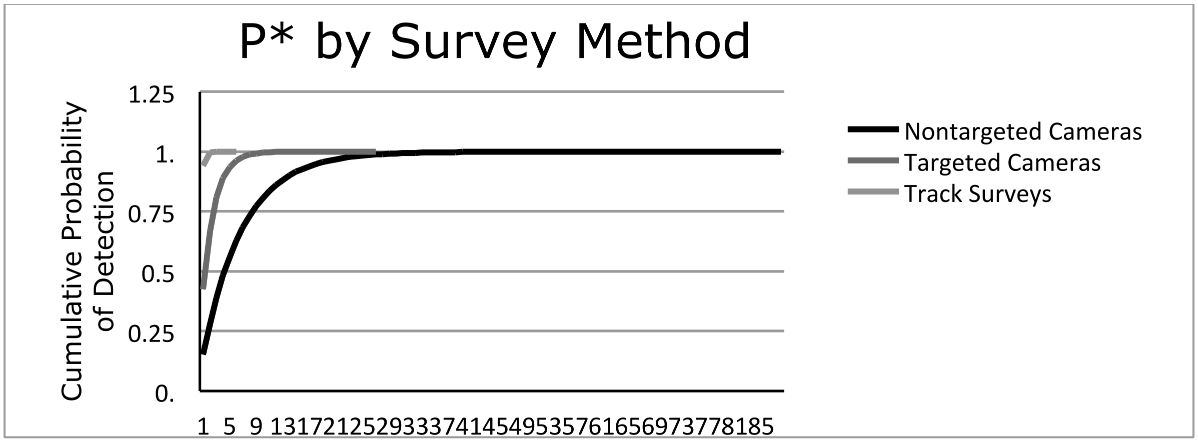

Figure 2.1 p*, defined as $p^*=1-(1-p_i)^K$, for each different survey method. This displays the number of surveys needed to detect a tapir with a 99% probability given its presence in a site. p = detection probability for a given method and K= number of surveys at a particular site.

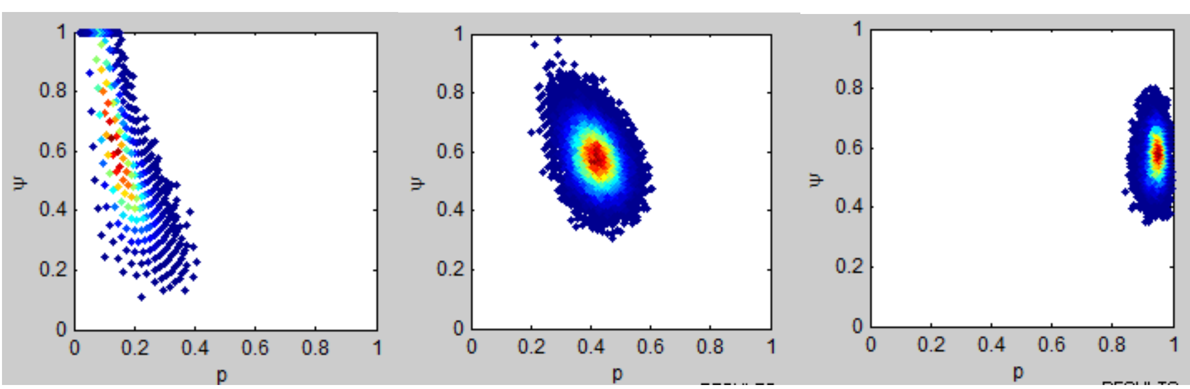

Figure 2.2 The distributions from three different simulations. The far left is the distribution from a simulation with Ψ =0.58, p=0.15, S=71 and K=4. The middle image is the distribution from a simulation with Ψ =0.58, p=0.42, S=71 and K=4. The far right image is the distribution from a simulation with Ψ =0.58, p=0.94, S=71 and K=4.

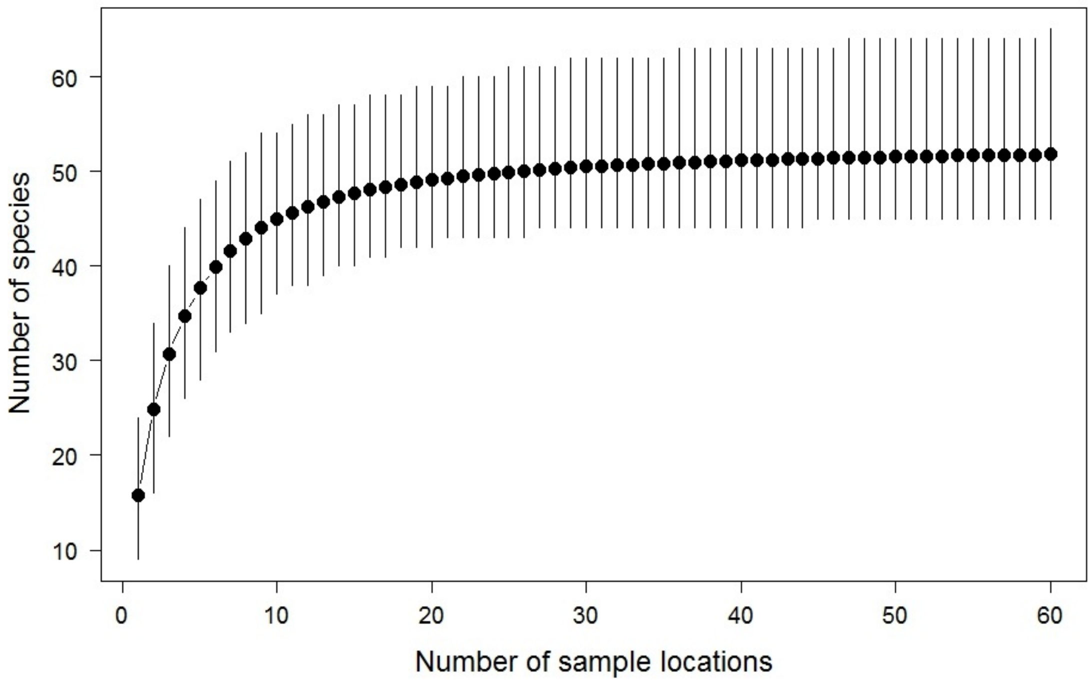

Figure 2.3 The species accumulation curve for species richness targeted cameras produced using the Dorazio et al. (2006) model to estimate species richness while accounting for individual species detection probabilities.

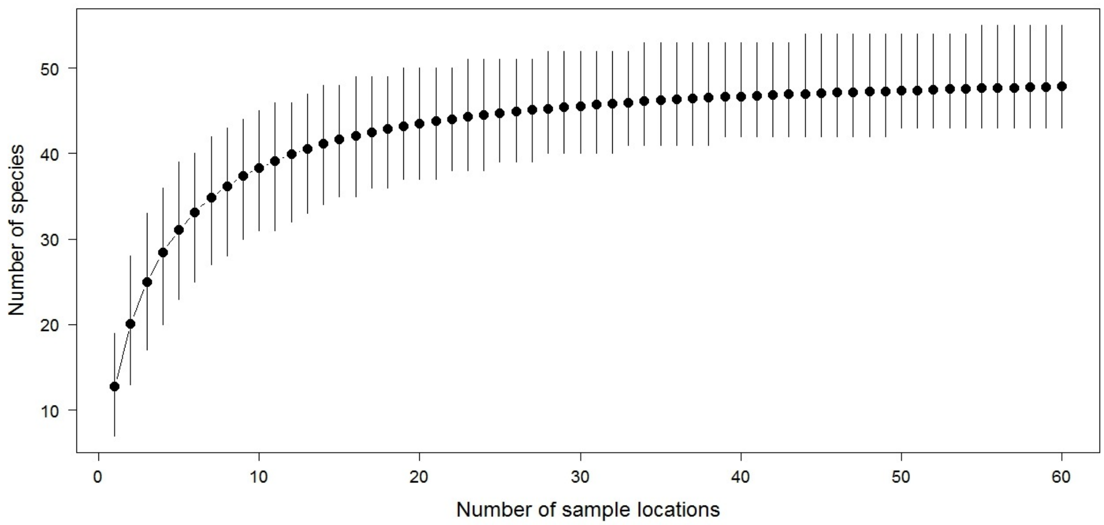

Figure 2.4 The species accumulation curve for tapir targeted cameras produced using the Dorazio et al. (2006) model to estimate species richness while accounting for individual species detection probabilities.

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CHAPTER THREE

THE VITALITY OF TRADITIONAL ENVIRONMENTAL KNOWLEDGE IN THE SOUTH CARIBBEAN COAST AUTONOMOUS REGION OF NICARAGUA

Abstract

The VITEK methodology is the Tierra Lingua's response to TEK researchers' call for a unifying methodology to quantify loss/retention of TEK in indigenous societies. This methodology is purported to acknowledge the culturally unique nature of TEK systems and the peoples who hold them while enabling cross-study comparison of rates of knowledge loss/retention. If true, the VITEK would function as an important indicator of cultural survival. Nonetheless, the methodology lacks the replication needed to assess its true utility. This proposal describes my initial effort to undertake the VITEK in two indigenous communities and one migrant community in the RACCS, Nicaragua. Results indicate that the indigenous communities have a culturally unified body of environmental knowledge accumulated through both practice and oral tradition, whereas the migrant community appears to have a smaller, shared body of knowledge accumulated primarily through practice. The VITEK methodology produced a wealth of information about local TEK corpuses and the processes of TEK loss and retention. Nonetheless, I was unable to use the VITEK methodology to determine whether or not observed trends are the result of TEK erosion or other local processes and phenomena. This is not a weakness of the methodology itself, as it could be addressed by replicating the methodology in many locations internationally and using the data to create a framework for VITEK researchers to better interpret their results. It could also be addressed by replicating the process in my study communities longitudinally; understanding how the trends in my data relate to future rates of TEK loss and retention would improve my ability to interpret VITEK results and use them to make predictions.

Introduction

Recently researchers began to lament the lack of a more unified methodology that enabled the cross-study comparison of loss and retention of traditional environmental knowledge (TEK) (Maffi 2005, Reyes-Garcia et al 2006). They argued that while the corpus of knowledge, its cultural foundation, its practical effect, and even the area of interest to the researcher were unique, rates of change in TEK across age groups or over time could be compared across studies and in this way accurately used as indicators of cultural survival. This methodological gap was closed in 2008 when the organization Terralingua, in conjunction with the Instituto Venezolano de Investigaciones Científicas, published a document describing the Vitality Index of Traditional Environmental Knowledge (VITEK) (Zent and Maffi 2008). The VITEK constitutes what the researchers consider a universally applicable methodology based on a number of cosmopolitan TEK domains. The suite of domains, or broad topics of knowledge, that Zent (2008) provides is hypothesized to include all potential areas within any given TEK system. The researcher subsequently uses the list of cosmopolitan domains as a foundation for in-site interviews that leads to the collection of a body of subsidiary information corresponding to those domains of interest. This body of subsidiary information is then used to create a site and study-specific TEK aptitude test (Zent and Maffi 2008). The test is administered across generations and a number of standard calculations are provided to quantify TEK loss and/or retention (Zent and Maffi 2008). One of the more appealing qualities of the VITEK is that the researcher or study community can choose a subset of knowledge domains to include in the study without compromising the ability to compare these calculations across studies, even with projects researching different knowledge domains. Although groundbreaking, the VITEK has been piloted in very few areas and more extensive tests of its applicability are essential. Indeed, only if the broad framework were replicated in a variety of contexts, would the potential of the VITEK calculations as indicators of cultural survival be realized.

In June and July 2010, I carried out the VITEK methodology in the indigenous Miskito community of Kahkabila along the South Caribbean Coast Autonomous Region (RACCS) of Nicaragua. Then in 2011 I replicated the process in the indigenous Ulwa community of Karawala and the Mestizo community of Pueblo Nuevo, both within the same autonomous region of Nicaragua. Given time constraints, I limited domains to those pertinent to forest plants and animals and related resource extractive activities. The test material consisted of information derived through focus groups and mental models interviews with locals. My work displays the wide potential applicability of the VITEK approach and assesses its ability to yield data that are comparable across projects, study sites, and years. It also offers a look at environmental knowledge systems of Caribbean Coast residents, how those systems may be changing and how they vary based on local culture.

Study Site

RACCS, Nicaragua is very ecologically diverse due to widely varying soil composition, topography, and elevation. Its ecosystems include mangrove forests, pine savannahs, lowland rainforests, and seasonally flooded swamp forests (Christie et al. 2000). The climate is characterized by a marked wet season from June to August during which 2,000 to 4,000 mm of rain fall, flooding large expanses of the region (Christie et al. 2000). Mean annual temperature ranges from 25.6°C to 27.7°C (Christie et al. 2000). There are numerous small communities that dot the coast, each historically comprised of residents from one of six different ethnicities: the afrodescendant Garifuna and Kriol groups, the indigenous Ulwa, Rama, or Miskito peoples, or Mestizo colonists of Pacific Coast origin. It is a very bioculturally diverse region with substantial variation in resource use practices and attitudes about wildlife and conservation between communities. Given the unique opportunity to research high levels of cultural and biological diversity simultaneously, these small communities have been the subject of numerous studies over the past 50 years, some related to TEK (i.e. Barrett 1994, Coe and Anderson 2005, Coe 2008, Loveland 1976, Nietschmann 1973) .

The VITEK methodology was carried out in three different communities: 1) The indigenous Miskito community of Kahkabila, 2) The indigenous Ulwa community of Karawala, and 3) the migrant, *Mestizo* community of Pueblo Nuevo.

Kakabila is located within the Pearl Lagoon Basin, about 5 km northwest of Pearl Lagoon Town, which is one of the region's emerging economic and cultural hubs. Roughly 80% of Kakabila's population of approximately 500 is of Miskitu descent. Agriculture and fishing remain the two predominant economic activities and the majority of residents earn an annual income of less than US$200.00. Despite this, Kahkabila has recently changed dramatically. Much of the change stems from the construction of a new road connecting Pearl Lagoon Town to the markets of Managua, bringing an influx of goods available on a year round basis and buyers of locally extracted resources (Schmitt and Kramer 2009). A small, but significant portion of Kahkabila has also begun working on international cruise ships, which allows many families to send children to nearby cities for high school and to purchase the newly available market items. Additionally, within the past two years governmental and nongovernmental organizations undertook projects to bring electricity and purified drinking water to the Miskito villagers; and an ecolodge to attract tourists was recently completed. In light of this, many community members' livelihoods have begun to shift away from local resource dependence. Of course, this development has not occurred evenly and the livelihoods of other community members remain fully dependent on traditional resource extractive activities. This dichotomy makes Kahkabila an important site to test for the loss and/or retention of traditional environmental knowledge as a number of the new aspects of development affecting the community, including market access, higher education, and non-traditional job opportunities, have historically been hypothesized to result in TEK loss.

Karawala is an indigenous community of approximately 1,700 residents, primarily of Ulwa descent, though there are several Miskito and Mestizo members. Agriculture, fishing, and timber extraction remain the most important economic activities for Karawala's residents. The community is roughly 70 km north of the Pearl Lagoon Town road and thus the effects of new local markets are expected to be much less significant. While some community members are investing in tourism endeavors and traveling out of the community for primary and secondary education, Karawala in many ways remains much more traditional than Kahkabila and more centered on their traditional subsistence economy and thus to some degree serves as a control with which to compare Kahkabila.

The migrant, *Mestizo* community of Pueblo Nuevo is located approximately 36.5 kilometers northeast from the new Pearl Lagoon Town road and its associated markets. It is difficult to estimate the population of the greater Pueblo Nuevo area as the community primarily lives on single-family cattle ranches dispersed across the entirety of the Wawashang Nature Reserve. As a *Mestizo* community, the residents of Pueblo Nuevo are predominantly dedicated to cattle ranching, the sale of dairy products, and corn monocultures. While some residents do also practice small-scale subsistence agriculture, they are not typically fishermen. The Costeños hold regional sea tenure and as they tend to view the *Mestizos* as invaders, they generally prohibit them from engaging in aquatic resource extraction. Pueblo Nuevo's residents do not originate from the Caribbean Coast but are rather colonists from several different communities in the Pacific region of Nicaragua. Pueblo Nuevo was chosen as the third study community to enable a comparison between the environmental knowledge of indigenous communities with that of a migrant community that is not centered around a large, densely populated community as are Kahkabila and Karawala.

Methods

TEK Aptitude Test

The community-specific TEK aptitude test was comprised of both its construction and administration. In Kahkabila I constructed the test in June 2010 and administered it at the end of June and through July of the same year. In Karawala and Pueblo Nuevo, the processes were carried out during 2011.

Prior research on TEK (Jordan et al. 2013) yielded a TEK corpus that was too extensive to include in a single test given the timeframe of this research. Thus all but two sections of Conceptual Knowledge, Plant and Animal Conceptual Knowledge, were removed from consideration for test questions. The Practical Knowledge domain was kept in full. This decision was made based on the idea that practice-based knowledge (i.e. Have you built a canoe?) and conceptually-based knowledge (What type of trees are good to build canoes?), although highly inter-related, constitute distinct bodies of knowledge (Godoy et al. 2005). Further, it is often assumed that practice-based knowledge is impacted before conceptually-based knowledge and that the decline of the former tends to precede declines in the latter (Godoy et al. 2005, Zent and Maffi 2008). In addition to this, I hypothesized, as had previous researchers, that many of the answers to the questions about TEK in practice could be analyzed in and of themselves and also used as covariates in regression analyses to help explain the observed patterns in conceptual knowledge loss and/or retention.

In all three study communities, the construction of the TEK aptitude test began with a whole community-meeting, as stipulated by local tradition, government regulations, community unwillingness to initiate a project without the sanction of local leaders, and proper protocol. At this meeting, the greater community was asked to select 6 men and 6 women considered experts in forest related knowledge. I then held focus group discussions with selected individuals, first with the men and then with the women. In Kahkabila the process was completed in three focus groups sessions with men, and three with women. In Pueblo Nuevo and Karawala, four focus group sessions were needed for each gender. To initiate each focus group discussion, the group was asked to free list: 1) 40 trees and palms, 2) 40 herbs, 3) 40 crops, 4) 100 animals, and 5) all activities they felt fell within the realm of the domains under consideration. These categories were based on the TEK domains described in my prior research (Jordan et al. 2013). Participants were allowed to stop when they were unable continue naming entities, even if the desired number was not reached.

After the five lists were compiled, the group then ranked the items on each list according to their own criteria of “cultural importance value” (Zent and Maffi 2008). Each item was described by the groups as belonging to one of three classes, 1: very important to know about, 2: important to know about, and 3: less important to know about. The group was asked to evenly divide each list into the three cultural importance classes. The participants were often reminded that they were not necessarily ranking the ecological importance of the item or how much they liked the item, but rather the importance of knowing about the item.

The final component of this focus group stage was to assign subsidiary information to each item on each list. The group was encouraged to re-visit each item and discuss all of the information they could remember about each one. Participants provided descriptions of uses, cultural significance, descriptions of morphology and ecology, resource extraction activities, and associated technologies. This entire process resulted in gender specific, annotated, ranked lists describing: A) Plant Conceptual Knowledge, B) Animal Conceptual Knowledge, and C) Practical Forest Knowledge.

Subsequent to this, I created gender specific TEK aptitude tests (Appendix B). For each community, three alternate tests were generated for both men and women. Questions for a community's tests were derived directly from the items and subsidiary information given in the focus groups from the same community. Likewise, the material for each gender's questions was derived exclusively from the information recorded in that gender's focus group. Each test began with a brief socioeconomic and demographic survey and contained a 27 question section on Conceptual Animal Knowledge, a 27 question section on Conceptual Plant Knowledge, and a section with questions on Practical Forest Knowledge. Each test contained questions about an equal number of entities ranked as high, middle, and low in terms of "cultural importance value" under the assumption that this would produce six tests of equal difficulty. Additionally, all tests had an equal number of multiple choice, true/false, and identification questions to avoid biases in scores caused by question type. For the majority of questions, a photograph, audio recording, leaf, seed, bark, or fruit was provided as non-verbal stimuli. Non-verbal stimuli are important in tests of TEK to avoid unfairly favoring literate community members (Godoy et al. 2005). All true/false and multiple choice questions included an "I don't know" option.

Scoring was as follows: correct answers received one point, incorrect answers were punished by 1/(# of potential responses) points, and "I don't knows" received 0 points. The practical knowledge component included several true/false and multiple choice questions, but also incorporated retrospective activity questions. These questions resulted in either binary data (i.e. 1 if you have built a dugout canoe, 0 if you have not) or fractional data (i.e. this person planted 8 of the 10 listed crops this year). These data were directly converted to test points (i.e. 1 point for having built a dugout canoe, .8 points for having planted 8 of the 10 listed crops). The practical knowledge sections were more extensive in Karawala and Pueblo Nuevo.

I stratified the community into three distinct age classes. From 18-30, 30-48, and 48+. I sought to test a minimum of 20 males and 20 females from each strata, but this was adjusted based on the availability of individuals from each age class. Individuals meeting the demographic requirements were approached and the purpose of the test, the rules for scoring, and their right to refuse to partake were described to them. If he/she agreed to participate, the test was administered verbally. In Kahkabila the tester read all questions and answers in English, however a local translator was hired to ensure the questions were clearly understood and each question was translated to Miskito if the individual being tested desired. Most respondents asked for translations of at least some of the questions. In Karawala, tests were written in Spanish but administered in Miskito by a local. In Pueblo Nuevo all tests were written in and administered in Spanish. One test took approximately 25-40 minutes. 6-10 tests were administered daily in Kahkabila and Karawala. Multiple field assistants were hired for the process in Pueblo Nuevo, thus I was able to administer 12-15 tests daily.

VITEK Calculations

To interpret the results of the TEK aptitude test, I calculated the three primary measures of the VITEK as described by Zent and Maffi (2008): intergenerational rate of retention (RG), the cumulative rate of retention (RC), and the annual rate of change (CA). RG indicates the rate of knowledge retention between any successive pair of age groups and is calculated as:

$$RG_t = \overline{g}_t / \overline{g}_r$$

where $\overline{g}t$ equals the mean score of the younger age group and $\overline{g}r$ is the mean score of the reference, or next ascending group. The RG_t of the oldest surveyed group was set at 1 given that no information about the aptitude level of the prior generation(s) is available, thus I cannot assume any previous losses or gains in knowledge (Zent and Maffi 2008).

The RC indicates the proportion of the baseline knowledge level retained by each succeeding age group. It is calculated by multiplying the reference RC by 10 raised to the power of the logarithm of the target RG (Zent and Maffi 2008). The RC of the oldest age group was once again set at 1. The formula is defined as:

$$RC_t = RC_r \, 10^{\log(RGt)}$$

Lastly, the CA reflects the average rate and "direction of change per year reflected by the target age group" and is calculated with the following equation:

$$CA_t = \frac{RC_t - 1}{yg_t}$$

where ygt equals the length in years of the target age group interval (Zent and Maffi 2008). This calculation can also be done for the entire sample by combining the individual equations through simple addition:

$$CA_a = \Sigma(CA_t - 1)/\Sigma yg_t$$

These community specific calculations describing the rates of change are simple, yet designed to enable meaningful cross-community comparison. Knowledge level, transmission, and loss have been shown to vary with not just age, but also gender and subject matter (Ruddle 1993). Thus I calculated these measures separately for each gender group from each community for the following test results: 1) Total Herb Knowledge, 2) Total Tree Knowledge, 3) Total Crop Knowledge, 4) Total Mammal Knowledge, 5) Total Bird Knowledge, 6) Total Other Wildlife Knowledge, 7) Total Conceptual Knowledge, 8) Total Practical Knowledge, and 9) Total Score.

ANOVA

I then ran a series of statistical analyses using R, version 2.11.1 (R Development Core Team 2005). After testing the raw score data for normality using the Shapiro-Wilk test, I decided to assess differences between age classes using analysis of variance (ANOVA). For each gender in each community, five different ANOVA were run with age class as the independent variable and each of the following as the dependent variable: 1) Total Plant Knowledge, 2) Total Animal Knowledge, 3) Total Conceptual Knowledge, 4) Total Practical Knowledge, 5) Total Score. After determining that at least one of the mean total scores and mean total conceptual scores were different from the others, I ran Tukey's Honest Significant Difference (HSD) test on all ANOVA results to determine which of the possible pairs of mean scores were significantly different.

Linear Regression

To further explore the effects of certain socioeconomic and demographic variables I used linear regression. Six general linear regression models were constructed in R version 2.11.1 for each gender from each community (R Development Core Team 2005). Two models were created with each of the following as a dependent variable: 1) Total Conceptual Knowledge, 2) Total Practical Knowledge, and 3) Total Score. One of the models for each dependent variable had age and number of monthly trips made outside of home community as the covariates. The second model used number of years living within study community and number of monthly trips made outside of home community as the covariates. Number of years living within study community and age were assumed to be correlated and were thus not included in the same model, however I hypothesized that the latter would explain an individuals' knowledge better than age and thus result in higher R-Squared values and a lower Akaike's Information Criterion (AIC) value (Burnham and Anderson 2002). I used extractAIC within program R to compare the fit of the different models.

A final covariate, number of years of schooling, had systematically higher values for younger participants given that educational infrastructure has improved dramatically in recent decades. In fact, older age classes in general had very little schooling. Thus regardless of TEK aptitude test scores, I assumed this covariate would be correlated with the test scores of the youngest age class. Due to this I only ran linear regression with this covariate with the data from the youngest age class. I ran three models for the youngest group from each gender group from each community with the number of years of schooling as a covariate and each of the following three as the dependent variable: 1) Total Conceptual Knowledge, 2) Total Practical Knowledge, and 3) Total Score.

These particular socioeconomic variables were included in the survey associated with the test and as covariates in linear regression models because similar characteristics have been important indicators of TEK loss and retention in previous studies. For instance, Reyes-Garcia

(2010) provides an excellent review of the relationship of Western style educations and TEK and how this relationship varies according to the context. Other covariates were hypothesized to be pertinent given the recent changes in market access and development described above.

Finally, I ran an additional model for each gender in each community to test for correlation between Total Practical Knowledge and Total Conceptual Knowledge Score, as mentioned above, declines in practical knowledge is often assumed to predict declines in conceptual knowledge.

Results

In the three study communities the focus group process produced highly detailed, gender specific, annotated, ranked lists describing: A) Plant Conceptual Knowledge, B) Animal Conceptual Knowledge, and C) Practical Forest Knowledge. For each gender in each community I produced three separate TEK aptitude tests. I administered a total of 492 tests across the three communities (**Table 3.1**). The fewest tests were administered in Kahkabila. I was able to administer a minimum of 20 tests for all age classes for both genders in all communities with the exception of Kahkabila, where it was not possible to reach the desired benchmark in the oldest age class for both men and women.

The VITEK measures were calculated according to the generational groups described earlier: 18-30, 30-48, and 48+, for each gender in each community for the various TEK test scores described above (**Tables 3.2-3.19**). Results indicate general declines in all types of conceptual knowledge across most generational groups in the indigenous communities, while practical knowledge is much more variable and in many cases is higher in younger generations.

In Kahkabila, mean conceptual and practical knowledge scores of 30-48 year olds are slightly lower than those of the older, reference group. For all results combined, the middle generational group has retained ~96% of their elder's knowledge for men and ~90% for women. ANOVA and Tukey HSD results also reflect this gentle decline as the analyses failed to find a statistically significant difference between the two groups at the 95% level. In contrast, mean conceptual and practical knowledge scores of Kahkabila residents within the 18-29 year age bracket are substantially lower than those of the two older generational groups. For instance, as a group, 18-29 year olds only possessed 70% of the total corpus of knowledge for men and ~64.6% for women. Both the VITEK calculations and the ANOVA results reflect this drop. The younger generation's mean scores in all areas of forest environmental knowledge included on the TEK aptitude test were found to be significantly different from the mean scores of the middle and oldest generational groups at very high levels of significance.

The results for Karawala are similar to the Kahkabila results for conceptual knowledge: the middle generational group has retained ~84.8% of their elder's knowledge for men and ~81.6% for women. All VITEK calculations reflect this gentle decline, as do the ANOVA and Tukey HSD analyses, which failed to find a statistically significant difference between the two groups at the 95% level. The 18-29 year old group only possessed ~68% of the total corpus of knowledge for men. One difference from the Kahkabila results is that the youngest group of women held much more environmental knowledge, ~82% of the knowledge of their reference group. The results for practical knowledge in Karawala varied considerably from the Kahkabila results; in Kahkabila the patterns for both conceptual and practical knowledge were largely identical. In the case of women in Karawala, both of the younger groups had higher practical knowledge scores than the elder group. In men, the middle group had a slightly slower practical knowledge score than the elder group, but the youngest group had the highest practical knowledge score of all groups.

In the Mestizo community, increases and declines in knowledge across generations are much less predictable between knowledge domains. For men, the middle age class holds an average of ~86.5% of the conceptual knowledge of the oldest group, while the youngest group holds ~95% of the knowledge held by their reference group. For women, the middle age class has more conceptual knowledge than the oldest group, while the youngest group holds ~81% of the knowledge held by their reference group. The CAa measures are, for the most part, lower than the CAa in the indigenous communities, for example, the CAa for Total Conceptual Knowledge for men is -0.0212 (Karawala = -0.0234, Kahkabila = -0.0259). The youngest group of men in Pueblo Nuevo also has the highest practical knowledge scores for the community; the middle group has ~95.5% of the score of their elders. In contrast, the middle age class of women in Pueblo Nuevo has the highest practical knowledge scores, while the youngest age class has ~78.4% the score of the middle age class.

In the indigenous communities, ANOVA and the following Tukey HSD tests reveal that in all cases the youngest generation has a significantly different mean score than the two older generations (**Tables 3.20-3.23**). In most cases within the indigenous communities, the middle age class is not significantly different than the oldest age class. In Pueblo, mean scores across age classes were different in a very limited number of comparisons (**Tables 3.24-3.25**)

The results of the linear regression modeling varied based on the community, gender, and type of knowledge included in the analysis (**Tables 3.26-3.27**). In all cases in indigenous communities, both age and years spent in community are significantly, positively correlated with conceptual knowledge scores. This is not always the case for Total Practical Knowledge, which varies based on gender and community. The results for Pueblo Nuevo are again much less predictable, and even when statistically significant, the effect size of the relationships between knowledge scores and covariates were much smaller and explain less of the variation in scores. AIC values were extremely similar between all comparable models and are not described here in detail. In general the models using age rather than years in community fit the models slightly better with the exception of the practical knowledge models, for which the years in community models typically exhibited slightly better fit.

Finally, the test for correlation between the Total Conceptual Knowledge Score and the Total Practical Knowledge Score revealed that in Kahkabila and Pueblo Nuevo the two were highly, positively correlated, while in Karawala there is no evidence of correlation (**Table 3.28**).

Discussion

VITEK/ANOVA Results

The VITEK results were successful in comparing knowledge loss and retention between the indigenous communities. They are supported by the ANOVA and Tukey HSD results, the main difference being that the former gives me more detail about the local body of environmental knowledge and the latter gives me a statistical basis for discussing the differences between generations.

The CAa, RG, and RC calculations reveal that Kahkabila has a larger gap in knowledge between generations than Karawala. Likewise they help me to compare differences between gender groups and types of knowledge within each community. In Kahkabila, for instance, women in general seem to be retaining less of the environmental knowledge of their elders than men. The opposite is true in Karawala, where the youngest women hold more of the environmental knowledge of their elders than do the youngest men.

In both communities, the middle group holds a majority of the information of the eldest group, while the younger group, with the exception of women in Karawala, holds a much smaller percentage of the eldest group's knowledge. What do these trends mean? The disparity between the two older generational groups is likely explained by the learning curve. In other words, it is probably the case that the eldest members simply have the most experience in the field and as the thirty somethings continue farming and hunting, their experience and knowledge about their local ecosystems will continue to accumulate (Zent and Maffi 2008). By the time they reach the age of 50, they will likely have closed the slight knowledge gap. Evidence from the literature supports this idea. As Zent and Maffi (2008) indicate, "the knowledge-on-age trendline in a stable (i.e. nonerosional) situation should reflect gradual increments of change" (34).

The declines in forest knowledge evident amongst the youngest community members, however, may be too drastic to attribute solely to the learning process. Again, Zent and Maffi (2008) write that "trendlines" that display "sharp breaks or noticeable tips are indicative of irreversible change (e.g. erosion) over time" (34) and in many cases the disparity between the middle group and the older group is quite large. In light of this, the VITEK results provide some evidence for a process of forest knowledge erosion across generations, particularly in Kahkabila. Nonetheless, the timeline for knowledge accumulation may also be changing. In both Kahkabila and Karawala, children spend a longer period of time in school and away from the forest than did their parents. Nonetheless the poor job market means most of them return to their family's farms after finishing their studies. Thus formal education may delay the process of environmental knowledge transmission for a number of years compared with historical rates, but it may not be permanent. Indeed, it is possible that the youngest community members will close the knowledge gap as they mature. This seems especially likely in Karawala where the youngest generations have some of the highest practical knowledge scores for their community, and perhaps in Kahkabila in the case of women, who have more than 75% of the practical knowledge scores as the elder most age class. For men in Kahkabila, however, the youngest generation has around half of the practical knowledge score of their elders; this disparity in practical experience may, in fact, result in permanent knowledge erosion. My research does not indicate whether or not knowledge that cannot be transmitted simply through field experience, such as local legends and history, is being passed down to the younger generations. If oral history transmission is not strong, this could result in gaps between generations that will not be closed over time with additional experience, both in Karawala and Kahkabila. This is an issue that merits additional research.

The VITEK measures also give me insight into specific components of knowledge transmission in communities. For instance, I am able to conclude that women in Karawala generally hold more of the plant knowledge and less of the animal knowledge of their elders. Such nuances, in addition to the general patterns already discussed can help in designing environmental education programs designed to help conserve TEK. The results can also help to design future research efforts that could determine why this is occurring. For instance, perhaps a study of the historical trends in the consumption of bushmeat within the community versus trends in the use of traditional herbal medicines could elucidate the drivers of the observed differences in Karawala's women's knowledge of plants versus animals.

While my results indicate that the VITEK measures are extremely useful and the methodology important for TEK research and cultural survival initiatives, my results from Pueblo Nuevo make it clear that the nuances of the study communities are required to truly understand the significance of the measures. For example, the CAa measures in Pueblo Nuevo are the smallest of my study communities, which would seem to indicate that it is the most effective community for environmental knowledge transmission across generations, i.e.

knowledge loss per generation is the lowest here. However, the mean scores in Pueblo Nuevo are very low to begin with and simply do not change considerably across generational groups. Thus, in Pueblo Nuevo, the scores start low and my ANOVA and Tukey HSD analyses reveal that these low scores do not vary across generations, thus there is no evidence for knowledge loss, but there is also no evidence of learning. Rather than indicative of successful knowledge transmission, then, I believe these results are more indicative of a lack of a culturally unified body of environmental knowledge in the community. This would make sense, given that residents hail from a wide variety of rural communities in Pacific Nicaragua rather than the Caribbean Coast. Thus the knowledge shared between generations probably reflects the knowledge the residents have acquired through personal experience in the forest rather than oral transmission from other community members or elders. This lack of a culturally unified body of knowledge makes it difficult to justify using the VITEK measures to compare Pueblo Nuevo with the indigenous communities. While not a critique of the methodology given that it was specifically designed for indigenous communities, it does underscore the need to have a comprehensive understanding of communities before research to avoid misinterpreting results.

This conclusion regarding Pueblo Nuevo is also very interesting in the context of Caribbean Coast Nicaragua. The invasion of Caribbean Coast lands by Pacific Coast *Mestizo* populations has resulted in the decline of several rare wildlife species due to their unsustainable, typically indiscriminate hunting and agricultural practices (Jordan et al. 2014). A lack of a unified body of knowledge about the Caribbean Coast ecosystems likely connotes a lack of cultural value for local plants and animals. Cultural value can be an important driver of sustainable practices, meaning that the lack of cultural value for plants and animals in *Mestizo* communities may be a major obstacle for conservation in the RACCS in future years.

As mentioned previously the differences in AIC values between comparable models were very small, indicating that both models had a similar amount of support as the best fitting model. This is likely because the models used in these analyses are quite simple, do not include many covariates or parameter estimates, and the models differ only in that two very similar covariates were swapped with one another. The regression results do, however, provide additional information about processes that contribute to or detract from the accumulation of forest related TEK:

Age

In the indigenous communities, age is significantly, positively correlated with total conceptual knowledge. In Kahkabila it is also positively correlated with total practical knowledge. The models including age have some of the highest R-Squared values, meaning that age and the forest experience that it brings can explain a lot of the variation in environmental knowledge seen in results. Nonetheless, in this case, it gives me little information that the VITEK measures do no already give us.

Years Spent in Community

In my socioeconomic section, I recorded how long participants had lived in the study community on the assumption that perhaps local experience would explain variations in environmental knowledge even more than age. While this covariate was significantly, positively related to most environmental knowledge scores, there was not considerable variation between this covariate and the age covariate and the R-Squared values of the two sets of models were similar. This may be a result of the fact that within the RACCS, even in a major city such as Bluefields, people are able to farm and interact with forests. Thus, spending a few years away from a community will not necessarily entail time away from local ecosystems. While it may be more likely to affect the transmission of more culturally based environmental knowledge transmission, I find no evidence for that here.

Market Integration

The number of weekly trips made outside of the community was included as a very rough proxy for connection to markets, assuming that more trips outside of the community would be an indicator of a market-based personal economy and thus less environmental knowledge. In some cases, this assumption appears correct, but in others this does not hold.

For instance, for men in Karawala, the number of trips outside of their home community per month is significantly, positively correlated with both Total Score and Total Practical Knowledge. It has no significant relationship to their Total Conceptual Knowledge. This is most likely the case because many men from Karawala travel to other communities to work for timber companies or to independently cut timber. Given that these activities are based on natural resource extraction activities included in the Practical Knowledge sections of exams, it is no surprise that trips outside of Karawala connote more environmental knowledge rather than less. For women in Karawala, however, trips outside of their home community per month is significantly, negatively correlated with total conceptual knowledge and total score. Given that there is no equivalent to sawing lumber for women, those women who leave Karawala more frequently probably have non-subsistence based obligations in other communities or cities, meaning their trips reduce their practical environmental experience and thus result in lower conceptual knowledge. For both women and men in Pueblo Nuevo, trips outside of the community is significantly, positively correlated with test scores, meaning that their trips outside of Pueblo Nuevo are probably also related to natural resource extraction.

An alternative explanation for such positive correlation is market based. The market for agricultural products (i.e. mangos, breadfruit, cassava, and plantain) in nearby large towns and cities, such as Pearl Lagoon Town, is substantial. The most active farmers, therefore, may frequently go to Pearl Lagoon to sell their agricultural goods. As buyers for their goods increase, these farmers may be encouraged to spend even more time on the farm and in and around their forested ecosystem to produce higher yields. Thus, in the context of farmers in the Pearl Lagoon area, it is possible that market integration encourages the retention and/or acquisition of forest related knowledge. Godoy et al. (2005) found a similar relationship between market integration and TEK aptitude in Honduras and argued that a strong local market for timber products encouraged highly "integrated" locals to spend more time than they previously had in and around their local forested ecosystems, increasing their TEK levels.

Education

While level of education is not significantly correlated with many of the test results, when there is a correlation, that relationship is negative, indicating that an increase in formal education connotes a decrease in environmental knowledge. The R-Squared values for models using only years of education as a covariate are extremely low, however, meaning that this negative relationship between a formal education and environmental knowledge is not strong. The negative correlations likely result from the fact that many students travel to nearby cities to study, which removes them from local ecosystems and probably reduces their practical environmental knowledge. Nonetheless, all three communities have secondary schools, meaning that attending school does not necessarily remove younger people from local ecosystems. In fact, most local students do not leave their communities to study. This helps explain why formal education does not more frequently have a significant, negative correlation with test scores, and why the R-Squared values of these models is so low even in those cases where it is. Although the negative correlations are not particular strong or common, including more traditional environmental education in local curriculums could address the negative relationship between education and traditional environmental knowledge.

Conceptual and Practical Knowledge Correlations

In both Kahkabila and Pueblo Nuevo, total practical environmental knowledge was positively correlated with total conceptual environmental knowledge. In Karawala, the two had a statistically significant negative relationship, thought the beta values were small and the standard error values were comparatively large. These results indicate that in Kahkabila and Pueblo Nuevo, the majority of conceptual environmental knowledge is gained through experience in the field. In Karawala, however, the results indicate that there is another process in the community that ensures environmental knowledge transmission across generations. One possible explanation is that the oral history tradition in Karawala is stronger than it is in Kahkabila and Pueblo Nuevo. This would mean that even those remaining in the community most frequently could receive an extensive traditional, environmental education.

Conclusion

The VITEK methodology was in general successful in collecting important information about local traditional environmental knowledge systems and comparing the dynamics of these systems across communities. At the same time, my results from Pueblo Nuevo underscore the importance of truly understanding the study communities before interpreting results. VITEK measures do not capture variations in culture and the local environmental knowledge body that can alter how some of the measures can and should be interpreted. Again, a comparison of my results from the indigenous RACCS communities with the results from the migrant community of Pueblo Nuevo makes this clear.

It is also essential to understand study communities comprehensively because the VITEK methodology also offers no way of assessing whether apparent declines in knowledge across generational groups is an artifact of the local learning curve or a result of TEK loss. Additional context and a detailed understanding of local communities can help in interpretation. Regarding the indigenous study communities, for example, there appears to be at least some concrete evidence of erosion in forest related TEK across generations, especially in Kahkabila. It is thus important to consider what, exactly, the results might mean in the context of what is known about this community. On the one hand, they could signify the general erosion of the local TEK corpus; that younger Kahkabila residents do and will hold less environmental knowledge than their elders. Based on my knowledge of Kahkabila, however, they could be the result of two additional processes: 1) An adaptation of the TEK corpus away from forest knowledge, and 2) A prolongation of the learning curve.

TEK systems have been described as adaptive in the sense that they are not stagnant tomes of facts and information, but rather fluid bodies of knowledge that are iteratively adapted over time to a dynamic local ecosystem (Berkes 1999). Significant changes in climate, resource availability, or local markets, could therefore alter the scope of information considered important within a TEK corpus. It is not difficult to imagine a scenario in which different generations within the same community might have different areas of ecological expertise as a result of such a change. In the case of Kahkabila, anecdotal evidence and comments from mental model interviews indicate that there has been a recent shift in the primary focus of resource extractive behaviors away from the forest and the farm and toward the lagoon and the sea due to the emergence of a national fish market in Pearl Lagoon. Thus, it could be that the corpus of TEK held by the younger generation is dominated to a much greater extent by marine knowledge than is the case for their elders. In this scenario, the observed loss of forest knowledge would not necessarily entail cumulative TEK loss, but instead a shift in the ratio of forest knowledge:marine knowledge in the TEK corpus. Conducting the VITEK with all knowledge domains would help to better understand this.

As mentioned above, my evidence for Kahkabila suggests that the knowledge gap is too substantial to be explained by the learning curve. This idea is supported by the literature, which indicates that indigenous peoples tend to accumulate the majority of TEK by the time they are 13-16 years old (Ruddle 1993, Zent and Maffi 2008). The youngest respondents from Kahkabila were 18 years old, well beyond this threshold. However, this interpretation does not consider the possibility that the learning curve has simply become much slower and longer than it was historically. As briefly described above, an increasing number of community members take advantage of new educational and occupational opportunities outside of Kahkabila. For example, many youths leave to work on cruise ships with the goal of saving money until they can return to their community and build a higher quality house or purchase a fishing boat. Others leave for their secondary education, but then return to Kahkabila to start a family. Due to the increased time spent outside the community and away from subsistence activities, it could simply take an additional 5-10 years for community members to acquire the complete corpus of forest TEK. Thus, instead of acquiring all TEK by the 13-16 years of age described by previous researchers, it is possible that Kahkabila residents are not experts until they are in their mid-twenties or later.

The linear regression models offer mixed results in that some covariates are significantly related with TEK in some scenarios and not in others. This is a result of working in a highly bioculturally diverse environment with large cultural and economic variations between communities and even between genders within the same community. Thus covariates and their relationship to TEK must be analyzed on a case by case basis. Given that most indigenous peoples live in locations with extremely high bicultural diversity, all VITEK researches must consider covariates and their significance carefully. Despite the considerable variation in my results across communities, my model output does indicate that it may be useful to include more lessons on local environments and TEK in RACCS curriculums.

The VITEK methodology was successful in generating important, interesting information about the state of forest TEK in my study communities, even allowing me to compare TEK levels across generations within communities. The results are valuable from both an academic and a cultural standpoint; they can easily be utilized to better understand local bodies of TEK in remote locations, but can also be used as educational resources in cultural survival initiatives. For instance, the VITEK calculations offer a comparative look at the composition of the forest TEK of elders and youths, and could therefore serve as a guide for designing and organizing educational workshops or publications. The annotated forest TEK lists, in turn, offer a wealth of educational material to enrich such projects. Nonetheless, in its current state the VITEK methodology falls short in its capacity to yield conclusions about TEK loss and retention because there is no database with which to compare rates of knowledge loss and retention in order to interpret whether or not results are indicative of TEK erosion, the local learning curve, or other learning processes. This can best be addressed in two ways: 1) Replicating the VITEK methodology in other communities globally, then creating a database TEK researchers can compare their results with; and/or 2) Replicating the VITEK methodology in the same communities longitudinally to document precisely how current VITEK measures relate to future TEK loss and retention.

APPENDICES

APPENDIX A: TABLES AND FIGURES

Table 3.1 Number of tests administered by community, age class, and gender.

Age Class	Community	Gender	Number of Tests
1	Kahkabila	Men	25
2	Kahkabila	Men	21
3	Kahkabila	Men	11
1	Kahkabila	Women	21
2	Kahkabila	Women	21
3	Kahkabila	Women	14
1	Karawala	Men	29
2	Karawala	Men	36
3	Karawala	Men	33
1	Karawala	Women	34
2	Karawala	Women	34
3	Karawala	Women	34
1	Pueblo Nuevo	Men	27
2	Pueblo Nuevo	Men	29
3	Pueblo Nuevo	Men	30
1	Pueblo Nuevo	Women	32
2	Pueblo Nuevo	Women	31
3	Pueblo Nuevo	Women	30
		Total	492

Table 3.2 VITEK measures for Total Conceptual Knowledge for Men in Kahkabila.

Kahkabila Men Total Conceptual Knowledge					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	39.4318	1	1		-0.0259
30-49	37.8452	0.9598	0.9598	-0.0020	
15-29	27.28	0.7208	0.6918	-0.0154	

Table 3.3 VITEK measures for Total Practical Knowledge for Men in Kahkabila.

Kahkabila Men Total Practical Knowledge					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	10.4482	1	1		-0.0259
30-49	10.0630	0.9631	0.9631	-0.0018	
15-29	5.8508	0.5814	0.5600	-0.0220	

Table 3.4 VITEK measures for Total Score for Men in Kahkabila.

Kahkabila Men Total Score					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	49.8800	1	1		-0.0259
30-49	47.9082	0.9605	0.9605	-0.0020	
15-29	33.1308	0.6915	0.6642	-0.0168	

Table 3.5 VITEK measures for Total Conceptual Knowledge for Women in Kahkabila.

Kahkabila Women Total Conceptual Knowledge					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	39.5	1	1		-0.0260
30-49	34.9286	0.8843	0.8843	-0.0058	
15-29	21.7738	0.6234	0.5512	-0.0224	

Table 3.6 VITEK measures for Total Practical Knowledge for Women in Kahkabila.

Kahkabila Women Total Practical Knowledge					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	5.014	1	1		-0.0258
30-49	4.9171	0.9806	0.9806	-0.0010	
15-29	3.8521	0.7834	0.7682	-0.0116	

Table 3.7 VITEK measures for Total Score for Women in Kahkabila.

Kahkabila Women Total Score					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	44.5142	1	1		-0.0260
30-49	39.8456	0.8951	0.8951	-0.0052	
15-29	25.6259	0.6431	0.5757	-0.0212	

Table 3.8 VITEK measures for Total Conceptual Knowledge for Men in Karawala.

Karawala Men Total Conceptual Knowledge					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	44.7273	1	1		-0.0234
30-49	42.7292	0.9553	0.9553	-0.0022	
15-29	31.8793	0.7461	0.7127	-0.0144	

Table 3.9 VITEK measures for Total Practical Knowledge for Men in Kahkabila.

Karawala Men Total Practical Knowledge					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	23.2121	1	1		-0.0232
30-49	20.6944	0.8915	0.8915	-0.0054	
15-29	27.7586	1.3413	1.1959	0.0098	

Table 3.10 VITEK measures for Total Score for Men in Karawala.

Karawala Men Total Score					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	67.9394	1	1		-0.0234
30-49	63.4236	0.9335	0.9335	-0.0033	
15-29	59.6379	0.9403	0.8778	-0.0061	

Table 3.11 VITEK measures for Total Conceptual Knowledge for Women in Karawala.

Karawala Women Total Conceptual Knowledge					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	42.0147	1	1		-0.0236
30-49	33.9853	0.8089	0.8089	-0.0096	
15-29	26.0714	0.7671	0.6205	-0.0190	

Table 3.12 VITEK measures for Total Practical Knowledge for Women in Karawala.

Karawala Women Total Practical Knowledge					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	17.7941	1	1		-0.0232
30-49	18.7647	1.0545	1.0545	0.0027	
15-29	19.5588	1.0423	1.0992	0.0050	

Table 3.13 VITEK measures for Total Score for Women in Karawala.

Karawala Women Total Score					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	59.8088	1	1		-0.0235
30-49	52.75	0.8820	0.8820	-0.0059	
15-29	45.6303	0.8650	0.7629	-0.0119	

Table 3.14 VITEK measures for Total Conceptual Knowledge for Men in Pueblo Nuevo.

Pueblo Nuevo Men Total Conceptual Knowledge					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	24.25	1	1		-0.0212
30-49	20.8917	0.8615	0.8615	-0.0069	
15-29	19.75	0.9454	0.8144	-0.0092	

Table 3.15 VITEK measures for Total Practical Knowledge for Men in Pueblo Nuevo.

Pueblo Nuevo Men Total Practical Knowledge					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	60.0323	1	1		-0.0211
30-49	57.3500	0.9553	0.9553	-0.0022	
15-29	62.2222	1.0850	1.0365	0.0018	

Table 3.16 VITEK measures for Total Score for Men in Pueblo Nuevo.

Pueblo Nuevo Men Total Score					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	84.2823	1	1		-0.0211
30-49	78.2417	0.9283	0.9283	-0.0036	
15-29	81.9722	1.0477	0.9726	-0.0014	

Table 3.17 VITEK measures for Total Conceptual Knowledge for Women in Pueblo Nuevo.

Pueblo Nuevo Women Total Conceptual Knowledge					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	21.6641	1	1		-0.0223
30-49	21.1935	0.9783	0.9783	-0.0011	
15-29	17.4848	0.8250	0.8071	-0.0096	

Table 3.18 VITEK measures for Total Practical Knowledge for Women in Pueblo Nuevo.

Pueblo Nuevo Women Total Practical Knowledge					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	35.0938	1	1		-0.0221
30-49	44.5484	1.2694	1.2694	0.0135	
15-29	34.9091	0.7836	0.9947	-0.0003	

Table 3.19 VITEK measures for Total Score for Women in Pueblo Nuevo.

Pueblo Nuevo Women Total Score					
Age Group	**Total Mean Score**	**RG**	**RC**	**CA**	**CAa**
50+	56.7578	1	1		-0.0222
30-49	65.7419	1.1583	1.1583	0.0079	
15-29	52.3939	0.7970	0.9231	-0.0038	

Table 3.20 Tukey Honest Significant Difference Test Results for Kahkabila Men for Total Conceptual Knowledge, Total Practical Knowledge, and Total Score.

Kahkabila Men Tukey HSD Results					
Age Classes	**Knowledge**	Est. Difference	Lower bound	Upper bound	P value
Young, Middle	Total Conceptual Knowledge	10.565	5.631	15.500	0.812
Young, Old	Total Conceptual Knowledge	12.152	6.120	18.183	0.0000314
Old, Middle	Total Conceptual Knowledge	1.587	-4.618	7.791	0.8119
Young, Middle	Total Practical Knowledge	4.212	1.731	6.693	0.00042
Young, Old	Total Practical Knowledge	4.597	1.565	7.630	0.002
Old, Middle	Total Practical Knowledge	0.385	-2.735	3.505	0.952
Young, Middle	Total Score	14.777	8.429	21.126	0.000002
Young, Old	Total Score	16.749	8.989	24.509	0.000009
Old, Middle	Total Score	1.972	-6.011	9.954	0.823

Table 3.21 Tukey Honest Significant Difference Test Results for Kahkabila Women for Total Conceptual Knowledge, Total Practical Knowledge, and Total Score.

Kahkabila Women Tukey HSD Results					
Age Classes	**Knowledge**	Est. Difference	Lower bound	Upper bound	P value
Young, Middle	Total Conceptual Knowledge	13.155	9.317	16.992	0.000000
Young, Old	Total Conceptual Knowledge	17.726	13.436	22.017	0.000000
Old, Middle	Total Conceptual Knowledge	4.571	0.281	8.862	0.034
Young, Middle	Total Practical Knowledge	1.065	-0.851	2.981	0.380
Young, Old	Total Practical Knowledge	1.162	-0.980	3.304	0.397
Old, Middle	Total Practical Knowledge	0.097	-2.045	2.239	0.993
Young, Middle	Total Score	14.220	9.434	19.006	0.000000
Young, Old	Total Score	18.888	13.53	24.239	0.000000
Old, Middle	Total Score	4.669	-0.682	10.020	0.099

Table 3.22 Tukey Honest Significant Difference Test Results for Karawala Men for Total Conceptual Knowledge, Total Practical Knowledge, and Total Score.

Karawala Men Tukey HSD Results					
Age Classes	**Knowledge**	Est. Difference	Lower bound	Upper bound	P value
Young, Middle	Total Conceptual Knowledge	10.850	6.898	14.802	0.0000000
Young, Old	Total Conceptual Knowledge	12.848	8.816	16.879	0.0000000
Old, Middle	Total Conceptual Knowledge	1.998	-1.819	5.815	0.429
Young, Middle	Total Practical Knowledge	-7.064	-19.313	5.185	0.359
Young, Old	Total Practical Knowledge	-4.546	-17.042	7.949	0.663
Old, Middle	Total Practical Knowledge	2.518	-9.313	14.349	0.868
Young, Middle	Total Score	3.786	-9.205	16.776	0.768
Young, Old	Total Score	8.301	-4.950	21.553	0.299
Old, Middle	Total Score	4.516	-8.031	17.063	0.669

Table 3.23 Tukey Honest Significant Difference Test Results for Karawala Women for Total Conceptual Knowledge, Total Practical Knowledge, and Total Score.

Karawala Women Tukey HSD Results					
Age Classes	**Knowledge**	Est. Difference	Lower bound	Upper bound	P value
Young, Middle	Total Conceptual Knowledge	7.914	3.194	12.634	0.0003692
Young, Old	Total Conceptual Knowledge	15.943	11.224	20.663	0.0000000
Old, Middle	Total Conceptual Knowledge	8.029	3.276	12.783	0.0003322
Young, Middle	Total Practical Knowledge	-0.794	-7.593	6.005	0.958
Young, Old	Total Practical Knowledge	-1.765	-8.563	5.034	0.811
Old, Middle	Total Practical Knowledge	-0.971	-7.818	5.877	0.939
Young, Middle	Total Score	7.120	-0.749	14.988	0.085
Young, Old	Total Score	14.179	6.310	22.047	0.0001229
Old, Middle	Total Score	7.059	-0.866	14.984	0.091

Table 3.24 Tukey Honest Significant Difference Test Results for Pueblo Nuevo Men for Total Conceptual Knowledge, Total Practical Knowledge, and Total Score.

Pueblo Nuevo Men Tukey HSD Results					
Age Classes	**Knowledge**	Est. Difference	Lower bound	Upper bound	P value
Young, Middle	Total Conceptual Knowledge	1.862	-2.623	6.348	0.585
Young, Old	Total Conceptual Knowledge	5.308	0.859	9.758	0.015
Old, Middle	Total Conceptual Knowledge	3.446	-0.922	7.814	0.150
Young, Middle	Total Practical Knowledge	-2.895	-25.046	19.256	0.948
Young, Old	Total Practical Knowledge	-0.189	-22.161	21.784	1.000
Old, Middle	Total Practical Knowledge	2.706	-18.864	24.276	0.952
Young, Middle	Total Score	-1.033	-24.972	22.907	0.994
Young, Old	Total Score	5.119	-18.627	28.866	0.865
Old, Middle	Total Score	6.152	-17.160	29.464	0.804

Table 3.25 Tukey Honest Significant Difference Test Results for Pueblo Nuevo Women for Total Conceptual Knowledge, Total Practical Knowledge, and Total Score.

Pueblo Nuevo Women Tukey HSD Results					
Age Classes	**Knowledge**	Est. Difference	Lower bound	Upper bound	P value
Young, Middle	Total Conceptual Knowledge	3.162	-0.853	7.178	0.151
Young, Old	Total Conceptual Knowledge	5.077	1.028	9.126	0.010
Old, Middle	Total Conceptual Knowledge	1.915	-2.166	5.996	0.505
Young, Middle	Total Practical Knowledge	8.548	-5.214	22.311	0.305
Young, Old	Total Practical Knowledge	1.433	-12.445	15.312	0.967
Old, Middle	Total Practical Knowledge	-7.115	-21.102	6.872	0.449
Young, Middle	Total Score	11.711	-4.019	27.440	0.184
Young, Old	Total Score	6.510	-9.352	22.373	0.593
Old, Middle	Total Score	-5.200	-21.186	10.785	0.719

Table 3.26 Covariates with statistically significant relationships to Total Conceptual Knowledge

Total Conceptual Knowledge					
Community	**Gender**	**Covariate**	**Beta (SE)**	**Pr (>\t\)**	**Adj. R2**
Kahkabila	**Men**	**Age**	5.1167 (0.979)	6.34E-06	0.2942
Kahkabila	**Men**	**Years in Community**	5.1297 (0.974)	4.79E-06	0.3012
Kahkabila	**Women**	**Age**	6.87 (0.946)	1.68E-09	0.5118
Kahkabila	**Women**	**Years in Community**	6.6731 (0.985)	1.05E-08	0.4776
Kahkabila	**Women**	**Years Education**	-2.908 (1.256)	0.0258	0.09615
Karawala	**Men**	**Age**	3.975 (0.821)	4.98E-06	0.2108
Karawala	**Men**	**Years in Community**	4.1098 (0.8253)	2.84E-06	0.2197
Karawala	**Women**	**Age**	5.7302 (0.8677)	1.96E-09	0.3549
Karawala	**Women**	**Trips Out/ Month (TOM)**	-1.5481 (0.8677)	0.0774	0.3549
Karawala	**Women**	**Years in Community**	5.476 (0.8733)	9.21E-09	0.3351
Pueblo Nuevo	**Men**	**Age**	2.60 (0.7504)	0.000838	0.1273
Pueblo Nuevo	**Men**	**TOM**	1.5964 (0.7504)	0.0363	0.1273
Pueblo Nuevo	**Men**	**Years in Community**	2.5049 (0.7526)	0.0013	0.1186
Pueblo Nuevo	**Women**	**Age**	2.724 (0.6681)	9.81E-05	0.1697
Pueblo Nuevo	**Women**	**TOM**	1.7837 (0.6681)	0.00901	0.1697

Table 3.27 Covariates with statistically significant relationships to Total Practical Knowledge

Total Practical Knowledge					
Community	**Gender**	**Covariate**	**Beta (SE)**	**Pr (>\t**	**Adj. R2**
Kahkabila	**Men**	**Age**	2.1246 (0.492)	6.74E-05	0.2303
Kahkabila	**Men**	**Years in Community**	2.0887 (0.489)	8E-05	0.2256
Karawala	**Men**	**Trips Outside of the Community per Month**	5.5503 (2.1565)	0.0116	0.05917
Karawala	**Women**	**Years Education**	-4.109 (2.211)	0.072	0.0673
Pueblo Nuevo	**Men**	**Trips Outside of the Community per Month**	6.44072 (3.75906)	0.0904	0.01185

Table 3.28 Linear modeling results describing correlation between Total Conceptual Knowledge and Total Practical Knowledge.

Correlation Between Conceptual and Practical Knowledge				
Community	**Gender**	**Beta (SE)**	**Pr (>\t**	**Adj. R2**
Kahkabila	**Men**	5.297 (0.0972)	7.26E-07	0.3509
Kahkabila	**Women**	3.071 (1.162)	0.0107	0.0981
Karawala	**Men**	-0.4557 (0.8731)	0.603	0.007558
Karawala	**Women**	-1.24 (1.034)	0.233	0.00427
Pueblo Nuevo	**Men**	2.1887 (0.7587)	0.00498	0.0793
Pueblo Nuevo	**Women**	2.5796 (0.6756)	0.000245	0.1286

APPENDIX B: EXAMPLE OF TEK EXAM

Mujeres Examen 1
Fecha:__/__/____

Datos Socioeconómicos

Edad: __ Comunidad:___________________ GPS de la Casa__________________
____
¿Cuantas veces por mes viajas a otra comunidad a vender productos?:____
¿Cuantas viajes afuera de la comunidad haces por mes?:___
¿Cuantas veces vas a la plantación por semana?:__
¿Por cuantos años asististe la secundaria?__
¿Has vivido en Bluefields? Si/No ¿Por cuantos años?___
¿Has vivido en Laguna de Perlas? Si/No ¿Por cuantos años?___
¿Has vivido en otra comunidad? Si/No Nombre de la comunidad:________
¿Por cuantos años viviste allí?___

Favor de poner estas actividades en orden de importancia con relación a como ganas la vida:
La Pesca__ Agricultura__ Aserrando madera__ Mi Venta__ La cacería__ Otro trabajo __
FADCANIC___

Ponga números: ¿Cual es más importante proteger? El bosque__ Las peces__ La comunidad__
Nuestra cultura___

De esta lista, ¿quién te ensenaba más sobre los animales y plantas del bosque?
Mis padres, mis abuelos, mis profesores, mis hermanos, otra persona (¿Quién?_______)

Pon en orden de importancia? ¿De qué deben aprender los niños?
Arboles__ Yerbas medicinales___ Animales___ Las peces___ La matemática___
La ciudad___ Los libros___

¿Dónde preferirías vivir? Aquí en Pueblo Nuevo, Bluefields, Laguna de Perlas,
Otro lugar:__________

¿A qué te dedicarás en 10 años?____________________________
¿Cuánto tiempo tienes de tener un celular ?___
¿En un mes, cuantas veces usas el Internet?___

ID de Hierbas

1) Favor de identificar este bejuco.
   R: Cuculmeca (1)

2) ¿Cuál es la hierba que tiene esta hoja?
R: Chote o labios de mujer (2)

3) ¿Cuál es la hierba que tiene esta hoja?
R: Platanillo (3)

Uso de hierbas

4) Se utiliza la cascara del indio desnudo para curar el aire.
R: Verdadero/<u>Falso</u>/No sé (1)

5) ¿Qué parte del Sorosi se cocina para preparar un té que sacar una calentura?
R: A) La hoja B) La Raiz C) Todo el bejuco
D) La fruta E) No sé (2)

6) El mozote con la flor morada es buena para medicina, pero el mozote con la flor amarilla no.
R: <u>Verdadero</u>/Falso/ No sé (3)

Descripción de Hierbas

7) ¿De qué color es la semilla de apasote cuando está madura?
R: A) Café B) Rojo <u>C) Amarillo</u> D) Morada E) No sé (1)

8) La fruta de la escoba tiene una flora fina y blanca.
R: Verdadero/<u>Falso</u>/ No sé (2)

9) ¿Cómo viene la semilla de Pico de Pájaro?
R: <u>A) En vaina</u> B) En racimo C) Cada semilla crece en el mero palo
D) Debajo de las hojas como yucca E) No sé (3)

ID de Arboles

10) ¿Cuál es el árbol que tiene esta semilla?
R: Caoba (1)

11) ¿Favor de identificar esta hoja?
R: Zopilote o Bota Rama (2)

12) ¿Cuál es el árbol que tiene esta semilla?
R: Palma Bruja (3)

Uso de Arboles

13) ¿Cuál de estos árboles tiene una fruta con que se puede sacar guapote?
R: A) Caoba <u>B) Cedro Macho</u> C) Ceiba D) Almendro E) No sé (1)

14) El aguacate montero es muy bueno para leña.
R: Verdadero/Falso/No sé (3)

15) ¿Cuál de estas plantas se puede ocupar para cazar guilla?
R: A) Guapinol B) Cola de Iguana C) Yoliyo D) Casca E) No sé (2)

Descripción de arboles

16) El árbol Leche Maria tiene otro nombre, "Araña," ¿por qué?
R: A) A las arañas les gusta hacer sus telarañas en las ramas B) Tiene una flor con ocho pétales C) Hay una araña que come de su fruta
D) Echa muchas raíces en el aire que se miran como patas de araña E) No sé (1)

17) El Ceibo tiene espinas cuando es pequeño.
R: Verdadero/Falso/ No sé (2)

18) La Palma Dulce tiene una flor moradita.
R: Verdadero/Falso/No sé (3)

ID de Cultivos

19) ¿Cuál es el nombre del cultivo con esta hoja?
R: Cacao (1)

20) ¿Cuál es el nombre del cultivo con esta hoja?
R: Tomate (2)

21) ¿Cuál es el nombre del cultivo con esta hoja?
R: Caimito (3)

Siembra/Cosecha de Cultivos

22) ¿Cuándo es el mejor momento para sembrar ayote?
R: A) Diciembre B) Después de la tercera lluvia en Mayo
C) En Mayo inmediatamente después de la quema
D) Se puede sembrar en cualquier momento E) No sé (1)

23) Es mejor sembrar la sandia en Mayo con las primeras lluvias .
R: Verdadero/Falso/No sé (2)

24) ¿Qué se siembra para que el Yampi pegue?
R: A) La cepa entera B) La semilla C) La rama D) Un puño de hojas
E) No sé (3)

Ecología de Cultivos

25) Aunque poco se sabe, la guanábana empieza a dar fruta después de 8-10 meses.
R: Verdadero/Falso/No sé (1)

26) ¿Para qué uso medicina sirve la hoja cosida del aguacate?
R: A) Para no tener hijos B) Ningún uso C) Para sacar calentura D) Para curar malaria E) No sé (2)

27) El ñami da una cepa grande, parecido al dachin .
R: Verdadero/Falso/ No sé (3)

ID de Mamíferos

28) ¿Cuál es el nombre del animal que se mira en esta foto?
R: Chancho de monte (1)

29) ¿Cuál es el nombre del animal que se mira en esta foto?
R: Guatusa (2)

30) ¿Cuál es el nombre del animal que se mira en esta foto?
R: Zorrillo (3)

Información de Mamíferos

31) ¿Para qué se ocupa el aceite de león?
R: A) Curar niños lloronas B) Ahuyentar animales dañinos C) Curar Dolor
D) Todas las respuestas A-C E) No sé (1)

32) La manada de Saíno puede ser más grande que 50 animales.
R: Verdadero/Falso/No sé (1)

33) La carne de guatusa no es muy grasosa.
R: Verdadero/Falso/No sé (2)

34) ¿Qué parte del cusuco tiene su secreto?
R: A) El pelo B) Las patas C) La concha D) La Cola E) No sé (2)

35) ¿Cuál de estos animales tenía el cuero más caro durante os tiempos de los tigreros?
R: A) Carzuelo B) Tigre C) León D) Tigrillo
E) No sé (2)

36) La defensa del zorrillo es su uña grande con que mata perros.
R: Verdadero/Falso/No sé (3)

ID de Aves

37) ¿Cuál es el nombre del ave que tiene este grito?
R: Pava loca (1)

38) ¿Cuale es el nombre del ave que tiene este grito?
R: Lora copete rojo (2)

39) ¿Cuál es el nombre del ave que tiene este nido?
R: Oropéndola (3)

Información de Aves

40) La gallina de monte tiene un huevo verde-azul.
R: <u>Verdadero</u>/Falso/No sé (1)

41) ¿Cómo se distinguen la hembra y el macho de la pava loca?
R: A) El macho es negro, la hembra pinto <u>B) No se distinguen</u> C) El macho tiene copete rojo
D) El macho tiene copete amarillo E) No sé (1)

42) ¿De qué color es la pata del perdiz?
R: A) Azul B) Amarillo C) Negro <u>D) Rojo</u>) No sé (2)

43) Varias Pilis suelen poner sus huevos en el mismo hueco.
R: <u>Verdadero</u>/Falso/No sé (2)

44) Si se encuentra el nido del Oropéndola en su finca, se dice que tendrás suerte con el dinero.
R: <u>Verdadero</u>/Falso/No sé (3)

45) ¿De qué color son las crías pequeñas del zopilote?
R: <u>A) Blanco</u> B) Negro C) Gris D) Rojo E) No sé (3)

ID de Otros Animales

46) ¿Qué es el animal que se mira en esta foto?
R: Mica (1)

47) ¿Qué es el animal que se mira en esta foto?
R: Chocoya (2)

48) ¿Qué es el animal que tiene este grito?
R:Sapo ¿ (3)

Información de Otros Animales

49) El coral, en cambio a otras culebras venenosas, pone huevos.
R: Verdadero/Falso/No sé (1)

50) ¿Para qué uso medicinal sirve la manteca de la Boa?
R: A) Sacar calentura B) Sentar lombrices C) Sacar caspas D) Curar inflamación E) No sé (1)

51) ¿Qué es la comida principal del Gusano Carcoma?
R: A) Hojas tiernas B) Madera podrida C) Lodo D) Guava E) No sé (2)

52) La langosta (el insecto) suele caer en el verano.
R: Verdadero/Falso/No sé (2)

53) ¿Qué parte del maíz se come por el Tecoron?
R: A) Hojas tiernas B) La mazorca C) La raíz de la planta chiquita D) La espiga E) No sé (3)

54) Se saca la leche del sapo disípela para hacer un remedio para la disípela.
R: Verdadero/Falso/No sé (3)

La Práctica

Aserrar Madera

55) ¿Cuántos de estos palos aserraste personalmente en el último año?
R: Cedro macho____ Santa María____ Laurel_____ Guanacaste_____ Jocote Real_____
Palo de Piedra______ Cortes_____ Nispero____ Caoba____ Bimbayan________

En la Plantación

56) ¿Cuáles de estos cultivos sembraste personalmente en el último año?
R: Frijol___ Maiz___ Banano___ Yuca___ Arroz___ Dachin___ Quequisque___
Platano___ Ayote___

57) ¿En el último año, cuántas veces fuiste al campo a deshierbar los cultivos?

58) ¿En promedio cuántas veces por semana vas al campo para vigilar los cultivos?

59) ¿Cuáles de estas actividades ayudaste a hacer en el último año?
R: Socola____ Desrriba____ Quema______

60) ¿Cuáles de estos cultivos cosechaste personalmente en el último año?
R: Frijol___ Maiz___ Banano___ Yuca___ Arroz___ Dachin___ Quequisque___
Platano___ Ayote___

Construccion y Coleccion

61) En la vida, ¿cuáles de esta plantas has utilizado para empajar techo, amarrar techo o hacer cama?
R: Palma hilera____ Palma real____ Maquengue______ Bejuco de hombre_____
Bejuco de mujer____ Guiriki___ Bejuco de hojachigue____

62) ¿Cuáles de estas maderas has ocupado en este año como leña o carbón?
R: Almendro___ Pino Montero_____ Guavo____ Algodón_____ Nancite___ Kerosín____

63) ¿En los últimos 5 años, cuáles de estos has construido utilizando recursos del bosque?
R: Silla____ Ropero____ Casa_____ Trastera____ Banca____ Mesa____ Molendero____
Lavatrastre____ Cocinero____ Cerco___

64) ¿Cuáles de estas frutas recolectaste para comer en el último año?
R: Almendro___ Leche vaca___ Jocobo___ Jocote Mico___ Granadilla montera ___
Calala verde____ Cacao montero____ Cabeza de mono______

Medicina Natural

65) ¿Cuáles de estas plantas recolectaste para ocupar en el último año?
R: Cuculmeca___ Yuquito___ Uña de Gato___ Hierba de Dolor___ Cilantro___ Dormilona____
Lapasote____ Hierva buena______

66) ¿Cuáles de estas enfermedades trataste con medicina natural en el último año?
R: Asma___ Diarrea___ Dolor de cabeza___ Malaria___ Un parto problematico___
Inflamación ___ Tos___

Animales

67) ¿Cuántas de estos animales domésticos cuidas por lo menos una vez por semana?
R: Chompipe___ Chancho casero______ Gallina____ Pato____ Perros_____ Gatos____

68) En este año, ¿Ayudaste a echar gallina?

R: Sí/No

69) En los últimos 10 años, ¿Ayudaste a amansar una bestia?
R: Sí/No

70) ¿Sales a cazar por lo menos una vez por año?
R: Sí/No

71) ¿En el último año cuales de estos animales preparaste para comer?___
R: Venado___ Guilla___ Cusuco___ Saíno___ Chancho de monte___ Pava___
Gallina de monte____ Guatuza____

72) ¿Cuáles de estos animales has mantenido como mascota?
R: Venado___ Guilla___ Lora___ Chocoyo___ Chancho de monte___ Otro___

73) ¿Cuantos cuajadas haces por por semana?

Otro

74) ¿Cuántas veces en este año fuiste a hacer camino?

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CHAPTER FOUR

EFFECTS OF LOCALIZED DEVELOPMENT AND NATURAL RESOURCE EXTRACTION ON OCCUPANCY RATES OF A NEOTROPICAL COMMUNITY IN CARIBBEAN COAST, NICARAGUA

Abstract

The last wild places in the world are changing in response to development projects and illegal land invasion and conversion. In the Caribbean Coast of Nicaragua, development is recently more prevalent as the Nicaraguan government favors large infrastructure projects as a strategy to reduce extreme poverty. In 2007, a road was completed to the town of Pearl Lagoon, Nicaragua. The road was hypothesized to result in an influx of markets and outsiders to the local forests surrounding the road, potentially altering local culture and natural resource extraction. I designed a camera-trapping project in conjunction with a larger socioeconomic survey to assess patterns in wildlife occupancy following road construction. I collected camera trap data on a suite of large and medium mammals in the forests surrounding seven treatment communities near the new road and six control communities away from the road annually from 2010-2012. I assessed relationships between wildlife occupancy rates and several environmental covariates describing: 1) local ecosystems, 2) local natural resource extraction, and 3) proximity to localized development (i.e. the road), with the objective of learning how processes of development and cultural change affect wildlife occupancy. My models revel that the areas controlled by indigenous and afro-descendant peoples in the vicinity of Pearl Lagoon retain habitat for most species, including those most sensitive to forest degradation and hunting. Nonetheless, in the treatment sites closest to the road my results revealed an apparent decrease in occupancy rates of species known to be sensitive to habitat alteration and hunting. It is necessary to replicate my sampling in coming years to confirm or refute apparent trends and to

generate the database necessary to develop sound wildlife conservation and management strategies for Caribbean Coast Nicaragua.

Introduction

Central America has lost more than 170,000 km^2 of forest over the past 15 years (Hansen et al. 2013). This loss is caused by land clearing for large agro-businesses, large infrastructure projects and the invasion of protected areas and indigenous lands by rural peasants and cattle ranchers. These processes likely have profound effects on local ecosystems, both directly through land use change and indirectly as the influx of cultures and new technologies influences behaviors related to local natural resource extraction.

Given the relatively small size of countries in Central America (Nicaragua is the largest at just over 130,000 km^2), and that many of the largest remaining forested areas are the property of indigenous peoples, most of the regions protected areas are inhabited landscapes utilized by local people. Rather, the protected area system in much of Central America is primarily a mosaic of small-scale subsistence agricultural plots and forests with human settlements that use their surrounding ecosystems for hunting, timber extraction, and the harvest of non-timber forest products. Implementing policies and management strategies that are just for these local peoples and result in sustainable resource use is an integral component of conservation initiatives throughout Central America, including large conservation corridor initiatives (Buck Holland 2012). Understanding how animal populations relate to the increasingly prevalent land and cultural conversion processes is essential for designing mitigation and management strategies that will protect the forests of Central America in a way that ensures the long-term conservation of biodiversity. This is particularly important in Nicaragua, a country with an increasingly strong interest in large development projects, including highways and the more recent proposal of an interoceanic canal (Meyer and Huete-Perez 2014, Schmitt and Kramer 2009).

Medium and large mammal communities are important components of forest dynamics in the Central American tropics, affecting seed dispersal, seed predation, and the control of pests. The species comprising these communities vary in their sensitivity to habitat loss, hunting, and fragmentation according to species specific characteristics (Rovero et al. 2014). For instance, meso-carnivores such as white-nosed coatis (*Nasua narica*) might be able to survive in landscapes with considerable anthropogenic disturbance, whereas large carnivores like jaguars (*Panthera onca*) and large herbivores like white-lipped peccaries (*Tayassu peccari*) are often some of the first species to disappear due to hunting or habitat loss. Due to this, the dynamics of large and medium mammal communities can be used to assess the impacts that natural resource extraction, local development projects, or land use change have on tropical forest condition (Rovero et al. 2014). In this paper, I use a hierarchical, community-level occupancy model to evaluate the relationships between the occupancy rates of medium to large neotropical mammals and covariates describing: 1) local ecosystems, 2) natural resource extraction by local people, 3) proximity to a new road, and 4) how these relationships may be changing over time.

Study Site

The South Autonomous Region of the Caribbean Coast of Nicaragua (RACCS) is very ecologically diverse due to widely varying soil composition, topography, and elevation. Its tropical ecosystems include mangrove forests, lowland tropical rainforests, and seasonally flooded swamp forests (Christie et al. 2000). The climate is characterized by a marked wet season from May/June to August during which 2,000 to 4,000 mm of rain fall, flooding large expanses of the region (Christie et al. 2000). Mean annual temperature ranges from 25.6°C to

27.7°C (Christie et al. 2000). Important tree and palm species include *Raphia taedigera*, *Astrocaryum alatum*, *Dipteryx panamensis*, *Elaeis oleifera*, *Swietenia mahagoni*, *Symphonia globulifera*, *Calophyllum brasiliense*, a variety of *Inga sp.*, *Posoqueria latifolia*, among others (Garth et al. 2013).

A culturally diverse set of human communities from six main ethnic groups occupies and relies on this diverse set of natural ecosystems: the Rama, Miskito, and Ulwa indigenous people, the Garifuna and Kriol afrodescendant groups, and the Pacific Coast *Mestizo* cattle ranchers. The first five groups communally own and manage local lands and historically used local forests for hunting and cleared small tracts of land for subsistence, swidden agriculture. The *Mestizo* cattle ranchers invaded Caribbean coast forests in the last few decades, cleared forests, and established cattle ranches within the poorly monitored areas of the indigenous territories. The RACCS was historically isolated from the capital city of Managua and to most global markets and remains one of the two least developed regions of Nicaragua. Within this relatively undeveloped context, a road was constructed from Managua to Pearl Lagoon town in 2007, increasing connection to global networks and markets (Schmitt and Kramer 2009). It was hypothesized that this new road connection would affect natural resource extraction behaviors and cultures of the local people (Schmitt and Kramer 2009).

I installed camera traps around 13 previously remote communities along approximately 125 km of the easternmost RACCS: Pearl Lagoon, Kahkabila, Brown Bank, La Fe, San Vicente, Orinoco, Pueblo Nuevo, Karawala, Kara, Monkey Point, Bangkukuk, Point of Rock, Corn River (**Figure 4.1**). Communities were chosen to coincide with the treatment and control study communities where the larger team of researchers that I am affiliated with were also administering extensive household socioeconomic surveys of the local people. These surveys were administered in 2009, 2010, and 2012. We initially chose these communities because they occur at a range of distance (<1 to >90 km) from Pearl Lagoon and the new road. Given the lack of roads in the RACCS, all else being equal, greater distance from a market and related development will should result in less rapid and less comprehensive development within a community. Thus, the first seven communities are within 20 km of Pearl Lagoon and were directly impacted by road construction and the influx of new markets. Local people in these communities historically lived in and used the forests in their immediate surroundings, which were in turn surrounded by a large forested reserve. Within the last decade, however, a frontier of *Mestizo* cattle ranchers originating in Western Nicaragua and sweeping across the indigenous forests along the Caribbean Coast effectively reached the coast and eliminated the majority of the forests, leaving only the community used, local forests (Petracca et al. 2013). The final six communities are greater than 70 km from Pearl Lagoon and significantly more isolated. They occur in relatively large, intact forested reserves and before 2013 were not significantly affected by the agricultural frontier. These six communities were chosen a priori as control communities while those closest to Pearl Lagoon represent treatment communities. Most of the local people in the communities I studied dedicate themselves to subsistence fishing, farming, and hunting. As the only *Mestizo* community, however, residents of Pueblo Nuevo are primarily cattle ranchers.

Methods

Camera Trapping

A network of camera traps was installed along the 125 km of the RACCS beginning in November 2009. The cameras were set primarily in lowland rainforest ecosystems utilized by the 13 study communities. Camera site selection was based on a grid of 4 km^2 cells placed over a georeferenced map of each community and its surrounding forest. The cells in each grid were assigned random numbers and the GPS coordinates of the centroid of each cell was determined in ArcGIS (Environmental Systems Research Institute, Redlands, Ca). Upon arrival in a community, I hired a local guide to help navigate to the centroid of the cell with the lowest random number in his community's forest. The first camera was installed in this cell. The second camera was subsequently installed in whichever adjacent cell had the lowest random number. In instances where a third camera was installed, the same process was used but based on the cell containing the second camera. Typically ≤3 cameras were set on a given day. This process was repeated three times per community in 2009, such that each community had three sets of camera sites with between 1-3 cameras per set. During my sampling seasons, the cameras were rotated from one set of cameras to the next approximately every two months. The initial intent was to select an equal number of camera sites from each community forest, but issues of accessibility prohibited this and the number of sites per community varied from 3-8.

The specific locations where the camera was installed in each of the randomly selected 4 km^2 cells were chosen by the local guide. After navigating to the centroid of the selected cell, the guide was asked to navigate to the spot where he believed the highest diversity of mammals would be encountered. The guide was allowed to walk the distance he preferred, provided that he did not leave the cell and remained >2 km from cameras in adjacent cells. This methodology constrained the local guide's search to those areas fairly close to the centroid and helped ensure a structurally diverse set of both on and off-trail sites. This is important in camera trap studies aiming to make unbiased inferences about whole species assemblages, as detection probabilities for different species using camera traps have been shown to vary based on site structure (Harmsen et al. 2010).

Data Analysis

I used the basic hierarchical modeling framework described by Royle and Dorazio (2008), to estimate occupancy dynamics of terrestrial mammal species in the treatment vs. the control camera sites. This model estimates species-specific model parameters in the context of a community-level distribution, which permits more accurate estimates for rare species. For my Nicaragua data, it was advantageous to use the detection histories of all species in my sample to inform parameter estimates for individual species as several species included in my models, especially those most sensitive to deforestation and hunting, had sparse detections.

As in prior applications of this model (i.e. Ruiz-Gutierrez et al. 2010), I assumed that occupancy was an imperfectly observed variable; if species *i* was detected at site *j,* then the species was present, but if the species was not detected, the species could either be present and unobserved, or truly absent. I divided camera trap data into multiple, ecologically justifiable sampling occasions in order to estimate detection probability and thereby differentiate true absences from non-detections. I assumed detection did not vary across sites or years.

To construct detection histories, I organized photos from the first 44 days of each camera by species and then divided each species' data into four 11-day sampling occasions. Thus each detection history indicated whether species *i* was detected (y=1) or not (y=0) during the 11 day survey interval *k* at site *j*. I selected an 11-day sampling occasion length due to my experience trapping Baird's tapirs for a GPS telemetry project; I observe that tapirs cycle through their entire home range over the course of 11-12 days. Despite the ability of hierarchical, community level models to accommodate rare species with sparse detections, the three years of data from my study were not sufficient to run dynamic models across years with acceptable precision, thus I stacked data across all years into a single model and included year as a fixed effect. Thus each species had a distinct detection history for every unique year/site combination.

In my final models I used detection histories for: Central American agouti (*Dasyprocta punctata*), ocelot (*Leopardus pardalis*), lowland paca (*Cuniculus paca*), white-nosed coati (*Nasua narica*), white-tailed deer (*Odocoileus virginianus*), jaguar (*Panthera onca*), Baird's tapir (*Tapirus bairdii*), and white-lipped peccary (*Tayassu peccari*). I chose a suite of species that I believe effectively represents the larger community of mammals in the sense that these species represent various levels of sensitivity to local land use change and hunting, and exhibit varying capacities to adapt to fragmented and heavily impacted landscapes. For instance, agoutis, pacas, and white-tailed deer thrive in areas with considerable land use change and human presence, therefore I predicted that these species would occur at similar rates in the treatment vs. control sites with with the exception of any severely degraded or over-hunted sites. As meso-predators, I predicted that white-nosed coatis and ocelots would occur at higher rates in regions with smaller patches of forest closer to communities and infrastructure as I expected that the larger carnivores would be rare in these locations. I predicted that the large species: jaguars, Baird's tapirs, and white-lipped peccaries, would respond negatively to increases in development, deforestation, and human activity. These three species had sparse detections and were thus combined into one "sensitive" species group.

I used logit-linear models for the probabilities of detection, p_{ijk}, and occupancy, ψ_{ij}, to model the effects of habitat covariates (Linden et al. 2012). I assumed that species-specific occupancy probabilities varied between the treatment and study communities, but assumed the probability of detecting the species when they were present did not vary. I also assumed that despite expected differences in occupancy between treatment and control sites, wildlife occupancy rates across all sites would respond similarly to environmental covariates. I used eleven environmental covariates in modeling: 1) Distance to Pearl Lagoon (DPL), 2) Distance to nearest community (DTC), 3) Tree diversity (DIVERSITY), 4) Mean canopy height (CANOPY), 5) Percent of Sampling Site Classified as Forested (FOREST), 6) Total terrestrial biomass harvested by nearest community scaled by distance of camera to community (BIOMASSC), 7) Proportion of the nearest community that considers themselves hunters scaled by the distance of camera to that community (HUNTC), 8) Total terrestrial biomass harvested by nearest community scaled by distance of camera to the Pearl Lagoon Town Road (BIOMASSPL), 9) Proportion of the nearest community that considers themselves hunters scaled by the distance of camera to the Pearl Lagoon Town Road (HUNTPL), 10) Total terrestrial biomass harvested by nearest community scaled by distance of camera to the nearest market of significant size (BIOMASSM), 11) Proportion of the nearest community that considers themselves hunters scaled by the distance of camera to the nearest market of significant size (HUNTM). In addition, I included two categorical covariates, 2011 and 2012, one indicating which detection histories were collected in 2011, and a second indicating those that were collected in 2012.

I collected covariates DIVERSITY, CANOPY, and FOREST for each site by sampling a 250 meter long transect centered on the site of camera installation. For CANOPY, I recorded the approximate canopy height at 25 meter intervals and then calculated the average for each transect. Along each transect, I identified all tree species within 10 meters, summed the total species count for trees, calculated the proportion of the total comprised by each species, and used the Shannon-Weaver formula (Shannon and Weaver 1948):

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

with R=total species, and p_i= the proportion of the total represented by species i to calculate DIVERSITY for the associated camera site. Along the same transect, I recorded cover type at each 25 m sampling point using one of five habitat classes: 1) Farm, 2) Forest, 3) Swamp, 4) Farm, 5) Abandoned Farm. I subsequently calculated the percentage of the transect that was comprised of forest cove type. The camera distance to community, the Pearl Lagoon road, and the nearest market of significant size were measured using ArcGIS.

Hunting covariates were derived from household survey data collected in all study communities with the exceptions of Kara. Values from the nearby community of Karawala were used for Kara. Surveys were conducted in 2010. I used data on the total biomass of terrestrial wildlife harvested per year for each community and the proportion of residents surveyed that consider themselves active hunters. I converted community specific data to a scale of 0-1, where 0 represents no terrestrial biomass harvested and 1 represents the community that harvested the highest amount of terrestrial biomass. I then scaled the distance to community and distance to Pearl Lagoon road measurements to values between 0-1, where 0 represents a camera within the community or Pearl Lagoon and 1 represents the camera location that is the farthest. To derive HUNTC and BIOMASSC, I then divided the scaled hunting data by the scaled distance to community data in order to standardize the data by distance from the nearest community to the camera. To derive HUNTPL and BIOMASSPL, I carried out the same process using the scaled distance to Pearl Lagoon data. To derive HUNTM and BIOMASSM, I carried out the same process using the scaled distance to nearest market of significant size data. Thus for BIOMASSC and HUNTC, I used the distance to the camera as a proxy for the difficulty of accessing the camera, assuming that hunting pressure from a community would be less at those locations that were more inaccessible. While Euclidean distance is not always the equivalent of accessibility, I assumed it would be a passable proxy in my study area. For BIOMASSPL and HUNTPL, I interpreted distance to Pearl Lagoon as a proxy for distance to development, thus scaling the hunting covariates by their proximity to a center of development. The same was the case for BIOMASSM and HUNTM, however for the southern sites, instead of Pearl Lagoon I used the distance to the markets in Bluefields.

Using both the linear and quadratic terms for environmental covariates, I created seven candidate occupancy models. The seven different models of detection were defined as:

1) $logit(\psi_{ij}) = \alpha.treatment_i * (1 - Ind_j) + \alpha.control_i * (Ind_j) + \alpha_{i1}2011 + \alpha_{i2}2012 + \alpha_{i3}BIOMASSPL + \alpha_{i4}BIOMASSPL^2 + \alpha_{i5}HUNTPL + \alpha_{i6}HUNTPL^2$

2) $logit(\psi_{ij}) = \alpha.treatment_i * (1 - Ind_j) + \alpha.control_i * (Ind_j) + \alpha_{i1}2011 + \alpha_{i2}2012 + \alpha_{i3}BIOMASSC + \alpha_{i4}BIOMASSC^2 + \alpha_{i5}HUNTC + \alpha_{i6}HUNTC^2$

3) $logit(\psi_{ij}) = \alpha.treatment_i * (1 - Ind_j) + \alpha.control_i * (Ind_j) + \alpha_{i1}2011 + \alpha_{i2}2012 + \alpha_{i3}BIOMASSM + \alpha_{i4}BIOMASSM^2 + \alpha_{i5}HUNTM + \alpha_{i6}HUNTM^2$

4) $logit(\psi_{ij}) = \alpha.treatment_i * (1 - Ind_j) + \alpha.control_i * (Ind_j) + \alpha_{i1}DIVERSITY + \alpha_{i2}DIVERSITY^2 + \alpha_{i3}CANOPY + \alpha_{i4}CANOPY^2 + \alpha_{i5}FOREST + \alpha_{i6}FOREST^2$

5) $logit(\psi_{ij}) = \alpha.treatment_i * (1 - Ind_j) + \ \alpha.control_i * (Ind_j) + \ \alpha_{\ i1}DIVERSITY + \alpha_{\ i2}DIVERSITY^2 + \ \alpha_{\ i3}CANOPY + \ \alpha_{\ i4}CANOPY^2 + \ \alpha_{\ i5}BIOMASSPL + \alpha_{\ i6}BIOMASSPL^2 + \ \alpha_{\ i5}HUNTPL + \ \alpha_{\ i6}HUNTPL^2$

6) $logit(\psi_{ij}) = \alpha.treatment_i * (1 - Ind_j) + \ \alpha.control_i * (Ind_j) + \ \alpha_{\ i1}DIVERSITY + \alpha_{\ i2}DIVERSITY^2 + \ \alpha_{\ i3}CANOPY + \ \alpha_{\ i4}CANOPY^2 + \ \alpha_{\ i5}BIOMASSC + \alpha_{\ i6}BIOMASSC^2 + \ \alpha_{\ i5}HUNTC + \ \alpha_{\ i6}HUNTC^2$

7) $logit(\psi_{ij}) = \alpha.treatment_i * (1 - Ind_j) + \ \alpha.control_i * (Ind_j) + \ \alpha_{\ i1}DIVERSITY + \alpha_{\ i2}DIVERSITY^2 + \ \alpha_{\ i3}CANOPY + \ \alpha_{\ i4}CANOPY^2 + \ \alpha_{\ i5}BIOMASSM + \alpha_{\ i6}BIOMASSM^2 + \ \alpha_{\ i5}HUNTM + \ \alpha_{\ i6}HUNTM^2$

8) $logit(\psi_{ij}) = \alpha.treatment_i * (1 - Ind_j) + \ \alpha.control_i * (Ind_j) + \ \alpha_{\ i1}DIVERSITY + \alpha_{\ i2}DIVERSITY^2 + \ \alpha_{\ i3}CANOPY + \ \alpha_{\ i4}CANOPY^2 + \ \alpha_{\ i5}DTC + \ \alpha_{\ i6}DTC^2 + \ \alpha_{\ i5}DPL + \alpha_{\ i6}DPL^2$

With *Ind* representing a vector of 1's and 0's describing whether a site was in the control or treatment groups. This produced occupancy estimates for each species by treatment and control sites. I assumed that the covariates would affect species similarly in both the treatment and control sites, though constructed the model in this way to more easily be able to visualize the size of the effect of specific covariates in the treatment vs. control sites.

I assumed that detection did not vary across sites and was not systematically affected by my methodologies or weather, and thus defined the detection model as:

$$logit(p_{ij}) = \alpha_i$$

I estimated the parameters using a Bayesian analysis in WinBUGS (Spiegelhalter et al. 2003) through the R2WinBUGS package (Sturtz et al. 2005) in program R (see Appendix B for sample code). I chose non-informative prior distributions. All covariates were converted to a scale of 0-1, with the hunting data further scaled as described above. I used 3 chains to evaluate model results, running 25,000 iterations after discarding the initial 5,000 iterations and thinning by 20. Convergence was assessed by reviewing the trace plots of the posterior distributions for the three chains and by assessing the potential scale reduction factor (Brooks & Gelman 1998). If the potential scale reduction factor is close to one, we can assume that each of the simulations approaches the target distribution (Brooks & Gelman 1998). I assumed that models converged if the trace plots indicated convergence and if the scale reduction factor was <1.1 for all parameters (Gelman et al. 2003).

Results

In total, I rotated cameras through 105 sites. Each year from 2010-2012, I installed cameras in each site for a minimum of 49 days. My cameras took 50,609 photos in 2010, 65,863 photos in 2011, and 38,913 photos in 2012. For other analyses not reported on here, I considered photos of the same species to be "unique events" if they were separated by more than five hours. My cameras collected data on 1,850 unique events in 2010, 2,575 unique events in 2011, and 7,358 unique events in 2012.

For occupancy modeling, when cameras remained in the sites for over 49 days, only the first 44 days were used in the present analyses. Nine sites located in mangrove forests were removed from analysis as communities use mangroves differently than other forest types and it was not possible to assign the mangrove sites to specific communities. Due to camera failure, for the analyses in this paper I used data from 65 sites in 2010, 57 in 2011, and 61 in 2012. I collected camera-trapping data on 45 species of terrestrial birds and mammals. Most had sparse detections, including those whose ecology makes them unlikely to be photographed, such as arboreal species like Central American spider monkeys (*Ateles geoffroyi*) and crested guans (*Penelope purpurascens*).

The model with the lowest deviance information criterion (DIC) value and thus the highest-ranking model was model one (DIC=4720.1). Model one was also the highest-ranking model that included hunting covariates; the second highest-ranking model was model two (DIC=4788.3). The highest-ranking model that included habitat covariates was model five (DIC=4862.2), followed by model six (DIC=4955.3). Only one model included the DTC and DPL, model 8 (DIC=5031.6). Models four (DIC=5033.0) and seven (DIC=5000.0) also had support in model ranking, thus I report on covariates affecting occupancy from all models. I conclude that covariates have a relationship with occupancy when the 95% credible interval (CRI) of the posterior distribution of a regression coefficient does not overlap zero (Figures **4.2-4.11**). Unless specifically specified, occupancy rates and detection probabilities by species are derived from model one, the highest-ranking model (**Table 4.1**).

Central American agouti

The occupancy rate of Central American agoutis was estimated to be higher in the control vs. the treatment sites, with a detection probability of .4 (**Table 4.1**). Model two provides evidence that agouti occupancy has a positive relationship with BIOMASSC (**Figure 4.2**). Model six provides evidence that agouti occupancy has a positive relationship with $HUNTC^2$ (**Figure 4.3**). Model eight offers evidence that Central American agouti occupancy has a positive relationship with DIVERSITY and $DIVERSITY^2$ and a positive relationship with DPL^2 (**Figures 4.4-4.6).**

Lowland paca

The occupancy rate of lowland pacas was estimated to be nearly twice as high in the treatment vs. the control sites with a detection probability of 0.28 (**Table 4.1**). Model three and model seven provided evidence that lowland paca occupancy has a positive relationship with $BIOMASSM^2$ (**Figures 4.7-4.8**). Model eight offers evidence that paca occupancy has a positive relationship with DPL^2 (**Figure 4.6**).

Ocelot

The occupancy rate of ocelots was estimated to be higher in the treatment vs. the control sites with a detection probability of 0.29 (**Table 4.1**). Model eight offers evidence that ocelot occupancy has a positive relationship with DTC (**Figure 4.9**).

White-nosed coati

The occupancy rate of white-nosed coatis was estimated to be approximately the same in both the treatment and the control sites with a detection probability of 0.69 (**Table 4.1**). Model one provides evidence that coati occupancy has a positive relationship with $HUNTPL^2$ (**Figure 4.10**). Model eight offers evidence that coati occupancy has a positive relationship with DPL^2 (**Figure 4.6**).

White-tailed deer

White-tailed deer occupancy rates were estimated to be slightly higher in control vs. treatment sites with a detection probability of .16 (**Table 4.1**). Model eight offers evidence that white-tailed deer occupancy has a positive relationship with DPL^2 (**Figure 4.6**).

Sensitive species assemblage

The sensitive species assemblage was estimated to have a much higher occupancy rate in control vs. treatment sites with a detection probability of 0.24 (**Table 4.1**). The occupancy rates of the sensitive species assemblage did not have a significant relationship with either of the categorical covariates for year. However, I ran three additional single season models, one for each of my three years of data, and occupancy rates in the treatment sites appeared to decline across years: ψ_{2010}=0.54 (SE=.126), ψ_{2011}=0.27 (SE=.13), ψ_{2012}=0.18 (SE=.141). They did not appear to decline in the control sites: ψ_{2010}=0.71 (SE=.151), ψ_{2011}=0.61 (SE=.148), ψ_{2012}=0.71 (SE=.166). Model six offers evidence that the occupancy rates of the sensitive species have a positive relationship with $HUNTC^2$ (**Figure 4.3**). Model eight offers evidence that the occupancy rates of the sensitive species have a negative relationship with DPL (**Figure 4.11**).

Discussion

Aside from the species-specific occupancy rates and detection probabilities (**Table 4.1**), the results are more suitable for a more general discussion without a unique section for each of the study species. Species-specific information is included when appropriate within this general discussion. Occupancy rates vary between the treatment and control sites, but aside from the occupancy rates of lowland pacas and the sensitive species assemblage, the differences are not very striking. In the treatment sites, those with the largest human impact and closest to the new Pearl Lagoon road, most species have occupancy rates of .60 or higher. In the case of ocelots, a small spotted cat species that, while able to adapt to human modified landscapes, is still relatively sensitive to human presence, their occupancy is actually higher in the treatment sites vs. the control sites. All of this offers evidence that, despite the high human impact and localized development projects in treatment sites, the forests remain viable habitat for a diversity of wildlife species. I do not see signs of the empty forest syndrome common to other regions of the world in forests with high levels of hunting and other human activities. Furthermore, neither of the two "year" categorical covariates (2011, 2012) were significantly correlated with the occupancy rates of any of the species in any models. This suggests that across the entire study site, species did not decline significantly from 2010-2012.

Even for the sensitive species: jaguars, white-lipped peccaries, and Baird's tapirs, their collective occupancy rate of 0.234, along with the occupancy rates of the other species suggests that it is not impossible that enough forested habitat remains in the treatment sites for them to, at the very least, function as viable corridors for these large species. This is reinforced by the fact that the occupancy rates of the sensitive species assemblage have a negative relationship with the distance to Pearl Lagoon covariate. Indeed, this result indicates that there exists viable habitat close to the new road, and that the development did not result in the degradation of habitat for sensitive species from the immediate vicinity. Rare, large mammals, including jaguars, have been found to be highly adaptable dispersers, thus a reasonable amount of informed forest management should be able to conserve such habitats over the long term (Rabinowitz and Zeller 2010). The higher occupancy rate for the sensitive species assemblage in the control sites suggests these regions may serve as core areas. These core areas are geographically located on either side of the treatment sites (**Figure 4.1**), which makes the potential corridor function of the treatment sites particularly important. More research is needed to determine how and if these sensitive species are moving through the landscape near the Pearl Lagoon road.

While the initial modeling did not indicate that any species declined significantly from 2010-2012, this was expected to some degree. I did not expect occupancy rates for any species to decline in the control sites. Including both the control and treatment sites in the same model therefore would, in theory, mitigate the apparent severity of any declines in the treatment sites. To examine if this was occurring, I also ran three similar, single-season models specific to each of the three years of data. These models included no covariates, but produced occupancy estimates separately for the treatment vs. control sites. The results of these models do seem to indicate that the occupancy rates of the sensitive species have declined precipitously between 2010-2012 in the treatment sites, yet the lack of precision means that I am unable to confirm that these trends are significant. Despite this, the results are enough evidence to raise a red flag and to underscore the need to replicate this camera trapping survey in future years to confirm or refute this apparent trend. Indeed, it is important to determine if the occupancy rates of sensitive species will continue to decline until reaching 0% in the treatment sites, if they will plateau at a certain point where the sensitive species are only using these habitats as corridors, and whether or not this is an early indicator of widespread habitat degradation that could eventually affect the other species in the assemblage. I hypothesize that including data from years after 2012 will reveal significant declines in multiple species assemblages as several regions near Pearl Lagoon, such as the Wawashang Reserve, have been almost completely destroyed within the last several years (Petracca et al. 2013).

Perhaps unexpectedly, the modeling results associated with the hunting covariates offer some hope that occupancy rates of the sensitive species will not decline to 0%. Indeed, my modeling offers evidence that the occupancy rates of nearly all species, including the sensitive species assemblage, are positively correlated with either the proportion of the nearest community that considers themselves hunters or the total terrestrial biomass harvested by the nearest community. In other words, their occupancy rates are correlated with apparent increases in hunting. While this may seem paradoxical, these measures of hunting are, for the most part, measures of hunting by the indigenous and afro-descendant people who have lived in these forests for centuries. These groups have high cultural value for the wildlife surrounding them and live in communities with social norms that discourage individuals from overhunting (Jordan et al. 2013). My research on hunting shows that indigenous and afro-descendant tapir hunting has not increased significantly over the past several decades (Jordan et al. 2014). Thus, if indigenous and afro-descendant hunters are not hunting unsustainably, but are still active in the forests, their presence likely prevents *Mestizo* hunters from the cattle ranches along the agricultural frontier from hunting within their communal forests. In this sense, the hunters we identified in our socioeconomic surveys likely function as forest rangers and as hunters. Given that local people use all of the forests I sampled, and all camera sites are at least somewhat affected by the agricultural frontier, it is not impossible that those sites with more indigenous and afro-descendant hunters are better protected from overhunting than those without the presence of hunters.

For some species, the positive relationship with the hunting covariates can be partially explained ecologically. In the case of white nosed coatis, the relationship may constitute evidence for the mesopredator release hypothesis (Groom et al. 2006). Indeed, as more and more biomass is harvested, there is less food for large predators such as jaguars, and the environment can sustain a smaller number of them. If a few of these large predators are also hunted, their density will decline even farther, allowing smaller carnivores such as white-nosed coatis to thrive. For prey species of these large carnivores, the subsequent reduction in hunting pressure may also allow them to thrive, yet this seems unlikely to be a valid explanation given that many of these species (i.e. lowland pacas, white tailed deer), are also preferred food species for the local human communities.

In general species seem to have a complex relationship with the distance to Pearl Lagoon covariate. This is probably due to non-random variations in the local context. For instance, close to Pearl Lagoon there remains habitat for wildlife in those areas controlled by the indigenous and afro-descendant populations. However at intermediate distances, there are regions controlled by *Mestizos* where very little forest cover remains. The most distant locations are those with the most extensive forests and presumably best habitat for most of the species in my models. Thus, due to the variation close to Pearl Lagoon, it is not unexpected that many species do not have a significant relationship with the DPL covariate. Due to the larger, distant reserves, it is also not unexpected that many species have a positive relationship with the quadratic term for this same covariate. Perhaps the one surprise is that the sensitive species assemblage has a negative relationship with distance to Pearl Lagoon. This is partially explained above, but may also be due to the fact that amongst the control sites, some of those that are closer to Pearl Lagoon have more detections of the sensitive species than the furthest sites.

A final, interesting result is that the habitat related covariates have very few significant relationships with the occupancy rates of any of the species. The only significant relationship is the positive correlation case is positive and between agouti occupancy rates and tree species diversity. The largest reserves also have the highest tree diversity, and the indigenous and afro-descendant people in these reserves do not hunt agoutis, as they prefer to focus their hunting effort on larger herbivores, primarily white-lipped peccaries. Thus, this relationship can perhaps be explained by the lack of agouti hunting in those regions with the highest diversity of trees. But why are there no other significant relationships between the habitat covariates and other species' occupancy rates? While my data are not sufficient to answer this question, it may simply be that the species in my models are using a variety of habitats and not just mature, species diverse forests. As a case in point, I mentioned in the study area description, the RACCS has extensive swamp habitats. Sampling grid cells with swamps are likely to have lower canopies, less arboreal diversity, and a lower percentage of forest cover, yet they probably still constitute important habitat for most if not all of my study species. In this scenario, it would make sense that my habitat covariates, which are essentially indicators of primary forests, do not have significant relationships with many of the species' occupancy rates.

Conclusion

My results indicate that all Caribbean Coast Nicaraguan forests sampled serve as habitat for the focal species, regardless of the level of development or hunting. This is encouraging in the sense that it indicates that there is space for conservation alongside development initiatives, and that development projects do not necessarily result in forests devoid of wildlife. At the same time, the development project under consideration in this context, the road construction in Pearl Lagoon, was a relatively minor project. The road is not paved and retains forests on either side in many locations, especially as one gets closer to Pearl Lagoon. Larger, more destructive development projects would be more likely to negatively affect wildlife over a short time frame. In addition, while forests may still serve as habitat immediately after development, the development itself may lead to increases in access and forest use that can lead to species' declines over the long term. In the case of Pearl Lagoon and the surrounding communities, my results indicate that there are potentially processes at work leading to the decline of certain rare species in those regions close to the new development. In particular, the threats to wildlife, including hunting, in this region have gotten considerably worse in the years since road construction (Jordan and Roe-Hulse 2011, Jordan et al. 2014). Thus, while the forests still served as habitat in 2012, over the long term they may be unlikely to be able to retain populations of endangered species living at low densities. Of course, these species are generally those we are most interested in conserving. Due to this, it is essential to replicate the sampling described in this paper in the next few years to confirm or refute the apparent negative trends in the occupancy rates of sensitive species.

My results also provide some evidence for the importance of indigenous peoples in wildlife conservation. Indeed, the occupancy rates of many of the species I modeled have a positive relationship with increases in indigenous hunting. As mentioned above, this is likely due to the fact that the indigenous and afro-descendant hunters in the RACCS are less likely to hunt unsustainably and less likely to tolerate the unsustainable hunting of others in their forests than the *Mestizo* populations. Thus, in the context of forests used by local people, indigenous and afro-descendant hunters are likely serving as forest rangers and are thus beneficial to wildlife. I would expect those regions controlled by *Mestizos* where indigenous and afro-descendant hunters are not present to be less suitable for wildlife. The overwhelmingly majority of *Mestizo* cattle ranchers working in the indigenous territories of the RACCS cleared forests and settled illegally on lands that are communally owned by the indigenous peoples. Law 445 gives the indigenous and afro-descendant people a legal basis and outlines a formal process, locally termed *saneamiento*, for removing these illegal colonists from their territories (Goett 2006). Thus, not only to ensure the autonomy and cultural survival of these indigenous and afro-descendant groups, but also to support the conservation of Caribbean Coast wildlife, it is important to support indigenous rights generally and the process of *saneamiento* specifically.

Given my results and the expected changes in years to come in the RACCS, it seems essential to increase rigorous research throughout the region in order to design and implementing wildlife conservation and management plans. Forests throughout the region are very poorly managed in general. To ensure that a diversity of terrestrial wildlife species are conserved over the long-term, it is essential to continue collecting data on wildlife and use them in meetings with the region's autonomous authorities and indigenous peoples to design effective conservation and management strategies.

APPENDICES

APPENDIX A: TABLES AND FIGURES

Table 4.1. Occupancy and detection matrix with standard errors for all species across all years in both treatment (T) and control (C) sites.

Species	Ψ(C)	Ψ (T)	p
Central American agouti	0.764 (0.07)	0.594 (0.06)	0.400 (0.03)
Lowland paca	0.442 (0.09)	0.821 (0.08)	0.281 (0.03)
Ocelot	0.535 (0.09)	0.735 (0.08)	0.286 (0.03)
White-nosed coati	0.632 (0.13)	0.751 (0.085)	0.693 (0.02)
White-tailed deer	0.762 (0.11)	0.592 (0.12)	0.161 (0.03)
Sensitive	0.665 (0.11)	0.234 (0.07)	0.244 (0.04)

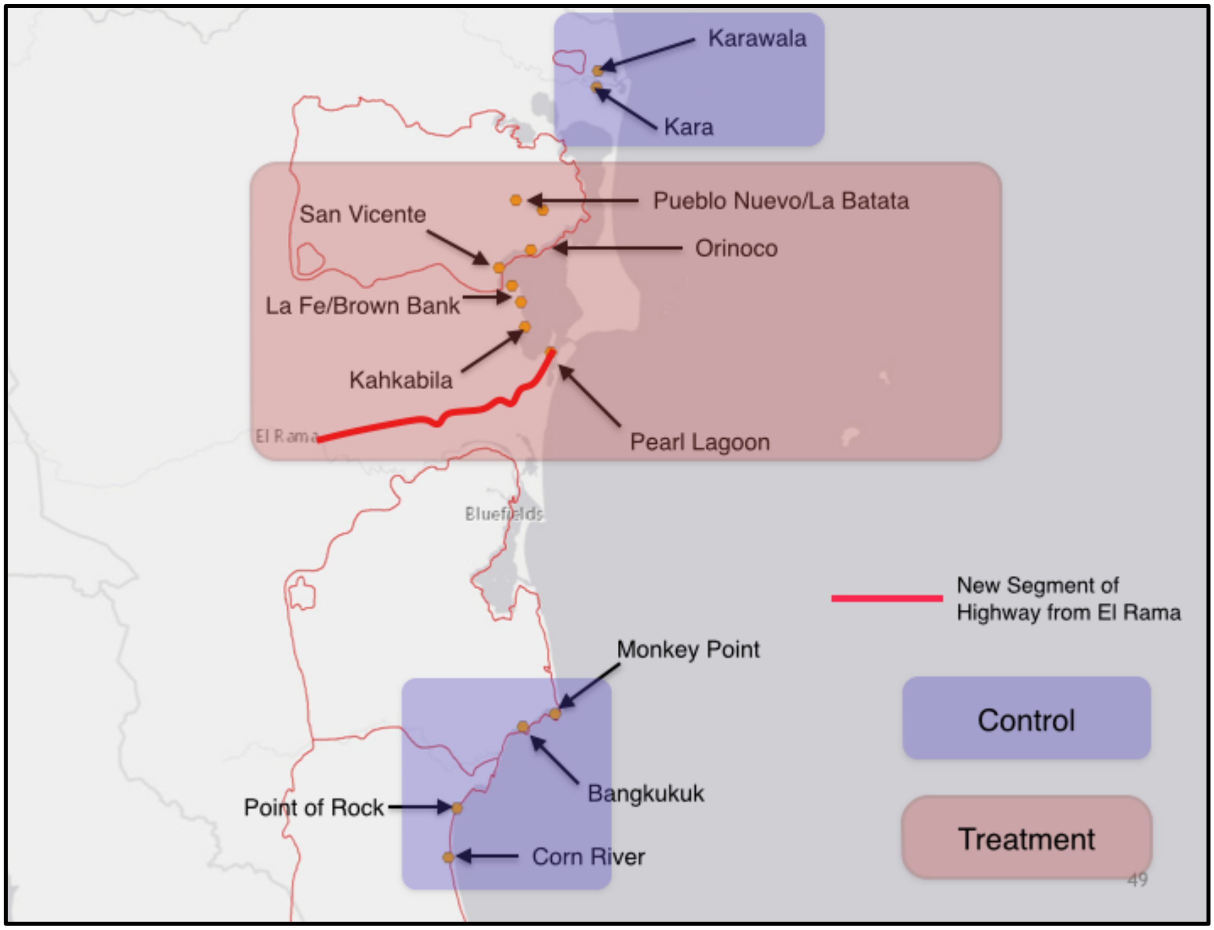

Figure 4.1 A map of the study area, including the 13 study communities. Purple boxes indicate the control communities and red boxes indicate the treatment communities. The red line represents the segment of the highway from Managua to Pearl Lagoon built in 2007.

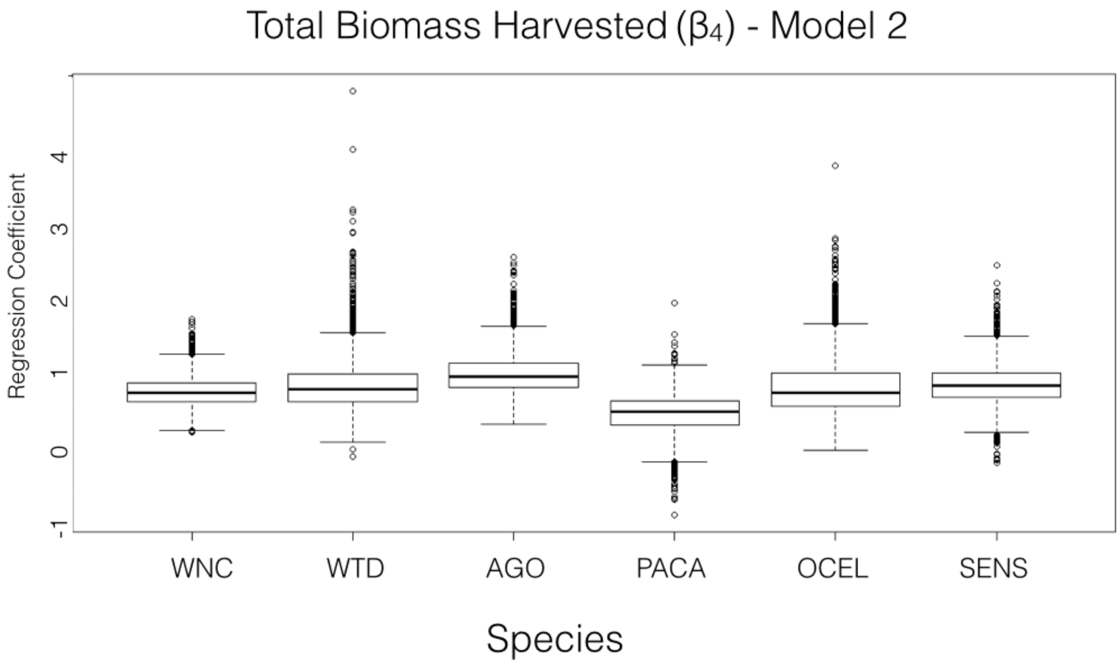

Figure 4.2 Posterior Estimation (Mean with 95% Credible Interval) of the regression coefficient for $BIOMASSC^2$ by species from logit-linear occupancy model two. WNC=White-nosed Coati, WTD=White-tailed deer, AGO=Central American Agouti, PACA=Lowland paca, OCEL=Ocelot, and SENS=Sensitive Species Assemblage.

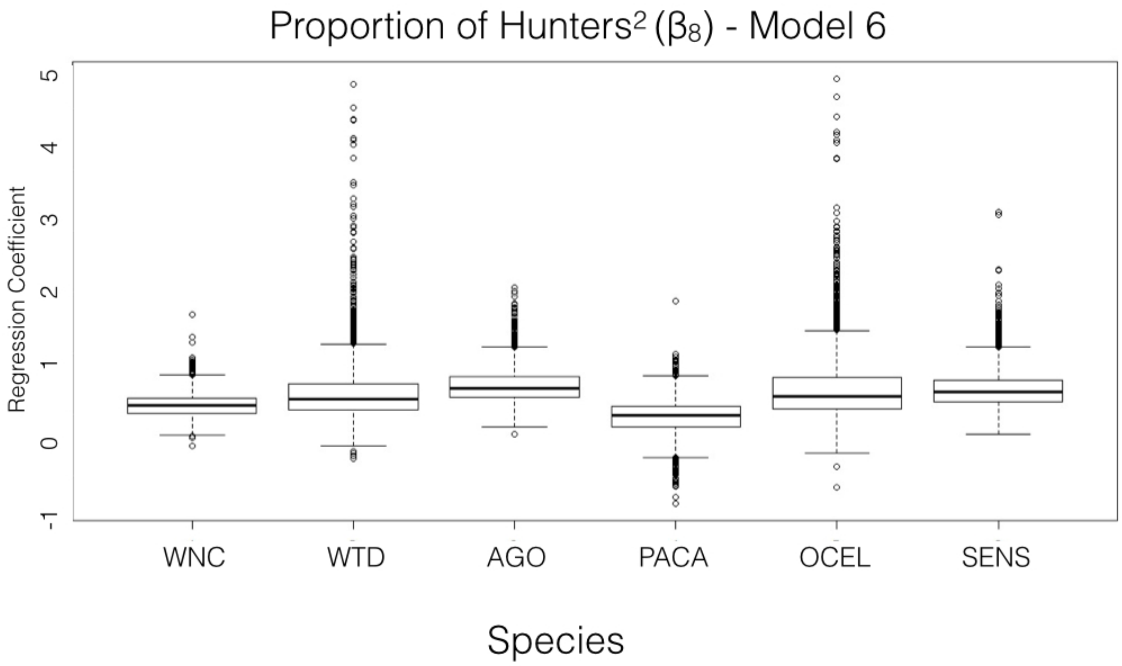

Figure 4.3 Posterior Estimation (Mean with 95% Credible Interval) of the regression coefficient for $HUNTC^2$ by species from logit-linear occupancy model six. WNC=White-nosed Coati, WTD=White-tailed deer, AGO=Central American Agouti, PACA=Lowland paca, OCEL=Ocelot, and SENS=Sensitive Species Assemblage.

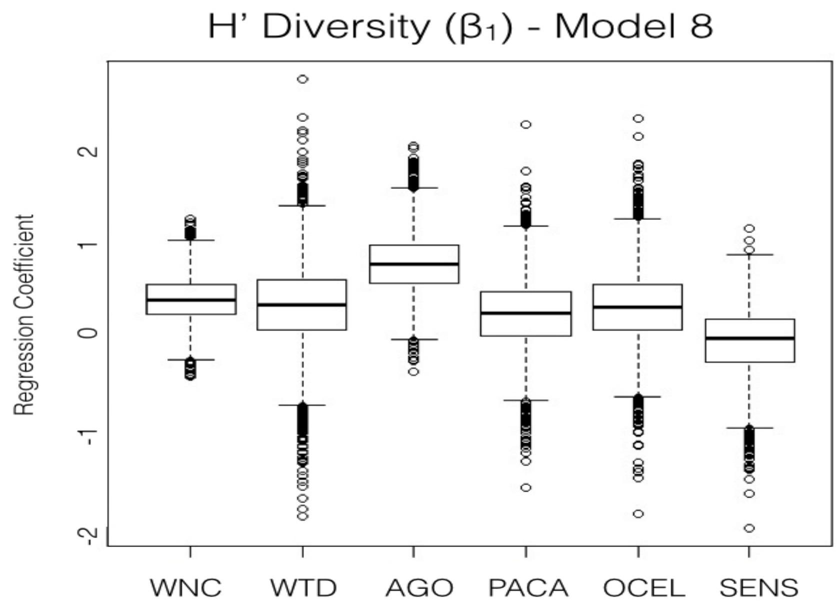

Figure 4.4 Posterior Estimation (Mean with 95% Credible Interval) of the regression coefficient for HDIV by species from logit-linear occupancy model eight. WNC=White-nosed Coati, WTD=White-tailed deer, AGO=Central American Agouti, PACA=Lowland paca, OCEL=Ocelot, and SENS=Sensitive Species Assemblage.

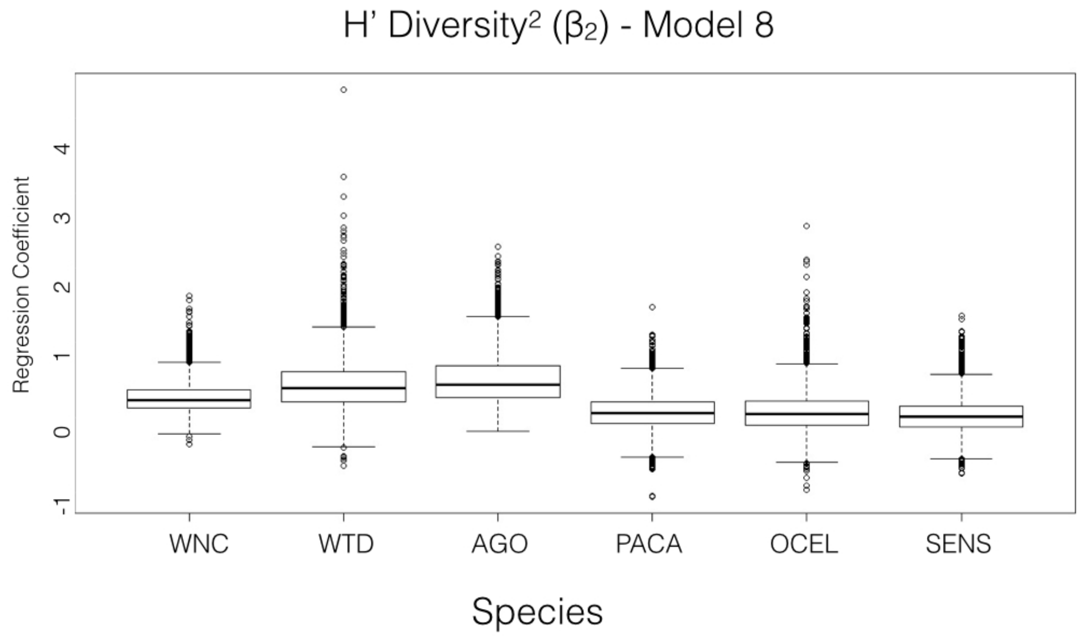

Figure 4.5 Posterior Estimation (Mean with 95% Credible Interval) of the regression coefficient for $HDIV^2$ by species from logit-linear occupancy model eight. WNC=White-nosed Coati, WTD=White-tailed deer, AGO=Central American Agouti, PACA=Lowland paca, OCEL=Ocelot, and SENS=Sensitive Species Assemblage.

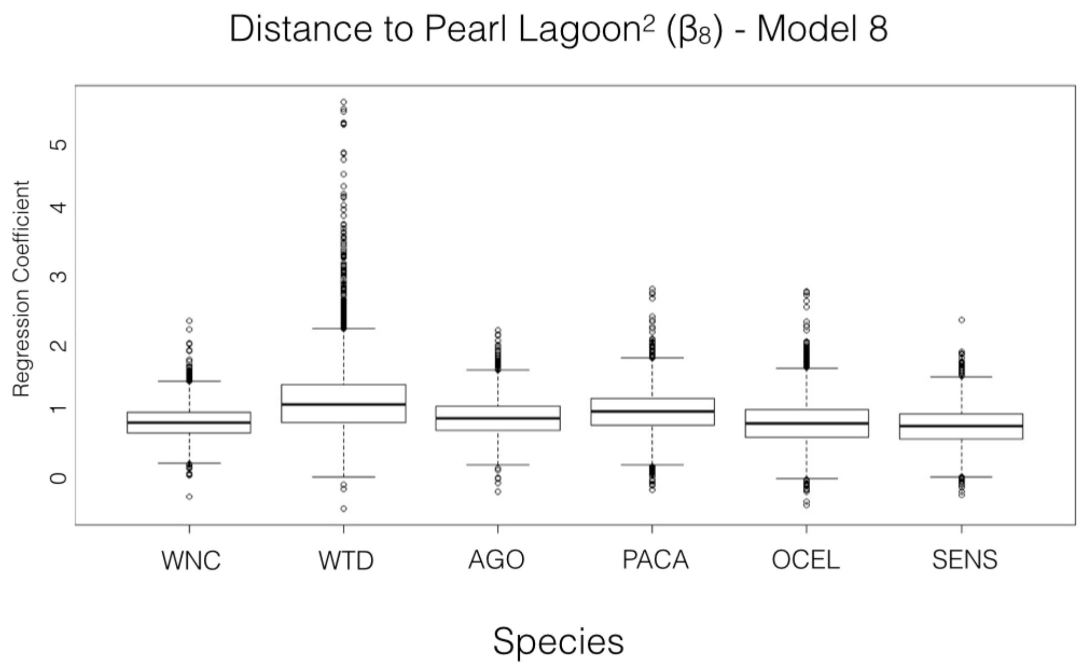

Figure 4.6 Posterior Estimation (Mean with 95% Credible Interval) of the regression coefficient for $DTPL^2$ by species from logit-linear occupancy model eight. WNC=White-nosed Coati, WTD=White-tailed deer, AGO=Central American Agouti, PACA=Lowland paca, OCEL=Ocelot, and SENS=Sensitive Species Assemblage.

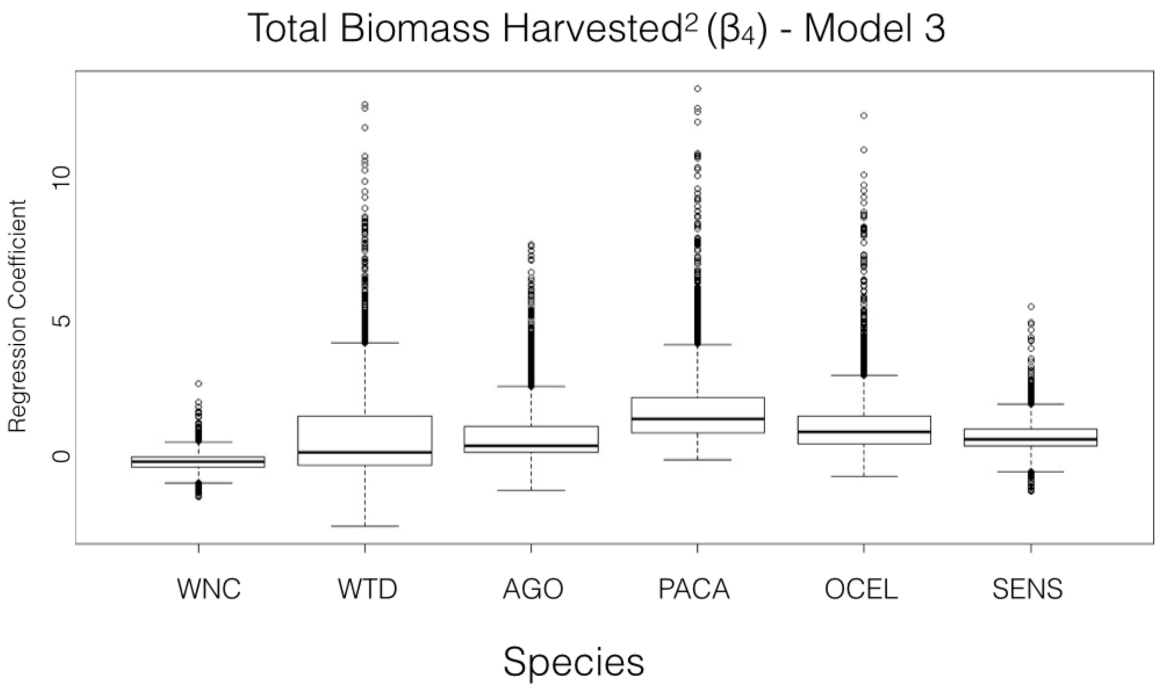

Figure 4.7 Posterior Estimation (Mean with 95% Credible Interval) of the regression coefficient for BIOMASSM^2 by species from logit-linear occupancy model three. WNC=White-nosed Coati, WTD=White-tailed deer, AGO=Central American Agouti, PACA=Lowland paca, OCEL=Ocelot, and SENS=Sensitive Species Assemblage.

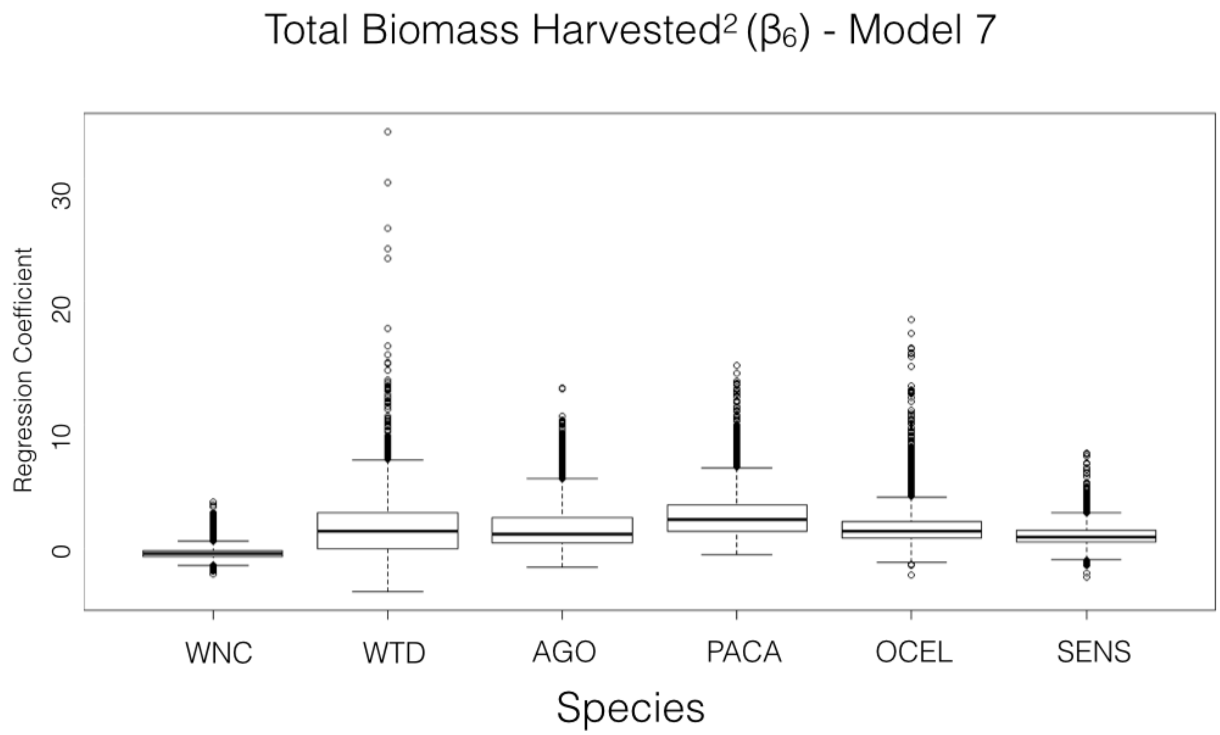

Figure 4.8 Posterior Estimation (Mean with 95% Credible Interval) of the regression coefficient for BIOMASSM^2 by species from logit-linear occupancy model seven. WNC=White-nosed Coati, WTD=White-tailed deer, AGO=Central American Agouti, PACA=Lowland paca, OCEL=Ocelot, and SENS=Sensitive Species Assemblage.

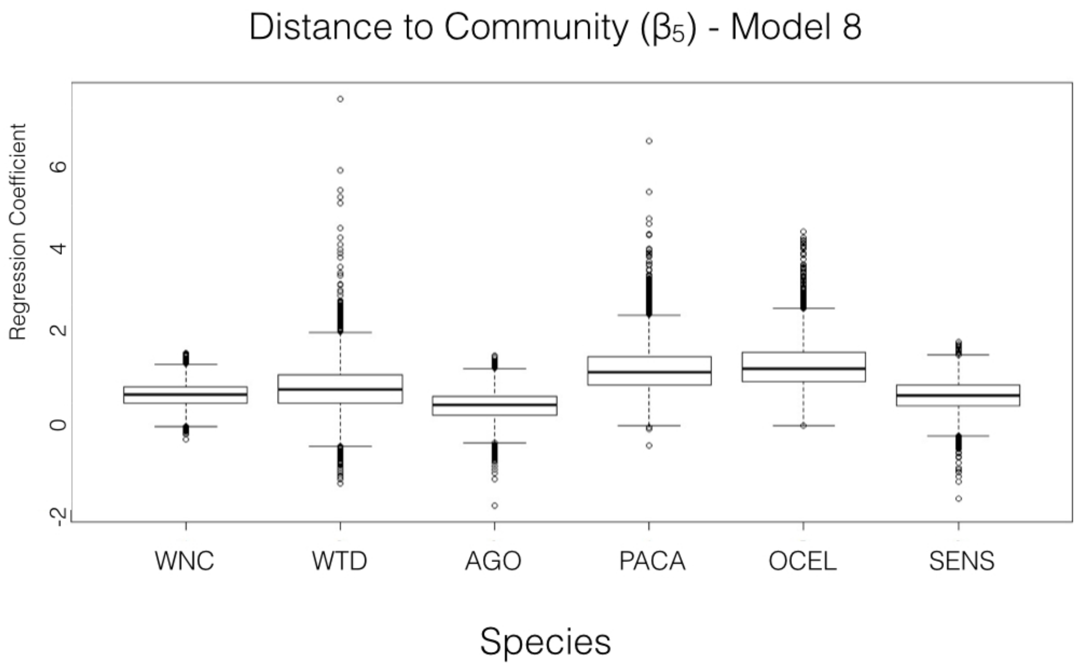

Figure 4.9 Posterior Estimation (Mean with 95% Credible Interval) of the regression coefficient for DTC by species from logit-linear occupancy model eight. WNC=White-nosed Coati, WTD=White-tailed deer, AGO=Central American Agouti, PACA=Lowland paca, OCEL=Ocelot, and SENS=Sensitive Species Assemblage.

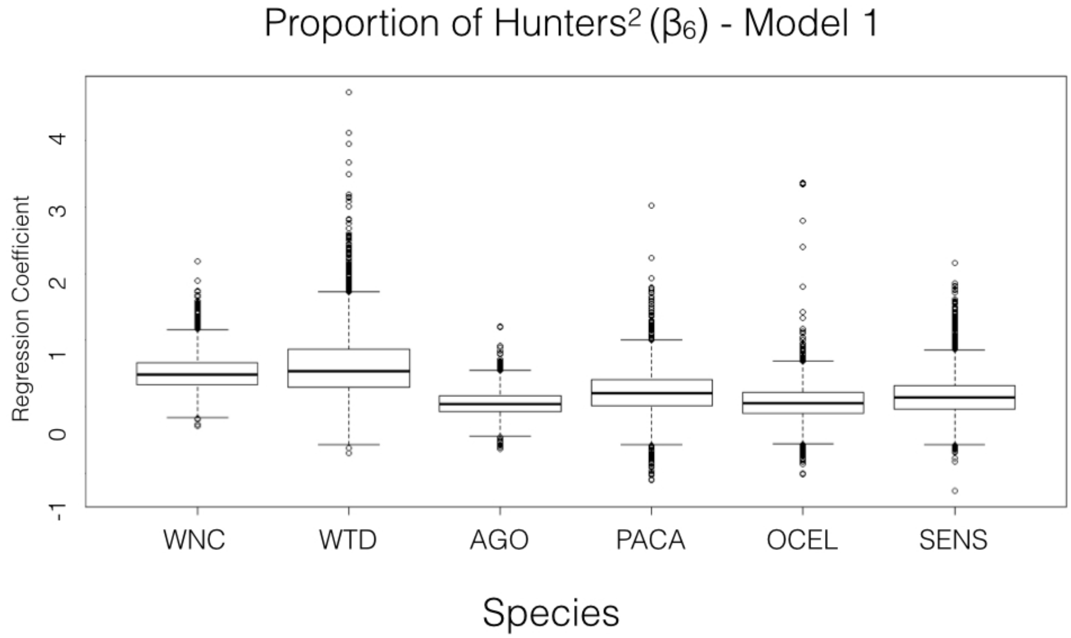

Figure 4.10 Posterior Estimation (Mean with 95% Credible Interval) of the regression coefficient for $HUNTPL^2$ by species from logit-linear occupancy model one. WNC=White-nosed Coati, WTD=White-tailed deer, AGO=Central American Agouti, PACA=Lowland paca, OCEL=Ocelot, and SENS=Sensitive Species Assemblage.

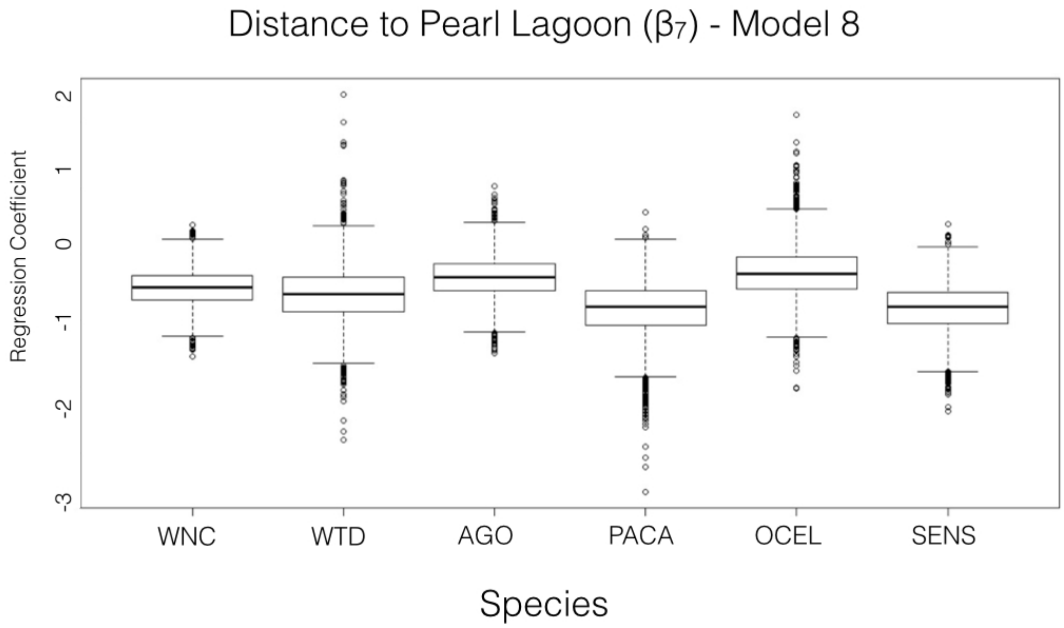

Figure 4.11 Posterior Estimation (Mean with 95% Credible Interval) of the regression coefficient for DTPL by species from logit-linear occupancy model eight. WNC=White-nosed Coati, WTD=White-tailed deer, AGO=Central American Agouti, PACA=Lowland paca, OCEL=Ocelot, and SENS=Sensitive Species Assemblage.

APPENDIX B: WINBUGS CODE SPECIFYING MODEL SEVEN

```
cat("
  m= model{

omega ~ dunif(0,1)

south.mean ~ dunif(0,1)
mu.usouth <- log(south.mean) - log(1-south.mean)

north.mean ~ dunif(0,1)
mu.unorth <- log(north.mean) - log(1-north.mean)


v.mean ~ dunif(0,1)
mu.v <- log(v.mean) - log(1-v.mean)
mua1 ~ dnorm(0, 0.001)
mua2 ~ dnorm(0, 0.001)
mua3 ~ dnorm(0, 0.001)
mua4 ~ dnorm(0, 0.001)
mua5 ~ dnorm(0, 0.001)
mua6 ~ dnorm(0, 0.001)
mua7 ~ dnorm(0, 0.001)
mua8 ~ dnorm(0, 0.001)

tau.usouth ~ dgamma(0.1,0.1)
tau.unorth ~ dgamma(0.1,0.1)
tau.v ~ dgamma(0.1,0.1)
tau.a1 ~ dgamma(0.1,0.1)
tau.a2 ~ dgamma(0.1,0.1)
tau.a3 ~ dgamma(0.1,0.1)
tau.a4 ~ dgamma(0.1,0.1)
tau.a5 ~ dgamma(0.1,0.1)
tau.a6 ~ dgamma(0.1,0.1)
tau.a7 ~ dgamma(0.1,0.1)
tau.a8 ~ dgamma(0.1,0.1)

for (i in 1:(n+nzeroes)) {

      w[i] ~ dbern(omega)
   u.south[i] ~ dnorm(mu.usouth, tau.usouth)
   v[i] ~ dnorm(mu.v, tau.v)
   u.north[i] ~ dnorm(mu.unorth, tau.unorth)
   a1[i] ~ dnorm(mua1, tau.a1)
   a2[i] ~ dnorm(mua2, tau.a2)
   a3[i] ~ dnorm(mua3, tau.a3)
   a4[i] ~ dnorm(mua4, tau.a4)
   a5[i] ~ dnorm(mua5, tau.a5)
   a6[i] ~ dnorm(mua6, tau.a6)
```

```
   a7[i] ~ dnorm(mua7, tau.a7)
   a8[i] ~ dnorm(mua8, tau.a8)

         for (j in 1:J) {
      logit(psi[j,i]) <- u.north[i]*(1-Ind[j]) + u.south[i]*Ind[j] + a1[i]*hdiv1[j] + a2[i]*hdiv2[j] +
a3[i]*canopy1[j] + a4[i]*canopy2[j] +a5[i]*tbmdtm1[j] + a6[i]*tbmdtm2[j] + a7[i]*phuntdtm1[j] +
a8[i]*phuntdtm2[j]

  mu.psi[j,i] <- psi[j,i]*w[i]
  Z[j,i] ~ dbern(mu.psi[j,i])

         for (k in 1:K[j]) {
   logit(p[j,k,i]) <-  v[i]
      mu.p[j,k,i] <- p[j,k,i]*Z[j,i]
      X[j,k,i] ~ dbern(mu.p[j,k,i])
}   }}

}
",file="covarmodel.txt")
```

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CONCLUSION

Berkes (2008) describes two disparate views of the concept of knowledge. The first view considers knowledge as that what we know; an entity that we endeavor to acquire. The second considers knowledge as an entire process. This second view of knowledge reflects the belief that understanding the processes, rituals, or experiences that lead to knowledge is often as important as the resulting facts or information we acquire. Working closely with indigenous and rural peoples requires researchers to not just head to the field in pursuit of facts and data, but to also to truly understand knowledge as a process. Without this understanding, it is exceedingly difficult to maximize efficiency in the field and impossible to ensure that research project results are relevant to local stakeholders. In addition, considering knowledge as a process is a much better strategy for preparing oneself for employment in conservation and research after graduation. To a certain extent this dissertation and to a much larger extent my dissertation experience as a whole underscores this idea.

Chapter One in particular describes a fairly straightforward, social science methodology that ecologists can use to learn about local people, their environmental knowledge, local processes of knowledge transmission, and how to more efficiently communicate with them. It also discusses interview results and how they have been and could be applied to benefit Western scientific research, local peoples, and cultural and ecological conservation. **Chapter Two** underscores the importance of understanding all components of data collection, especially in coupled natural and human systems. Not taking into account local environmental knowledge or understanding precisely how to interact with local guides about research can result in biased results. In other words, just installing cameras without considering the larger context of ecological sampling can reduce both efficiency and the integrity of research. Although to a certain extent my dissertation fieldwork was collected simultaneously, **Chapter Three** and **Chapter Four** integrate many of the lessons learned in **Chapters One** and **Two** to consider the two main research topics, TEK in Nicaragua and neotropical wildlife, on a broader scale.

In this way, the four chapters consist of one larger process; the first two chapters directly explore components of knowledge acquisition and different processes that can affect data collection. Then the final two chapters use the lessons learned from initial fieldwork to more efficiently tackle questions that are larger in scope and scale. In a larger sense, approaching my entire dissertation experience with this more holistic philosophy ensured that I learned how to communicate with and work with local peoples, how to engage local politicians and encourage them to act, and how to maintain a functional relationship with the central government. In other words, my approach prepared me to work effectively in Nicaraguan conservation after graduation.

In addition to the benefits and importance of viewing knowledge as a process, the results within the four dissertation chapters highlight the various levels and complexity of conducting wildlife research in bioculturally diverse, coupled natural and human systems such as Caribbean Coast Nicaragua. There are many elements that influence trends in wildlife, local natural resource use, and traditional environmental knowledge transmission. In some cases, the same elements in one community can have different effects across neighboring communities due to cultural, economic, or social disparities. This is discussed multiple times in the context of both TEK and wildlife research. These results lead to three additional suggestions for wildlife professionals working in similar contexts as my field site of Caribbean Coast, Nicaragua:

1) Whenever possible, pair wildlife research or conservation initiatives with small social science based surveys or interviews designed to increase your understanding of local ways of

knowing and using the forest. This approach proved invaluable to my understanding of local ecosystems and how to work effectively within them.

2) Use the information gleaned from social science interviews to carefully design the collection of data for use as covariates. It is not always straightforward to choose covariates well in highly complex landscapes, thus the more care taken in designing sampling protocols, the better modeling results are likely to be.

3) Likewise whenever possible, and particularly in the case of conservation, employ an adaptive management approach. Given the high degree of variation within communities, an approach that functions in one community may not function in a second. Many initiatives in rural locations fail because professionals attempt to implement a single, rigid methodology across a broad study area. Assessing what is functioning on the ground and using that to adapt conservation approaches is essential to long-term success.

Finally, each of the chapters in the dissertation also offers certain policy implications regarding development infrastructure, environmental education, and cultural survival. Nonetheless, all of the policy implications in the work will not help protect local peoples and ecosystems if the central government is not willing to abide by them. It has become abundantly clear to me over the past few years that while research is an essential and very important component of working with wildlife in remote locations, there are times when it isn't enough. In Nicaragua, we need action in the short term to stabilize protected area borders and ensure that core populations of internationally endangered species are protected over the long-term. Indeed, without improving things like the law enforcement in Nicaragua's protected areas, we will find ourselves without many of the species we want to research and monitor. Of course the ideal scenario is to conduct comprehensive plans that include protective action in protected areas carried out alongside research on the effects of globalization and local development on forested ecosystems and wildlife in the matrix between well-protected reserves. This would ensure both that protected areas are stabilized in the short term and that we are generating the information needed to design long term, effective management and conservation plans to maintain genetic connectivity for wildlife outside of those reserves. I hope that the continuation of my dissertation fieldwork and related research projects in future years will be a part of such comprehensive, adaptive approaches and will have a long-term positive impact on Nicaragua's Caribbean Coast forests and people.

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