CONSERVATION INITIATIVES, COMMUNITY PERCEPTIONS, AND FOREST COVER CHANGE: A STUDY OF THE COMMUNITY BABOON SANCTUARY, BELIZE

By

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To the residents of the Community Baboon Sanctuary, Belize

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The Community Baboon Sanctuary (CBS), Belize, an IUCN Category IV protected area, was established in 1985 to protect forest habitat for the black howler monkey (*Alouatta pigra*). Nature-based tourism and a pledge were created to promote conservation. This study assessed conservation from three perspectives: 1) the landowner (place-based meanings and benefit perceptions attributed to riparian forests), 2) the landscape (social and land-use/land-cover change analyses to assess deforestation drivers), and 3) howler habitat (forest cover change and fragmentation). Methods incorporated household interviews and remote sensing to conduct change detection analyses, landscape metric analyses and modeling using Landsat satellite imagery from 1989, 1994, 2000, and 2004. Results show 1) a significant relationship between initiative involvement and higher perceived benefits (importance) and place attachment towards riparian forests and conservation; 2) involvement in tourism and pledging together decreased deforestation probability, with other influential variables including road and river distance, tenure, cattle, agriculture, and education level; and 3) a 23% forest cover loss between 1989 and 2004 and increased forest fragmentation. However, high connectivity exists between most forest patches and indicates dispersal potential has not been jeopardized. Additionally, howler populations have increased dramatically in the last 20 years.

CBS conservation may be more complex than simply saving forests and, therefore saving howlers, as increased fragmentation actually provides better habitat for *ficus spp.* (e.g., figs), the preferred food source. Under IUCN Category IV designation, one could argue conservation success, as documented by howler population increases. However, if the conservation objective is forest preservation, the 23% forest cover decrease would signal conservation failure. This indicates the CBS should not be managed for a single outcome (e.g., howlers). As deforestation is tied to livelihoods, the two initiatives should be closer examined.

On one level these initiatives are a strong basis for conservation. However, benefit and participation inequality exit. Additionally, other variables are more influential deforestation drivers. Therefore, without addressing these discrepancies, this foundation is not enough to compete with the important economic opportunities forests provide and reiterates the lesson that the success of any conservation initiative must be linked to local communities benefiting from their conservation of biodiversity.

CHAPTER 1
INTRODUCTION

The overall focus of this dissertation examines conservation within the Community Baboon Sanctuary (CBS), Belize from three different perspectives: 1) human perceptions and values (e.g., focusing on perceived benefits and place-based meanings of riparian forest landscapes); 2) land cover change (e.g., focusing on the influence of these initiatives on deforestation probabilities, in addition to other locational and socio-economic variables); and 3) black howler monkey habitat (e.g., focusing on forest fragmentation based on howler habitat criteria). The research is presented as three separate papers, presented in publication style for submission to academic journals. Therefore, each paper is a stand-alone document, addressing different aspects of the research statement described below. The first paper, "Examining the linkages between community benefits, place-based meanings, and conservation program involvement: A study of the Community Baboon Sanctuary, Belize" expands on sense of place and place attachment conceptualizations as an incentive to conserving forests, in addition to the role these conservation initiatives play in managing community benefits. The second paper, "Integrating social and land-use/land-cover data to assess drivers of deforestation: A study of the Community Baboon Sanctuary, Belize" integrates remote sensing and spatial modeling to quantify and analyze the relative influence of tourism and the pledge, along with locational and socio-economic variables, as drivers of deforestation within the CBS over a 15 year time period (1989-2004), using information from 33 landowners. The third paper, "Forest fragmentation and habitat conservation for the black howler monkey: A study within the Community Baboon Sanctuary, Belize" assesses the performance of conservation within the CBS as an IUCN Category IV protected area by examining changes in forest cover and forest fragmentation within the CBS over a 15 year time period (1989-2004) from the perspective of suitable habitat for the black howler monkey, the impetus for the creation of the CBS, based on habitat criteria.

Study Overview

A response to deforestation worldwide has been the creation of protected areas for fragile natural and cultural resources (Primack et al. 1998; Brandon et al. 1998; Bates and Rudel 2000; Langholz 2002). Nearly 35% of Belize has been designated some type of protected area status (Primack et al. 1998). However, designation alone is insufficient. Many protected areas are, in reality, "paper reserves" and "paper parks" (e.g., only protected on paper), which have resulted in land conflicts and continued extractive uses of the forest now deemed illegal. This inability to manage and police protected areas, coupled with an environmental justice narrative, has called attention to the needs of local people living within and around these areas with schemes for community management of natural resources advancing as an alternative option (Alcorn 1993; Primack et al. 1998). Many researchers and conservation practitioners posit that conservation of tropical forests is more effective and efficient at small-scale and local-level regimes and that, in certain circumstances, and under an emerging set of institutional conditions, local communities are the most effective managers of local natural resources because of their dependence, contact, and subsequent knowledge of local resources (Lepp and Holland 2006; Agawal and Gibson 1999; Tisdell 1995).

In conjunction with conservation, community-based conservation initiatives are increasingly developing revenue-generating activities, using market incentives to promote conservation (Tisdell 1995; PfB 2000; Wunder 2000; Langholz and Brandon 2001; Murphree 2003). Many criticize, however, that economic incentives alone may not be the only factors involved in impacting land-use decisions, and there is not necessarily a connection between economic income and pro-environmental behavior (Funder 1995; Wunder 2000; Salafsky et al.

2001; Stem et al. 2003). Even where economic factors have a strong influence on people's behaviors, it is often associated with social, infrastructural, and psychological factors, as seen in the following examples: Salafsky et al. (2001) found that the projects that generated the most community support for conservation were those that provided non-cash benefits. In addition, a study by Funder (1995) on the impacts of the Campfire program on two communities in Zimbabwe found that women's evaluation of income-generating projects focused more on the provided services than on the revenues generated. Such findings suggest that other types of benefits must be considered in communal approaches to management and conservation. It is through the extension of conservation's benefits, argues Hulme and Murphree (1999), that attitudes towards conservation will be improved that, ultimately, will foster pro-conservation behavior.

Community Benefits

Research does not often examine both the economic and non-economic benefits potentially associated with protected areas in developing countries. Research in the U.S., Canada, New Zealand, and Australia that has examined these potential benefits shows improved and more efficient planning of natural areas that directly involves the community (Driver 1996; Moore and Driver 2005). Research is needed in developing countries where community-based conservation is often targeted as a solution for protecting natural areas.

It is by focusing on both intangible and tangible benefits from conservation that management plans will better respond to local resident needs (Stein et al. 1999; Davenport and Anderson 2005). For example, a Hulme and Murphree (1999) study on the Kuenene region of Namibia show that the intrinsic values (e.g., benefits) of wildlife and the importance of passing them on to future generations plays an important role in wildlife conservation. Also, a study by Stein et al. (1999) identifying how two state parks in northern Minnesota benefit rural communities showed that attracting tourism dollars to surrounding communities was just one of a variety of benefits of conservation community stakeholders felt were important. In fact, benefits such as pride were considered more important than economic benefits for stakeholders of one state park.

Place-Based Meanings

Although understanding local residents' perceived benefits of natural areas and conservation will better enable management to respond to local resident needs, research that examines the specific benefits residents attain from nature might not address the relationship of people's attachments to specific areas. The emerging research on place-based meanings provides an opportunity to more thoroughly explore locals' relationships with natural areas. One framework for addressing place-based meanings to natural areas is with the place attachment framework.

Following the expansion of protected areas worldwide and an interest in understanding the relationships between protected areas and local people and the social outcomes of conservation, the application of place attachment is now expanding internationally (Kaltenborn et al., 1999; Kappelle 2001; Leppens 2005; McCleave et al. 2006) and is accepted as a relevant theoretical framework to understanding these relationships between local people and protected areas (Zube and Busch 1990; Williams et al. 1992; Brandenburg and Carroll 1995). Protected area managers are recognizing that the successful management of parks and protected areas must consider socio-cultural issues along with nature conservation (Stankey 1989). For example, following national park expansion in southern Norway, understanding the complex meanings and relationships local people develop with their surroundings has become an important management strategy when addressing contested issues and development planning (Kaltenborn et al. 1999). Furthermore, the importance of considering people-park relationships has been emphasized in several international environmental summits, such as the Durban Accord developed at the Fifth World Parks Congress in 2003, where input and involvement from locals within and around protected areas was stressed to ensure their needs and interests are considered when management decisions are made (IUCN World Commission on Protected Areas 2003).

Land Use Land Cover Change

In addition to understanding the relationships between protected areas and local people, land-use / land-cover change (LULCC) studies are an important component in examining community-based initiatives for forest conservation. Change dynamics of land-cover (i.e., the biophysical attributes of the land surface) and land-use (i.e., the anthropogenic influences on the land) are considered one of the main driving forces of global environmental change and its research is considered fundamental to sustainable development efforts (Meyer and Turner 1992; NRC 1998; Lambin et al. 2000; Geist and Lambin 2002). Within the umbrella of LULCC research, the need to understand the relationships between cleared and forested landscape patterns and agricultural land use dynamics within tropical forests has been stressed (Lambin et al. 2000; Mertens et al. 2000; Geoghegan et al. 2001; Klepeis 2003; García-Barrios and González-Espinosa 2004). As trends in Belize show agricultural intensification replacing forested landscapes and forests becoming more important in creating connectivity between smaller, fragmented, isolated habitat patches (PfB 2000), LULCC research within the CBS has an important role.

Remote sensing data provide information on the differences in land cover characteristics on spatial and temporal levels and has been used on a wide range of analyses, one of which is forest change detection (Fernside 1986; Vogelmann and Rock 1988; Skole and Tucker 1993; Sader et al. 1994; Jha and Unni 1994; Foody et al. 1996; Di Fiore 2002; Southworth et al. 2004). Remote sensing has also been used extensively with ethnographic methods, from household surveys to socio-economic data, to better understand the drivers of land-use change (Guyer and Lambin 1993; Sussman et al. 1994; Mertens et al. 2000; Sader et al. 2001; Hayes et al. 2002; Southworth et al. 2002; Schweik and Thomas 2002; Bray et al. 2003; Dalle et al. 2006). The use of remote sensing data to measure forest cover change after implementation of community-based conservation initiatives has also demonstrated an objective way to evaluate the long-term effectiveness of these initiatives (Dalle et al. 2006).

Research Statement

The Community Baboon Sanctuary (CBS), the focus of this study, is not community-based conservation as commonly discussed in the literature. In most cases, the concept of community-based conservation focuses on government-owned protected areas (e.g., National Park) with people living outside its borders. In contrast, the CBS consists of private landowners who have voluntarily pledged to set aside their land and to manage it in a particular way that increases its conservation value by creating an inter-connected habitat within a large landscape.

Despite the fact that the CBS has existed since 1985, little monitoring has been conducted to assess the effectiveness of the conservation initiatives in promoting conservation and deterring deforestation. Also, research has not explained the potential influence of other factors (e.g., locational and socio-economic variables); the level of deforestation and forest fragmentation that has occurred (specifically riparian forest cover, considered critical habitat for the black howler monkey); or residents' perceived benefits and place-based meanings of riparian forest landscapes as an incentive to conservation (the initial habitat focus of conservation within the CBS). This dissertation hopes to address these issues through a holistic overview of conservation within the CBS to more effectively base future management decisions and contribute to a better understanding of community-based initiatives for forest conservation.

Objective 1: Assess perceived benefits and place-based meanings of riparian forest landscapes,

Objective 2: Assess the relative influence of tourism and pledging on deforestation probabilities, in addition to other locational and socio-economic variables, and

Objective 3: Assess forest fragmentation for the black howler monkey based on habitat criteria

Chapter 2 addressed the first objective and expanded on sense of place and place attachment conceptualizations by applying a framework within a less developed country (Belize) that has only been employed in the US and a few other more developed countries (e.g., Australia). The objectives of this paper are to identify the importance and attainment of community benefits from riparian forest landscapes (the focus of the conservation initiatives), measure CBS residents' attachment to riparian forests, and understand if involvement in the two conservation programs (nature-based tourism or pledging) is related to residents' perceptions of community benefit importance, community benefit attainment, and attachment to riparian forests.

Chapter 3 addressed the second objective conducted parcel-level spatial models (binary logit models) to assess the relative influence of the two conservation initiatives (nature-based tourism and pledging) on deforestation probability. In addition, this paper evaluates the relative influence of other variables (locational and socio-economic) driving deforestation within the CBS, using information from thirty-three landowners and their parcels over a 15 year time period and 4 satellite image dates. Overall land cover change trends within the CBS, as well as along a 120 meter river buffer within and outside the CBS are also assessed.

Chapter 4 addressed the third objective examined changes in forest habitat for the black howler monkey (the impetus for the establishment of the CBS). Using remote sensing of satellite imagery and landscape metrics, this study reviews the performance of the CBS as an IUCN Category IV protected area by assessing changes in forest cover and forest fragmentation within the CBS and 500 meter river buffer over a 15 year period (1989-2004) and how this has impacted habitat for the black howler monkey, based on specific habitat criteria.

Importance of the Study

Combined, these papers provide an overview of conservation and the effectiveness of two conservation initiatives (nature-based tourism and pledging) in deterring deforestation and promoting conservation within the CBS. This study takes into account human perceived benefits and place-based meanings, potential drivers of deforestation, and fragmentation of howler monkey habitat. It is through this triangulation of social and spatial data, from understanding the human perspective, to forest cover change, to howler habitat fragmentation, that conservation assessment and future management decisions can be more effectively made. It is also hoped that the methods employed will encourage others to also examine conservation initiatives from different perspectives to provide a more thorough and accurate assessment of the effectiveness of conservation. It is from here that more appropriate decision-making can be made to improve the role conservation initiatives play in not only meeting conservation goals, but also in managing for community benefits, considering community-based conservation is often argued, in some circles, to be the solution for protecting natural areas.

CHAPTER 2
COMMUNITY BENEFITS, PLACE-BASED MEANINGS, AND CONSERVATION: A STUDY OF THE COMMUNITY BABOON SANCTUARY, BELIZE

Introduction

A response to deforestation worldwide has been the creation of protected areas for fragile natural and cultural resources (Brandon et al. 1998; Langholz 2002; West et al. 2006). There has been a dramatic increase in the area falling under protected status within the past 25 years with current figures indicating over 100,000 protected areas worldwide, covering 11.5% of the world's land surface (17.1 million km^2) (IUCN 2004; West et al. 2006). Defined as "an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means" (IUCN 2003), 84.5% of the world's protected areas (under IUCN categories) are open to human use at some level (Naughton-Treves 2005).

Designation alone is insufficient. Many protected areas are, in reality, "paper reserves" and "paper parks" (i.e. only protected on paper) which have resulted in land conflicts and continued extractive uses of the forest now deemed illegal. This inability to manage and police protected areas, coupled with an environmental justice narrative, has focused attention on the role of local communities and the decentralization of resource management and conservation, with schemes for community management of natural resources advancing as an alternative option (Agrawal and Gibson 1999; Gibson et al. 2002; Schmink 2003). Those in support of community-based conservation posit that the conservation of tropical forests is more effective and efficient at small-scale and local-level regimes and that, in certain circumstances, and under an emerging set of institutional conditions, local communities are the most effective managers of local natural resources because of their dependence, contact, and subsequent knowledge of local resources (Tisdell 1995; Agrawal and Gibson 1999; Lepp and Holland 2006).

It is worth noting, however, that the conservation community is divided on its support of protected areas as they relate to the coexistence of land use to improve livelihoods and biodiversity conservation to protect ecosystem services (Brechin et al 2002; Adams et al. 2004, DeFries et al. 2004). While one side favors the community-based conservation narrative and balancing human well-being with nature conservation (Adams and Hulme 2001, Schwartzman et al. 2000), others argue in favor of 'fortress conservation' claiming that development and conservation are contrasting goals (Oats 1999; Redford and Sanderson 2000; Terborgh 2000).

The Millennium Ecosystem Assessment (Brown et al. 2005) and World Resources Institute (2005) recognize livelihood needs and biodiversity conservation as complementary goals and support the integration of livelihood needs and ecosystem management. Considering these new protected area directions, some conservationists have changed their approach to meet these goals through various strategies linking development and conservation, including integrated conservation development projects (ICDPs) and community-based natural resource management (Naughton-Treves 2005). Considering forests can provide multiple products and services, including non-timber forest products (NTFPs) and nature-based tourism, community-based conservation initiatives are increasingly developing revenue-generating activities, using market incentives to promote conservation (Tisdell 1995; Wunder 2000; Langholz and Brandon 2001; Murphree 2003).

In conjunction with an increase in protected areas, the number of privately-owned reserves worldwide is also increasing (Langholz 1996), with those owned or operated by NGOs or communities increasingly developing nature-based tourism. Reserves with nature-based tourism have been categorized as 1) communally-managed, by usufruct rights, leased or owned lands, 2) NGO managed, or 3) owners of contiguous, small-size holdings jointly managing their lands (Langholz and Brandon 2001). In both private and common property (a form of private property where members of a recognized group share rights to a resource) examples, nature-based tourism initiatives within communities can be considered a common pool resource where benefits from tourists using a resource are shared by the providing community (Healy 1994). Tourism landscapes, stresses Healy (1994), can have 'common pool problems' characterized by the susceptibility to overuse or damage a resource and the potential for 'free-riding'. Even where complex property rights with competing users exist over common pool resources (including 'open access', public and/or private property rights), collective action and rules must be devised that prevent depletion or degradation of the resource (Healy 1994; Lindberg et al. 1996; Edwards 2004).

Although revenue-generating activities, such as ecotourism, can provide important financial benefits to communities and aid in conservation goals, financial incentives alone are not the only factors affecting land-use and resource-use decisions. There is a connection between financial income and pro-environmental behavior but, equally, many people's behaviors are driven by non-financial incentives (Wunder 2000; Salafsky et al. 2001; Stem et al. 2003). Even where income factors have a strong influence on people's behaviors, they are often complemented by social, infrastructural, and psychological factors, as seen in the following examples: Salafsky et al. (2001) found that the projects that generated the most community support for conservation were those that provided non-cash benefits. Furthermore, a study by Funder (1995) on the impacts of the CAMPFIRE program on two communities in Zimbabwe found that women's evaluation of income-generating projects focused more on the provided services than on the revenues generated. Aside from a few case studies, however, there is a lack of good, empirical data for understanding the social impacts of protected areas and the positive and negative impacts conservation has on communities (Igoe 2006).

Along this same vein of social impacts, the comparison between potential financial and non-financial benefits associated with protected areas and conservation in developing countries is not often examined (Zube and Busch 1990, Salafsky et al. 2001). In the U.S., Canada, New Zealand, and Australia, a wider view of these potential benefits shows improved and more efficient planning of natural areas that directly involves the community (Stein 1999; Kappelle 2001; Davenport and Anderson 2005; McCleave et al. 2006). Based on this broad understanding of conservation incentives, a range of complementary benefits must be considered in communal approaches to management and conservation. It is through the extension of conservation's benefits, argues Hulme and Murphree (1999), that attitudes toward conservation will be improved that, ultimately, will foster pro-conservation behavior.

The Role of Benefits in Conservation

The role of identifying and managing benefits effectively in conservation is a difficult task. With little research addressing local residents' perceived benefits of protected areas, one approach taken in this study is to look at the Benefits Based Management (BBM) framework. Although initially applied to recreation and leisure management, BBM is applicable to the broader context of amenity resources such as cultural resources, wildlife, wilderness, and scenic values, which also includes the physical, social, and psychological benefits that individuals, families, communities, and even societies at large might gain from exposure to these resources (Driver 1996; Moore and Driver 2005). Considering the purpose of BBM is to assist managers to better define how their actions will benefit humans or the natural environment, the concept of BBM is appropriate for my current study to better understand how to best provide community benefits.

Under the BBM framework, a *benefit* is defined as "(a) a change in a condition or state viewed as more desirable than a previous one; (b) maintenance of a desired condition and thereby prevention of an unwanted condition from occurring, prevention of an undesired condition from becoming worse, or reduction of the unwanted impacts of an existing undesired condition; and (c) the realization of a satisfying recreation experience" (Moore and Driver 2005, p.38). This concept has often been used in research within the human dimensions of natural resource management (Anderson et al. 2000; Booth et al. 2002).

Of equal importance with providing benefits from conservation, but an often overlooked part of the process, is the understanding of community benefits attributed to natural areas that can help ensure that management plans are responsive to local resident needs (Stein 1999; Davenport and Anderson 2005). For example, research by Jones and Murphree (1999) in the Kuesene region of Namibia shows that the intrinsic values of wildlife and the importance of passing them on to future generations play an important role in wildlife conservation. Also, a study by Stein et al. (1999) on how two state parks in northern Minnesota benefit rural communities showed that attracting tourism dollars to surrounding communities was just one of several benefits of conservation community stakeholders felt were important. In fact, benefits such as pride were considered more important than financial benefits for stakeholders of one state park.

Theoretical Framework: The Place Attachment Framework

Although understanding local residents' perceived benefits of natural areas and conservation will better enable management to respond to local resident needs, research that examines the specific benefits residents attain from nature might not address the relationship of people's attachments to specific areas. Emerging research on place-based meanings provides an opportunity to more thoroughly explore locals' relationships with natural areas. One framework for addressing place-based meanings of natural areas is through the place attachment framework.

Initially coined by Tuan, a human geographer, place attachment applies to places that gain meaning and definition through the individual experiences that occur within those places (Tuan 1980). The concept of place attachment has been found in various disciplines including human geography, psychology, and anthropology with the accepted basic definition as an emotional bond between people and places (Proshansky et al. 1983; Low 1992; Williams et al. 1992; Cuba and Hummon 1993; Vaske and Kobrin 2001; Williams and Vaske 2003; Kyle et al. 2004; Davenport and Anderson 2005). Research on place attachment has been conducted largely in the U.S. to examine how natural areas influence how residents feel about their community (Williams et al. 1992; Eisenhauer et al. 2000) and residents' attitudes toward tourism development within natural areas (Sheldon and Var 1984; Um and Crompton 1987; McCool and Martin 1994; Williams et al 1995).

The place attachment framework, when used to understand the links between natural resource management and these emotional connections to natural landscapes, includes two constructs: *place identity* and *place dependence* (Williams et al. 1992). The construct *place identity* concerns symbolic meanings of place and is based on the notion that places affect the development of individual and community identity and promotes a sense of "belongingness." *Place dependence*, in contrast, reflects more tangible meanings of place that represent an area's physical characteristics (Stokols and Shumaker 1981; Williams et al. 1992; Williams and Vaske 2003).

Study Objectives

Following the expansion of protected areas worldwide, the application of place attachment is now expanding internationally, albeit primarily in more developed countries, to examine the relationships between protected areas and local people, and the social outcomes of conservation (Zube and Busch 1990; Kaltenborn et al. 1999; Kappelle 2001; Leppens 2005; McCleave et al. 2006). Considering the increase in protected areas (West et al. 2006) and the rise in community-based conservation initiatives developing revenue-generating activities to promote conservation (Tisdell 1995; Wunder 2000; Langholz and Brandon 2001; Murphree 2003), examining the relationships between protected areas and local residents and the social outcomes of conservation has an important role; the Community Baboon Sanctuary (CBS) in Belize is one such example. Objectives of this study were to assess the social impacts of the CBS by

1. Identifying the importance and attainment of community benefits from riparian forests, the impetus for the creation of the CBS,
2. Measuring CBS residents' attachment to riparian forests, and
3. Assessing if involvement in one or both of the two conservation programs (nature-based tourism or pledging, described below) is related to residents' perceptions of community benefit importance, community benefit attainment, and attachment to riparian forests.

Methods

Study Site

The Community Baboon Sanctuary (CBS), Belize (17°33'N, 88°35'W), was established in 1985 to protect one of the largest remaining populations of black howler monkeys (*Alouatta pigra*), locally called "baboons", in Meso-America (Figure 2-1). The CBS is not community-based conservation as is normally conceived. The concept of community-based conservation under the IUCN definition is based on communities next to public protected areas. The CBS, however, is a unique situation with private landowners agreeing to manage their land in a particular way that would increase its conservation value and create an inter-connected habitat in a larger landscape.

This effort to create a community baboon sanctuary began when two American scientists recognized the area for its howler population and the positive attitudes villagers had toward the howler monkeys. After approval from the villagers and Village Council to investigate the potential of creating a community-based sanctuary in the area, and with support of a local non-governmental organization (the Belize Audubon Society), the lands for this sanctuary were set aside by private landowners from seven Creole communities situated along 33 kilometers of the Belize River (Horwich and Lyon 1990). For 20 years various residents within the CBS communities have participated in two conservation strategies: 1) a written, voluntary pledge for private landowners to leave a strip of riparian forest and forested corridors that provide habitat connectivity for howler monkey populations and 2) nature-based tourism centered on the howler monkey that provides financial incentives to landowners protect howler monkey habitat.

Pledge: The private landowners who make up the CBS share a common pool resource for conservation and nature-based tourism: the howler monkey. Because this resource is mobile, although tends to remain in close proximity to the Belize River, pledging landowners have accepted a form of ‘conservation easement’ on their private property where forested corridors and their integrity, along with the howler monkey population, depend upon the collective action by all landowners to observe a set of rules. This collective action has been established in the form of a voluntary, written, public pledge and landowners are encouraged to sign and agree to do their part in protecting howler monkey habitat.

The concept of pledging is a form of commitment to a particular conservation practice by an individual landowner. The idea behind a landowner pledge was that by signing this voluntary, written pledge, landowners agree to not clear their land along the riverbank and to leave a forested corridor between property boundaries. River property is highly valued for its fertility, compared with other soils of the area, which reflects the location of farming in these areas. Furthermore, those residents with cattle and river property often maintain cattle here so cattle can easily access water.

Although the pledge was not initially linked with any financial compensation with money that was collected through tourism, CBS records and research by Lash (2003) indicate that pledged landowners were paid twice (1998 and 2000 totaling ~$250 per landowner) by the CBS management at the time, but presently no residents are given any financial compensation for pledging. Because of this initial payment, pledged residents expect to be paid; reality now associates the pledge with financial compensation.

Nature-based tourism: Nature-based tourism centered around the howler monkey was initiated with the establishment of the CBS as a way to create a financial incentive for residents to conserve important forest habitat. Residents involved in tourism obtain both permanent and seasonal employment, ranging from tour guiding, selling crafts, housing visitors, trail maintenance, and visitor center / museum assistance. The CBS tourism headquarters that house the museum and visitor center are located in Bermudian Landing village. Tourist visitation to the CBS has dramatically increased in the last few years (Figure 2-2) due, almost exclusively, to the introduction of cruise ship tourism to Belize. Decreased numbers from 2005, relative to 2004, reflect that year’s active hurricane season that cancelled many cruise ship docks in Belize City which, subsequently, affected tourism numbers to the CBS.

CBS management: From its inception, management of the CBS (pledging, museum, tour guides, and education programs) was given to a local resident manager under the guidance of the

Belize Audubon Society (BAS). In 1994, autonomy of CBS management responsibilities (e.g., all accounting and marketing, museum, tourism guides, etc.) was given over to a local CBS committee (Lash 2003).

CBS management has changed at least seven times in its first thirteen years, with various combinations of the BAS, a local committee, and resident managers in charge (Bruner 1993; Horwich and Lyon 1998). The only consistencies within the CBS (Lash 2003) are as follows:

1. The body of the CBS comprised of pledged landowners
2. The CBS headquarters (museum) housed within Bermudian Landing village
3. The continued involvement of one specific family within the CBS to some extent (a member of this family was selected as the first manager of the CBS)

Since 1998, the Women's Conservation Group (WCG), a committee made up of women representatives from the different CBS villages, has managed the CBS (in 1998 the former committee was asked to resign). This committee was responsible for one of the two payments to pledged residents (Lash 2003). Currently the director of the CBS and Women's Conservation Group, as well as the manager / lead tour guide position are occupied by family members from one family that has always been involved with the CBS. Another barrier to effective management of the CBS are the external influences of a negative context (such as drug use) have a presence within the CBS and have not been appropriately addressed or resolved.

CBS villages: Today there are 222 households within the seven villages of the CBS, comprising approximately 1500 people (Jones and Horwich 2005). Within the literature, the CBS is designated as a 4800 ha area (Horwich and Lyon 1990). However, this did not include the full village boundaries or account for households located on properties away from the river. Because of this inclusion within my study, the total study area encompassed 8703.54 ha (87.04 km^2).

Land tenure is roughly evenly divided between titled and government leased lands (20 year leases). Despite the difference in de jure property rights, there is little variation between de facto property rights of the two land tenure regimes; the majority of residents are long-term residents, many having lived here for generations, and possess high perceived land security.

Ethnic composition is overwhelmingly “Creole” (descendants of British settlers and African slaves) within the seven villages of the CBS. Although only comprising a few families each, the other ethnic groups represented within the seven CBS villages include Asian, Hispanic/Mayan (from Guatemala and Honduras), and Caucasian (US Mennonites). These other ethnic groups have migrated to the area over the past ten years for various reasons. Those leaving Guatemala and Honduras were looking for employment and land opportunities; in the late 1980s, the Chinese population increased dramatically with immigration from Hong Kong and Taiwan; and US Mennonites are increasing their presence and missionary work in rural parts of Belize (Merrill 1992).

An interesting duality exists in this area that is located very close to Belize’s largest city but still maintains forest cover and some of the traditional ways of living and income generation. Information from interviewing residents reveals that although farming and other traditional land and forest use are less common today with more people choosing to work outside the home and often outside the villages, residents (young and old) still prefer to live in the “country” and view living in Belize City as expensive, dirty, and dangerous. The main livelihood activities of the CBS villages include: employment with nature-based tourism (primarily in the village of Bermudian Landing); small-scale agriculture; small-scale cattle raising; small-scale coconut oil and cohune nut oil (*Orbignya cohune*) production; cashew; and outside wage employment (primarily in or around Belize City).

There are several households in each village that have over 50 head of cattle but many residents have a few head of cattle that serve as a bank account in many ways; if someone is sick or another occasion to need cash presents itself, a cow can immediately be sold. Agriculture is an important livelihood activity for residents of the CBS, especially for those with river property where the soils are the more fertile of the area. Slash-and-burn agricultural plots are locally called "plantations" or "milpas" and primarily are used for home consumption or local sale (within villages). The villages are located roughly 35 miles from the nearest district market where agricultural and forest products are sold, including medicinal plants and game meat (Belize City). The closest market where a good variety of agricultural products are sold is in a neighboring town en route to Belize City named Burrell Boom (located roughly 15 miles from the villages). It isn't uncommon for individual residents to simply take their products around their village and neighboring villages to sell along the roadside or even try to sell these goods house to house. These products range from agriculture crops, fish and game meat, and cohune and coconut oil. Collecting cashew seeds and cashew fruit for a few months every year is a period when local residents can supplement their income. At least one middle man in a neighboring town (Burrell Boom) purchases the cashew seeds from residents. Although small-scale, many residents also living in villages with cashew trees collected and roasted nuts for sale in Belize City and for visiting tourists to the CBS.

Sixty-three percent of the 135 households interviewed for this study have at least one family member who works outside of the CBS. The 5 year-old paved road that crosses through four of the seven villages has increased bus service with access to 6 of the 7 villages several times daily (Monday through Friday) to Belize City in the mornings and returning to the CBS villages in the evening (approximately a 35 mile / 56 km commute). This has made living in the

CBS villages and working in Belize City very feasible. Another important income source is remittances. One-third of the interviewed population receive remittances from family members who have left and live and work in the U.S. From the 135 households interviewed, 45 households reported receiving remittances; together remittances totaled $95,850 BZE (approx US $ 47,925) over the course of one year, accounting for 28.5% of their total income (wage and other) (Table 2-1). Additionally, out of the 45 households who received remittances, 11 households reported remittances as the only source of monetary income.

Although the pledge and nature-based tourism have existed for over 20 years within the CBS (at different levels of activity), little monitoring has been done to assess the effectiveness of these conservation initiatives. Additionally, little is known about the communities' perceived benefits of riparian forests and the function of place attachment as an incentive to conserving forests, in addition to the role that these two conservation initiatives play in managing community benefits. Considering this, it is worth examining the non-financial benefits and ways residents perceive riparian forest landscapes, along with the financial benefits that are presumed to come from tourism and pledging. The significance of assessing both importance and attainment of community benefits, as well as place-based meanings attributed to riparian forest landscapes, addresses not only what benefits residents feel are most important, but also how much they feel these benefits actually improve their livelihoods. This study will aid future planning and management to determine how to improve the integration of nature-based tourism and pledging into community development and environmental conservation strategies.

Data Collection

Semi-structured interviews and one focus group meeting were used to initially identify perceived benefits residents attributed to riparian forests, nature-based tourism, and pledging (Table 2-3). In total, 135 resident interviews from the 7 villages (61% of the CBS population, approximately 20 households per village) collected quantitative and qualitative data on perceived social, environmental, and financial community benefits and residents' place-based meanings towards riparian forests within the CBS. Initially, a stratified sample was conducted with all pledged and tourism households. Twenty-six households participating in tourism (out of approximately 35 total, with 12 households participating only in tourism) and 51 households participating in the pledge (out of approximately 75 total, with 37 household participating in only the pledge) agreed to participate in the study. Approximately half of those households involved in tourism are also pledged households (n = 14). The remainder of the household interviews (n = 58) were composed of randomly selected households (all non-tourism / non-pledged households) (Table 2-4).

Questions were presented verbally with the head of the household (if the household was not involved in either tourism or the pledge) or with the individual who was involved with the pledge or tourism initiative. Interviewees were shown and explained the Likert-type scale with the value system presented to help residents gauge the strength of the answer (e.g., very important versus somewhat important), with examples demonstrated for clarity before the interview process began. Data analyses used SPSS 11.5 to generate descriptive statistics and T-tests, using Levene's test for equality of variance. The survey consisted of two parts: community benefits and place attachment of riparian forest landscapes.

Community benefits. One nine-item question on community benefits asked if riparian forests are providing benefits. Interviewees answered from an *Importance* category (five-item Likert-type scale) and an *Attainment* category (four-item Likert-type scale) developed from nominal group meetings conducted with residents, and from the established literature (Davenport and Anderson 2005; Stein et al. 1999).

Place attachment. Place attachment questions consisted of a twelve-item Likert-type scale adapted from a variety of literature (Williams et al. 1992; and Jorgensen and Stedman 2001; Davenport and Anderson 2005). Based on work by Davenport and Anderson (2005), scale items fell under the following categories: *Place dependence*: economic stability, nature and natural processes and *Place Identity*: family legacy, community character, and self identity.

Results

The 26 residents interviewed who are participating in tourism estimated their total tourism earnings to be US $14,005.00 during the year of this study (July 2005 – July 2006) (Table 2-2). Out of the 35 estimated residents known to be participating in tourism over the course of study (but not all interviewed), the largest amount of residents,13 (37%), were residents of Bermudian Landing village (the CBS and tourism headquarters) (Figure 2-3). The village with the second largest number of residents participating in tourism (n = 6) was Double Head Cabbage, followed by Scotland Half Moon and St. Paul's Bank (both n = 5). The remaining three villages had 3 or less residents participating in tourism.

Community benefits: Importance (general means). Overall, all benefits of riparian forest landscapes identified through focus group meetings and past literature were rated important (all above 3, out of 5) by residents (Table 2-5). "Living in a healthy environment" was ranked highest for importance (mean = 4.6). Benefits specifically addressing quality of life (e.g., "providing a good quality of life") and future generations ("knowing conserved natural resources exist for future generations") received the second highest importance means (means = 4.2). "Attracts tourism dollars to my community" was tied for the fourth most important perceived benefit of riparian forests with "a feeling that your community is a special place to live" (means = 4.1).

Community benefits: Attainment (general means). Respondents believe they are attaining their most important benefit “living in a healthy environment,” giving it the highest attainment mean (mean = 3.6 out of 4). “Attracts tourism dollars to my community” received the lowest mean (1.6). Based on this benefit’s high importance, results show a disconnect between respondents’ importance and attainment of this benefit (Table 2-6).

Community benefits: Pledging and tourism. From examining the differences between tourism only (n=12) and non-tourism residents (n=123), tourism residents had slightly higher means on most perceived *importance* of riparian forest benefits. Considering statistically significant differences, those involved in tourism thought riparian forests were more important in providing “a greater concern for the natural environment” than those not involved in tourism (mean = 4.1 / 3.7) (Table 2-5). Under perceived *attainment* of these benefits, “living in a healthy environment” was ranked the highest, with “attracts tourism dollars to my community” ranked the lowest for tourism residents. With respect to significant differences, no differences were found for attainment of these benefits between tourism and non-tourism residents (Table 2-6).

From examining the differences between pledged only (n=37) and non-pledged residents (n=98), pledged only residents had slightly higher means on conservation-related scale items under perceived *importance* of riparian forest benefits. Considering statistically significant differences, those pledged only residents thought riparian forests were more important in “knowing conserved natural resources exist for future generations” (Table 2-5).

Under perceived *attainment* of these benefits, pledged only residents ranked “living in a healthy environment” as the most perceived attained benefit from riparian forest landscapes (mean = 3.7), with “attracts tourism dollars to my community” as the lowest (mean = 1.6). Additionally, pledged only residents’ scores were significantly higher than non-pledged residents for *attainment* of specific benefits associated with community character and nature and natural processes ("Knowing conserved natural resources exist for future generations", "Providing a good quality of life", and "A natural setting in which your community takes great pride") (Table 2-6).

In comparing benefit *importance* means between those residents involved in both tourism and pledging (PT) (n=14) and those not involved in either (Non-PT) (n= 121), "attracts tourism dollars to my community" was ranked the second most important benefit from riparian forest landscapes for PT residents (mean = 4.4), while ranked fourth for Non-PT residents. "A greater concern for the natural environment among residents" and "improved care for community aesthetics" was of statistical significance between PT and Non- PT residents (Table 2-6). In examining benefit *attainment* means, "attracts tourism dollars to my community" was the lowest ranked perceived attained benefit for PT residents, although significantly higher than Non- PT residents (mean = 2.1 / 1.6).

Place attachment: Tourism. Tourism only residents (n=12) rated items tied to water quality and habitat for wildlife significantly higher than non-tourism residents (n=123) (Table 2-7). "These riparian forests are important in providing habitat for wildlife" was ranked highest by tourism residents (mean = 7.0). The two place attachment scale items ranked the lowest by tourism only residents were related to economic scale questions: "My community's economy depends on riparian forests" (mean = 3.8) and "My family's income or livelihood depends on riparian forests" (mean = 2.8).

Place attachment: Pledging. Those residents who pledged only had significantly higher means ($p \leq 0.05$) on all place attachment scale items, with exception to the two economic items and "these forests have helped put my community of the map" (Table 2-7). "These riparian forests are important in providing habitat for wildlife" and "My community's history is strongly tied to this riparian forest" were ranked highest by pledged only residents (mean = 7.0) followed by "This riparian forest contributes to the character of my community" as the third highest ranked item (mean = 6.4). The two economic items, "My community's economy depends on riparian forests" (mean = 4.0) and "My family's income or livelihood depends on riparian forests" (mean = 3.0) were ranked the lowest by pledged only residents.

PT residents also ranked these economic questions the lowest (mean = 4.0 and 2.4). From examining statistical significance, PT residents ranked the following place attachment scale items significantly higher than Non-PT residents: "This riparian forest contributes to the character of my community", "These forests have helped put my community on the map", "Many important family memories are tied to these areas", "This riparian forest is a special place for my family", and "I feel a sense of pride in my heritage when I am there".

Discussion and Implications

While there are only slight differences between the scores for many of the scale items under perceived benefits, attained benefits, and place-based meanings between residents (tourism, pledged, PT, and non-), there are some important differences and results worth noting. Although CBS residents as a whole perceive that riparian forests are providing conservation and environmental benefits, riparian forests are *not* perceived to be providing substantial financial benefits (including those residents involved in tourism), based on their lowest rankings acknowledged through place attachment and community benefits questions. In addition, through statistical analysis, there does appear to be a significant relationship between being involved in a conservation initiative (pledging or tourism) and placing more importance in certain perceived benefits and place-based meanings (attachment) towards riparian forests and conservation.

Pledging

Results show residents who pledged only and PT residents have higher perceived benefits and place-based meanings towards riparian forest landscapes. This indicates that they are likely more aware of the connections and benefits of riparian forests to conservation and quality of life issues than non-pledged residents. In fact, pledged only residents had significantly higher place attachment scores for all dimensions except economic items and one community character scale item. The benefits pledged only residents believe they are attaining might help explain these results. They believe they are receiving benefits associated with health, quality of life, sustainability, and pride to a greater extent than non-pledged residents. These correspond to place attachment items relating to water quality, history and family ties to the forest, and personal attachment to the forests.

Another reason for this relationship might be explained through the very act of making a commitment. Unlike CBS's tourism program, which requires much planning, management, and coordination among residents, the pledge is a simple process of landowners making a written, public, and voluntary pledge to manage their property under certain guidelines. Although these data do not show direct cause and effect relationships, past research on the concept of commitment is based on the premise that once a pledge is formally made, a bond is strengthened between the promise and future action (McKenzie-Mohr and Smith 1999). Others propose that commitment can make one's beliefs more salient (Pallak et al. 1980) and, therefore, less likely to be ignored when faced with an opportunity to demonstrate that commitment. Some scholars within the field propose that commitment functions on the feared social disapproval of others when a public commitment is not made (Wang and Katzev 1990) and the expectation on ourselves, as well as others who have made a commitment, to honor them completely (Katzev and Wang 1994). It is not surprising that pledged residents ranked economic scale items low since reality now associates the pledge with some financial payment resulting from past payments. The fact that pledged residents are not given any financial compensation for pledging but are aware tourism is bringing in money (and many are probably aware of its growth), may explain the low scores on economic scale items.

Tourism

Results show residents involved in tourism only do not perceive tourism to be a major benefit from riparian forests, nor impact their attachment to riparian forests. CBS residents involved in tourism only were more likely to rate only three out of the lowest four benefits more important than residents not involved in tourism ("A place to conserve various natural and unique ecosystems," "Improved care for community aesthetics," and "A greater concern for the natural environment among residents"), with only one scale item significantly different ("A greater concern for the natural environment among residents"). Additionally, tourism only residents did not significantly differ from non-tourism residents in their perception of attainment of any benefits.

A surprising result was the lowest ranked scale item for tourism only and PT residents, considering tourism residents are receiving financial revenue indirectly from these forests. Under place attachment, "My family's income or livelihood depends on riparian forests" had mean scores of 2.8 and 2.4. For perceived benefit attainment, "Attracts tourism dollars to my community" had mean scores of 1.6 and 2.1 (Table 2-2). Nearly 13,000 tourists visited the CBS in 2005 (Figure 2-2), correlating with the time of this study, yet benefits that would be directly tied to these visitors (i.e., financial) were not perceived to be attained by tourism residents (nor non-tourism residents). This may relate to perceived inequality in the distribution of tourism jobs and money that the management may wish to explore.

Elite capture of benefits is not an uncommon occurrence within development projects (Bardhan 2002, Platteau 2004) as development projects can set off local political struggles and rent-seeking opportunities (gaining control of resources) that elites can often easily dominate (Tai 2007). The concern with conservation initiatives is that the stakeholders who should be benefiting the most, based on their activities that impact the environment (with expectations that they will promote conservation in return), are seeing the benefits go to only certain stakeholders, such as the local political elites (Chan et al. 2007). For example, a study on community-based ecotourism development in Gales Point, Belize, showed that the majority of people employed through tourism belonged to only five households (Belsky 2000).

Where tourism shows equity in benefit distribution, conservation successes have been reported. For example, The Cofan Community Ecotourism Program in Zabalo (Cuyabeno Reserve), Ecuador, where tourism benefits have been shown to be equitably distributed, has resulted in the protection of the more rare and attractive wildlife species due to their recognition as being important for ecotourism (Ceballos-Lascurain 2001). In another example, a nature-based tourism project to protect wildlife within a Maasai community adjacent to Amboseli National Park, Kenya also transformed conservation attitudes of the local community (Fitter 1986). Benefits from tourism, such as employment and community development projects from concession leases, have resulted in no poaching or harassment of wildlife on the whole within the community-owned lands, in contrast to neighboring areas where bush meat poaching is now rampant and causing a serious decline in wildlife (Lusigi 1981). In both these cases, the equitable distribution of tourism benefits transformed attitudes resulting in tangible conservation outcomes. Additionally, if the financial benefits from tourism are not being equally or fairly distributed throughout the CBS, then it is not likely that benefits indirectly associated with nature-based tourism (e.g., “A place to conserve various natural and unique ecosystems” and “A greater concern for the natural environment among residents”) would be attained.

These results show that Bermudian Landing village had the largest number of households participating in tourism, the same village where the CBS headquarters are located (Figure 2-3). This demonstrates the spatial distribution of tourism income within the CBS. Distance and travel time is likely a factor, as being involved with tourism in most situations requires coming to the CBS visitor center in Bermudian Landing village. In an attempt to benefit communities outside Bermudian Landing, a Creole Heritage Museum was built in St. Paul’s Bank village around 1998 with the help from Program for Belize (PfB), a Belizean non-profit. For about a year PfB arranged for tourist visits but today this museum is only visited on rare occasions by school groups, arranged through the CBS. During my study, two residents from St. Paul’s Bank earned some tourism money from a few school visitors, although this was the smallest amount of money earned by tourism residents during this year of field work. Other residents in St. Paul’s Bank earned tourism money from housing visiting US students. The same situation applies in Flowers Bank, the most rural and least accessible of the CBS villages, where one family occasionally houses visitors. Housing visitors is an attractive job, compared to other tourism related jobs, as it happens infrequently (approximately 7 days per year) and is lucrative. This, too may be an example of elite capture as families that are better off financially are those with more developed homes and are, therefore better able to receive visitors. Belsky (2000) found in her study of community-based ecotourism in Gales Point, Belize that logically, it tends to be the families in a community that are better off that are chosen to house visitors, as these households have the sanitation and cooking facilities and additional bedroom space.

Some residents upset over the lack of tourism benefits they are receiving have taken matters into their own hands and are developing tourism on their own properties (and also focusing on the howler monkey and experiencing Creole culture). In some cases they are also siphoning off of tourists driving to the CBS. Four households are trying to promote their own tourism efforts, at different levels and with varying success. Two are located in Scotland Half Moon, one in Isabella Bank, and one in Flowers Bank; all households are located on the Belize River.

Results suggest that tourism and place attachment have a slightly stronger relationship in the CBS than tourism and perception of benefits, with scale questions showing statistical significance related to conservation ("These riparian forests are important in providing habitat for wildlife" and "These riparian forests are important in protecting water quality"). The explanation for this significance with conservation-related scale items is likely related to the fact that many of those involved in tourism, especially those employed as a tour guide or clearing trails, will have a higher tendency than those residents not involved in tourism to spend time in and around these forest landscapes. Past research has shown that attachment to a place increased with more frequent visitation, which also fostered an increased perceived familiarity and the belief that the place was special (Williams and Vaske 2003; Davenport and Anderson 2004). Considering that the majority of residents interviewed within the CBS have at least one household member working outside (63%), the majority of residents may not have the leisure time or necessity to spend time in these landscapes.

Limitations

This study was not without its limitations. I took note of the non-responses in my study, of which a variety of reasons exist. For example, some residents are American Mennonites who are a fairly closed group and did not want to participate in my study. However, these residents are not involved in pledging nor tourism and are not long-time residents of the area. Other residents were not available for interviews despite repeated attempts to contact them. Additionally, some residents were working temporarily outside of the CBS during my research. However, considering I interviewed 26 out of the 35 residents involved in tourism, 51 out of the 75 residents involved in pledging, and a total of 135 out of 222 existing households (approximately 20 households in each of the 7 villages) demonstrates that I incorporated a good representative sample of the area.

In addition, applying theoretical frameworks (e.g., place attachment) that were developed in western cultures to less developed countries may also present some issues. However, there has been an expansion of protected areas worldwide and an interest in understanding the social outcomes of conservation. Therefore, it was important to attempt to expand this application within protected areas in less developed countries where community-based conservation is seen, in some circles, to be an important component for protecting natural areas.

Conclusion

The concern with some conservation initiatives is that the benefits (and participation) are not being distributed equally or are not going to the residents who should be the focus of these initiatives. This appears to be occurring within the CBS where there is a perception of skewed distribution of both tourism participation and benefits, signaling a potential elite capture of benefits. Although tourism might impact residents' attitudes, this study shows it must be managed more effectively and equitably to have any other significant impacts on improving people's attitudes toward riparian forests or actively helping conserve those forests.

This inequality of benefits can have additional impacts on community-based conservation. Where community conservation could fail is where the collective action and involvement with protecting howler monkey habitat is jeopardized. According to Burger et al.

(2001), unless a resource provides some benefit, individuals are not apt to accept the costs involved in protecting or managing that resource. Benefits from tourism do not appear equitably distributed, nor are funds going to pledged residents for protecting howler monkey habitat on their properties, while at the same time the number of tourists are increasing (nearly 13,000 in 2005). Because of these factors, there is probably not much incentive from those not benefiting from tourism directly or indirectly (e.g., pledging) to participate. This could impact collective action and involvement with protecting howler monkey habitat.

On another note, this research has revealed some positive points. Although the tourism and pledging initiatives might be perceived as income-generative failures by respondents, the people involved in the activities value, benefit from, and feel attached to the forest for a variety of non-financial reasons. In particular, pledging residents are more highly aware of the non-financial benefits and feel more attached to riparian forests. Since this study does not indicate causal patterns, it is not known if the activity helped to instill these attitudes and values, or if people with these existing attitudes and values were self-selected for pledging. Regardless, this study shows that involvement in either conservation initiative, whether they are financially successful or not, is related to higher conservation values and perceived community benefits and is a strong basis for conservation. Such perceived benefits would not have been realized without investigating place-based meanings and perceived benefits and demonstrate their important role in conservation program analysis and planning. As conservation policy discussions today emphasize the importance of local communities benefiting from their active role in biodiversity conservation, the findings from this study have implications for local planning and management by identifying how community residents believe nature-based tourism and pledging provide incentives and barriers to improving livelihoods and conserving natural resources. It is this type of information that will aid future planning and management to determine how to improve the integration of initiatives such as nature-based tourism and pledging into community development and environmental conservation strategies.

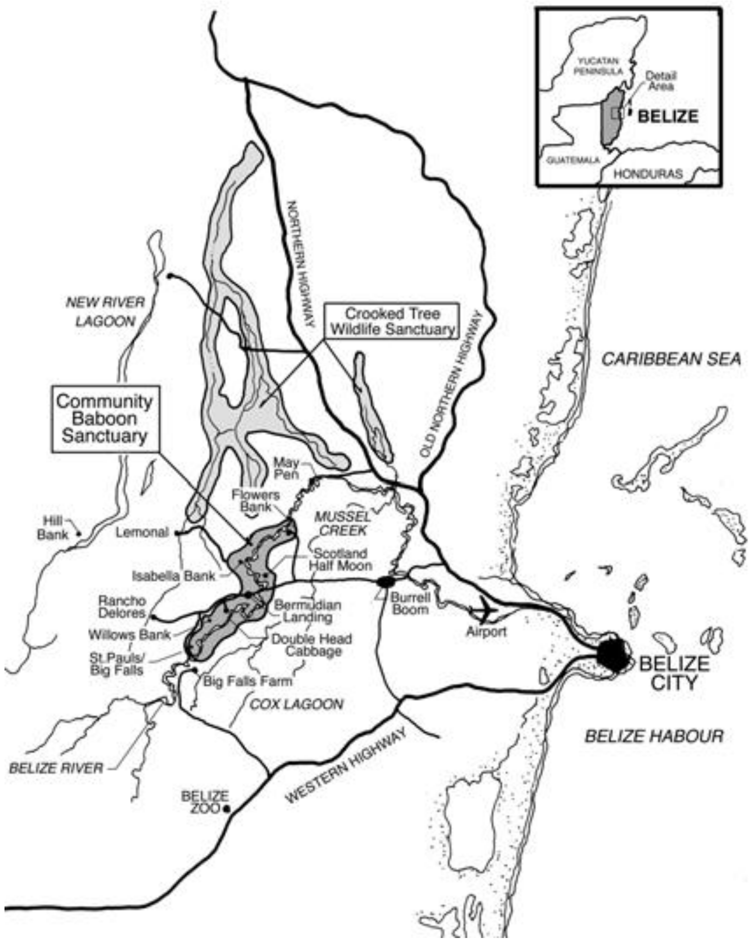


Figure 2-1. Map of the Community Baboon Sanctuary and Belize River Valley area (Lash 2003)

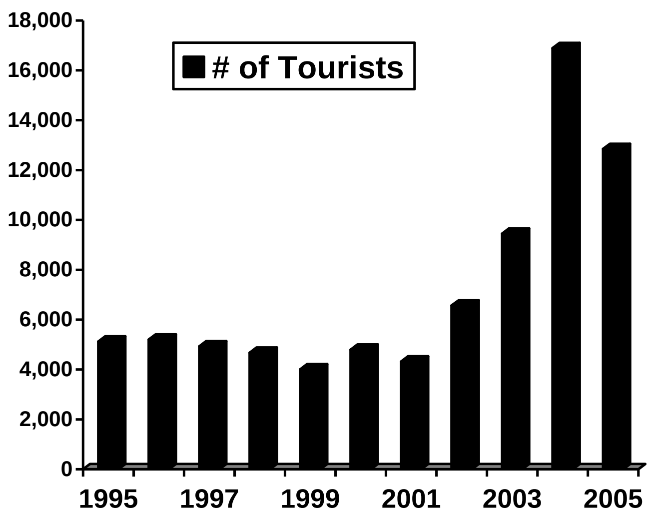


Figure 2-2. Tourist Figures to the Community Baboon Sanctuary, Belize.

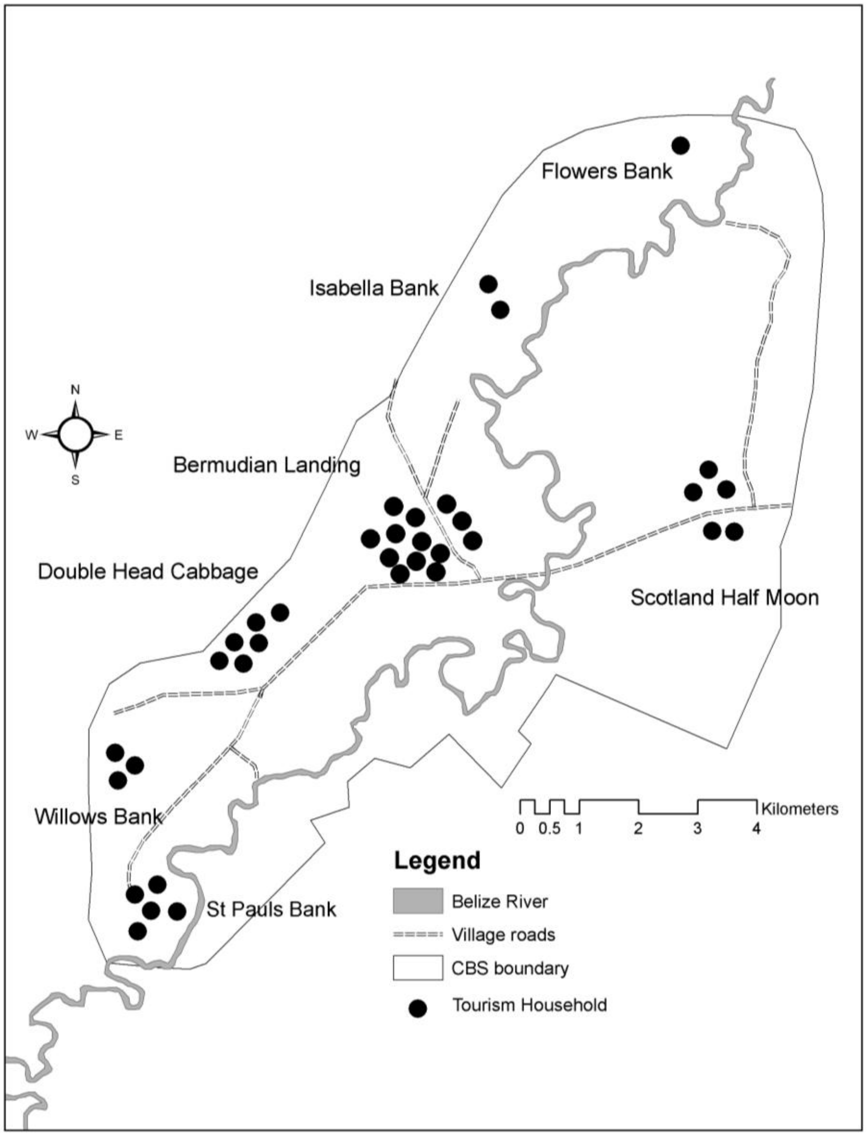


Figure 2-3. Households involved in tourism by village. There are an estimated 35 households participating in tourism during the course of this study. Although only 26 were interviewed, the other residents involved were identified.

Table 2-1. Reported Household Income from the 45 households receiving remittances

Type of Income	Amount in BZE $	Amount in US $	Percentage of total income
Wage Income	$163,073.00	$81,536.50	48.6%
Remittances	$95,850.00	$47,925.00	28.5%
Other non-wage income	$76,939.00	$38,469.50	22.9%
Total	$335,862.00	$167,931.00	

Table 2-2. CBS tourism participation and financial income by village. As reflected in this table, in Bermudian Landing there are seven more households benefiting from tourism that declined to be part of this study (out of 135 residents interviewed).

Village Name	Number of CBS households involved in tourism in 2005 (interviewed)	Number of CBS households involved in tourism in 2005 (not all interviewed)	Total tourism income earned in 1 year (US$) by households per village	Village household size (during year of data collection)
Willows Bank	3	3	4,410	35
Isabella Bank	2	2	4,275	23
Bermudian Landing	6	13	2,325	39
St Pauls Bank	5	5	950	26
Double Head Cabbage	4	6	910	43
Scotland Half Moon	5	5	825	32
Flowers Bank	1	1	310	24
Total	26	35	14,005	222

Table 2-3. Results from nominal group meeting and first-round interviews regarding costs and benefits of pledging and tourism.

Pledging		Tourism	
Benefits	Costs	Benefits	Costs
People still abide by it / have respect for it	No economic benefits of pledging	Money	Tourists take liberties with their safety (encourages behavior from others to take advantage of tourists)
People are not cutting down forests where baboons live	Conservation limits other activities, such as hunting	Jobs	Endangered / threatened species (that ecotourism is focused on) can't be hunted and / or sold
Trees preserve the bankside (river erosion lessened and more people are becoming aware of this)	One can't clear the land as you would want – especially riverside for pasture	Generate Ideas/ Learning and Educational	We have to be on our "best behavior" when tourists are around
Benefits everything: protects animals (animals, birds) and river systems (water, fish) that humans depend on	Baboons eat all (fruit trees) and there are none left for people	Incentive to keep your place and your village clean and nice-looking	
Jobs are scarce and the forest (protected through pledging) allows people to have tourism on their land	One has to clean up leaves (under the trees that are left from the pledge)	Contacts made with those from away	

Note: This was later used, along with the established literature, to develop scale items for place attachment and benefit questions.

Table 2-4. Survey sample

Survey sample	Number of CBS households
Tourism-only	12
Pledged-only	37
Pledged and Tourism (PT)	14
Non-Pledge / Non-Tourism	72
Total	**135**

Table 2-5. Community Benefits (Importance) Means. Likert – Scale (1 = not very important, 5 = very important) * $p \leq 0.1$ ** $p \leq 0.05$

Community benefits (importance)	Overall N=135	P&T N=14	Non PT N=121	Tourism only N=12	Non tourism N=123	Pledge only N=37	Non pledge N=98
Living in a healthy environment	4.6	4.6	4.6	4.6	4.6	4.5	4.6
Providing a good quality of life	4.2	4.2	4.3	4.4	4.2	4.2	4.2
Knowing conserved natural resources exist for future generations	4.2	4.3	4.2	4.2	4.2	4.4**	4.2**
A feeling that your community is a special place to live	4.1	4.2	4.1	4.2	4.1	4.1	4.1
Attracts tourism dollars to my community	4.1	4.4	4.1	4.2	4.1	4.1	4.1
A natural setting in which your community takes great pride	4.0	4.1	3.9	4.0	4.0	3.9	4.0
A place to conserve various natural and unique ecosystems	3.9	4.1	3.8	4.1	3.6	4.0	3.8
Improved care for community aesthetics	3.8	4.1*	3.8*	4.0	3.8	3.9	3.8
A greater concern for the natural environment among residents	3.8	4.1*	3.7*	4.1**	3.7**	3.8	3.7

Table 2-6. Community Benefits (Attainment) Means. Likert – Scale (1 = not attained, 4 = fully attained) ***** $p \leq 0.1$ ****** $p \leq 0.05$

Community benefits (attainment)	Overall N=135	PT N=14	Non-PT N=121	Tourism only N=12	Non tourism N=123	Pledge only N=37	Non pledge N=98
Living in a healthy environment	3.6	3.8	3.6	3.7	3.6	3.7	3.6
Providing a good quality of life	2.7	2.5	2.7	2.5	2.7	3.0**	2.6**
Knowing conserved natural resources exist for future generations	3.1	3.1	3.1	3.0	3.2	3.4**	3.0**
A feeling that your community is a special place to live	2.8	3.0	2.8	2.7	2.8	2.8	2.8
Attracts tourism dollars to my community	1.6	2.1**	1.6**	1.6	1.6	1.6	1.6
A natural setting in which your community takes great pride	2.6	2.9	2.6	2.7	2.6	2.9**	2.5**
A place to conserve various natural and unique ecosystems	2.6	2.6	2.6	2.4	2.6	2.8	2.5
Improved care for community aesthetics	2.2	2.1	2.1	2.2	2.1	2.1	2.1
A greater concern for the natural environment among residents	2.2	2.4	2.2	2.1	2.2	2.3	2.2

Table 2-7. Place Attachment of Riparian Forests Means. Likert-scale (1 = strongly disagree, 7 = strongly agree) * $p \leq 0.1$ ** $p \leq 0.05$

Place-Attachment Items	Overall	PT N=14	Non-PT N=121	Tourism only N=12	Non tourism N=123	Pledge only N=37	Non pledge N=98
These riparian forests are important in providing habitat for wildlife	6.8	6.9	6.7	7.0**	6.7**	7.0**	6.7**
My community's history is strongly tied to this riparian forest	6.6	6.6	6.6	6.1	6.7	7.0**	6.5**
This riparian forest contributes to the character of my community	5.9	6.4	5.9	5.8	5.9	6.4**	5.8**
These forests have helped put my community on the map	5.7	6.5	5.6	5.7	5.7	5.8	5.6
This riparian forest is a special place for my family	5.6	6.5	5.5	5.3	5.6	6.0**	5.4**
Many important family memories are tied to these areas	5.5	6.4	5.4	4.8	5.5	6.1**	5.3**
I am very attached to this riparian forest environment	5.4	5.9	5.3	5.0	5.4	6.0**	5.1**
I feel a sense of pride in my heritage when I am there	5.2	6.1	5.1	5.4	5.2	5.7**	5.0**
These riparian forests are important in protecting water quality	4.9	5.3	4.8	5.6*	4.8*	5.4**	4.7**
My community's economy depends on riparian forests	3.7	4.0	3.6	3.8	3.7	4.0	3.6
My family's income or livelihood depends on riparian forests	2.5	2.4	2.5	2.8	2.5	3.0	2.3

CHAPTER 3
INTEGRATING SOCIAL AND LAND-USE/LAND-COVER CHANGE DATA TO ASSESS DRIVERS OF DEFORESTATION: A STUDY OF THE COMMUNITY BABOON SANCTUARY, BELIZE.

Introduction

Dynamics of land-cover (e.g., the biophysical attributes of the land surface) and land-use (e.g., the anthropogenic influences on the land) change are considered two of the main driving forces of global environmental change (Meyer and Turner 1992; NRC 1998; Lambin et al. 2000; Geist and Lambin 2002). Understanding these dynamics help inform, manage, and predict impacts from land-use changes, such as carbon storage, biodiversity, and ecological services (Skole 1995; Turner et al. 1995; Olson et al. 2004). Within Land-Use / Land-Cover Change (LULCC) research, tropical deforestation is considered one of the most significant threats to biodiversity (Laurance 1999). To better conserve tropical forests the proximate causes of deforestation must be investigated, in addition to assessing forest cover and forest loss (Roy Chowdury 2006a). Therefore, research is increasingly focusing on linking social survey information from local land managers to land-cover changes (Lambin et al. 2000; Mertens et al. 2000; Geoghegan et al. 2001; Klepeis 2003; García-Barrios and González-Espinosa 2004). This study assesses forest cover trends, and examines the relative influence of factors affecting deforestation, within the Community Baboon Sanctuary (CBS), Belize by linking social survey and locational information from local land managers to land-cover change.

At the household level, any land manager's land-use decisions are shaped by many factors including land characteristics, land ownership, household socio-demographics, economic and livelihood activities, and any institutions or policies that present opportunities or limitations for a particular land-use activity (Olson et al. 2004). To better understand and identify the causes and driving forces of deforestation at the household level, past research has focused on the factors of location, socio-demographic, tenure, socio-economic variables and conservation initiatives.

Areas more suitable to agriculture, such as forests in more level areas and areas of higher soil fertility, are more likely to be deforested (Kaimowitz and Angelsen 1998; Geist and Lambin 2001; Gibson et al. 2002; Gautam et al. 2004). Locational variables, such as distance to roads (access to transportation routes and markets) also promote deforestation (Chomitz and Gray 1996).

People are connected to their natural environment through the system of property rights (Hanna et al. 1996). Insecure land tenure can encourage deforestation; people will deforest or harvest what they can when unclear restrictions to resources exist (Wood and Walker 1999). Chambers (1993) argues that unless people have secure rights to the resources they use, people will not be motivated to manage and protect them. Overall, the literature supports that secure title and control over land resources encourages organizational capacity and can be linked to sustainable forest management and improved economic opportunities (Ostrom 1990; Godoy and Bawa 1993; Nelson et al. 2001; Murphree 2003).

Among characteristics of the individual land owner, higher education levels were found to decrease deforestation where it provided greater opportunity for non-farm wage income (Pinchon 1997; Irwin and Geoghegan 2001; Roy Chowdury 2006b). Another household characteristic, increasing household size, has been found to increase deforestation probability due to subsistence demand, although lifecycle phases can also relate to land clearing activities (Moran 2000).

The uses to which scarce land is allocated is usually determined by the relative value of alternative uses of the land. Socio-economic drivers to deforestation, such as cattle or agriculture, can be linked to external market demands (Lambin et al. 2001; Hubacek and Vazquez 2002). Analyses of driving forces of land-use change studies worldwide have identified agricultural expansion (ranching and/or cultivation) as the leading proximate driver, which is often accompanied by timber extraction and transportation infrastructure (Lambin et al. 2001; Geist and Lambin 2002; Lambin et al. 2003).

Additional factors that may influence deforestation and land-use intensification can be linked to projects (government or NGO-sponsored) intended to promote development or conservation (Gibson et al. 2000; Lambin et al. 2001). Conservation policy discussions today emphasize the importance of local communities benefiting from their conservation of biodiversity. Increasingly, community-based conservation initiatives are integrating revenue-generating activities and market incentives with conservation (Tisdell 1995; PfB 2000; Wunder 2000; Langholz and Brandon 2001). Under this scenario, nature-based tourism has been recognized as an approach for providing communities local financial incentives for conservation (Tisdell 1995; Kangas et al. 1995; Bookbinder 1998; Kimmel 1999; Langholz 2002). The impetus for many community nature-based tourism projects is to reduce the local threats to biodiversity, such as unsustainable harvesting of wild plants, hunting, and expanding agriculture by providing socio-economic alternatives to current forest depletion and unsustainable agricultural practices (Boo 1990; Lindberg et al. 1996; Wunder 2000; Nyaupane and Thapa 2004).

Another factor tied to conservation strategies shown to influence conservation behavior is the act of making a commitment or pledge to conservation behaviors. 'Commitment' within social marketing is defined as "a binding or pledging of the individual to an act or a decision" (Kiesler and Sakumura 1966: 349). The theoretical foundation of commitment is based on the premise that once a pledge is formally made, the bond is strengthened between the promise and future action. An important element of commitment and conservation behavior change is that over time, if a behavior continues, a change in attitude will also occur (Werner et al. 1995). Commitment theory suggests that a public, voluntary, and written pledge not to deforest should decrease the probability of deforestation.

Many decisions to modify land-use are taken by the household. Therefore, this study links remote sensing and household socio-economic data to integrate factors affecting deforestation (McCracken et al. 1999). Decision making at finer scales (e.g., the household level) has 0to be structured within a broader set of issues at coarser scales (including the community) and policy, pricing and regulatory issues at regional, national, and even global scales (e.g., public policy and institutions, global markets and prices) (Walsh et al. 2003). To understand land-use change at more aggregated scales, research must examine individual land-use decisions at the parcel level (Ludeke et al. 1990). The objectives of this study were:

1. Determine rates and trends of forest cover change within the Community Baboon Sanctuary (CBS), Belize landscape over a 15-year time period (1989, 1994, 2000, 2004);
2. Determine and compare rates and trends of forest cover change of the 120 meter riparian forest buffer landscape within and outside the CBS over a 15-year time period (1989, 1994, 2000, 2004); and
3. Evaluate the relative influence of locational, land tenure, socio-demographic, socio-economic, and conservation initiative variables as drivers of deforestation within the CBS from the development of spatial, statistical models.

Methods

LULCC in Belize

The deforestation rate (2.3% per year) in Belize surpassed that of Central America (1.2% per year) during 1990-2000, increasing abruptly from an annual forest loss of only 0.2% in the early 1980s (DiFiore 2002). In 2007, Belize had 79% forest cover (FAO 2007), down from 97%

forest cover in the early 1980s. However, as of 1992, the north-central part of the country retains only 30% of its original forest cover (King et al. 1992). The main drivers encouraging deforestation and fragmentation of remaining forests in Belize are large-scale agriculture, milpas (small-scale slash and burn farming), large- and small-scale cattle ranching, large- and small-scale logging, and urban growth (Horwich and Lyon 1990).

Study Site

Established in 1985 through the efforts of the Belize Audubon Society and two American scientists, the Community Baboon Sanctuary (CBS) was created to protect habitat for the black howler monkey (*Alouatta pigra*) along the Belize River (Horwich and Lyon 1998) (Figure 3-1). The CBS is not a conventional protected area (e.g., national park) with people living outside its borders. In contrast, the CBS is comprised of seven Creole villages with private landowners who have agreed to manage their land in a particular way that increases its conservation value. The CBS totals approximately 8700 ha located in the climatic region of north-central Belize (17° 33'N, 88° 35'W) with forest cover classified as lowland, semi-deciduous rainforest. An annual rainfall of 60-70 inches (150-175 cm) is typical of the region, with a pronounced dry season from February through May (Horwich and Lyon 1998). The forests within the CBS (as throughout Belize) have been periodically logged for the past 300 years and today are comprised of secondary forests (10-75 years old) with cleared areas and secondary growth (Horwich and Lyon 1990). The main livelihood activities within the CBS villages include employment with nature-based tourism (primarily in the village of Bermudian Landing); small-scale agriculture; small-scale cattle raising; small-scale coconut oil and cohune nut oil (*Orbignya cohune*) production; cashew harvesting; and outside wage employment (primarily in or around Belize City, roughly 35 miles away).

Since 1985 various residents within the CBS communities have participated in two conservation initiatives: nature-based tourism focused around the howler monkey and a written, voluntary conservation pledge for private landowners to leave a strip of riparian forest and forested corridors that provide habitat connectivity for howler monkey populations. Little monitoring, however has been conducted to assess the effectiveness of these two initiatives and other factors that influence deforestation.

Household Surveys

This study evaluated the relative influence of landowner characteristics on deforestation probability. Remote sensing data were linked with the following land and landowner characteristics: locational, land tenure, socio-demographic, socio-economic, and participation in conservation initiatives.

Locational: The locational factors chosen for this study include distance to the Belize River and road networks from each forested pixel. Riparian areas are often chosen for agriculture within the CBS because of their more fertile soils. Most of the riverine and cohune palm forests of the CBS are located on alluvial soils of the *Bermudian Landing Series* (USDA: Vertic Europept) (Horwich and Lyon 1990). In addition, road networks throughout the CBS have increased access to Belize City for outside employment opportunities and markets (roughly 35 miles away).

Land tenure: The CBS includes private (titled) and government leased (20 year) landholdings. The majority of the 33 landowners interviewed have title to their land (n = 27), with six households possessing government leases. Within the CBS, as well as throughout Belize, property is transferred through formal title or leased land that has been 'worked' (e.g., cleared for agriculture or livestock) (Lash 2003) and, as such, there is a disincentive to leave large tracks of forest in place.

Socio-demographic: Two demographic variables considered were family size and education level (number of years of education) of the household head. Family size of the 33 households interviewed ranged between 1 to 10 members (mean = 4.8). Education level of the household head for these 33 households ranged between 0 to 18 years of schooling (mean = 8 years).

Socio-economic: Agriculture and cattle activity were the two variables examined under socio-economic variables. Although not as prevalent as years past, cattle ranching (both large and small-scale) and small-scale agriculture (mostly for home consumption) are common livelihood activities. From the 33 households interviewed, 21 practiced agriculture in 2005, cultivating 101.5 acres (out of an approximate 2566 acres total within the 33 parcels). The majority of those with cattle have less than 50 head, but cattle serve as a type of savings account for many residents; when instant cash is needed for medical emergencies or events such as weddings and funerals, a cow can be sold immediately either within the villages or in Belize City. Twenty of the 33 households interviewed (61%) manage some cattle, accounting for a total of 432 head of cattle. Cattle are also often kept by the river where they can easily access water.

Conservation initiatives: Nature-based tourism and a conservation pledge were two conservation initiatives examined within the CBS. The black howler monkey (*Allouta pigra)* is the focus of tourism within the CBS, developed to provide economic incentives for residents to protect forest landscapes (especially riparian forests). Tourism related jobs range from employment in the visitor center and museum to tour guiding, housing visitors, and maintaining trails, involving both seasonal and permanent positions. Ten out of the 33 households interviewed have at least one family member currently involved in tourism. There does appear to be some inequality of tourism benefits, with the majority of residents currently involved in tourism residing in the village of Bermudian Landing, the location of the visitor center. Still, a few residents from other CBS villages are also involved with and benefiting financially from tourism, with some residents even starting to develop tourism opportunities on their own lands (see chapter two).

The voluntary, written, public conservation pledge asks landowners to agree to do their part in protecting forest habitat for the howler monkey. By signing this pledge, landowners agree ('commit') not to clear their land along the riverbank (the main focus) and to leave a forested corridor between property boundaries. Although the pledge was not initially linked with any financial reward, CBS records and research by Lash (2003) indicate that pledged landowners were paid twice (1998 and 2000 totaling ~$250 per landowner) by the CBS management at the time, but presently no residents are given any financial compensation for pledging. Currently, 11 out of the 33 households interviewed are involved in tourism only, 10 households are involved in pledging only, and 8 are both pledged and tourism households.

Remote Sensing

Because of the different drivers contributing to land-use decisions, understanding LULCC requires the integration of multiple disciplines and tools, in this case remote sensing and socio-economic data. Remote sensing data provides information on the differences in land-cover characteristics on spatial and temporal levels and have been used on a wide range of analyses, one of which is forest change detection (Fernside 1986; Vogelmann and Rock 1988; Skole and Tucker 1993; Sader et al. 1994; Jha and Unni 1994; Foody et al. 1996; Di Fiore 2002; Southworth et al. 2004). Remote sensing has also been used extensively with ethnographic methods, from household surveys to socio-economic data, to better understand the drivers of land-use change (Guyer and Lambin 1993; Sussman et al. 1994; Mertens et al. 2000; Sader et al.

2001; Hayes et al. 2002; Southworth et al. 2002; Schweik and Thomas 2002; Bray et al. 2003; Dalle et al. 2006).

Image pre-processing*:* Three Landsat TM satellite images and one Landsat 7 ETM+ SLC-off satellite image (Path 19, Row 48) were processed from 1989, 1994, 2000, and 2004 to analyze land-cover change within the CBS and outside landscape. To decrease errors associated with seasonal variations on biophysical properties and subsequent change detection analyses, these images were taken between November and March, corresponding with the study site's dry season (Jensen 2005). Preceding year/month climate information of the area, in particular precipitation levels, were obtained and considered for the change analysis process considering extremely wet or dry conditions on one of the dates can cause serious change detection issues (Table 3-1).

Each Landsat image was corrected for atmospheric, sensor, and illumination variance sources through radiometric calibration and atmospheric correction procedures (Green 2000) to ensure change detection accuracy at the Earth's surface (Jensen 2005). The 2004 image was corrected geometrically using a 1:50,000 scale map of the study area obtained from the Belize Land Information Center (UTM Zone 16, WGS 1984). Points from the 2004 rectified image were then used to register the other images, maintaining the root mean square (RMS) error of each registration below 0.5 pixels (<15 m).

Image classification: Training sample protocol forms from the *Center for the Study of Institutions, Population, and Environmental Change* (CIPEC) were used (CIPEC 1998) for ground truthing the 2004 image within the CBS between September and December, 2005. Areas to include in a training sample covered a 90 X 90 m area to ensure that at least one full pixel fell within that particular land-cover. In total, sixty-six training sample points were taken (31 for “forest” and 35 for “non-forest”) which included as many different types of forest and non-forest cover in and around the CBS. Locations were recorded with a GPS (global positioning system) unit and other information, such as qualitative descriptions (e.g., photographs) was recorded for reference and comparison with classified maps and satellite imagery. A class was considered “forest” if it had a canopy covering 25% or more, using a definition of forest that functioned both socially and physically for the CBS. Training samples within the CBS were primarily taken along roads and the Belize River but in areas difficult to access, vantage and edge training sample points were also taken. To further aid with the training samples, the nature and extent of land-use was obtained through informal landowner interviews and personal observations.

Before classifying the images, clouds were removed from each image to create a mask that was then applied to all images. Training sample data and GPS points were then used to conduct a hybrid supervised / unsupervised classification using the Gaussian Maximum Likelihood technique on the 2004 image, starting with an unsupervised classification of 60 classes. Considering forest was the class interest, other non-forest areas (e.g., wetlands, built, agriculture) were merged into a final class: non-forest (NF) after all the spectral reflectance differences were represented. An accuracy assessment on the 2004 classified image resulted in an overall classification accuracy of 84.85% and an overall Kappa Statistics of 69.47%, with no individual class less than 80% (Table 3-2). An overall accuracy of 85% (with no class less than 70%) has been established as a target for accuracy assessments (Thomlinson et al. 1999). The remaining images were classified through comparison with signature mean plots of 2004 classes, and also contrasting vegetation using the NDVI and thermal band of each image. The result of the classification process was the creation of “forest” (F) and “non-forest” (NF) classifications for each image date.

Data analysis (change detection): For the landowner property change detection analyses, a 1992 CBS property owner map (1:50,000 scale map) was georeferenced to the 2004 Landsat image in ArcMap, using roads and rivers as ground control points (GCPs) maintaining a RMS error below 0.5 pixels (<15 m). Individual properties were then digitized as shapefiles in ArcMap. Out of a total of 77 river property owners, 33 landowner properties were analyzed for this study, which accounted for those landowners who were interviewed, whose properties had not changed for the entire 15 year duration, and whose property boundaries were not impacted by cloud coverage in the satellite images (Figure 3-2).

The Belize River was digitized to create a shapefile in ArcMap. There is no existing precedence for establishing river buffer widths in Belize (for wildlife use or any other ecosystem function). Specific to the Belize River within the CBS, 120 meters has been suggested by Dr. Robert Horwich (personal comm. 2008), a primatologist familiar with the riparian forest areas of the CBS, as the approximate river buffer area of flooding and higher soil fertility.

Two types of change detection analyses were conducted: a change detection analysis of the CBS area over the four image dates (1989, 1994, 2000, and 2004) and a comparison of an 120 meter buffer of the Belize River within and outside the CBS over the four image dates. For these analyses, the Spatial Modeler function in ERDAS Imagine software was used to create change detection images using the four images as inputs to develop an image differencing algorithm as the function and create a change detection image as the output. These change detection analyses using the four image dates created 16 change classes. To better assess general trends of forest cover change over this 15 year period, the 16 change classes were grouped into five categories: stable forest, stable non-forest, tending towards deforestation (starting with F and ending in NF), tending towards reforestation (starting in NF and ending in F), and transitional.

Spatial Regression Models of Deforestation

The model of deforestation within the CBS employs binomial logit models with the classification derived dependent variable (stable forest versus deforestation during the two image comparison) and landscape and socio-economic GIS layers as independent variables to produce a predicted probability of deforestation, as well as parameter estimates. Munroe et al. (2004) found that binomial logit models yielded better model fit, compared to multinomial logit models, in examining land-cover change in Honduras. Roy Chowdury (2006a, 2006b) also applied binomial logit models to understand parcel-scale deforestation decisions in Southeastern Mexico.

Decisions about deforestation on parcels within the CBS are informed by considerations on (1) locational factors, such as distance to roads and distance to the Belize River from each forested pixel, (2) land tenure, (3) socio-economic and socio-demographic factors (for model 3 only), and (4) participation in conservation initiatives (nature-based tourism and pledging). Following Geoghegan et al. (2001) and Roy Chowdury (2006a, 2006b), for the classification derived-dependent variable, the probability of deforestation at a pixel can be given as:

$$Pr(y_j = 1|x_j) = \frac{e^{\beta_0+\beta_1 x_1 + \beta_2 x_2 \ldots}}{1+ e^{\beta_0+\beta_1 x_1 + \beta_2 x_2 \ldots}}$$

W here

y_j = 0 if pixel j was forest in the first year of the model and remained forested in the last year of model (stable forest) or 1 if pixel j was forest in the first year of the model and was deforested in the last year of model (deforestation)

x_j = value of independent (explanatory) variable at pixel j

β = estimated parameters (coefficients) for each independent variable that can be estimated using a binomial logit specification (Maddala 1983).

Preliminary statistical analyses: Steps were taken to assess which variables were most important for modeling deforestation for the 2000 – 2004 time period (model 3), based on a priori information from the literature, as well as their importance within the region and the CBS. Tests of collinearity were conducted between the binary independent variables using Chi-square analyses, and between continuous and continuous-binary interactions using Pearson's correlation. Consideration was given to both the p-value and the magnitude of the value. A value of 0.50 or greater was a measure of high correlation, following Munroe et al. (2004). After eliminating some of the independent variables due to high collinearity, a binominal logit regression was conducted for each of the three two-year period combinations (1989 – 1994, 1994 – 2000, and 2000 – 2004). Model 1 (1989 – 1994) and model 2 (1994 – 2000) assessed the impacts of 4 variables (tenure, pledge, distance to river, and distance to roads), due to temporally restricted variables while model 3 (2000 – 2004) employed a stepwise regression and addressed other socio-economic and socio-demographic variables collected from household interviews conducted in 2005.

Next, spatial autocorrelation of residuals for each model was assessed through calculating Moran's *I* value, using ArcGIS spatial statistics. Moran's *I* is one of the most common ways to measure spatial autocorrelation, and is defined as a measure of the correlation among neighboring observations in a pattern (Boots and Getis 1988) and refers to the fact that the value of a variable at one point in space is related to the value of that same variable in a nearby location. This statistic is used to evaluate the presence or absence of spatial autocorrelation and is interpreted like a correlation coefficient, with values near +1 indicating strong positive spatial autocorrelation, values near -1 indicating strong negative autocorrelation, and values near 0 indicating an absence of spatial pattern (Rogerson 2005). Spatial autocorrelation was expected to exist within the models, as it is common in remote sensing studies (Munroe et al. 2004) and because much of the data for this study is measured at the parcel level (socio-economic data) but the unit of analysis is at the pixel level (data are at mismatched scales). Measures of spatial pattern were included in the analysis, such as distance to the Belize River and distance to the nearest road measured from each pixel, to decrease autocorrelation (Moran's *I* values) to 0.07, 0.06, and 0.05 for the three models. After these preliminary statistical analyses, a final model was created for each two-year period combination (three models in total). All data were standardized (subtracting the mean and dividing by the standard deviation) to enable comparison between binary and continuous variables within each model. Measures of accuracy (*pseudo* R^2 and overdispersion parameter) and model validation were then assessed for model goodness of fit.

Results

To adequately address conservation success, research must first assess forest cover and forest change before examining the causes of change. Therefore, this study's first two objectives were to assess land-cover change trends of the CBS landscape and land-cover trends of the 120 meter river buffer within and outside the CBS. If conservation loss is occurring, the proximate causes of deforestation must also be investigated (Roy Chowdury 2006a), and this study's third objective, which was to determine the relative influence of chosen variables on deforestation probability, was designed to understand these causes.

CBS Land-Cover Trends

Covering the entire 15 year time period (1989 – 2004), the largest proportion of the CBS landscape follows the "stable forest" trajectory, comprising 33.4% (2908.98 ha) of the landscape. The second largest proportion of the CBS landscape follows the "tending toward deforestation" trajectory, comprising 29.7% of the landscape (2582.79 ha). "Tending toward reforestation" and “stable non-forest” accounted for 18.9% (1647 ha) and 13.8% (1200.6 ha) of the landscape, respectively, with the “transitional” trajectory accounting for 4.1% (361.17 ha) of the landscape (Figure 3-3 and Table 3-3). Major results indicate the CBS landscape follows both stable forest and deforestation trends.

River Buffer Trends

Although assessment of the entire CBS landscape is important as a community reserve, the river buffer is the focus of conservation with the goal of protecting habitat for the black howler monkey (*Alouatta pigra*) (the impetus for the creation of the CBS) and can serve as a proxy for conservation within the CBS. A 120 meter Belize River buffer running through the CBS was compared to the non-protected segment of the Belize River buffer running north and south of the CBS. The leading land-cover trend within the CBS’ 120 meter river buffer followed “tending toward deforestation.” Although a difference in total river distance exists, attributed to cloud coverage on the satellite images and the importance of focusing on similar rural areas, the major land-cover changes that have occurred along the river buffer within the CBS from 1989, 1994, 2000, and 2004 are the same changes that have occurred along the river buffer outside the CBS (Figures 3-4 and Tables 3-4). The largest proportion of the 120 meter river buffer both inside and outside the CBS falls under the land-cover trajectory “tending toward deforestation,” accounting for 30.95% (257.22 ha) of the CBS river buffer and 29.83% (99.18 ha) of the river buffer outside the CBS. A close secondary leading land-cover trend was “stable forest,” accounting for 26.09% (216.18 ha) of the CBS river buffer and 28.1% (93.42 ha) of the outside river buffer. The next land-cover trajectory is that proportion “tending toward reforestation,” accounting for 25.71% (213.66 ha) within the CBS and 23.09% (76.77 ha) outside the CBS. “Stable non-forest” and “transitional” land-covers account for the smallest proportions of both river buffer landscapes, covering 10.55% (87.66 ha) and 6.71% (55.8 ha) within the CBS and 9.64% (32.04 ha) and 9.34% (31.05 ha) outside the CBS.

Drivers of Deforestation

To determine the major drivers of deforestation within the CBS, variables were chosen a priori from the literature and/or based on the observations and information obtained by the research during field work. Because much of the household characteristic information (e.g., socio-economic and socio-demographic) was only relevant during the last time period modeled (2000 – 2004), this information was not included in the two earlier models (1989 – 1994 and 1994 – 2000). The results of the three separate binomial logit models of deforestation for the periods from 1989 – 1994 (model 1), 1994 – 2000 (model 2), and 2000 – 2004 (model 3) are presented in Tables 3-5, 3-6, and 3-7. These tables present the values of the parameter estimates (coefficients) with their corresponding Z value statistic and indicated significant probability. Positive values of parameter estimates indicate that larger values of the explanatory variables increase the likelihood of deforestation (given statistical significance), while negative values indicate the opposite. By addressing deforestation probability, the binomial logit models also address stable forest probability, covering the two dominant land- cover trends within the CBS landscape and 120 meter river buffer (Table 3-3 and Table 3-4).

Model 1 (1989 – 1994)

Only those variables relevant during the 1989 – 1994 time period for the 33 landowners and their parcels were analyzed in this model. These variables included distance to river from each pixel, distance to roads from each pixel, land tenure, and participation in the pledge. Distance to road was the most influential variable in the model. Areas further from the road and the Belize River, as well as titled tenure decreased the probability of deforestation (p = 0.001). Participation in the pledge increased the probability of deforestation (p = 0.01) (Table 3-5).

Model 2 (1994 – 2000)

Only those variables relevant during the 1994 – 2000 time period for the 33 landowners and their parcels were analyzed in this model. These variables included distance to river from each pixel, distance to roads from each pixel, land tenure, and participation in the pledge. Similar to model 1, areas further from the road and the Belize River and titled tenure decreased deforestation probability. In contrast to model 1, participation in the pledge decreased the probability of deforestation (p = 0.001) (Table 3-6), perhaps coinciding with one of the payment years for pledgers.

Model 3 (2000 – 2004)

Since surveyed data were relevant to current participants, the last model included all variables of interest. Cattle, cattle income, agriculture, education level of the household head, and tenure were the five most influential variables in this model. Increasing cattle income, education level of the household head, titled tenure, distance from roads, distance from the Belize River, family size, agricultural income, and involvement in both the pledge and tourism were significantly linked (p = 0.001) to decreasing probabilities of deforestation. Pasture also decreased deforestation probabilities but at a lower significance level (p =0.05). Cattle, agriculture, remittances, and involvement in tourism were significantly linked (p = 0.001) to increasing probabilities of deforestation. Working outside the CBS and involvement in the pledge also increased probabilities of deforestation but at lower significance levels (p = 0.05) (Table 3-7).

Because of the large number of variables in this model and the large number of pixels, it is possible that many of the variables that show statistical significance in the model may not be good predictors of deforestation within the CBS. To better assess their influence, all variables were plotted individually and examined in more detail on their strength of effect using logistic regression. Results show that the most influential variables in this model were distance to the Belize River and distance to roads (figure 3-5), cattle (figure 3-6a), agriculture (figure 3-7a), education of household head (figure 3-8a), and participation in both pledging and tourism (figure 3-10). The least influential variables in this model (with low predictive power) included cattle income (figure 3-6b), agricultural income (figure 3-7b), family size (figure 3-8b), tenure (figure 3-9a), remittances (figure3-9b), outside work (figure 3-11a), and pasture (figure 3-11b). Both distance to river and distance to roads have an approximate 50% decrease in deforestation probability (from 0.4 to 0.2) as distance increases to 2500 meters away. Owning cattle also shows a 17% difference in deforestation probability difference between those residents with cattle (39%) and those without (22%). In contrast to owning cattle, which is statistically significant and influential, an increase in cattle income only slightly decreased deforestation probability. Agriculture was also fairly influential showing an approximate 9% decrease in deforestation probability between those carrying out agricultural practices (37%) and those not (28%). However, agricultural income, although showing a decrease in deforestation in the model, has very strength of effect when plotted. Education of household head had strong strength of effect and decreased deforestation probability by approximately 50%. In comparison, although greater family size was predicted to increase deforestation probability, results show this was not influential within the CBS. Tenure, although one of the top five influential variables in the model, did not show strong strength of effect and indicated only a slight decrease in deforestation probability for those with titled land ownership. Remittances, although increasing the probability of deforestation in the model, showed very low strength of effect when plotted. Additionally, outside (CBS) work and having pasture, two of the three least influential variables in the model, both showed very low strength of effect when plotted. Lastly, comparing the two conservation initiatives (tourism and pledging), there was a 12% decrease in deforestation probability between those households involved in both pledging and tourism (26%), compared to those households not involved in either initiative (38%). Households involved in either tourism (30%) or pledging (32%) showed a 6-8% decrease in deforestation probability compared to those households not involved in either initiative.

Model Validation

There are several ways to assess model accuracy. One indicator of model fit is the overdispersion parameter. This parameter is useful for indicating whether the relevant model has been applied and if outliers exist in the data, measuring a model's residual deviance over degrees of freedom (Burnham and Anderson 2002). With a value of "1" considered a strong fit, parameter results were 1.13 (model 1), 1.01 (model 2), and 1.19 (model 3), indicating no issues with outliers and overall correct model choice. The second model (1994 - 2000) had the highest prediction accuracy result for deforestation (74%) and stable forest (78%). The first model (1989 - 1994) had the second highest prediction accuracy for deforestation (68%) but the lowest prediction accuracy for stable forest (72%). The third model (2000 - 2004) had a prediction accuracy of 69% for deforestation and 70% for stable forest (Table 3-8).

Additionally, many LULCC modeling studies report a *pseudo* R^2, as the R^2 statistic as a traditional measure of fit is not easily calculated in a categorical regression framework. A pseudo R^2 statistic was calculated for each model (based on the ratio of restricted and unrestricted log-likelihood function). The pseudo R^2 results were 0.116 (model 1), 0.063 (model 2), and 0.129 (model 3). Although the model chose the most significant variables influencing the probability of deforestation, these low pseudo R^2 values signal that overall these variables are not the most influential predictors of deforestation probability and that other important variables are missing from the model (information that was either not available for this study or was not collected) that predict deforestation probability.

Lastly, following other LULCC modeling studies, a predicted versus observed deforestation / stable forest map was created to assess the spatial pattern of model performance, using 50% as the threshold for the model-predicted probability of deforestation to classify a pixel as deforested (Figures 3-11, 3-12, and 3-13). Generally speaking, all models show most incorrect predictions of deforestation (where stable forest actually occurred) located around correctly deforested pixels. In models 1 and 2 this over-prediction of deforestation was likely distance-related, considering that the two largest z values belonged to the 'distance to road' and "distance to river' variable, and could be responsible for this over-prediction. In addition, the spatial pattern of pixels where all the models over-predict stable forest (where forest was actually deforested) does not appear necessarily random, but does not fit any distance-based criteria and is difficult to interpret any consistent spatial patterns. This may indicate that other variables not captured by the models may be influencing deforestation in certain areas, or even other spatial processes that are occurring in these areas (e.g., soil maps for the region were not at the detail needed to show differentiation within the CBS).

In comparison to the other models, although some correct predictions for deforestation in model 3 are located near roads and rivers, overall these predictions appear to be more unique to each land parcel, potentially pointing to the role of household survey-derived socio-economic and socio-demographic variables over distance-related variables in this model (e.g., cattle and agriculture). However, there were no clear patterns or variables unique to these landowners from the model that would explain this, which also signals that other variables not included in the model are probably influencing deforestation within these parcels.

Discussion

Although the two leading land-cover trajectories within the CBS were stable forest and deforestation, leading land-cover trends of the 120 meter river buffer within and outside the CBS also needed to also be examined, considering the conservation focus of riparian forests. Within the 120 meter river buffer the leading land-cover trend both within and outside the CBS was tending toward deforestation. This result of similar land-cover trends inside and outside the CBS riparian buffer indicates riparian forests are not any more conserved within the CBS as they are outside. In addition, areas within the 120 meter river buffer are more likely to be deforested than other areas within the CBS. Following these analyses, modeling social survey and locational characteristics of individual landowners with land-cover change provided insight into the relative influence of these factors on deforestation probability within the CBS.

Drivers of Deforestation

Locational: As predicted, distance to river was an influential variable in all three models negatively linked to probabilities of deforestation (increased probabilities of deforestation the closer a pixel is to the river). Distance to river also had high predictive power in model 3 (2000 – 2004) and supports "tending towards deforestation" as the leading land-cover trend within the 120 meter river buffer. In addition to distance to river, distance to roads in all three models was negatively related to probabilities of deforestation (increased probabilities of deforestation the closer a pixel is to the road) with high predictive power in model 3 (2000 – 2004). This follows a wealth of past research, as well as intuitive sense that infrastructure and clearing would take place closer to roads for access. Access and distance to markets is an important driver explaining contrasting patterns of land-cover and land-use in other areas (Chomitz and Gray 1996 on commercial agriculture and Kaimowitz and Angelsen 1998; Wickham et al. 2000; Nepstad et al. 2001; and Nelson et al. 2001 on access to markets and deforestation).

Land tenure: In all modeled time periods titled land ownership significantly decreased probabilities of deforestation as households moved from leased (lower) to titled (higher) ownership. Although statistically significant, tenure did not have strong predictive power in model 3, indicating there were other more influential variables. Nevertheless, the findings from these models follow the hypothesis that secure title and control over land resources can be linked to more sustainable forest management (Godoy and Bawa 1993; Nelson et al. 2001; Murphree 2003).

Socio-demographics: Education level of the household head in model 3 was influential in decreasing deforestation probabilities and followed the prediction that higher education levels of the household head can lead to other employment and economic activities (flexibility), which put less demand on clearing land. In comparison, family size did not follow my prediction that larger families increase deforestation probabilities from increased subsistence needs. Roy Chowdhury (2006a) attributed larger families and lower deforestation probability to larger households farming the same area for longer periods of time. Additionally, Roy Chowdhury (2006a) emphasizes that this result could occur if families are further along in their lifecycle. Even though family size showed a decrease in deforestation probability, its predictive power in the model was very small, indicating this variable it is not a strong predictor of deforestation within the CBS, compared to other variables. Although family size among the 33 landowners ranged between 1 and 10 (mean = 4.8), this study would speculate that CBS families today do not grow the majority of their food. Because of this, family size would not considerably decrease or increase the amount of agricultural activity (and deforestation) by the household.

Socio-economics: Cattle is the most influential variable in model 3 and showed high predictive power linked to an increase in deforestation probability. Agriculture also had high predictive power on increasing deforestation probability. This presence of cattle as the leading driver of deforestation also follows in line with the worldwide leading proximate driver of deforestation (agricultural expansion for ranching and/or cultivation) (Lambin et al. 2001; Geist and Lambin 2002; Lambin et al. 2003). As mentioned earlier, having a few head of cattle is a good financial investment as one can readily sell a cow when there is an urgent need for money. Access to roads and distance to markets may be another factor encouraging cattle ranching as a good road network through most of the communities make transportation to Belize City an easy commute (roughly 35 miles). The low predictive power of cattle income in model 3 may signal that not many people sell their cattle and when they do, with the exception of a few cattle herders, the money does not get reinvested into land intensification but, rather, other household needs (e.g., emergency expenses, education, house improvements, etc). The low predictive power of agricultural income in model 3 also indicates that few people actually sell their agricultural crops (primarily for home consumption) and when it is sold, it is not invested into deforestation. In fact, families may farm the same areas over several years, as was observed by Roy Chowdury (2006a).

Conservation initiatives: Out of the 33 households interviewed, 11 households are involved in tourism-only, 10 households are involved in pledging-only, and 8 households are involved in both tourism and pledging. Pledging, a variable that could be modeled over the three time periods, followed the transition from increasing deforestation probability in model 1 (1989 – 1994), decreasing deforestation probability in model 2 (1994 – 2000), and then increasing deforestation probability again in model 3 (2000 – 2004). Tourism-only and pledge-only residents increased deforestation probability in model 3. The second chapter of this dissertation showed why tourism and the pledge might be considered financial failures for conservation, pointing to the inequitable distribution of tourism participation and benefits from an elite capture of benefits by a few households since 1998. Tourism jobs and income may motivate residents to protect howler monkey habitat and deforest less. However, if benefits are not linked to conservation 'inputs' or the benefits are considered too small, revenue received may actually be reinvested into activities that undermine conservation efforts (e.g., cattle ranching) (Christ et al. 2003; Aylward 2003; Kiss 2004).

Current dissatisfaction in the pledge can be linked to no current financial compensation when earlier payments were made in 1998 and 2000. Pledging influences a decrease in deforestation probability during model 2 (1994 – 2000), which may be explained through coinciding with these two payment years. However, by this same argument this decrease in deforestation probability should have also been observed in model 3 (2000-2004), accounting for the impact from the received payment, rather than increasing deforestation probability. This may signal that other influential variables in this model (e.g., cattle, agriculture) or other variables not accounted for in the model (an indicator of the low pseudo R^2 value) may have provided greater incentive than the payment from pledging provided.

In comparison to the pledge-only and tourism-only variables, those involved in both pledging and tourism decreased deforestation probabilities in model 3 and showed strong predictive power. The combination of being involved in both tourism and the pledge actually decreasing deforestation probabilities may indicate that having both the values of pledged residents (whether the pledge influenced these residents or these residents had these conservation values to begin with is not known) and the income from tourism participation may actually create a stronger connection between tourism dollars received from the resource attraction (the howler monkey) and the habitat (forest) it is dependent upon. This connection can also be observed from chapter two of this dissertation where residents involved in both pledging and tourism had significantly higher perceived benefit attainment values of tourism dollars to their communities, something tourism-only and pledge-only residents did not (see chapter two).

Limitations

The accuracy of predicted deforestation and stable forest in all the models was greater than 50%, implying that each model was likely capturing more than random variation. However, the low pseudo R^2 values revealed that the variables used together do not explain the majority of deforestation that is occurring. This indicates there are other important variables missing from the models that would help explain deforestation probability (and stable forest probability) within the CBS, such as other biophysical or spatial processes (e.g., soil quality) or socio-economic variables (e.g., national policy institutions). Despite the overall low explanatory power of the variables assessed in this study, there was a need to assess the influence of the two conservation initiatives and this study helped to better understand their role on deforestation probability. In addition, this study provided a better understanding of the influence of other potential drivers chosen a priori from the established literature and from time spent in the research site and region.

Modeling studies conducted by Roy Chowdhury (2006a, 2006b) linking social survey data with land-cover change also revealed fairly low pseudo R^2 values, indicating variables used in this study were also not explaining the majority of deforestation occurring. This is an important step in better understanding data, however, and the knowledge gained can be used in subsequent studies to incorporate other factors that might be more influential. It was not possible to obtain reliable figures for population within the CBS and various macro-level policy institutions that may have encouraged or discouraged land intensification practices were not known (e.g., subsidies, market changes, agricultural loans, etc.). With regard to spatial processes, one limitation to this study was that the Belize ARC GIS soil and geologic cover maps were not at the detail needed to show differentiation within the CBS. Further research should incorporate other factors to better explain deforestation trends within the CBS.

Conclusion

Relationships between humans and the landscape are complex, and vary greatly according to biophysical, cultural, socio-political and economic perspectives. It is these interrelationships between areas such as biophysical and locational properties, land tenure**,** economic, and socio-political that will allow a better understanding of drivers of LULCC (Binswanger 1991; NRC 1998; Mertens et al. 2000; Geist and Lambin 2001; Nelson et al. 2001; Hubacek and Vazquez 2002).

Across the models, trends show riparian areas are more likely to be deforested, as are areas closer to road networks. Agriculture and cattle are the activities most influential in driving deforestation in the last modeled time period, which is also linked to riparian areas, while higher levels of education for the household head decreased deforestation probability. Of statistical significance in the model but of lower influence were secure land title and pledging and tourism working together. Titled land ownership decreased the probability of deforestation in all three models, although did not show strong strength of effect in the last modeled time period. This indicates that it has importance in the model, but much less influence than other variables (e.g., cattle and agriculture). Similarly, pledging and tourism working together during the last modeled period indicated some level of decreased deforestation probability but not as influential as other leading drivers.

The models created in this study, similar to other LULCC modeling studies, simplify complex processes at various dimensions and, in reality, highlight only some of the variables most likely influencing deforestation within the CBS. Nevertheless, this study helped to explore and identify the relevant influence of some of the factors affecting deforestation. This information can be used to assess the effectiveness of conservation initiatives and impact of other land-use activities and predict future landscape change. In addition, this study will contribute to more reliable decision making with respect to conservation planning and landscape management and is part of an emerging focus of research coming out of the LULCC community linking social survey information from local land managers to land-cover changes.

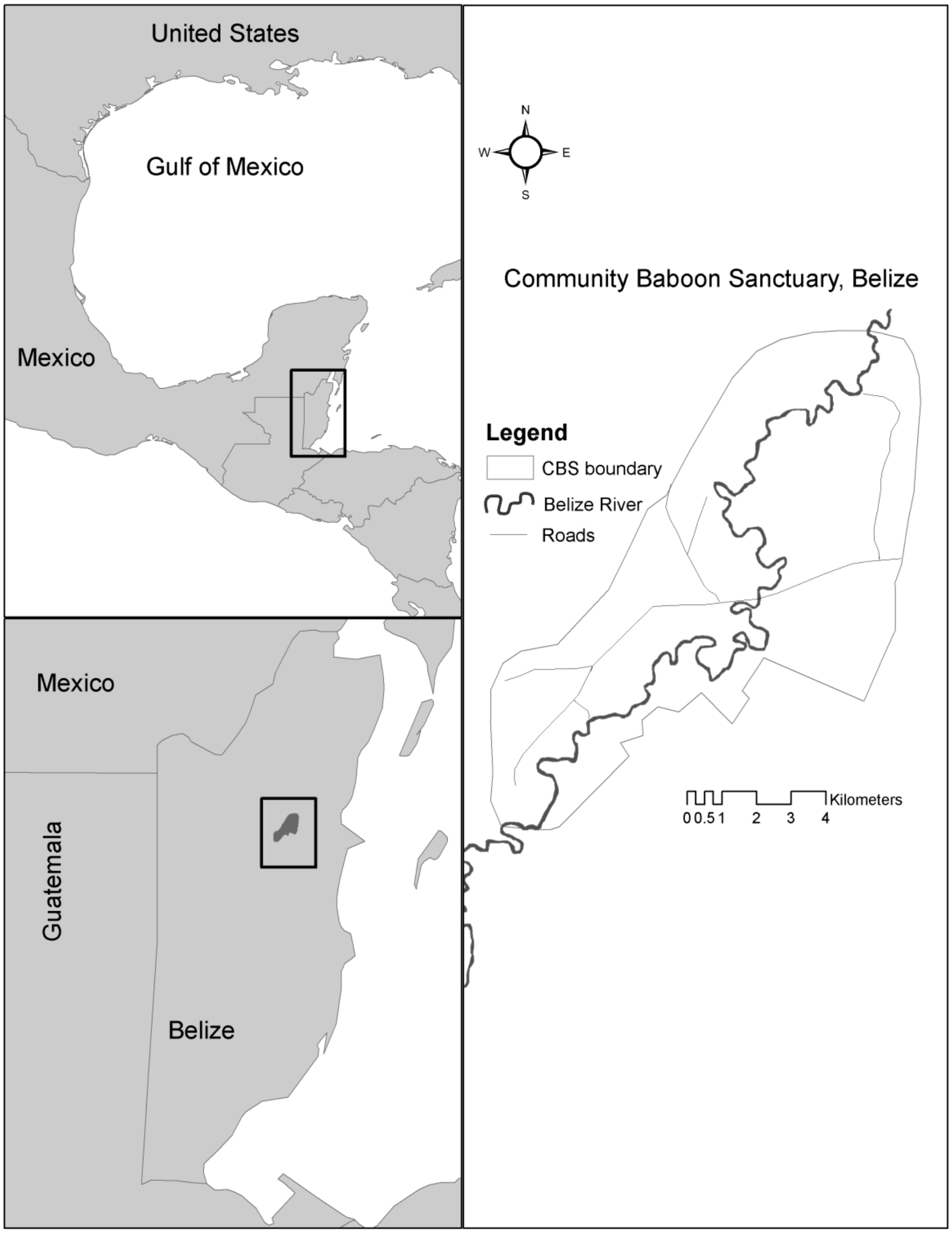


Figure 3-1. Map of the Community Baboon Sanctuary, Belize, Central America

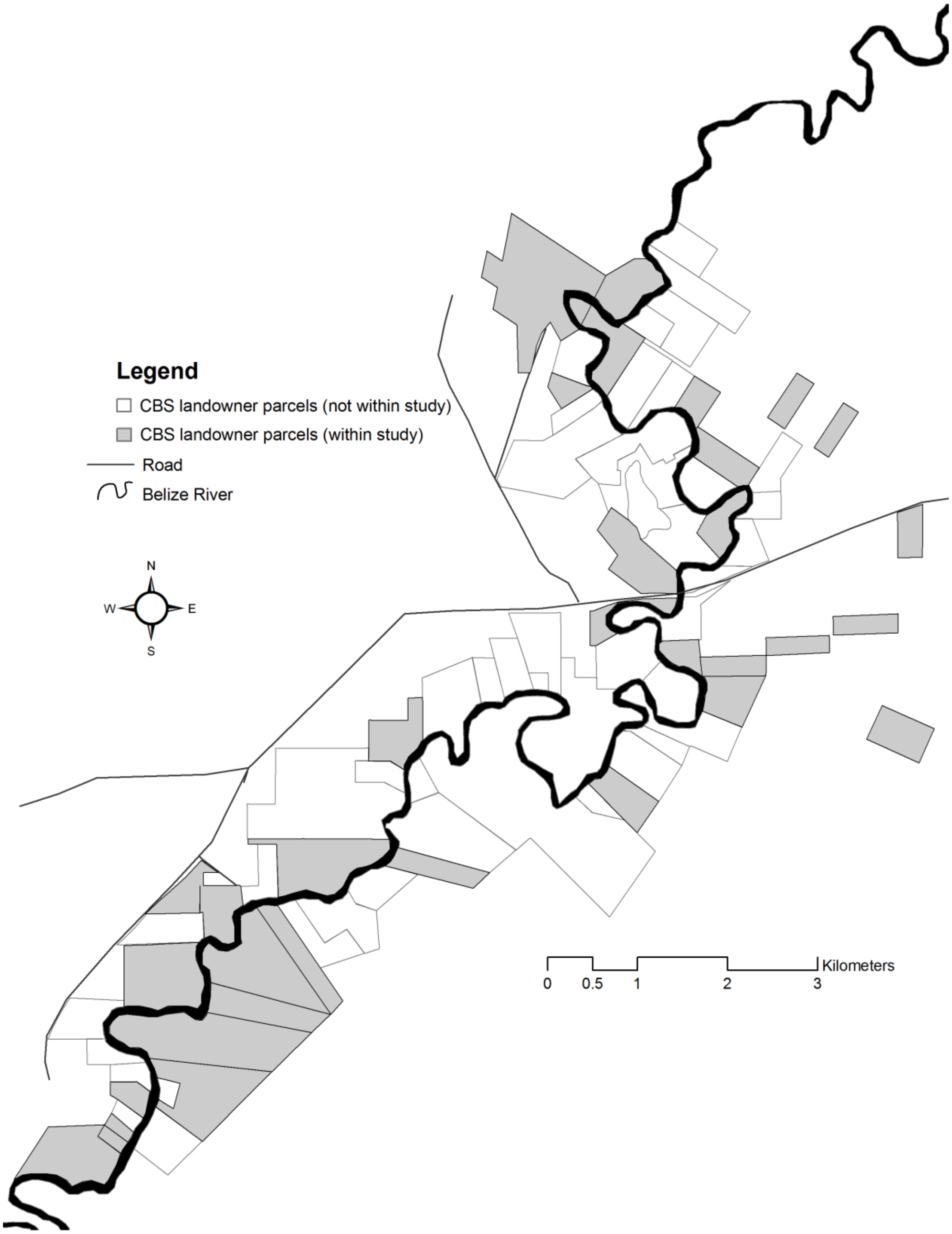


Figure 3-2. CBS parcel map of study location

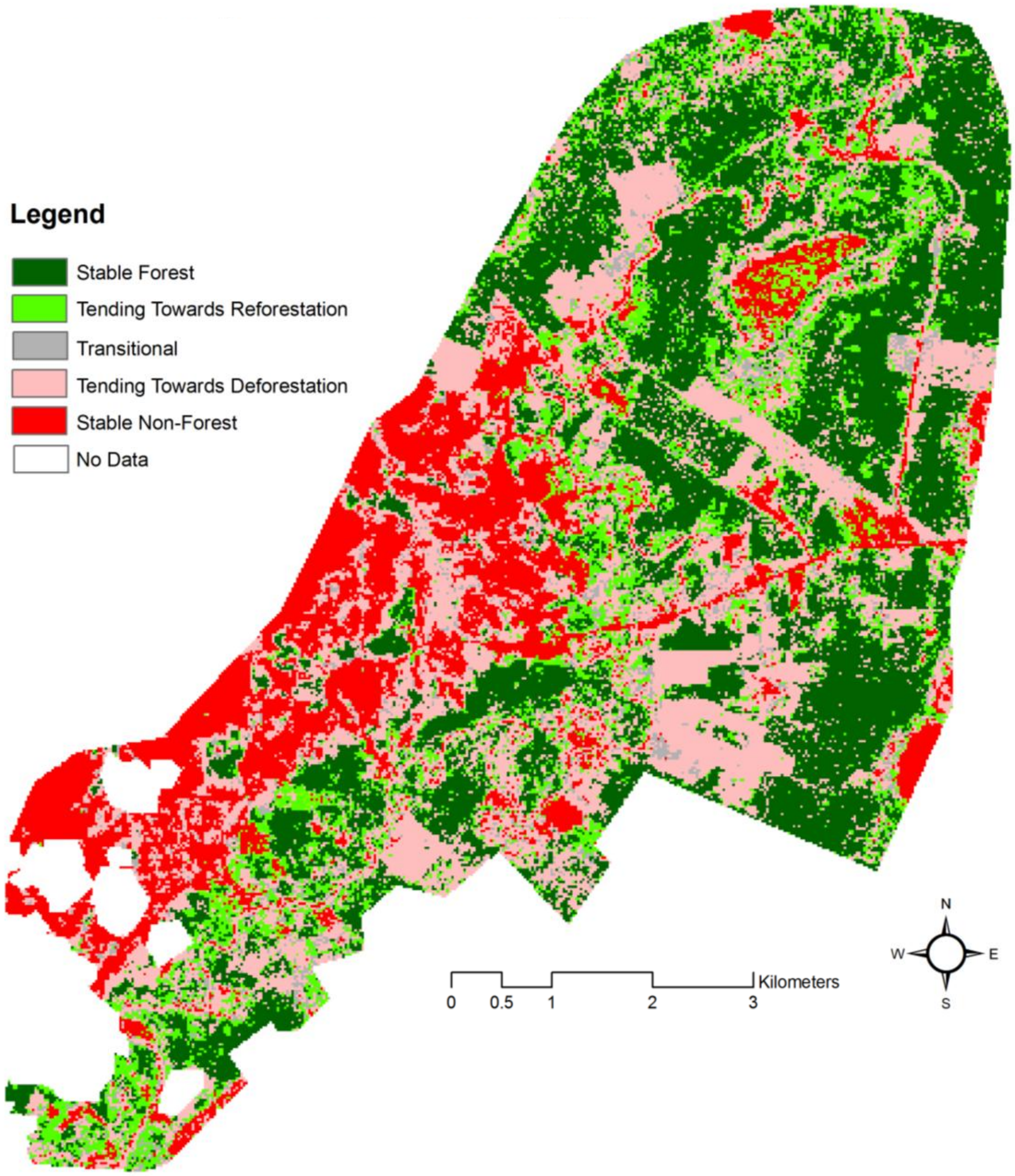


Figure 3-3. Land-cover change trends for CBS.

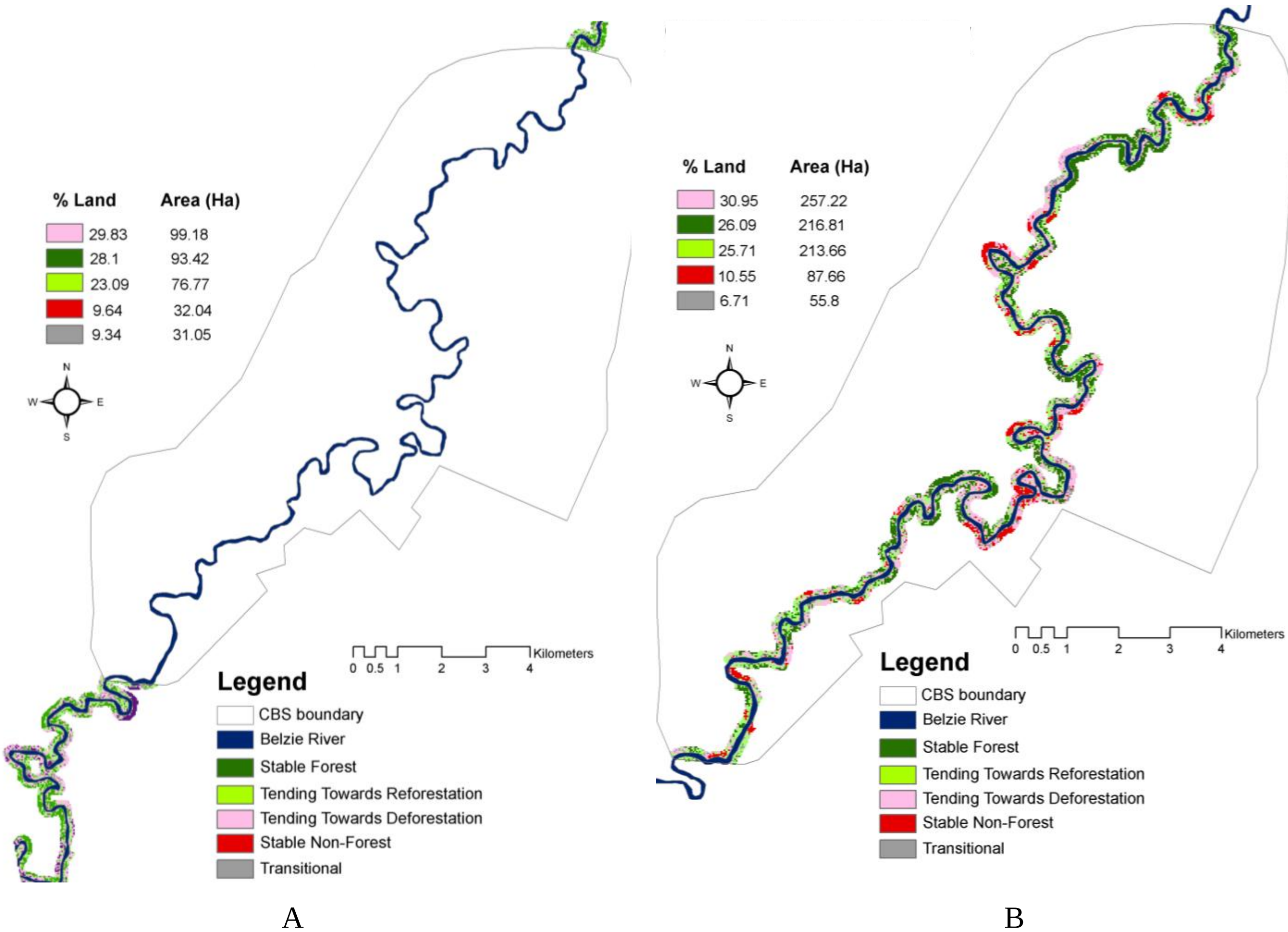
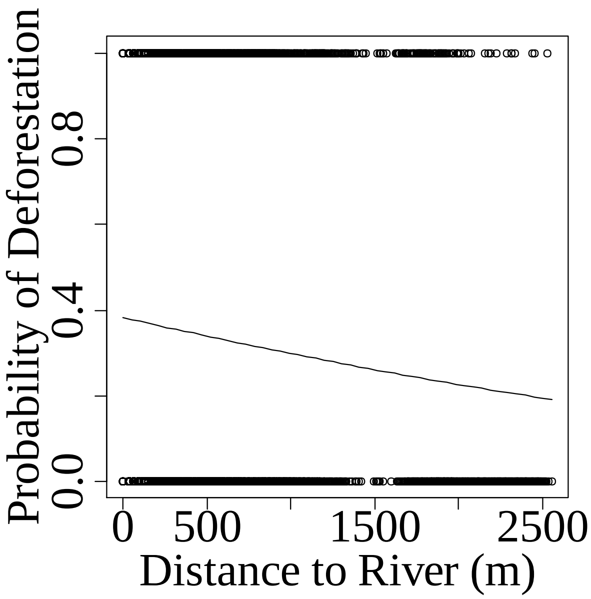
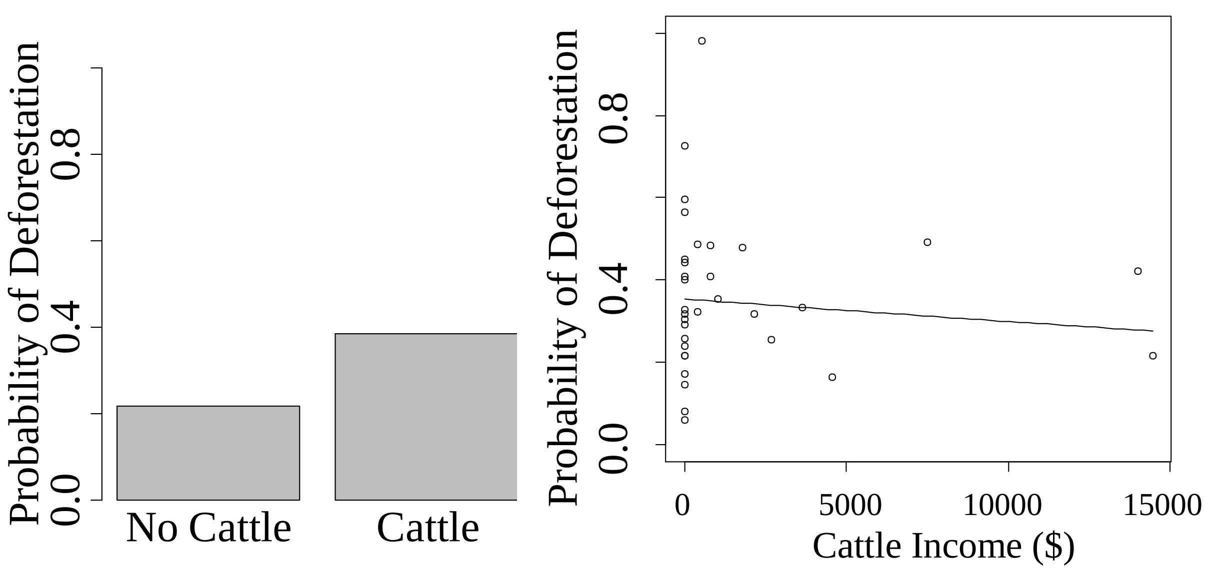


Figure 3-4. Change detection analysis for 120 meter river buffer outside (A) and inside (B) the CBS.



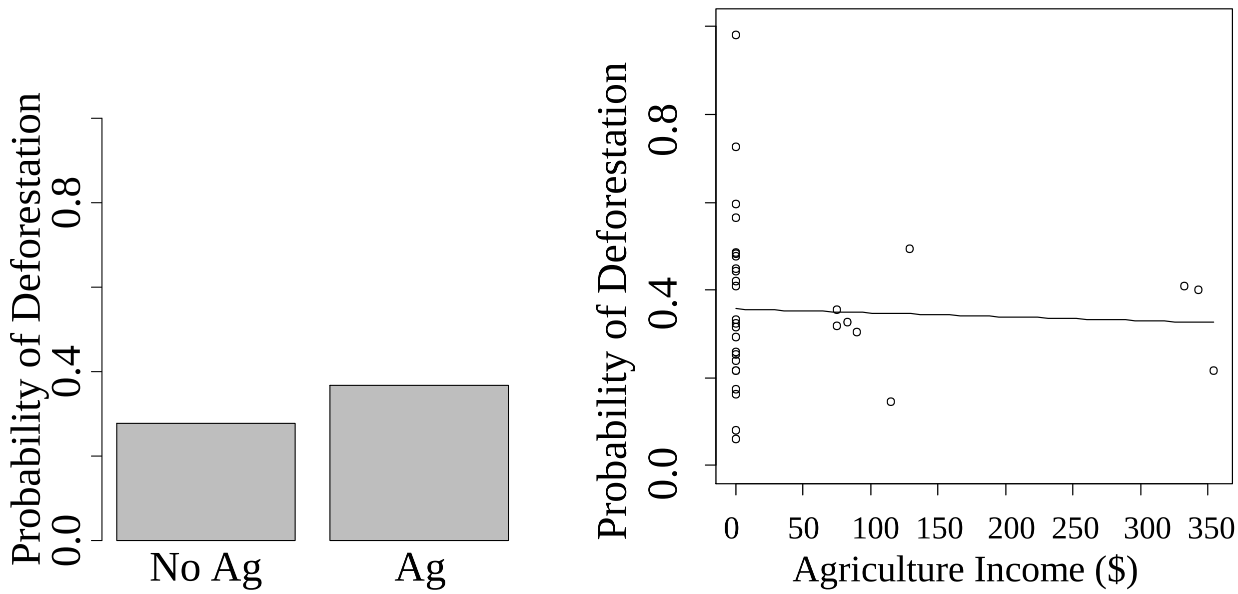
A B

Figure 3-5. Probability of deforestation as a function of distance to (A) river and (B) road networks in Model 3 (2000 – 2004).



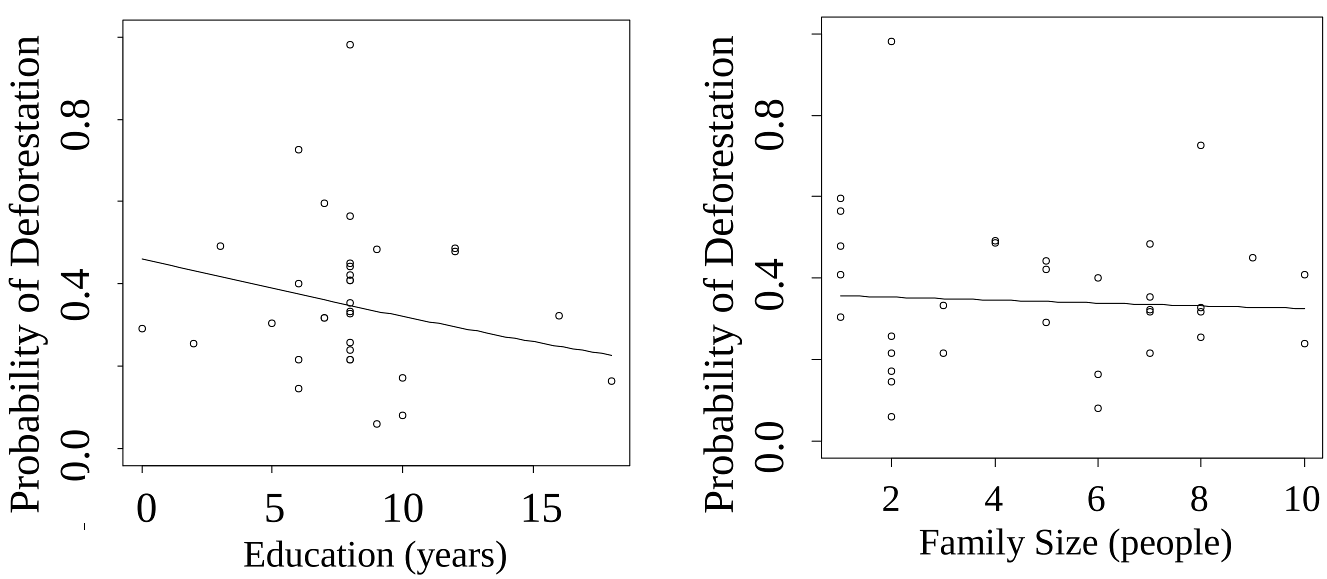
A B

Figure 3-6. Probability of deforestation as a function of (A) Cattle (B) Cattle Income in Model 3 (2000 – 2004).



A B

Figure 3-7. Probability of deforestation as a function of A) agriculture and B) agriculture income in Model 3 (2000 – 2004).



B

Figure 3-8. Probability of deforestation as a function of (A) education of household head and (B) family size in Model 3 (2000 – 2004).

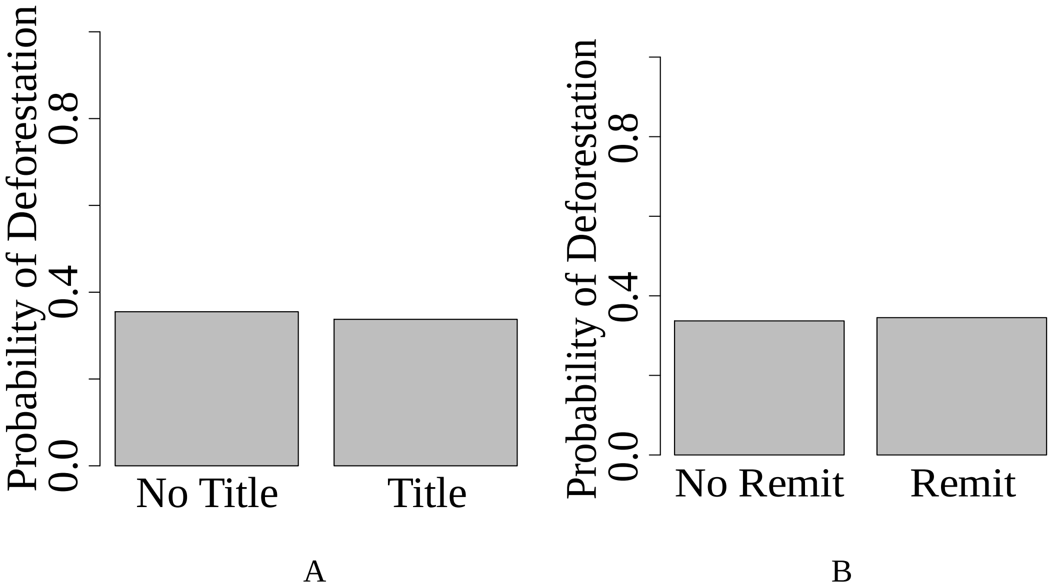


Figure 3-9. Probability of deforestation as a function of A) tenure and B) remittances in Model 3 (2000 – 2004).

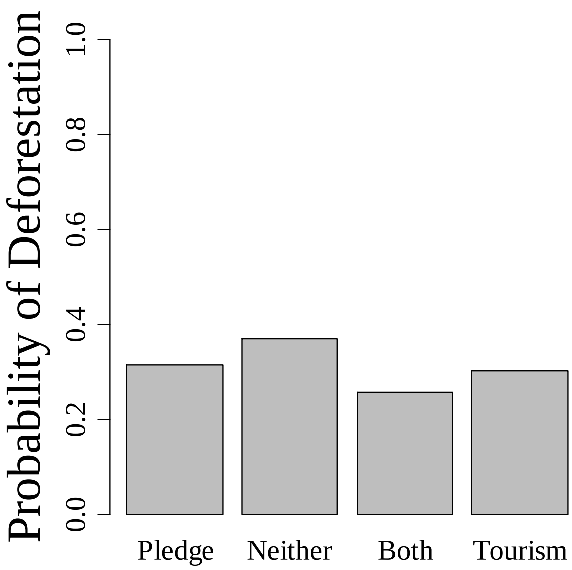


Figure 3-10. Probability of deforestation as a function of conservation initiative in Model 3 (2000 – 2004).

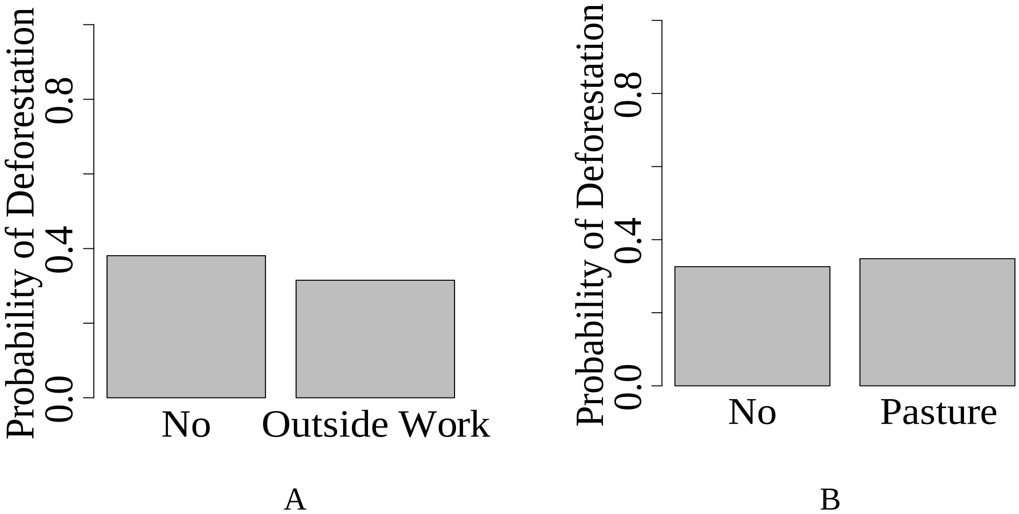


Figure 3-11. Probability of deforestation as a function of A) outside (CBS) work and B) pasture in Model 3 (2000 – 2004).

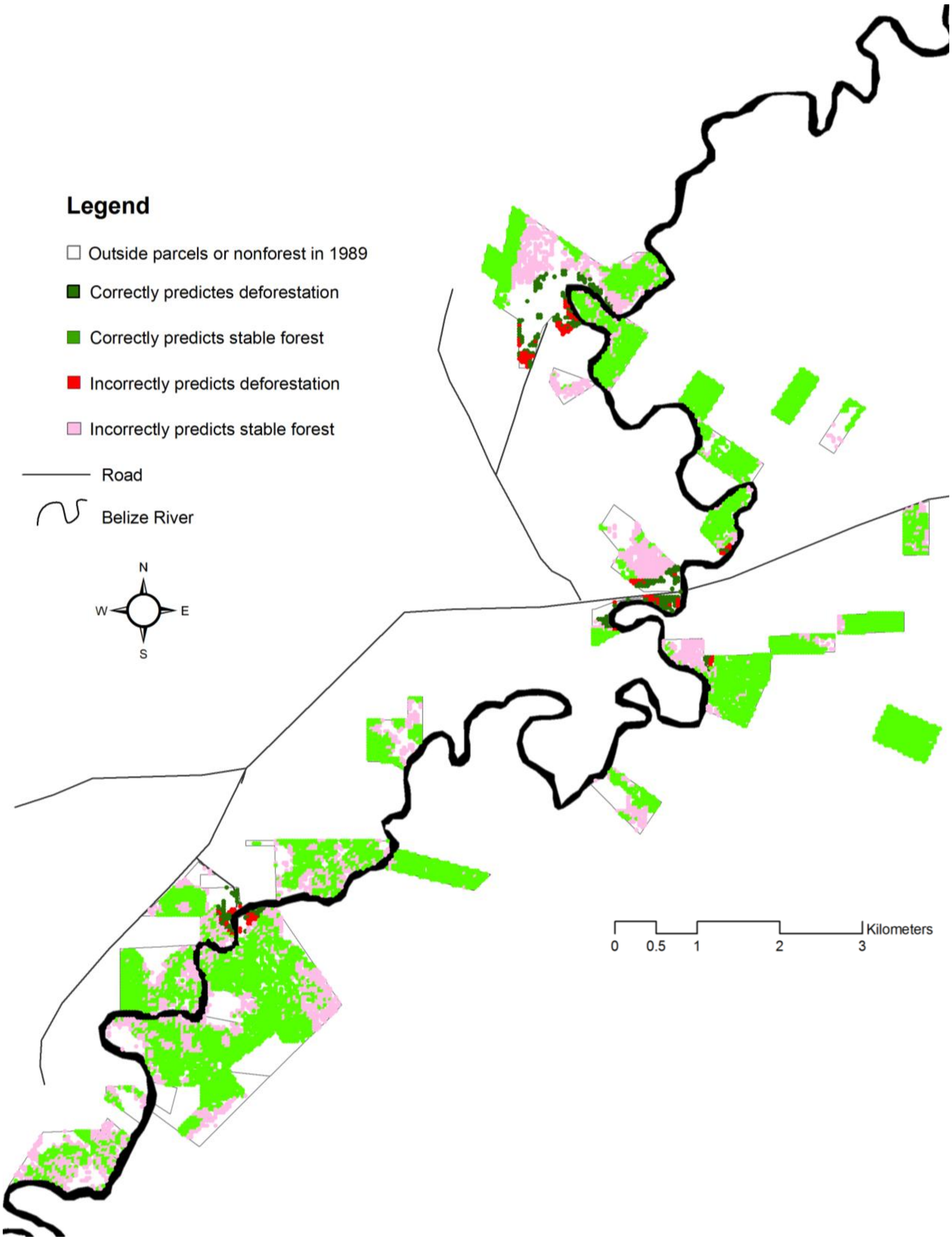


Figure 3-11. Predicted versus observed pixel deforestation / stable forest for 1989-94 (Model 1).

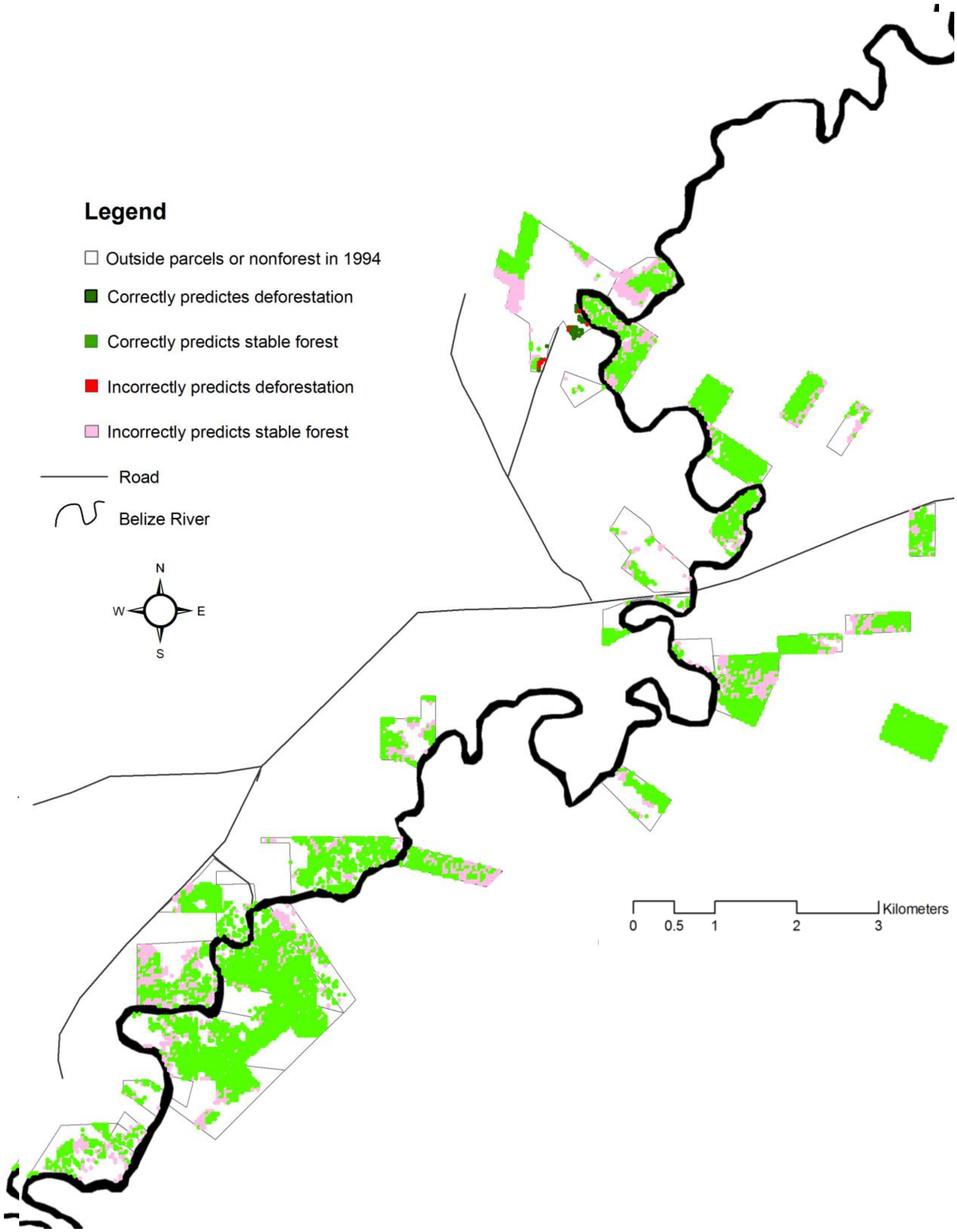


Figure 3-12. Predicted versus observed pixel deforestation / stable forest for 1994 - 2000 (Model 2).

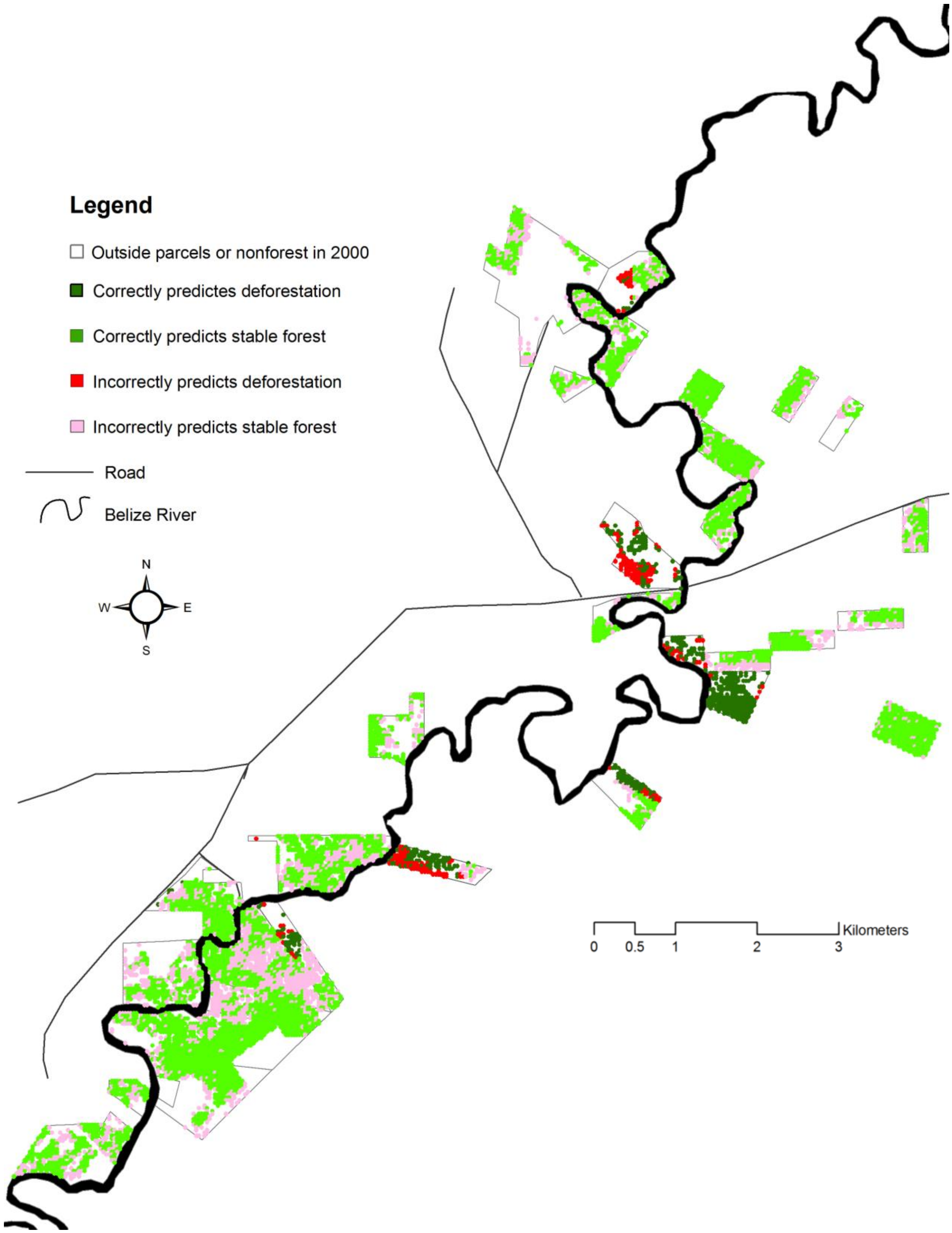


Figure 3-13. Predicted versus observed pixel deforestation / stable forest for 2000 - 2004 (Model 3).

Table 3-1. Preceding year/month precipitation information of the CBS area. To assess if rainfall patterns might impact classification, image year rainfall was compared to the 30 year average, looking at the 2-3 months prior to image month. Rainfall for the CBS is recorded at the Phillip Goldson International airport (~40 km away).

	Rainfall (mm)	30 Yr Ave	Percentages	
Nov-84	96.4	227.385	42.39506	below
Oct-84	308.7	282.2663	109.3648	normal
Sep-84	208.5	272.023	76.64793	below
Dec-89	35.1	176.4367	19.89382	below
Nov-89	196.1	227.385	86.2414	below
Oct-89	286.6	282.2663	101.5353	normal
Mar-94	24.9	47.28607	52.65822	below
Feb-94	56	79.45614	70.47914	below
Jan-94	185.2	137.0435	135.1395	above
Mar-00	32	47.28607	67.67321	below
Feb-00	32.2	79.45614	40.5255	below
Jan-00	102.8	137.0435	75.01266	below
Nov-04	229.2	227.385	100.7982	normal
Oct-04	194.2	282.2663	68.80027	below
Sep-04	195.9	272.023	72.01597	below

Rainfall Percentage	Category
<50%	Well below normal
50 – 90%	Below normal
90 – 110%	Normal
110 – 150%	Above normal
> 150%	Well above normal

Table 3-2. Accuracy Assessment of 2004 Landsat ETM+ image. The Producer's Accuracy indicates the probability of a reference pixel being correctly classified and is a measure of omission error. The User's Accuracy is the probability that a pixel classified on the map actually represents the category on the ground. This divides the total number of correct pixels in a category by the total number of pixels that were actually classified in that category. This is an accuracy measurement between the reference data and the remote sensing-derived classification map. The Kappa coefficient represents the decrease in error obtained from the classification process compared with the error that would have been obtained from random classification.

	Total number trng points	Number correct	Producers	Users	Kappa
Forest (1)	31	25	86.21%	80.65%	0.6548
Non-forest (2)	35	31	83.78%	88.57%	0.7399

Table 3-3. Change Detection Analysis of the CBS landscape. This covers the 4 image dates (1989, 1994, 2000, and 2004) with the 16 change trajectories aggregated into 5 land-cover categories.

	% CBS landscape	Ha
Stable Forest	33.4	2908.98
Tending Towards Deforestation	29.7	2582.79
Tending Towards Reforestation	18.9	1647
Stable Non-forest	13.8	1200.6
Transitional	4.1	361.17

Table 3-4. Change Detection Analysis of a 120 meter river buffer inside and outside the CBS. This covers the 4 image dates (1989, 1994, 2000, and 2004) with the 16 change trajectories aggregated into 5 land-cover categories.

	Inside the CBS		Outside the CBS	
	% landscape	Ha	% landscape	Ha
Tending towards Deforestation	30.95	257.22	29.83	99.18
Stable Forest	26.09	216.81	28.1	93.42
Tending Towards Reforestation	25.71	213.66	23.09	76.77
Stable Non-forest	10.55	87.66	9.64	32.04
Transitional	6.71	55.8	9.34	31.05

Table 3-5. Deforestation probability on household land parcels, binomial logit regression model for Model 1 (1989 to 1994), n = 8361 pixels on land parcels belonging to 33 landowners.

Variable	Coefficient	Std.Error	Z value	P value	Significance
(Intercept)	-1.0062	0.0271	-37.0760	< 2e-16	***
Distance: road	-0.5639	0.0306	-18.4350	< 2e-16	***
Distance: river	-0.3894	0.0351	-11.0880	< 2e-16	***
Tenure	-0.2329	0.0263	-8.8670	< 2e-16	***
Pledge	0.0884	0.0272	3.2440	0.00118	**

*p = 0.05, **p = 0.01, ***p = 0.001; Moran's I = 0.07, *pseudo* R^2 = 0.12 overdispersion parameter = 1.13

Table 3-6. Deforestation probability on household land parcels, binomial logit regression model for Model 2 (1994 to 2000), n = 6436 pixels on land parcels belonging to 33 landowners.

Variable	Coefficient	Std. Error	Z value	P value	Significance
(Intercept)	-1.3306	0.0319	-41.6590	< 2e-16	***
Distance: road	-0.3196	0.0358	-8.9170	< 2e-16	***
Distance: river	-0.1785	0.0385	-4.6390	3.50E-06	***
Tenure	-0.2377	0.0292	-8.1540	3.51E-16	***
Pledge	-0.1987	0.0312	-6.3660	1.94E-10	***

*p = 0.05, **p = 0.01, ***p = 0.001; Moran's I = 0.06, *pseudo* R^2 = 0.06, overdispersion parameter = 1.01

Table 3-7. Deforestation probability on household land parcels, binomial logit regression model for Model 3 (2000 to 2004), n = 6895 pixels on land parcels belonging to 33 landowners.

Variable	Coefficient	Std. Error	Z value	P value	Significance
(Intercept)	-0.7209	0.0280	-25.7700	< 2e-16	***
Cattle	0.7330	0.0465	15.7590	< 2e-16	***
Cattle income	-0.5926	0.0498	-11.8918	< 2e-16	***
Agriculture	0.5259	0.0491	10.7221	< 2e-16	***
Education (HH Head)	-0.4011	0.0424	-9.5400	< 2e-16	***
Tenure	-0.3802	0.0452	-8.4158	< 2e-16	***
Distance: road	-0.2925	0.0354	-8.2620	< 2e-16	***
Family Size	-0.3108	0.0403	-7.7100	1.26E-14	***
Agriculture income	-0.4555	0.0695	-6.5511	5.71E-11	***
Remittances	0.2907	0.0470	6.1911	5.97E-10	***
Pledge*tourism	-0.2319	0.0401	-5.7860	7.21E-09	***
Distance: river	-0.1703	0.0403	-4.2279	2.36E-05	***
Tourism	0.1343	0.0376	3.5770	3.48E-04	***
Outside (CBS) work	0.1004	0.0342	2.9358	3.33E-03	**
Pasture	-0.1057	0.0480	-2.2009	2.77E-02	*
Pledge	0.0770	0.0355	2.1670	3.02E-02	*

*p = 0.05, **p = 0.01, ***p = 0.001; Moran's I = 0.05, *pseudo* R^2 = 0.13, overdispersion parameter = 1.19

Table 3-8. Prediction results for binary logit models

Prediction type	Pixel (number)	Proportion
Model 1 (1989 - 1994)		
Correct stable forest	5791	0.72
Incorrect stable forest	2226	0.28
Correct deforestation	236	0.68
Incorrect deforestation	108	0.31
Total	8361	
Model 2 (1994 - 2000)		
Correct stable forest	5005	0.78
Incorrect stable forest	1396	0.22
Correct deforestation	26	0.74
Incorrect deforestation	9	0.26
Total	6436	
Model 3 (2000 - 2004)		
Correct stable forest	4322	0.70
Incorrect stable forest	1858	0.30
Correct deforestation	494	0.69
Incorrect deforestation	221	0.31
Total	6895	

CHAPTER 4
FOREST FRAGMENTATION AND HABITAT CONSERVATION FOR THE BLACK HOWLER MONKEY: A STUDY WITHIN THE COMMUNITY BABOON SANCTUARY, BELIZE

Anthropogenic activities have led to forest cover loss worldwide, with forest fragmentation within developing tropical regions occurring at an alarming rate (Rudel and Roper 1997; Laurance 1999; Sanchez-Azofeifa et al. 2001; Lamb et al. 2005; Abdullah and Nakagoshi 2007). Fragmentation, defined as the *"*breaking up of a habitat or cover type into smaller, disconnected parcels*"* (Turner et al. 2001, p.3) affects forest habitat when large, continuous forests are divided into smaller blocks, either by roads, clearing for agriculture, urbanization, or other human development (Kupfer et al. 2006). The concern with extensive deforestation is the resulting 'forest island' habitats within a fragmented landscape that can be more easily accessed for further degradation, such as over-hunting, ground fires, and logging (Horwich and Lyon 1990; Cayuela et al. 2006). Smaller forest fragments can also result in the "empty forest" syndrome (and often from human activity) where trees are still standing but the species that make up the complex ecosystem are not (Redford 1992; Robinson 1996).

Fragmentation affects a variety of population and community processes over a range of temporal and spatial scales with significant implications for biodiversity conservation (Lovejoy et al. 1986; Kapos 1989; Saunders et al. 1991; Debinski and Holt 2000; Laurance et al. 2000; Fahrig 2003; Githriu and Lens 2007). Habitat area loss and patch isolation can change predator-prey dynamics, competitive interactions, and species composition, which may affect community structure (Fahrig and Merriam 1985; Hobbs 1993; Palomares et al. 1996; Debinski and Holt 2000) or lead to extinction of vulnerable species (Burkey 1995; Weaver et al. 1996). Characteristics that determine the principle effects of a fragment are isolation (connectivity, surrounding landscape change, distance from other remnants, and time since isolation) and microclimate change (wind and edge effects, radiation, water fluxes). In addition, remnant size and shape, and position within the landscape can also influence the effect of fragments (Marsh 1999). In a fragmented forest, edge effect is one of the distinguishing features, defined in conservation biology as "the distinct edge between previously undisturbed forest and deforested clearing" (Lovejoy et al. 1986).

Landscape ecology seeks to understand spatial arrangements and their ecological effects, examining interactions between the spatial landscape structure, function, and temporal change. It is through the identification and quantification of landscape patterns that our understanding of these interactions between landscape structure and ecological processes develops (Turner et al. 2001). Measuring fragmentation (e.g., habitat fragmentation and forest fragmentation) is one way to quantify landscape pattern. The effects of forest loss and fragmentation can be interpreted with landscape metrics, algorithms that quantify specific spatial characteristics of patches, classes of patches, or entire landscape mosaics (McGarigal and Marks 1995).

Studies on forest fragmentation have used island biogeography theory (within the landscape ecology discipline) to estimate species survival within fragments (Saunders et al. 1991; Redford 1992; Bierregaard and Dale 1996), the optimum size of fragments for species conservation (e.g., SLOSS; Single Large Or Several Small: Gilpin and Diamond 1980; Shafer 1995), and predicting species numbers (MacArthur and Wilson 1967; Wilcox 1980; Shafer 1995). Another theoretical framework for studying forest fragmentation out of landscape ecology, metapopulation theory, assesses the impact of habitat fragmentation on population viability. This theory differs from island biogeography in that it assumes no persistent mainland habitat, but rather a network of small patches, and also focuses on a single species. The importance is on dispersal among habitat fragments, where inadequate dispersal and habitat loss past a certain critical threshold will lead to extinction (Harrison and Bruna 1999).

Primate Populations

Forest fragmentation has become a principle focus of conservation and ecological research on organisms in tropical regions, including primate populations (Lovejoy et al. 1984; Offerman et al. 1995; Laurance and Bierregaard 1997; Schelhas and Greenberg 1996; Harrison and Bruna 1999; Clarke et al. 2002; and Laurance et al. 2002). Research on the effects of deforestation on primates has largely focused on habitat degradation, reduction, and isolation (Andren 1994; Marsh 2003). When primate populations are isolated from each other due to habitat fragmentation, continued habitat decline (including human encroachment and hunting) further endangers these populations (Rylands et al. 1995; Estrada and Coates-Estrada 1996; Crockett 1998; Estrada et al. 1999). How severe a disturbance is to a primate species depends on the composition and spatial layout of remaining habitat patches, such as shape, size, isolation from other habitat patches, and amount of edge habitat (Saunders et al. 1991; Collinge 1996).

Concern for the black howler (*Alouatta pigra)* stems from substantial habitat loss (56%) within the howler's range with a predicted 70% population decline over the next 30 years if trends continue (IUCN 2003). *A. pigra* occurs in Belize, northern Guatemala, and parts of Mexico (Campeche and Quintana Roo, northern Chiapas, and parts of Tobasco states) (Horwich and Johnson 1986). Black howler monkeys are found primarily in low altitude areas under 1,000 ft. (300m) asl, and in riparian and seasonally flooded forests (Freese et al. 1982; Horwich and Johnson 1984; Horwich and Lyon 1990; Horwich 1998; Silver et al. 1998). Although *A. pigra* is classified at a low risk of extinction according to the Mace-Lande system (Rylands et al. 1995), their restricted geographic distribution in habitats that are being rapidly fragmented and converted to agriculture and pasture places this primate species at risk (Estrada et al. 2006).

Some scientists believe *A. pigra*'s preference for riverine and seasonally flooded forests explains its narrow distribution, compared to other howler species (Horwich and Johnson 1986; Estrada et al. 2002).

Their association with riverine areas has been explained by the high numbers of figs (*Ficus spp.*), an important food source with fruits available throughout the year (Milton 1991) that affects population and troop size (Horwich and Johnson 1986). A study by Estrada and Coates-Estrada (1984) in Los Tuxtlas, Mexico found *A. palliata* spent an average 49% of their feeding time monthly eating *Ficus* spp. fruits. Within the Community Baboon Sanctuary, Belize, *Ficus* spp., especially fruits and leaves of strangler figs, are an important year-round food source (Estrada and Coates-Estrada 1984), which also may point to howlers as important fig dispersers in areas with high howler populations (Marsh 1999). *Ficus* spp. has been considered to play an important role in howler conservation (Coates-Estrada and Estrada 1986; Milton 1991; Serio-Silva et al. 2002) and has even been suggested as a keystone tropical forest resource (Terborgh 1986). Ficus *spp.* are also considered forest-fringe species, found both along river edges and forest edges (Estrada et al. 2000; Kratter et al. 2001; Andrews and Bamford 2008) which would increase their availability in fragmented forest environments.

Initial concern for *A. pigra* was stimulated by Smith (1970) who suggested they prefer "extensive, undisturbed and mesic tropical forest" (p. 365). More recent studies, however, suggest *A. pigra* inhabit a wider range of evergreen and semi-evergreen forests, including disturbed and riverine forests (Crockett 1997). Indeed, Marsh (1999) regularly observed *A. pigra* using forest edges for feeding, traveling, resting and howling, while Jones (1995) suggests *A. pigra's* high reproductive rates, their ability to colonize new patches and their folivorious diet of leaves, which in comparison to flowers and fruits are an abundant and stable source of food, may even contribute to their survival in fragmented habitats.

Black howler monkeys typically live within troop sizes under 10 individuals (Horwich and Gebhard 1983; Ostro et al. 2001), with territory size ranging from 3 to 25 acres (Horwich 1998; Belize Zoo 2006). Small troop size may be an adaption for surviving in fragmented habitats (Ostro et al. 1999) and a function of resource distribution (Chapman and Chapman 1990). However, mean troop size in continuous forest was 3.16 individuals at Muchukux, Quintana Roo (Mexico) (Gonzales-Kirchener 1998) and 6.3 individuals at Tikal, Guatemala (Coelho et al. 1976), while in fragmented riverine forests in Belize, troop size was between 3 and 9 individuals (Silver et al. 1998). Howlers typically have smaller home ranges (<10 ha) than other primates, which may explain their persistence in forest fragments (Crockett and Eisenberg 1987). *A. pigra* is generally found to have the lowest densities of howlers (Chapman and Balcomb 1998). However, in reports from the Community Baboon Sanctuary, Belize, population densities were among the highest documented in the literature for *A. pigra*, with population densities reported as high as 178 individuals per km^2 in 1999 (Horwich et al. 2001), up from 31.9 per km^2 in 1985 (Jones and Horwich 2005). This suggests tolerance of *A. pigra* to habitat reduction and fragmentation but may also suggest a high animal load on the resources present (Estrada et al. 2002)

For primates in general, body size and habitat specialization have been considered the most important parameters related to extinction. However, diet requirements and social structure are also important survival factors, considering howlers are still found in small forest fragments despite being one of the largest New World primates (Marsh 1999), weighing between 15-20 lbs / 6-7 kg (Horwich and Lyon 1990). Black howlers are best described as “folivore-frugivores”

(Crockett and Eisenberg 1987) with studies in the Community Baboon Sanctuary, Belize showing young leaves accounting for 37% and fruit 41% of their diet (Sliver et al.1998). In addition, a study of 2519 trees sampled in adult tree transects of troop home ranges, 71% were used by howlers (Marsh 1999). Bernstein et al. (1976) attributes howler adaptability to fragmented environments following agricultural expansion in northern Columbia to their flexible diets. It is thought that the howler is able to minimize energy expenditure through small home ranges (and short day ranges), relatively small troop size, and highly folivorous and flexible diets which, combined, improves conservation likelihood (Milton 1980; Estrada et al. 1999; Bicca-Marques 2003; Fuentes et al. 2003).

Belize Forests

Deforestation and increasing human population are causing declines of fauna throughout most of the tropics but the forests of Belize have been a concern for conservation biologists since the 1980's (Parker et al. 1993). Beginning in the 1980's, Belize was thought to be 97% forested with only a 0.2 % annual forest loss. During 1990-2000, however, Belize's deforestation rate (2.3% per year) surpassed that of Central America (1.2% per year) (DiFiore 2002) and forests in Belize now total only 59% of the total land cover (FAO 2001), with trends showing agricultural intensification replacing forested landscapes (PfB 2000). In north-central Belize deforestation has been more severe with only 30% of the original forest cover remaining (King et al. 1992). The main activities encouraging deforestation and fragmentation of remaining forests in Belize are cattle ranching, large-scale agriculture, milpas (small-scale slash and burn farming), urban growth, and logging (Horwich and Lyon 1990).

Study Objectives

Along with retaining certain habitat areas, conservation strategies are increasingly focusing on the spatial configurations of habitat across landscapes (Thomas et al. 1990; Pulliam et al. 1992). How severe a disturbance is to a primate species depends on the composition and spatial layout of remaining habitat patches, such as shape, size, isolation from other habitat patches, and amount of edge habitat (Saunders et al. 1991; Collinge 1996). Considering some of the most threatened primate communities now survive only in fragmented forest habitats (Cowlishaw and Dunbar 2000; Marsh 2003), the quality and spatial characteristics of forest fragments plays an important role in understanding how to best conserve and manage current populations (Lindenmayer 1999; Chapman and Lambert 2000; Harcourt 1998, 2002; Fahrig 2003; Marsh 2003). To understand the tolerance of *A. pigra* to habitat fragmentation, information on forest fragmentation and rates of forest loss, along with demographic information for *A. pigra* populations is needed (Estrada and Coates-Estrada 1996; Cuarón 2000). In addition, information linking data from such sources as satellite imagery, forest cover, habitat fragmentation, and human land-use patterns, among others, is also needed to better understand relationships between areas of human population and primate survival (Garber et al. 2006).

This study assessed forest fragmentation within the Community Baboon Sanctuary (CBS), Belize, a community reserve that has existed since 1985 with little monitoring of deforestation and, more specifically, forest habitat fragmentation for the black howler monkey, the impetus for the creation of the CBS. This study focuses on the following objectives:

1. To examine forest cover change of the CBS landscape and 500 meter river buffer from two time periods over 15 years (1989 and 2004);

2. To assess how forest habitat for the black howler monkey has changed over this 15 year time period and how much suitable habitat currently exists (for the year 2004), based on minimum patch size and distance requirements; and

3. To assess the performance of the CBS as a IUCN Category IV protected area in terms of forest cover and fragmentation results and howler monkey populations (from past population surveys).

Methods

Study Site

The Community Baboon Sanctuary (CBS), Belize (17° 33'N, 88° 35'W), an IUCN Category IV protected area, was established in 1985 to protect black howler monkey (*Alouatta pigra*) populations and their forest habitat (Figure 4-1). As a Category IV protected area, the conservation focus is defined as an "area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species" (IUCN 1994). The CBS was the effort of two American scientists and a local non-governmental organization (Belize Audubon Society) who worked with private landowners of 7 villages to encourage them to pledge to help protect riparian forest landscapes (Horwich and Lyon 1998) for black howler populations. Located in the climatic region of north-central Belize, the forests of the CBS are classified as lowland, semi-deciduous rainforest. Today the CBS is a patchwork of secondary forests from 10-75 years old, interspersed with cleared areas and secondary growth from 300 years of periodic logging (Horwich and Lyon 1990).

There are roughly 220 households in 7 villages for a human population density of ~106.38 individuals per km^2 (Jones and Young 2004). Although the literature cites the CBS as an area of 4800 ha ($48km^2$) (Horwich and Lyon 1990), this study incorporates twice this amount (8703.54 ha) as defined by village boundaries. Although less prevalent as in the past, slash and burn agriculture ("milpa") is still practiced within the villages, although primarily for home consumption. Riverine areas are favored for agriculture because of their more fertile soils. Cattle ranching (both large and small-scale) is also a common livelihood activity, with cattle often kept by the riverside where they can easily access water.

When the CBS was established, some households signed a voluntary, written pledge to not clear forest down to the water's edge and to leave a strip of forest between property boundaries, ensuring greater habitat protection and connectivity for howler monkeys. Although landowners were not initially paid to pledge, the CBS resident management committee paid pledged landowners $125 twice (1998 and 2000) (Lash 2003). In addition, tourism focused around the howler monkey was also established to provide residents financial incentives to protect forests. Tourist numbers have increased dramatically in the last few years (13,000 in 2005) from the arrival of cruise ship tourism to Belize (see chapter 2). Tourism employment includes both permanent and seasonal jobs. However, a disproportionate number of families benefitting from tourism (13 out of 35 total in 2005) are from one village, pointing to an inequitable distribution of tourism benefits and participation which have caused dissatisfaction and resentment towards current CBS management (see chapter two).

Despite these concerns toward CBS management and the conservation initiatives, black howlers are not threatened by local residents. Howlers only occasionally damage crops, and are rarely killed as agricultural pests (Crockett 1997). Furthermore, past studies show positive views towards howlers and howler protection, with residents recognizing their local abundance and tourism attraction (Hartup 1994; Bruner 1992). Additionally, the howler's survival is greatly improved as the only primate species within the CBS with little hunting or predation threats (Jones and Young 2004; Silver et al. 1998).

The Community Baboon Sanctuary Howler Populations

Howler populations and population densities within the CBS appear to have been expanding rapidly since 1985 (Table 4-1) from an estimated 800 individuals in 1985 to an estimated 3000 – 5000 individuals in 2003 (Brocket 2003). The last population density survey was conducted in 1997, and howler population densities were estimated as high as 178 individuals per km^2 in 1999 (Horwich et al. 2001), the highest ever recorded in the literature for *A. pigra*. Howler surveys were conducted using similar methodology. In 1985 and 1999, surveys were carried out within a $4.05km^2$ study area (1985) and in a $0.63km^2$ primary study site (from 1990 to 1999) (Jones et al. 2008). These actual counts of howlers were then multiplied by the CBS area to estimate the total population (Horwich pers.comm. 2008). The survey conducted in 2003 was carried out in a similar manner: 1581 individuals were counted covering a portion of each of the 7 CBS villages.

Remote Sensing

Remote sensing enables an assessment of the CBS to protect forest habitat of the black howler monkey (*Alouatta pigra*) and offers a unique opportunity for long-term assessment. A change detection analysis of the forest landscape on a spatial and temporal scale evaluated the rates and trends of forest change over 15 years (1989 and 2004) of the CBS and within a 500 meter buffer of the Belize River (within the CBS). Image processing and spatial analyses were performed in Erdas Imagine and ArcGIS.

A 1989 Landsat TM image and a 2004 Landsat ETM+ were used to analyze spatial distribution and extent of forest cover within the CBS and within a 500 meter river buffer along the Belize River. Images were taken between November and December, both considered to be within the dry season, to decrease the impacts of seasonal variations on biophysical properties and change detection analysis processes (Jensen 2005).

Radiometric calibration and atmospheric correction procedures (Green 2000) were conducted to correct each Landsat band for sensor, illumination, and atmospheric sources of variance to ensure that the change detection analysis truly detected changes at the Earth's surface

(Jensen 2005). Geometric correction of the 2004 image was performed using a 1:50,000 scale map of the study area from the Land Information Center (LIC) in Belize (UTM Zone 16, WGS 1984). Image-to-image registration was then performed using points from the already rectified 2004 image to register the 1989 satellite image. The root mean square (RMS) error of each registration was maintained below 0.5 pixels (<15 m).

Ground truthing of the 2004 image was conducted from September through December, 2005 within the CBS. Training sample protocol forms from the *Center for the Study of Institutions, Population, and Environmental Change* (CIPEC) were used (CIPEC 1998), and locations were recorded with a GPS (global positioning system). Other qualitative descriptions, including photographs, were recorded for reference and comparison with classified maps and satellite imagery. Informal interviews with landowners and personal observations added information on the nature and extent of land uses. Training samples covered a 90 x 90 m area to ensure that at least one full pixel fell within that particular land cover. Sixty-six training sample points were taken (31 for "forest" and 35 for "non-forest"), including as many different types of land cover in and around the CBS as possible. Although training samples within the CBS were primarily taken along roads or along the Belize River, vantage and edge training sample points were also taken in areas difficult to access. The forest class was defined as having a canopy cover of 25% or above. This was based on two sources of data: data from a study conducted within the CBS that estimated deciduous forest habitat to have 40–75% canopy cover and riparian forest habitat to have 65–100% canopy cover (Jones unpubl. data) and an estimate by Horwich (personal comm. 2008) based on knowledge of howlers' tolerances to some disturbance and less dense forests, including their preferences for certain vegetative growth.

A hybrid supervised / unsupervised classification with 60 classes was conducted on the 2004 image, using collected training samples and GPS point data. Clouds were first removed from both images and a mask was then applied to each image prior to classification. After classifying the various land cover classes, non-forest classes (both natural and anthropogenic non-forest areas) were merged into a final non-forest class (NF). The other class was a forest (F) class. An accuracy assessment on the 2004 classified image resulted in a producer's accuracy of 86% (F) and 84% (NF) and a user's accuracy of 81% (F) and 89% (NF) for an overall classification accuracy of 85% and an overall Kappa Statistics of 69%. Thomlinson et al. (1999) set as target an overall accuracy of 85% with no class less than 70%. The 1989 image was classified through comparison with signature mean plots of 2004 classes, and also contrasting vegetation in ArcGIS using the NDVI (Normalized Difference Vegetative Index) and the thermal band. The result of the classification process was the creation of "forest" and "non-forest" classifications for the two image dates (Figure 4-2).

Landscape Metrics

Landscape ecology explains the ecological effects of spatial arrangements, especially interactions between the landscape's structure and function over time. Quantification of landscape patterns improves understanding of these interactions between landscape structure and ecological processes (Turner et al. 2001). Measuring fragmentation (e.g., habitat fragmentation and forest fragmentation) is one way to quantify landscape pattern. The effects of forest loss and fragmentation can be interpreted with landscape metrics that quantify specific spatial characteristics of patches, classes of patches, or entire landscape mosaics (McGarigal and Marks 1995; He et al. 2000). The sensitivity of landscape metrics to changes in levels of forest loss also shows their importance in assessing and monitoring forest fragmentation (McGarigal and Marks

1995; Trani and Giles 1999). Fragstats software (McGarigal et al. 2002) was used to run landscape metrics on the 1989 and 2004 classified images (F and NF). The following metrics were analyzed: patch size, total patch count, mean patch area, median patch area, ENN (Patch-level analysis) and Clumpy metrics (Class-level analysis). Given the important habitat needs (size, number of patches) and dispersal (distance between patches, patch aggregation), these metrics are *functional* metrics that explicitly measure landscape pattern that is relevant to the species under consideration.

The Euclidean Nearest Neighbor distance (ENN) metric measures the distance (in meters) to the nearest neighboring patch of the same type, based on shortest edge-to-edge distance, and is used extensively to quantify patch isolation. The clumpiness index (CLUMPY) metric measures pixel adjacencies (the frequency that a patch type appears next to another similar patch type on the map) (McGarigal and Marks 1995). With a range between -1 and +1, "-1" indicates the focal patch type is maximally disaggregated, "0" indicates the focal patch type is distributed randomly, and "1" indicates the patch type is maximally aggregated. To assess the suitability of howler monkey habitat using fragmentation metrics, the following criteria was used:

1. A forest patch must be greater or equal to 3 acres (1.21 ha) (Horwich 1998; Belize Zoo 2006).

2. To be considered connected, forest patches must be less than or equal to 60 meters apart. Although 50 meters appears to be the more appropriate distance, based on a studies by Onderdock and Chapman (2000) and Pozo-Montuy and Serio-Silva (2003) and Horwich (personal comm. 2007), 60 meters was chosen as the distance because of the 30 meter pixel size of the satellite image used.

For statistical analysis, Chi-square tests were conducted to assess whether ENN (using the proportion of patches that met this requirement) differed significantly ($p \leq 0.05$) across dates.

Results

In 2004, 47.61% of the CBS landscape was comprised of forest, a decrease of 23% compared to 1989 (70.87%) (Table 4-2 and Figure 4-2), with similar results for the 500 meter buffer of the Belize River, decreasing from 74.34% in 1989 to 50.64% in 2004 (Table 4-3 and Figure 4-3).

Landscape Fragmentation

The total number of forest patches within the CBS landscape in 2004 (n=1323) was more than twice that amount in 1989 (n=628), with the mean patch area in 2004 decreasing by one-third (Table 4-4). The number of forest patches that met the 3 acre or greater area requirement was 48 of 628 (7.64%) in 1989 and 102 of 1323 (7.71%) in 2004. Although the mean patch area in 2004 decreased by one-third, the median patch size for both years was the same (Table 4-4). This can be explained by several large patch sizes in 1989 that adjusted the average size.

Considering forest patches must be less than or equal to 60 meters apart to be considered connected (howler habitat requirement), the ENN metric result indicates that in 1989, 510 of 628 (81.2%) of the CBS forest patches were within this 60 meter distance from other forest patches. In comparison, in 2004 1025 of 1323 (77.5 %) forest patches within the CBS were within this 60 meter distance from other forest patches (Table 4-4). For patches greater than or equal to 3 acres in size, 44 of 48 (91.7%) patches within the CBS in 1989 and 96 of 102 (94.1%) patches within the CBS in 2004 met this criteria (Table 4-4). A Chi-square test confirmed the proportion of CBS forest patches greater or equal to 3 acres in size that had other forest patches within 60 meters did not differ significantly ($p = 0.57$) across dates.

The patch level analysis of the 500 meter river buffer shows comparable patterns to the larger CBS landscape. The total number of forest patches within the river buffer in 2004 (n=669) was greater than twice that amount in 1989 (n=267). Although the mean patch area in

2004 decreased by over two-thirds, the median patch size for both years was the same (Table 4-4). This can be explained by several large patch sizes in 1989 that adjusted the average size. The number of forest patches that met the 3 acre or greater area requirement was 17 of 267 total forest patches (6.4%) in 1989 and 64 of 669 (9.6%) in 2004.

The ENN metric result indicates that in 1989, 233 of 267 (87.3%) forest patches within the 500 meter river buffer were within this 60 meter distance from other forest patches. In comparison, in 2004 545 of 669 (81.5%) forest patches within the 500 meter river buffer were within this 60 meter distance from other forest patches (Table 4-4). For patches greater than or equal to 3 acres in size, 16 of 17 (94.1%) patches within the river buffer in 1989 and 62 of 64 (96.9%) patches within the river buffer in 2004 met this criteria (Table 4-4). A Chi-square test confirmed forest patches greater or equal to 3 acres in size within the river buffer did not differ significantly ($p = 0.59$) across dates.

Clumpy values for both forest and non-forest patches only decreased slightly in 2004 compared with 1989 values (Forest = 0.6599 [1989], 0.6499 [2004]; Non-forest = 0.6602 [1989], 0.6455 [2004]). Values for both forest and non-forest patches indicate these classes are fairly aggregated within the CBS landscape (Table 4-5). Clumpy values within the 500 meter river buffer are similar for both forest and non-forest classes across both time periods (Table 4-5). CONNECT metric values, however, show forest patches were 78% connected in 1989 but dropped to only 26% connectivity in 2004. Non-forest patches were slightly more connected in 2004 (21%) compared to 1989 (14%) (Table 4-5).

Discussion

Forest cover declined for both the CBS and 500 meter river buffer by roughly 23% between 1989 and 1994 (Table 4-2). This 23% decrease within the CBS follows similar trends for Belize with a 20% decrease in forest cover since the early 1980’s (FAO 2007). In addition, there has been a magnitude increase in the number of total forest patches from 1989 to 2004 in both the CBS and 500 meter buffer. Although the number of forest patches has increased, indicating increased forest fragmentation, overall the patch size has not changed.

Although only a small proportion of forest patches meet the 3 acres or greater size criteria, the majority of patches are highly connected to eachother, indicating dispersal potential has not been jeopardized. Additionally, both forest and non-forest patches within the CBS landscape and 500 meter river buffer are highly aggregated. Aggregation of forest patches is beneficial for howler movement. However, the fact that non-forest patches are also aggregated may impact movement across these areas and create increased fragmented ‘islands’ of forest and non-forest habitats.

Current Suitable Howler Habitat

Using habitat criteria for the howler monkey (forest patches greater than or equal to 3 acres and less than or equal to 60 meters apart) to assess the current suitability of habitat, in 2004 this comprised 44.72% of the CBS landscape and 46.74% of the 500 m river buffer landscape (Table 4-6). Considering a landscape with less than 30% habitat connectivity is considered poor fragment connectivity (Mandujano et al. 2006), the CBS has not yet met this threshold. Although howlers may need forest patches greater than or equal to 3 acres for survival processes (foraging, nesting, etc.), howlers can still move through forest patches less than 3 acres in size, as long as they are less than or equal to 60 meters apart (e.g., forest corridors for travel). Considering this, forest patches that meet the 60 meter distance requirement from other forest patches comprise 44.86% of the CBS landscape and 49.79% of the 500 meter buffer landscape. (Table 4-6).

Howler Populations

As part of a re-introduction project, sixty-two monkeys were translocated from the CBS to Cockscomb Basin Wildlife Sanctuary in Southern Belize in 1993-1994 (Koontz et al. 1993). Despite this translation, in addition to increased deforestation and forest fragmentation of the CBS landscape and 500 meter river buffer, black howler monkey populations have increased from an estimated 800 individuals in 1985 to an estimated 3,000-5,000 individuals in 2003 (Brockett 2003) (Table 4-1); several factors may explain this.

First, the flexible diet of *A. pigra* appears to be an important factor contributing to its continued subsistence within the CBS. Habitat disturbance has less effect on primate species that rely on leaves for their diet (Crockett 1997), with folivores recovering much faster from habitat disturbance than frugivores (Johns and Skorupa 1987). *A. pigra*'s description as a "folivore-frugivore" (Crockett and Eisenberg 1987) and their dietary flexibility (Milton 1980; Silver et al. 1998) probably explains their ability to subsist in a variety of habitats, including forest fragments (Horwich and Johnson 1986; Crockett 1998; Ostro et al. 1999). Spider monkeys, in comparison, are less flexible in food species selection and often cannot survive in fragmented areas (Neville et al. 1988). Riviera and Calme (2005) found in the Calakmul Biosphere Reserve, Mexico that within fragmented forest environments, howler monkeys would diversify their diet where their preferred fruit and leaf species were absent.

Secondly, the availability of figs (*Ficus spp*.) within the CBS probably has a strong role in black howler persistence. The common cohune palm (*Orbigyna cohune*) which is left uncut due to difficulty in felling and its usefulness for products and shade, is highly infested by strangler figs (42-86%) which are an important food source for the howlers (Lyon and Horwich 1996). *Ficus spp.* are also considered forest-fringe species, both along river edges and fragmented forest edges (Andrews and Bamford 2008; Kratter et al. 2001; Estrada et al. 2000).

Therefore, increased fragmentation within the CBS has most likely increased *Ficus spp.* growth and availability. In fact, a study by Marsh (1999) concluded that the forest fragments within the CBS are exceptionally good habitat for the howlers because the availability of *Ficus spp.* and other fruiting species found in fragments.

Thirdly, howler populations can increase dramatically from disease, hurricanes, and drought where they, and their habitats, are protected (Crockett, 1996; Crockett and Eisenberg, 1987; Horwich and Lyon, 1987) and can exist in disturbed and fragmented forests, and in close proximity to human populations, when there are no hunting pressures (Crockett 1997). Considering howlers are not hunted within the CBS and have few predators, these factors may also contribute to the growing population of howlers within the CBS. It is not well-known if the estimated population of howlers within the CBS in 1985 (800 individuals) was recovering from a population decline or had been stabilized at this population level for some time. Howlers throughout Central America have undergone four known population declines that have affected both the population sizes and the behavioral dynamics of remaining troops. Devastating hurricanes in 1931, 1954, and 1978 swept through the CBS (Bolin 1981; Hartshorn 1984), and in 1971, a yellow fever epidemic decimated Central American howler monkeys (Baldwin 1976; Hartshorn 1984). However, the first documented population survey of howlers within the CBS occurred in 1985.

It should be noted that along with howler population increases within the CBS, howler population densities have also dramatically increased over the past 20 years. Past studies within the CBS indicate howler densities have increased from 31.9 individuals per km^2 in 1985 (Jones and Horwich 2005) up to as high as 178 individuals per km^2 in 1999, overcrowding forest fragments (Silver et al.1998; Ostro et al. 1999; Horwich et al. 2001). Additionally, the 2003 CBS suvey (Brockett 2003) found increased overlap in troop home ranges, multi-male troops, and the first documented observance of infanticide associated with male takeovers, all of which is attributed to high population densities (and none of which had been observed in past surveys).

Although howlers appear to be adaptable to habitat fragmentation and have increased in number within the CBS over the past 20 years, in the long run increased forest fragmentation may not ensure their population viability (Bicca-Marques 2003). For example, even though howler monkeys have been found to travel across cornfields and grasslands in Mexico (Pozo-Montuy and Serio-Silva 2003; Mandujano et al. 2004), long-distance terrestrial movement of arboreal primates is relatively uncommon and most likely reflects a scarcity of resources such as food, shelter and refuge from predators (Waser et al. 1994; Bennett 1998; Olupot and Waser 2001; Baum et al. 2004). There are likely decreases in reproductive potential and inbreeding if fragmentation impacts connectivity and prevents dispersal opportunities between forest fragments (Crockett 1998; Estrada and Coates-Estrada 1996; Clarke et al. 2002). Neotropical primates in isolated fragments (inhibiting migration) that experience population declines below a certain threshold are prone to extinction (Coehlo et al. 1976).

Limitations

The distance between forest patches primates will travel is not well known or documented within the literature and has only been estimated by a few studies, ranging from 50 m (Onderdock and Chapman 2000) to 80 m (Pozo-Montuy and Serio-Silva 2003) to 150 m (Mandujano et al. 2006) to 2.6 km (Estrada et al. 2002). It is possible this study may have underestimated the distance black howlers will travel between forest patches (60 meters) but the distance was chosen with consideration from these studies' estimates and estimates by Horwich (personal comm. 2007). Considering the 30 m pixel size of the satellite image used (Landsat), and the Fragstats software's method for measuring distance (cell center to cell center), the chosen distance needed to link with the 30 m pixel size.

Continued monitoring should be conducted within the CBS on both howler population and densities and forest cover change and fragmentation to better advise community management decisions. As metapopulation theory predicts a low probability of persistence (on a regional scale) if occupation of fragments are limited, combined with a decrease in colonizing empty fragments (Ovaskeinen and Hanski 2004), future research within the CBS could complement and build on this study by identifying the occupied and unoccupied patches within the CBS, including their size and distance to other patches, to better assess dispersal and persistence probability.

Conclusion

This study examined forest cover change of the CBS landscape and 500 meter river buffer covering two years over a 15 year time period (1989 and 2004) and assessed fragmentation of forest habitat for the black howler monkey based on minimum patch size and distance requirements. Results show a 23% decrease in forest cover within the CBS and the 500 meter buffer between 1989 and 2004, with increased fragmentation of forest habitat. However, connectivity between habitat patches (less than or equal to 60 meters apart) is presently high (81.5% of the 500 m buffer forest habitat and 77.5 % of CBS forest habitat) which indicates dispersal and colonizing between most forest patches has not been jeopardized.

Reaching a verdict on the effectiveness of conservation within the CBS may be a little more complex than merely saving forests and, therefore saving howlers within the CBS, as increased fragmentation actually provides better habitat for *ficus spp.* (e.g., figs), the preferred food source for howlers. As an IUCN Category IV protected area, the aim is "…to ensure the maintenance of habitats and/or to meet the requirements of specific species" (IUCN 1994).

Therefore, if the conservation objective is the howler monkey, one could say the CBS appears to be succeeding. However, if the objective is forest preservation, it is not. If trends continue, at some point deforestation and fragmentation will reach a level where dispersal among patches is not possible or population densities reach their carrying capacity and populations begin to decline. This may signal that the CBS should not be managed for a single (or narrow) outcome (e.g., howlers) as IUCN Category IV protected area designation provides. With a concern that residents have realized few financial benefits from tourism and cooperative agreements intended to deter deforestation (pledge) (see chapter 2), this may necessitate the development or improvement of conservation initiatives within the CBS that will result in realized collaborative conservation action for forest preservation.

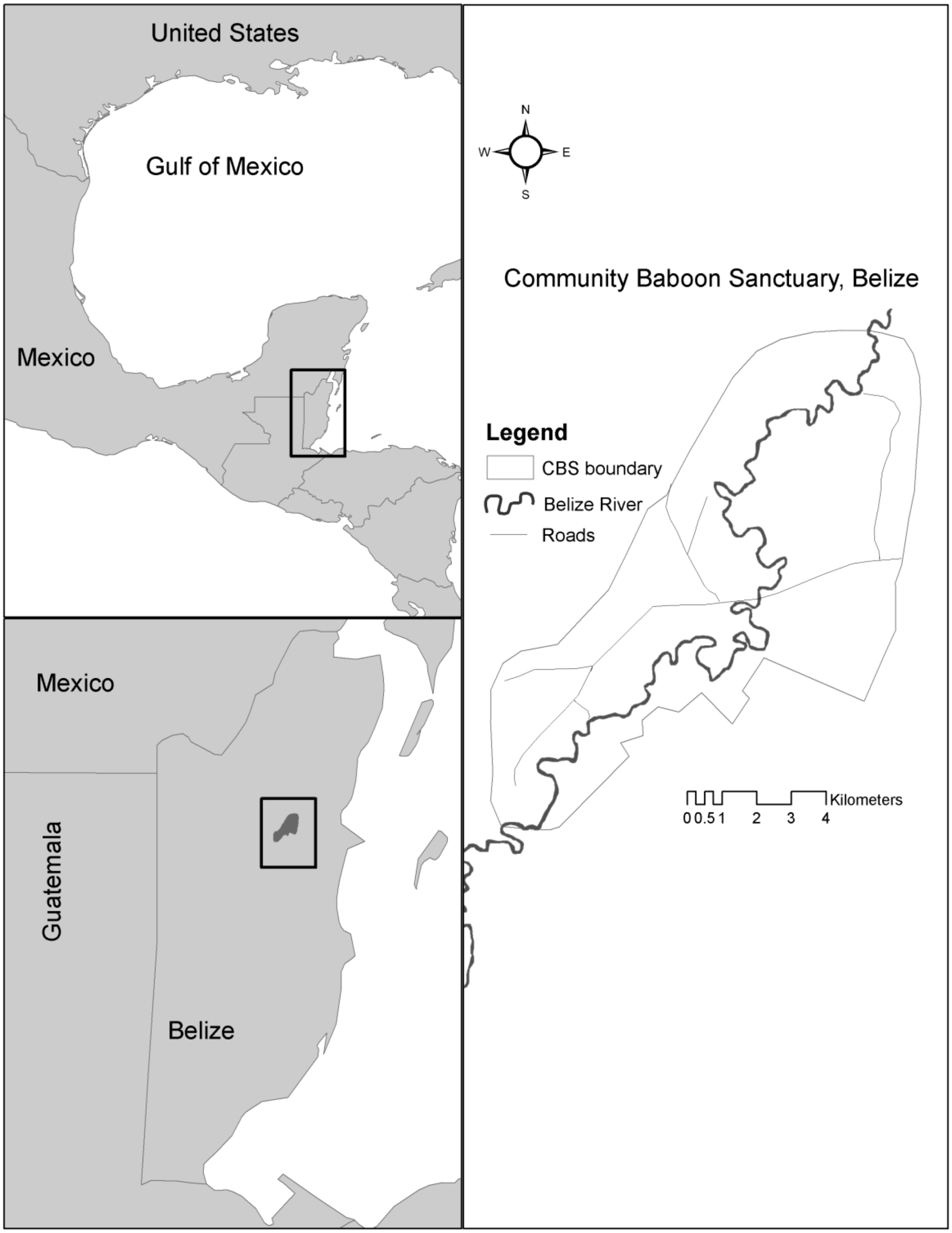
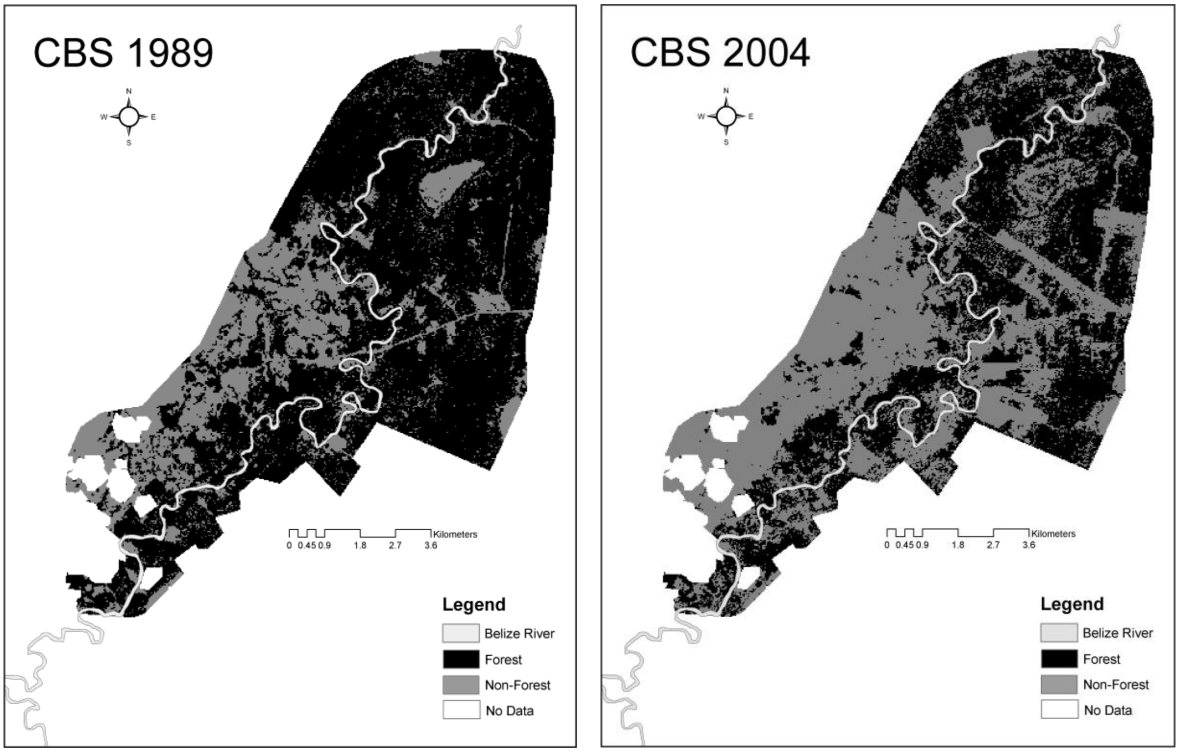
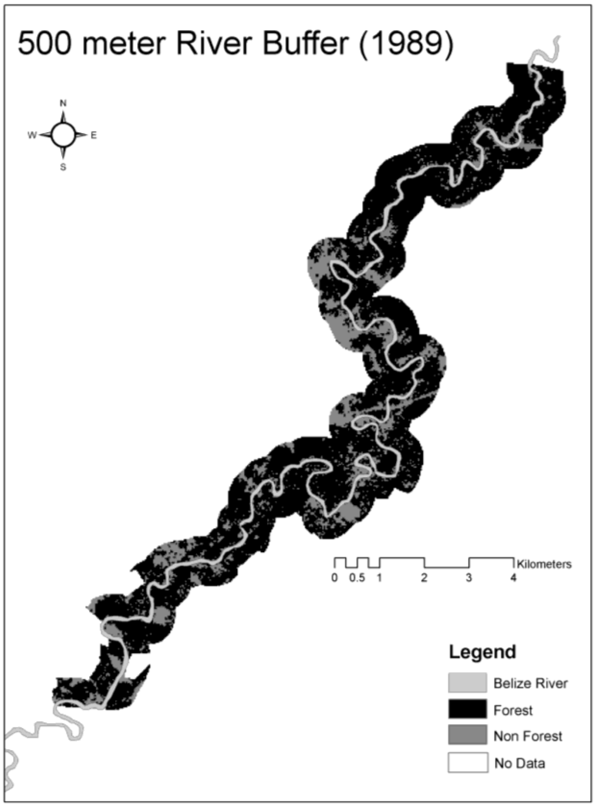


Figure 4-1. Map of the Community Baboon Sanctuary in Belize, Central America

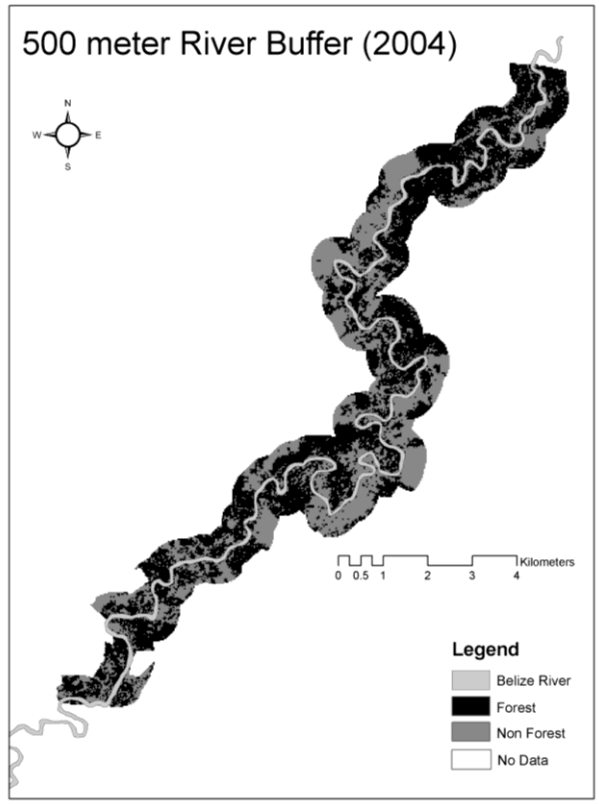


A B

Figure 4-2. CBS forested and non-forested landscape. A) in 1989 and B) in 2004



A



B

Figure 4-3. CBS 500 meter river buffer landscape. A) in 1989 and B) in 2004

Table 4-1. CBS black howler monkey population and population density estimates

Year	Howler population (individuals) estimates	Source	Howler density (individual / km2)	Source
1985	800	Brockett (2003)	31.9	Jones and Horwich (2005)
1997	> 1,500	In Lash (2003)	178 (in 1999)	Horwich et al. (2001)
2003	3,000 – 5,000	Brockett (2003)	Not available	

Table 4-2. Area (ha) and percent land cover of CBS forested and non-forested landscapes in 1989 and 2004

Year	Landscape	Total Area (ha)	% Land
1989	Forest	6167.79	70.87%
1989	Non-Forest	2535.75	29.13%
2004	Forest	4144.05	47.61%
2004	Non-Forest	4559.49	52.39%

Table 4-3. Area (ha) and percent land cover of forested and non-forested CBS 500 meter river buffer landscape in 1989 and 2004

Year	Landscape	Total Area (ha)	% Land
1989	Forest	2231.37	74.34%
1989	Non-Forest	770.4	25.66%
2004	Forest	1520.01	50.64%
2004	Non-Forest	1481.76	49.36%

Table 4-4. Forest Patch Level Analysis of the CBS landscape and 500 meter river buffer. Forest patch level analysis of the CBS landscape and 500 meter river buffer from two different years (1989 and 2004) from the following metrics: number of patches ≥ 3 acres, total number of patches, mean patch area, median patch area, # ENN patches for total patches and for patches ≥ 3 acres.

Landscape	Year	# Patches ≥ 3 acres (1.21 ha)	Total # Patches	Mean Patch Area (ha)	Median Patch Area (ha)	# ENN Total patches	#ENN patches ≥ 3 acres
CBS	1989	48	628	9.8213	0.09	510	44
CBS	2004	102	1323	3.1323	0.09	1025	96
River	1989	17	267	8.3572	0.09	233	16
River	2004	64	669	2.2721	0.09	545	62

Table 4-5. Class Level Analysis of the CBS landscape and 500 meter river buffer. Class level analysis of forested and non-forested patches within the CBS landscape and 500 meter river buffer from two different years (1989 and 2004) from Clumpy metric.

Landscape	Vegetation	Year	Clumpy
CBS	Forest	1989	0.6599
CBS	Non-Forest	1989	0.6602
CBS	Forest	2004	0.6499
CBS	Non-Forest	2004	0.6455
River	Forest	1989	0.4981
River	Non-Forest	1989	0.5338
River	Forest	2004	0.5494
River	Non-Forest	2004	0.5540

Table 4-6. Suitable howler habitat. Suitable howler habitat looking at two different criteria: A) forest patches ≤ 60 m from another and B) forest patches ≥ 3 acres (1.21 ha) and forest patches ≤ 60 m from another) in 2004 within two different landscapes (entire CBS area and 500 meter river buffer within the CBS).

Criteria	Landscape	Year	% of landscape
A. Forest patch ≤ 60 m from another	CBS	2004	44.86%
	River	2004	49.79%
B. Forest patch ≥ 3 acres AND	CBS	2004	44.72%
forest patch ≤ 60 m from another	River	2004	46.74%

CHAPTER 5
CONCLUSION

Although there have been several social science research studies conducted within the CBS (Bruner 1993; Hartup 1994; Alexander 2000; Lash 2003; Jones and Young 2004), a comprehensive study that connects household information to conservation practices, forest cover change, and habitat fragmentation did not exist. Therefore, the overarching objective of this dissertation was to provide an overview of conservation within the CBS. Specifically, this research consisted of the following objectives:

Objective 1: Assess perceived benefits and place-based meanings of riparian forest landscapes,

Objective 2: Assess the relative influence of tourism and pledging on deforestation probabilities, in addition to other locational and socio-economic variables, and

Objective 3: Assess forest fragmentation for the black howler monkey based on habitat criteria

Perceived Benefits and Place-Based Meanings of Riparian Forest Landscapes

Although results show tourism and pledging initiatives may be considered financial failures by residents, those involved in these initiatives value, benefit from, and feel attached to the forest for a variety of non-financial reasons. This study showed a significant relationship exists between initiative involvement (pledging or tourism) and higher perceived benefits (importance) and place attachment (meanings) towards riparian forests and conservation. However, all residents interviewed, regardless of initiative involvement, agreed that riparian forests are not providing financial benefits. Regardless, this study shows that involvement in either conservation initiative, whether they are financially successful or not, is related to higher conservation values and perceived community benefits and is a strong basis for conservation.

Relative Influence of Factors on Deforestation Probability

In an attempt to assess what factors may be driving deforestation or actually decreasing deforestation probability, this study examined the relative influence of locational, land tenure, socio-economic, socio-demographic, and conservation initiative variables. From the variables applied to all modeled time periods, trends show areas closer to the Belize River are more likely to be deforested, as are areas closer to road networks. Additionally, having secure land title decreases the probability of deforestation, although this did not have strong strength of effect in the last modeled time period (2000 – 2004). Looking at influential socio-economic variables from the 2000 – 2004 modeled time period with strong effect strength, agricultural and cattle activities are influential in increasing deforestation probability, while higher levels of household head education decreased deforestation probability.

Pledging was shown to increase deforestation probabilities during the 1989 – 2000 modeled time period, a decrease during the 1994 – 2000 modeled time period, and an increase during the 2000 – 2004 modeled time period. Tourism, a variable that was only able to be accurately measured during the 2000 – 2004 time period, indicated an increase in deforestation probability. Although involvement in either of these initiatives during the 2000 – 2004 time period did not show a decrease in deforestation probability, the combination of being involved in both tourism and pledging actually decreased deforestation probabilities during 2000 – 2004. This indicates that having both the values of pledged residents (whether the pledge influenced these residents or these residents had these conservation values to begin with is not known) and the income from tourism participation may actually create a stronger connection between tourism dollars received from the resource attraction (the howler monkey) and the habitat (forests) it is dependent upon.

Although some of these variables have strong influence with the models created, goodness of fit values (pseudo R^2) indicate that they only explain a small proportion of deforestation within the CBS and suggest there are other variables not included in the model that are more influential at explaining deforestation probability within landowner parcels (e.g., biophysical and institutional). Nevertheless, this study helped to explore and identify the relevant influence of some of the factors affecting deforestation.

Forest Habitat Fragmentation

Overall landscape trends within the CBS between 1989 and 2004 indicate there has been a 23% decrease in forest cover within the CBS and 500 meter river buffer, along with increased fragmentation of forest habitat. This coincides with the 20% decrease in forest cover for Belize since the early 1980s (FAO 2007). Additionally, the second largest proportion of the CBS landscape and the largest proportion of a 120 meter river buffer follows the "tending towards deforestation" land cover trajectory. Since the 120 meter river buffer analysis outside the CBS followed the same trajectory as the 120 meter river buffer within the CBS, riparian forests are not anymore protected within the CBS, despite it being labeled as a "sanctuary" and considered a protected area.

Despite increased deforestation and fragmentation within the CBS, the black howler monkey (*Alouatta pigra*) possesses many traits that make it adaptable to increased habitat fragmentation. Additionally, it should be noted that howler populations have increased dramatically over the past 20 years within the CBS, from an estimated 800 individuals in 1985 to 3,000 – 5,000 individuals in 2003 (Brockett 2003). A preferred food source for the howler, the fig (*Ficus spp.*), is a forest-fringe species found along the river and in forest fragments. Therefore, the fragmented forests have actually been beneficial for the howlers in providing this important food source.

Despite increased fragmentation and deforestation, connectivity between forest patches has remained high indicating dispersal and colonizing potential between most forest patches has not been jeopardized. However, continuing trends of increased deforestation and fragmentation of CBS forest habitat, along with reported increases in howler population densities, will likely place increased pressure on these populations.

Conclusion

Conservation within the CBS may be a little more complex than simply saving forests and, therefore saving howlers, as increased fragmentation actually provides better habitat for *ficus spp.* (e.g., figs), the preferred food source for howlers. The CBS falls under the IUCN Category IV protected area designation with the aim "…to ensure the maintenance of habitats and/or to meet the requirements of specific species" (IUCN 1994). Under this designation, one could say the CBS has been successful in protecting and maintaining howler populations, as documented by increases in their population. However, if the conservation objective is forest preservation, the 23% decrease in forest cover and increased forest fragmentation would point to conservation failure.

The concerns for the future of the CBS are the continued trends in deforestation and fragmentation. These trends, if continued, would eventually reach a level that impacts dispersal among patches or where howler population densities reach a carrying capacity level and populations would begin to decline. This may signal that the CBS should not be managed for a single outcome (e.g., howlers) as IUCN Category IV protected area designation provides. As deforestation is tied to livelihoods of private landowners, closer examination was given to the two conservation initiatives (tourism and a conservation pledge) established to deter deforestation.

In closer examination of these two conservation initiatives, the CBS is in a unique position. A strong basis for conservation does exist and an indication that involvement in both tourism and pledging had some influence in decreasing deforestation probability between 2000 – 2004. However, without building upon the other influential factors (e.g., financial payment for pledged residents, distribution of tourism participation and benefits, land tenure, expanding agriculture and cattle, etc.), these conservation initiatives will not be as effective at promoting conservation goals within the CBS and will not be able to compete with other opportunities the land provides. Although these conservation initiatives working together may have some influence in slowing deforestation within the CBS, this study's findings indicate that both conservation initiatives must be managed more effectively and equitably to have any other significant impacts on improving people's attitudes towards riparian forests or actively helping conserve those forests. Overall, this study reiterates the lesson that the success of any conservation initiative must be linked to local communities benefiting from their conservation of biodiversity.

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BIOGRAPHICAL SKETCH

My undergraduate degree in environmental science and past field and work experiences have shaped my professional interests towards community-based, natural resource management issues. In the past I have be involved with animal ecology research on the Guanaco (*Lama guanicoe)* in Patagonia, southern Chile; grassroots environmental and community organizing in Minnesota; and research developing model progressive, state, environmental legislation.

My love of travel, of languages, and of the environment has also guided my career interests. After receiving a B.S. in environmental sciences from the University of Massachusetts, I spent the next 6 months living and working on an Israeli kibbutz. Returning to the U.S., I worked with US Public Interest Research Group (PIRG), a non-profit, non-partisan environmental and consumer rights advocate organization and co-directed a campaign office in Minneapolis, Minnesota. There I really learned the power of community organizing, working with the media, and building coalitions. After a year with the PIRGs I had the opportunity to work on an animal ecology research project on the Guanaco (*Lama guanicoe)* in Parque Nacional Torres del Paine in Patagonia, Southern Chile in conjunction with Iowa State University. The next year I returned to Minnesota and served as an Americorps / Vista (Volunteers In Service To America) volunteer working as a community organizer with a tenant's right organization organizing in manufactured (mobile) home park communities around Minnesota.

These experiences made me realize that my passion was working with communities on environmental conservation issues. This brought me to pursue an M.S. degree in natural resource management / environmental education and interpretation from the University of Wisconsin – Stevens Point where I worked with a rural Mayan ejido (community) in southeastern Mexico in the development of an ecotourism management plan. This plan was requested as the initial organizational step to developing and implementing community-based ecotourism within this ejido, a document for potential funders, and a framework for other communities within the Calakmul Model Forest area interested in ecotourism development. This plan was later used by the community to secure funding from the Rigoberta Menchu Organization.

My M.S. research and exploratory travel within the Maya Forest region spurred my interests in more closely examining the popularity of community conservation initiatives combining economic development as a way to protect natural and cultural resources while also providing for local people's needs. This led to my doctoral research within the Community Baboon Sanctuary, Belize where I examined conservation from various perspectives.

Aside from my professional interests, in my spare time I enjoy gardening, playing music (guitar and banjo), canoeing, and travelling.