THE ROLE OF ACCULTURATION IN INDIGENOUS PEOPLES' HUNTING PATTERNS AND WILDLIFE AVAILABILITY

The case of the Tsimane' in the Bolivian Amazon

Ph.D. dissertation presented by:

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Para o Sebastião e o Manel

"According to their beliefs, the lucky hunter is the one who knows the origin of the game. And if certain animals can be tamed, it is because the magicians know the secret of their creation."

E. Nordenskiöld (1932)

Abstract

Wildlife hunting is an important component of indigenous peoples' subsistence strategies in Amazonia, but also a major threat to biodiversity when it reaches unsustainable levels. Changes in the livelihoods of indigenous peoples, often related to their adaptation to the national society and the market economy, produce changes in their subsistence patterns and in the way they use and manage wildlife. From the many socioeconomic changes that affect indigenous peoples way of life, previous researchers have mainly focused on how integration into the market economy drives changes in hunting behavior and communal management of wildlife. Cultural processes, such as acculturation, or the loss of traditional knowledge, beliefs and values, have received less attention.

This PhD thesis aims at filling a gap in the literature on how acculturation affects hunting patterns and wildlife availability, by presenting a case study of a native group of the Bolivian Amazon, the Tsimane'. Although the Tsimane' culture is relatively well documented, there is a general lack of reliable ecological data for game vertebrates diversity and abundance in the territory inhabited by the Tsimane', making it difficult to analyze interactions between the social and the ecological systems. This dissertation examines *(i)* the composition and structure of the game community available in the Tsimane' territory, as well as, the game harvest profile of Tsimane' villages (chapter 1), *(ii)* the variation among Tsimane' villages in terms of acculturation, hunting pressure, and wildlife availability, and the association between those phenomena (chapter 2), *(iii)* the cultural and socioeconomic determinants of individual hunting behavior (chapter 3), and *(iv)* the role of traditional hunting norms regulating communal game management (chapter 4).

Research was conducted between March 2008 and July 2010 in 40 Tsimane' villages, in lowland Bolivia. Given the complexity of the interactions among acculturation, the livelihood of indigenous societies, and wildlife conservation, this study uses a multidisciplinary approach that relies on the collection of social and ecological data and its analysis using geographical and econometric tools. Surveys were conducted among hunters to evaluate their cultural and socioeconomic characteristics, as well as their game harvest profile and rates of game extraction. Wildlife transects were conducted to estimate game abundances in areas surrounding the Tsimane' villages where survey data were collected.

The results of this dissertation suggest that wildlife hunting continues to be an important subsistence activity for the Tsimane' society, but its patterns and cultural importance are changing. Together with changes in the Tsimane' economic systems (i.e., integration into the market economy), changes in the cultural system (i.e., the acculturation process) help explain changes in Tsimane' hunting behavior. Specifically, the results presented along the four chapters suggest, that: *(i)* current game community composition and structure seem to respond to overhunting and habitat degradation. Villages' harvest game profile suggest that Tsimane' hunt according to game availability, except for some species, for which cultural preferences seem to prevail; (*ii*) the diminishment of hunting pressure -observed over a decreasing gradient from close to market-town to remote villages- is associated to both changes in the traditional cultural system and wildlife scarcity; *(iii)* there is a negative and statistically significant association

between years of schooling and the probability that a hunter engages in hunting activity. The association is also found when considering the returns of wild meat harvested during the hunting excursions; and *(iv)* traditional hunting norms are eroding among the Tsimane' hunters culture. The finding of a significant inverse U-shaped relation between attachment to hunting norms and the amount of game harvested suggests that there is a disruption in the cultural identity that manifests on the communal wildlife management.

Therefore, this work highlights that the viability of subsistence hunting among the Tsimane' and its cultural importance are threatened by the acquisition of new forms of human capital and new economic opportunities that come with acculturation. Moreover, results suggest that there is also a feedback loop, so changes in wildlife abundance and diversity, in turn, generate changes in cultural aspects. This thesis brings in new insights to the theoretical discussion about the effects of acculturation in the way indigenous societies manage their natural resources. Results from this work can inform local wildlife management policies. Specifically, this dissertation stresses the importance of creating a wildlife management project by, and for the Tsimane', which could support sustainable harvesting, and at the same time built resilience among the Tsimane' society by providing a framework for the maintenance of their culture and traditional ecological knowledge.

Key words: acculturation; Amazonia; hunting patterns; indigenous peoples; traditional belief system; tropical rainforest; Tsimane'; wildlife conservation

Resumen

La cacería es una componente importante de las estrategias de subsistencia de los pueblos indígenas en la Amazonía, pero también una gran amenaza para la biodiversidad cuando alcanza niveles insostenibles. Los cambios en las condiciones de vida de los pueblos indígenas, a menudo relacionados con su adaptación a la sociedad nacional y a la economía de mercado, producen cambios en los patrones de subsistencia y en la forma de uso y manejo de los recursos. La literatura científica se ha centrado principalmente en la variación de los patrones de caza y de la gestión comunal de la fauna como consecuencia de la integración en la economía de mercado. Los procesos culturales, como la aculturación, o la pérdida de los conocimientos, creencias y valores, han recibido menos atención.

Esta tesis doctoral tiene como principal objetivo llenar parte del vacío existente en la literatura sobre cómo la aculturación afecta los patrones de caza y la disponibilidad de fauna, mediante la presentación de un caso de estudio con un grupo indígena de la Amazonía Boliviana, los Tsimane'. A pesar de que la cultura Tsimane' está relativamente bien documentada, se carece de datos ecológicos fiables sobre los vertebrados de caza en relación a su diversidad y abundancia en el territorio habitado por los Tsimane'. Esta falta de información, hace difícil evaluar las interacciones entre los sistemas sociales y ecológicos. Esta tesis analiza (*i*) la composición y estructura de la comunidad de especies de caza disponibles en el territorio Tsimane', así como, el perfil de la cacería en las comunidades Tsimane' (capítulo 1); (*ii*) la variación entre las comunidades Tsimane' en términos de aculturación, presión de la caza y disponibilidad de las especies animales, y la asociación entre estos fenómenos (capítulo 2); (*iii*) los factores culturales y socioeconómicos determinantes de la conducta de caza individual (capítulo 3); y (*iv*) el papel de las normas tradicionales de caza como reguladoras de la gestión comunal (capítulo 4).

La investigación se llevó a cabo entre Marzo de 2008 y Julio de 2010 en 40 comunidades Tsimane', en la Amazonía Boliviana. Dada la complejidad de las interacciones entre la aculturación, los medios de subsistencia de las sociedades indígenas y la conservación de la fauna, este estudio utiliza un enfoque multidisciplinario basado en la recopilación de datos sociales y ecológicos, y el uso de herramientas geográficas y econométricas. Las encuestas se realizaron entre los cazadores para evaluar sus características culturales y socioeconómicas, así como su perfil de caza y las tasas de extracción de especies animales. Se llevaron a cabo transectos sobre las especies de caza para estimar la abundancia de los recursos animales en las zonas alrededor de las comunidades Tsimane' donde se recogieron los datos de las encuestas.

Los resultados de esta tesis sugieren que la caza sigue siendo una actividad de subsistencia importante para la sociedad Tsimane', pero sus patrones y la importancia cultural están cambiando. Juntamente con los cambios en el sistema económico de los Tsimane' (p.e., la integración en la economía de mercado), los cambios en el sistema cultural (p.e., el proceso de aculturación) contribuyen a explicar la adaptación del comportamiento de caza entre los Tsimane'. En concreto, los resultados que se presentan a lo largo de los cuatro capítulos sugieren que: (*i*) la actual composición y estructura de la comunidad de especies de caza parece responder a la caza excesiva y a la degradación del hábitat. El perfil de cosecha de fauna de las

comunidades sugiere que los Tsimane' cazan de acuerdo a la disponibilidad de recursos animales, a excepción de algunas especies, por lo que las preferencias culturales parecen prevalecer; (*ii*) la disminución de la presión de caza –que presenta un gradiente decreciente desde las comunidades más cercanas a la ciudad mercantil hasta las comunidades más lejanas - se asocia tanto a cambios en el sistema cultural tradicional como a la escasez de fauna; (*iii*) existe una relación negativa y estadísticamente significativa entre años de escolaridad de los individuos y la probabilidad de que uno se dedique a la actividad de la caza. La asociación también se encuentra cuando se considera la cosecha de animales silvestres recolectados durante las cacerías; y (*iv*) las normas tradicionales de caza se están erosionando entre la cultura de los Tsimane'. Se encontró una relación significativa en forma de U invertida entre el apego a las normas de caza y la cantidad de carne de caza cosechada, lo que sugiere que hay una desapego a la identidad cultural, que se manifiesta en el manejo comunal de la fauna.

Los resultados de esta tesis demuestran que la viabilidad de la caza de subsistencia entre los Tsimane' y su importancia cultural se ven amenazados por la adquisición de nuevas formas de capital humano y de las nuevas oportunidades económicas que vienen con la aculturación. Además, los resultados sugieren que existe también un efecto de feedback; éste se expresa como la generación de cambios en los aspectos culturales del sistema de caza debido a los cambios en la abundancia de especies. Esta tesis aporta nuevas perspectivas a la discusión teórica acerca de los efectos de la aculturación en las actividades de subsistencia de las sociedades indígenas y en el modo de gestionar sus recursos naturales. Las implicaciones políticas y de gestión de este estudio incluyen la necesidad y importancia de crear un proyecto de manejo de la fauna por y para los Tsimane', que podría apoyar a la caza a través de cosechas sostenibles, y al mismo tiempo construir resiliencia en la sociedad Tsimane' al ofrecer un marco para el mantenimiento de su cultura y conocimiento ecológico tradicional.

Palabras clave: aculturación; Amazonia; conservación de fauna; patrones de caza; selva tropical; sistema cultural tradicional; sociedades indígenas; Tsimane’

CONTENTS

List of figures

List of tables

Acknowledgments

"Practically, all works we usually call our own, represent only a few scoops of originality added on top of a mountain of knowledge received from others"

(Georgescu-Roegen)

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INTRODUCTION

The central focus of this work is to understand how subsistence hunting (one of the most important economic activities of millions of indigenous peoples around the world) changes and adapts to the challenges presented by the impacts of the Western society on traditional cultures and the environment. Specifically, I want to comprehend how the Tsimane', a hunter-horticulturalists society who lives in the Bolivian Amazon, modify their hunting patterns along with cultural and socioeconomic changes faced by their society. Understanding these trends will bring new perspectives on the implications that such changes have in the future of indigenous livelihoods and wildlife conservation.

Tropical forests are among the most species-rich ecosystems on the planet (Bradshaw et al. 2009; Gibson et al. 2011; Laurance et al. 2012) playing an essential role on ecological processes and on the lives of human populations (Redford & Padoch 1992; Cardinale et al. 2012). Not only tropical rainforests contain much of the world's biodiversity, but they are -at the same time- home to a diversity of indigenous peoples who have used and managed these ecosystems for millenniums (Redford & Stearman 1993; Redford & Sanderson 2000; Toledo 2001; Sunderlin et

al. 2005). Nowadays, the livelihoods of many indigenous peoples of Amazonia continue to be subsistence-oriented, being largely dependent on swidden agriculture and the appropriation of resources found in the surrounding landscape, including plants, fish, and wildlife (Primack & Corlett 2005). But for many indigenous peoples, subsistence hunting is not only a source of protein and income, but also a defining identity element, intimately linked to their cosmologies (Chicchon 1992; Robinson & Bennett 2000). Because of the overlap between high diversity and indigenous peoples' lands, the role of indigenous societies and their social, economic and belief systems in the management of natural resources and ecosystems has received particular attention in the last decades (e.g., Berkes et al. 2000; Berkes 2004; Olsson et al. 2004; Pretty et al. 2009).

Researchers have noticed that, although certain game species have been hunted sustainably in the past (Alvard 1994, 2000; Robinson & Bennett 2000; Fa et al. 2002), in the last decades indigenous societies have changed their traditional ways of living by adapting and developing new economic strategies in regard of the Western development and globalization (Godoy et al. 2005b). Consequently these changes are affecting many wildlife populations. In fact, all around the world and due to population growth and to the unprecedented demand on natural resources, hunting is now rapidly increasing in extent and scale (Nasi et al. 2008; Wilkie et al. 2011). Therefore, the debate on the role of indigenous on wildlife conservation continues to be relevant in order to shed some light in the ways indigenous people should be incorporated in the management of natural resources and maintenance of wildlife.

Most empirical studies linking hunting -or game management- with changes in the indigenous people's livelihoods have focused on how social and economic changes affect the harvest and consumption of wild meat. For instance, the effects of integration into the market economy in wild meat consumption have now been studied for some years, as several authors argue that there is a probability that with the raise of income wild meat consumption, in some cases, would be alleviated and wildlife conservation can be promoted (Robinson & Bennett 2002; Sanderson & Redford 2003; Brashares et al. 2004). In addition to the effects of integration into the market economy on wild meat consumption, I argue that it is important to

understand the effects of changes in cultural systems on wildlife harvesting and consumption. Changes in the cultural and belief systems of indigenous peoples can also affect the way they use and manage wildlife. As people loss their cultural knowledge and believes, they must acquire new skills, attitudes and values that might also affect the way they use and manage wildlife.

Currently, there is a gap in the literature on how acculturation, or the loss of traditional cultural knowledge, believes and values, affects hunting patterns and wildlife consumption of indigenous peoples. Acculturation can be difficult to assess, as it is not a linear process that necessarily leads to assimilation and a loss of a person's ethnic identity (Thomson & Hoffman-Goetz 2009). Moreover, it can affect societies' livelihood and the way they interrelate with natural resources in different ways. For instance, previous research has found that the acquisition of the language of the national society can be related with new economic opportunities (e.g., cash-cropping, wage labor) (Godoy et al. 2005a; Gray et al. 2008), although the acquisition of formal education can help curve deforestation (Godoy et al. 1998). This gives us an idea of how different acculturation proxies can be associated with different outcomes in the management of natural resources.

In this dissertation I study the effects of acculturation on subsistence hunting by focusing on the hunting activity of the Tsimane', from the lowland Bolivian Amazon. As most of the Amazonian indigenous peoples, the Tsimane' heavily rely on hunting as an essential mean of subsistence, a source of protein (Chicchon 1992), and a distinctive element of their cultural identity (Huanca 2008). Contrary to previous studies that link subsistence hunting with indigenous cultural changes exclusively through the use of individual surveys, I rely on estimations of game vertebrate abundances to assess the relations between acculturation and hunting patterns. Specifically, *(i)* I study differences among Tsimane' villages in terms of wildlife abundance and acculturation, and *(ii)* I relate wildlife abundance with the predominance of hunting activity and with the amount of game harvested.

Finding the relation between hunting activity, sociocultural factors, and wildlife abundances is important in order to understand the impact of hunting on game species. It can also help understand how subsistence hunting changes during the acculturation process of indigenous peoples. The study is centered in the

Tsimane', one of the most autarkic societies living in the Bolivian Amazon, while still presenting a very interesting variation in levels of acculturation that allow the comparison between individual and communities. An additional reason to focus on the Tsimane' is that, although the Tsimane' territory is in one of the regions with more biodiversity in the world there is a lack of literature regarding game vertebrate estimates in the area. Therefore, the Tsimane' represent an ideal case study for addressing the link between cultural and socioeconomic changes and wildlife use and management.

This study brings significant insights, both on methodological and theoretical levels. On the methodological level, this study gives a multidisciplinary dimension to the assessment of the activity of hunting, by putting together social and ecological data. Anthropologists were among the first to start systematizing subsistence hunting by indigenous communities in the tropics (Gross 1975; Ross 1978; Hames & Vickers 1982). Later, conservation biologists attempted to quantify the sustainability of game harvesting (Robinson & Redford 1991a; Robinson & Bodmer 1999), a necessary approach to evaluate the impact of hunting on ecosystems and species populations. More and more multidisciplinary approaches have been made to discuss the problem of ensuring the livelihoods of indigenous people while succeeding in wildlife (and biodiversity) conservation. Nevertheless, there is a lack of accepted methodologies to relate biological and social systems (Pretty et al. 2008),although understanding the complexity inherent to the relationships among culture, economics, and ecosystems, observed in the hunting system, requires such an approach. In this work I combine both methods of the social and ecological fields, sometimes integrated through the use of Geographical Information Systems (GIS) that enable this match.

On the theoretical level, this dissertation contributes to the growing literature discussing the effects of acculturation in indigenous societies (e.g., Gross et al. 1979; Brosi et al. 2007; Gray et al. 2008; Guèze 2011), as well as, to the ongoing debate on the role of indigenous peoples in the management of ecosystems and conservation of biodiversity (e.g., Redford 1991; Smith & Wishnie 2000; Hames 2007). However the ideas discussed in this thesis do not intent to identify a unifying theory for the relationships between sociocultural features and wildlife harvesting

or even management guidelines with general applicability, but instead aims to add a contribution and a different perspective from a local case study to the current literature.

State of the art

Although there is a gap in the literature covering the relation between acculturation and hunting, there is a wide range of literature about hunting and indigenous peoples in the tropics. This literature covers different topics such as the sustainability of the hunting systems, different components including cultural and socioeconomic practices, natural environment and the conservation of biocultural diversity (e.g., Robinson & Redford 1991b; Robinson & Bennett 2000; Milner-Gulland & Akçakaya 2001; Jerozolimski & Peres 2003; Milner-Gulland et al. 2003; Nasi et al. 2008; Wilkie et al. 2011). Due to the breadth of research, a truly comprehensive review is probably impossible, and certainly beyond the scope of this thesis. The following brief literature review presents the main subjects that will be discussed on the next chapters and aims to ease the comprehension of the empirical analyses taken further.

Indigenous peoples and biodiversity

Indigenous peoples inhabit some of the most biologically diverse territories in the world (Toledo 2001; Sunderlin et al. 2005). They are responsible for a great deal of the world's linguistic and cultural diversity, and their traditional knowledge has been and continues to be recognized as the foundation for intricate resource management systems that have sustained indigenous societies for millennia (e.g., Berkes et al. 2000; Toledo 2001; Berkes 2004; Olsson et al. 2004; Pretty et al. 2009; Reyes-García et al. 2012a). The concept of biocultural diversity emerged out of the realization that there is a geographical overlap between biological diversity and the diversity of languages as cultural representations (Harmon 1996; Maffi 2005; Pilgrim et al. 2009).

Biocultural diversity has recently become an additional strategy for biodiversity conservation (UNESCO 2008), as the convergence of biologically-rich areas with indigenous territories presents an enormous opportunity to expand conservation efforts beyond national parks and reserves (Ostrom & Nagendra 2006). Over the past few decades, researchers' interest in understanding the role of indigenous peoples in shaping biodiversity has grown. Several authors argue that indigenous peoples can live in perfect harmony with their environment (Nadasdy 2005), as their cultural and belief systems allows them to balance their behavior with nature, being considered allies for conservation (Smith & Wishnie 2000). Authors have relied on examples from different indigenous societies to show how such societies hold a spiritual respect for, and a sustainable practical understanding of the natural world (Alvard 1994). To that view, other authors have contested that conservation of natural resources by native peoples did not necessarily always occur (Hardin 1968) or occurred as a side effects of low population density, simple technology, and lack of external markets to impel over-exploitation, rather than as the product of some conservationist behavior (Redford 1991; Smith & Wishnie 2000; Hames 2007). Specific examples of no sustainable behavior by small-scale societies include anthropogenic faunal extinctions and habitat degradation, as well as patterns of subsistence behavior that seem to conform to economic optimization rather than to resource or habitat conservation (Redford 1992; Bodmer et al. 1997; Bennett et al. 2002; Wilkie et al. 2011).

However, expecting indigenous people to retain traditional, low-impact patterns of resource use is also to deny them the right to grow and change in ways compatible with the rest of humanity. Indigenous peoples themselves have often embraced the conservationist discourse, an attitude that has been criticized by some conservationists who argue that this conservationist image was used because indigenous peoples recognize the power of this concept in rallying support for their struggle for land rights, particularly from important international conservation organizations (Nadasdy 2005).

In sum, examples on the effects of indigenous peoples' livelihoods on biodiversity are everything but uniform. Some, as the case of overhunting among indigenous societies (e.g., Redford 1992), show resource depletion. Some other

examples have shown that the use of natural resources by indigenous peoples can boost species diversity, especially when the use and management of resources occurs at intermediate levels of frequency and intensity (Smith & Wishnie 2000; Guèze 2011). In fact, some studies have showed that forest cover and wildlife diversity is better maintained by indigenous societies at local scale, when compared with the surrounding colonized areas (Redford & Robinson 1987; Lu et al. 2010), or even at regional scale when compared to natural protected areas (Porter-Bolland et al. 2012). In some Amazonian countries (as in other parts of the world) community wildlife management programs have been implemented for some years (Newing & Bodmer 2003; Noss et al. 2005; Constantino et al. 2008; Zapata-Ríos et al. 2009). In these programs, hunters are not only an important element in self-monitoring game offtakes and wildlife populations, as well as in raising awareness of wildlife management issues at the community or indigenous territory level (Noss et al. 2004).

Thus, examples of the contribution of indigenous peoples to wildlife conservation does exist and appears to be increasing, especially as native peoples gain legal control over their territories and resources. But the diversity of effects found in the literature, calls for studying each case separately.

Wildlife hunting

In tropical forests across the globe, the meat of wild animals has long been a crucial part of the diet of forest-dwelling peoples (Wilkie et al. 2011). Invertebrates, amphibians, insects, reptiles, birds and mammals are hunted for local consumption or for sale, mainly as food, but they can be also used as medicines or for other traditional uses, trophies, pelts, and even pets (Nasi et al. 2008).

Wildlife hunting in tropical forests is an issue of concern for three main reasons: its rapid increase, the pernicious effects of wildlife depletion on the livelihood of indigenous peoples around the world, and the seemly inability of governments to regulate it. First, hunting has always occurred throughout the world, but recent changes are rapidly increasing its extent and magnitude. The harvest of wildlife is often directly correlated with human population densities

(Robinson & Bennett 2004), which continues to increase in many tropical forest areas. Additionally, pressure on wildlife populations has increased dramatically with the commercialization of wildlife, as an important source of income for many forest-dwellers (Nasi et al. 2008). Furthermore, processes such as the expansion of the natural resources extraction and land clearance for agricultural intensification (e.g., Suárez et al. 2009; Poulsen et al. 2009), the increased road and other infrastructure construction (Wilkie et al. 2000), the use of efficient modern hunting technologies (Espinosa 2008), have increased the extent of wildlife hunting. Likewise, the loss of traditional hunting taboos and beliefs, that in the past sometimes seemed to help control communal game management, seem to have impact on certain species populations (Jones et al. 2008; Lingard et al. 2012).

This increase in wildlife hunting has important effects on biodiversity. Hunting has long been recognized as a primary cause of species depletion, leading to the *empty forest syndrome* (Redford 1992) and to the disruption of forests dynamics and resilience (Peres 2000; Peres & Palacios 2007; Altrichter et al. 2011). According to Wilkie et al. (2011), nowadays there is still an *unseen extinction crisis* occurring. The world's tropical forests are losing their fauna as wildlife populations become depleted because game species are continually overhunted. Large-bodied vertebrates are those undergoing the greatest impacts, especially primates and ungulates, because they constitute the highest biomass income while being ecologically very vulnerable species (Peres 2000). Overhunting (and habitat destruction) has resulted already in population declines and local extinctions for many of these species (Jerozolimski & Peres 2003).

The second issue of concern regarding wildlife hunting is that wildlife depletion is intimately linked to food security and to the livelihood of numerous tropical forest-dwellers and rural populations. Many of these forest-dwelling or rural people have few alternative sources of protein and income. This is particularly the case for many indigenous people inhabiting the lowland rainforests of Amazonia, who still heavily really on wild meat consumption (Milner-Gulland et al. 2003). Although these indigenous societies are facing livelihood changes resulting from contact with the Western societies and the market economy, subsistence hunting is still an important component of their cultural identity and belief system

(Fortier 2001). In fact, in some cases, changes in indigenous diet habits are not exclusively due to their participation in the market economies, but also because of the game scarcity observed in their territories (Zycherman 2012, unpublished). Moreover, decreased access to wildlife, when protein alternatives are limited, may have significant and lasting effects on the health of local human populations (Golden et al. 2011).

These factors relate with the so-called *bushmeat crises*, a term used to describe overhunting of wildlife for human consumption in tropical areas (Nasi et al. 2008). The term is frequently associated with the hunting in Africa, where the situation has reached crisis levels (Milner-Gulland et al. 2003), especially due the commercialization of wildlife that plays an important role in the harvesting rates.

An additional reason of concern regarding subsistence hunting relates to the seemly inability of governments to regulate it. Specifically, the current wildlife legislation in the Amazonian countries is generally poorly refined and enforced. Furthermore, when existing, it is ignored by most of the people and public institutions, probably with the exception of protected areas and some indigenous territories (Shepard et al. 2010).

Indigenous current changes

ACCULTURATION AND MARKET INTEGRATION

In light of the current patterns of economic development, often linked to resource extraction, the question of how globalization affects biocultural diversity has become a major concern in international conservation policies (UNESCO 2008). In the Amazonia, indigenous peoples are experiencing deep changes such as acculturation and integration into the market economy that lead to modifications in their sociocultural and economic systems, which in turn may impact their livelihoods and the biodiversity of the areas they inhabit (Stearman 2000; Robinson & Bennett 2004; Lu 2007; Levi et al. 2009).

Acculturation refers to the process of cultural change that happens when groups of individuals from different cultures come into continuous contact with one

another leading to changes in the cultural patterns of either or both groups (Lopez-Class et al. 2011). When a minority group with a distinct cultural background, such as that of the indigenous peoples come into contact with cultural settings of the mainstream or Western society, they tend to adopt the other's behaviors, languages, beliefs, values, social institutions, and technologies (Sam & Berry 2010). The contrary can also hold true, however small population societies are oftentimes outruled by the dominant narrative or setting of cultural influence.

Acculturation should be conceptualized as a multidimensional process that occurs over time and place, and not as a linear course of action because it does not necessarily leads to assimilation and a loss of a person's ethnic identity (Thomson & Hoffman-Goetz 2009). Common measures of acculturation include proficiency in the national language and level of formal education (Sternberg et al. 2001), values and identity orientation (Dressler 2004; Guèze 2011), years of contact or interaction with members of dominant culture (Berry et al. 1986), participation in national politics (Berry 2008), and distance to the nearest market-town (Morsello & Ruiz-Mallén 2012). In measuring degrees of acculturation, not all measures are related (Chun 2003). According to some authors, acculturation is primarily an individual process (Sam & Berry 2010), which means it will not necessarily change in the same way or to the same degree for different people during their acculturation process (Nauck 2008). Also, changes arising from acculturation at the individual level are often different from those taking place at the group level (Berry 1997). The way in which individuals interact with the ecological and cultural contexts can be distinct from the group acculturation response.

Moreover, the examination of the literature reveals that acculturation is often misapplied and mistaken with market integration. Although acculturation and market integration are processes linked and often difficult to dissociate, they affect different aspects of the society (Godoy et al. 2005b). While acculturation is related with cultural processes, integration into market economy is connected with economic activities. Measures of market integration are mainly related with levels of income and wealth (Godoy et al. 2005b). Several authors have analyzed the effects of integration into the market economy on wildlife hunting, suggesting that market integration can increase pressure on wildlife through increase in access to

new hunting technologies (Lu 2007; Espinosa 2008; Godoy et al. 2010), and means of transportation that allow the displacement to new hunting grounds (Wilkie et al. 2000). Likewise, it has been argued that the increase of income and wealth on the indigenous societies changes wild meat consumption patterns, although, contradictory trends have been found (Brashares et al. 2011). Thus, in some cases poverty alleviation leads to reduced reliance on wildlife through the possibility of access to alternative sources of meat (Brashares et al. 2004), whereas in other cases the demand for wildlife, increases as household wealth grows (Godoy et al. 2010).

In this work, I will mainly focus on -a less studied process- how acculturation might affect wildlife hunting and wildlife availability, although at some point along this dissertation, associations to both processes will be made, since people who acquire new values, attitudes and skills will have probably higher access to markets or increased propensity to enter into market economy. The process of acculturation has received researchers' attention because it affects societies' livelihood and the way societies interrelate with natural resources. For example, changes in people's knowledge and cultural belief system can affect their traditional subsistence practices and the way they use and manage their environment (Ross 1978; Gross et al. 1979; Jones et al. 2008; Dominguez et al. 2010; Reyes-García et al. 2010). Despite this interest, the way in which acculturation impacts the hunting habits of indigenous peoples, and consequently biodiversity, is far from fully understood.

However the limited research on the link between acculturation and hunting patterns has produced different not mutually exclusive results. Some authors argue that as indigenous societies become more acculturated, there is a shift in their time allocation from more traditional subsistence practices to new market-based economic activities (Gross et al. 1979; Ringhofer 2010), thus reducing their pressure over wildlife hunting (with the exception of where wildlife hunting provides economic returns). Other authors have argued that the acculturation process erodes some well-established wildlife management strategies. Those authors advocate that some indigenous societies have developed informal institutions (i.e., cultural norms or rules) that allow them to manage common resources in a sustainable way (Colding & Folke 2001; Pacheco 2008; Jones et al. 2008; Lingard et al. 2012). The erosion of certain cultural beliefs or practices

determinants of the subsistence patterns can alter people's hunting behavior leading to population decline of some species (Etiendem et al. 2011; Jenkins et al. 2011).

In sum, the acculturation process and market integration that indigenous societies are undergoing in face of the changes and globalization of the Western society are changing the subsistence patterns of indigenous societies and the way they use and manage natural resources. However, different trends are found among the distinctive elements linked to acculturation and market integration, resulting in different outcomes as regard the individual and communal management of natural resources.

To the lands and world of the Tsimane'

Study area: summary biogeography and ecology

The Tsimane' inhabit a large territory (14º10' – 15º40'S, 66º20' – 67º20'W) in the southwestern department of Beni, mainly in the south of the Ballivian and Yacuma provinces of the Bolivian Amazon. Their territory lies from the Andean piedmont to the vast planes of the savannas of Moxos. The climate of the region is thermotropical with summer rains from October to April. From May to August there is a period of reduced precipitation -less than 100mm- and the presence of episodic southern cold winds. The mean annual temperature is 25.8°C, and the mean annual rainfall is 1743 mm, ranging from 1000 to 4000 mm depending on the years (Godoy et al. 2008).

Habitats in the area range from wet to moist sub-tropical and gallery forests, some of which flooded savannas (Killeen et al. 1993). Elevation in the area varies between 150 m to 1500 m around the Cara Cara mountains, but Tsimane' villages are only settled till the 500 m upstream the Maniqui River. Most of the territory is covered with Amazonian lowland forests with a high semi-deciduous canopy reaching 40 m (Guèze 2011). In southwestern hills at higher altitudes, forests are more similar to mountain forest whereas in the northeastern parts of the territory

predominate the flooded savannas and occasionally some forest islands occur in higher terrains (Killeen et al. 1993). In the present study we focus on the first type of forest: the *terra firme* lowland Amazonian rainforest.

The forest surrounding the Tsimane' territory supports about 30 game vertebrate species between ungulates, primates, caviomorph rodents, cracids, tinamous, and tortoises. These species represent the principal of the vertebrate biomass in Amazonian rainforests (Peres 2000) where they occur at different densities in different ecosystems (Robinson & Bennett 2004). Large-bodied ungulates and rodents, such as peccaries (*Pecari tajacu* and *Tayassu pecari*), deers (*Mazama americana*) or pacas (*Agouti paca*), predominate in more open habitats as secondary forests whereas primates, as the spider (*Ateles chamek*), brown capuchin (*Cebus apella*) or the howler monkeys (*Alouatta* sp.), occur most commonly in undisturbed forests (Robinson & Bennett 2004). The spider monkey, classified as an endangered species, and the white-lipped peccary, considered near threatened by IUCN 2010, are among the favorite hunting species of the Tsimane' (Chicchon 1992). Those two species are reported as locally extinct in some areas of the Beni Biological Station (Herrera-MacBryde et al. 2000), a protected area that overlaps with part of the Tsimane' territory. Likewise, the giant anteater (*Myrmecophaga tridactyla*) and the giant armadillo (*Priodontes maximus*) are both considered vulnerable by the IUCN (2010) Red List.

Historical context

The origins of the Tsimane' society, as we know it today, are uncertain. Most of the ethnographic work relates the Tsimane' with the Mosete, Yuracaré and probably the Leco peoples, who inhabited the Andes and migrated into the Amazon in pre-hispanic times (Reyes-García et al. 2012c). During the times of the Spanish colony, the Tsimane' had less contact with Spaniards than other Amazonian groups. The first record of contact assigned to the Tsimane' was in 1621 through the Franciscan priest Gregorio de Bolívar, who attempted and failed to Christianize and settle the Tsimane' into missions (Chicchon 1992; Huanca 2008). During that time, different religious groups working in the lowlands founded several missions, including San Francisco de Borja (in the actual San Borja), a mission established by

the Jesuits that became the main point of trade and contact with western for the Tsimane' since 1691 (Martínez-Rodríguez 2009). Till the 18th century, the process of evangelization continued in the province of Beni, but missionaries still failed to convert the Tsimane' into Christians. In 1805, the Franciscan missionaries re-established in the town of San Borja, after it had been abandoned by the Jesuits, and created two smaller missions within the Tsimane' communities along the Maniqui river (Perez Diez 1983). Once again, historical records point that the missionaries seem not to have succeeded in establishing the Tsimane' in those missions. Chicchon (1992) points out as one of the main reasons for failure, Tsimane' extensive use of natural resources, especially hunting, which did not allow them to stay in one place for a long time. Huanca (2006) adds the fear of catching diseases from outsiders and, interestingly, argues that the shamans' role in that period also might have prevented their conversion.

The significant first changes in Tsimane' subsistence economic activities could have occurred during the 1930s, when cattle ranchers began to develop agricultural production in the Beni region. Cattle raising and agricultural activities relied heavily on indigenous peoples' labor, and the Tsimane' started working as ranch laborers, becoming entangled in the debt peonage system (Martínez-Rodríguez 2009). At the same time, the Tsimane' began trading non-timber forest products for tools and weapons. The most important non-timber product used for trade was the thatch palm (*Geonoma deversa*), used for roofs in the countryside and in many urban dwellings in Beni. This forest product continues to be a factor in the articulation of the Tsimane' with the regional economy.

Associated with the cattle ranching and commercialization of beef, in the 1950s the trade of animal pelts began in the region of San Borja, an economic activity that seems to have affected the Tsimane' and their natural environment. Trade of animal pelts mostly occurred around San Borja, in the River Apere area, and in the Moxos province. Local people quickly started to barter and pay low salaries to Tsimane' for them to track animals (Huanca 2008). The commercialization of animal skins continued till the 1980s, when many Tsimane' reported scarcity of game and the depletion of species such as white-lipped peccary and tapir (*Tapirus terrestres*). During these years many Tsimane' families

abandoned the Maniqui River to find better hunting grounds in more inaccessible areas, where game was still abundant, like upstream Maniqui River or at the Secure river (Huanca 1999; Bottazzi 2009a). According to Huanca (2008), some food taboos regarding wild animals were broken during this time, and the Tsimane' started to include into their diet animals that were prohibited before according their cultural norms, such as the capybara (*Hydrochoerus hydrochaeris*). During those years, in 1953 the Catholics Missionaries established the Fátima mission in the Maniqui River, and during the same period the Protestants missionaries also began to permanently settle within the Tsimane', by establishing two educational centers, one in La Cruz and the other near San Borja (Huanca 1999). These missions, still existing, and changed the traditional communal structure, by clustering many households in more permanent settlements (Reyes-García 2001).

In the 1970s, the Tsimane' area was affected by several waves of government-planned Andean colonization, mainly to reduce demographic pressure in the Bolivian highlands. At the same time, and with the construction of new roads, many logging companies started operating in the Tsimane' area to extract precious wood, in particular mahogany (*Swietenia macrophylla*) (Gullison et al. 1996). From then on, the Tsimane' have suffered incursions of colonists and loggers, incursions that have affected Tsimane' settlement patterns and the availability of natural resources in the area. New communities started to establish themselves along the new constructed roads, and Tsimane' families started working for the Andean settlers' or logging companies. Still, some families opted to go further into the forest where their traditional subsistence was assured (Reyes-García et al. 2012c). Moreover, with the arrival of settlers and the increased accessibility to previously remote areas with the opening of new roads by the logging companies, the Tsimane' found competitors in their hunting activity. Ethnographic research in the area suggest that the Tsimane' still associate the decrease of wildlife populations to these events, as well as, the destruction of traditional hunting trails because of the construction of logging roads (Ringhofer 2010).

The high pressure on biodiversity due the pelt commercialization and the operation of logging companies, was in the origin of the creation of the Beni Biological Station (EBB) in 1982, a natural protected area declared Biosphere

Reserve by MAB-UNESCO later in 1986, that overlaps with part of the Tsimane' territory. In the EBB, all extractive activities where prohibited, except those involved in the subsistence activities of the indigenous peoples previously living within the protected area. Later on, because of the pressure of logging companies during the decades of the 1970s and 1980s, the *Gran Consejo Tsimane'* (GCT, Grand Tsimane' Council), the first political representative authority of the Tsimane' people was created. One of the first demands of the GCT were Tsimane' territorial rights, so they put forward a territorial claim, requesting an area that includes the entire region of the Maniqui River, the Eva Eva Cordillera and part of the pampas (Bottazzi 2009b). After the famous "March for Territory and Dignity" of 1990, organized by the Central de Pueblos Indigenas del Beni (CPIB) claiming the recognition of the territorial rights and citizenship of the lowland indigenous peoples, the government finally restructured the national land system and recognized 392,220 ha along the Maniqui River as the *Territorio Indígena Chimane* (TICH, Tsimane' Indigenous Territory) (DS No. 23611), as well as the *Territorio Indígena Multiétnico* (TIM, Multiethnic Indigenous Territory) a territory shared by Moxeños, Tsimane', Yuracaré, and Movima. Another decree (DS No. 22610) converted part of the Isiboro-Securé National Park into Indigenous Territory of Mojeños, Yuracarés, and Tsimane' (TIPNIS) (Reyes-García et al. 2012c). Following this initial territorial concessions, in 1992, the government also proclaimed the creation of the Indigenous Territory and Biosphere Reserve of Pilón-Lajas, with dual official status, as a protected area and as indigenous territory (Bottazzi 2009b). With the recognition of these indigenous territories, the Tsimane' (or the indigenous people's inhabiting the territory in general, gained exclusivity of extraction to resources in their land, such as game meat. However, despite this theoretical protection, today we still see illegal encroachment on the Tsimane' lands, especially for selective logging and land clearance for agriculture (Reyes-García et al. 2012b).

In 2005, the election of Evo Morales, the first indigenous president of Bolivia, lead to several additional changes in the Tsimane' daily life. For example, the new indigenous organization advanced significantly the process of titling indigenous' and farmers' lands. However, the same administration also promoted the Andean colonization, especially since 2010 when they passed a decree (DS No. 727) converting all TCOs into a new land category named TIOCs (*Territorios Indígenas*

Originarios Campesinos) (Reyes-García et al. 2012c). That same year, Jorge Añes, previously the president of the GCT was elected mayor of San Borja, a move that many thought would give a stronger political representation to the Tsimane' and defense of their land against all the different encroachments they have suffered along the years. Still, until today the Tsimane' communities, the *Gran Consejo Tsimane'* or the local government entities have not yet presented any proposal for wildlife management, as well as for other natural resource (e.g. timber) or developing plans.

Present context

Nowadays, the Tsimane' are the third largest indigenous groups inhabiting the lowlands of Bolivia. Unofficial estimates set the Tsimane' population at about 10,000 people scattered along 125 communities. The core of the Tsimane' territory coincides with the Maniqui River (Fig. 1) where many communities are settled along its banks. Other communities are established in areas of logging concessions, private lands, and in the Beni Biological Station. Traditionally semi-nomadic hunter-gatherers who also practiced small-scale slash-and-burn agriculture (Vadez et al. 2008), nowadays many Tsimane' are progressively adopting new modes of subsistence, such as temporary seasonal wage labor, trade and forestry.

As it has been the case of other Amazonian groups (Zent 2001), the foundation of schools in villages (and sometimes health posts) contributed to the permanence of the pre-existent settlements and in some cases to the increased population cluster. In remote areas of the Tsimane' territory there are small villages without schools, with two to ten households related by kin, whereas in areas close to roads and towns large permanent villages of 10 to 50 or more households exists, with government schools. This remoteness gradient, allied with different historical elements and different levels of contact with outsiders, has contributed to a growing socio-cultural and economic differentiation between Tsimane' living in different communities, but also within communities. Although the Tsimane' continue to be a highly autarkic society (Godoy et al. 2010 reported that 16% of the households do not have any kind of monetary earnings in a panel study between 2002 and 2006), there are individuals who only speak Tsimane', and have limited economic contacts

with outsiders to the bartering of rice and thatch palm, for salt, sugar and some tools. Other Tsimane', often those living in villages closer to market-towns, typically speak Spanish and have access to cash income from wage labor in logging camps, cattle ranches, and in the homestead of colonist farmers, or from the sale of crops (rice, plantains, maize, manioc, and fruits), or illegal selective logging (Vadez et al. 2008).

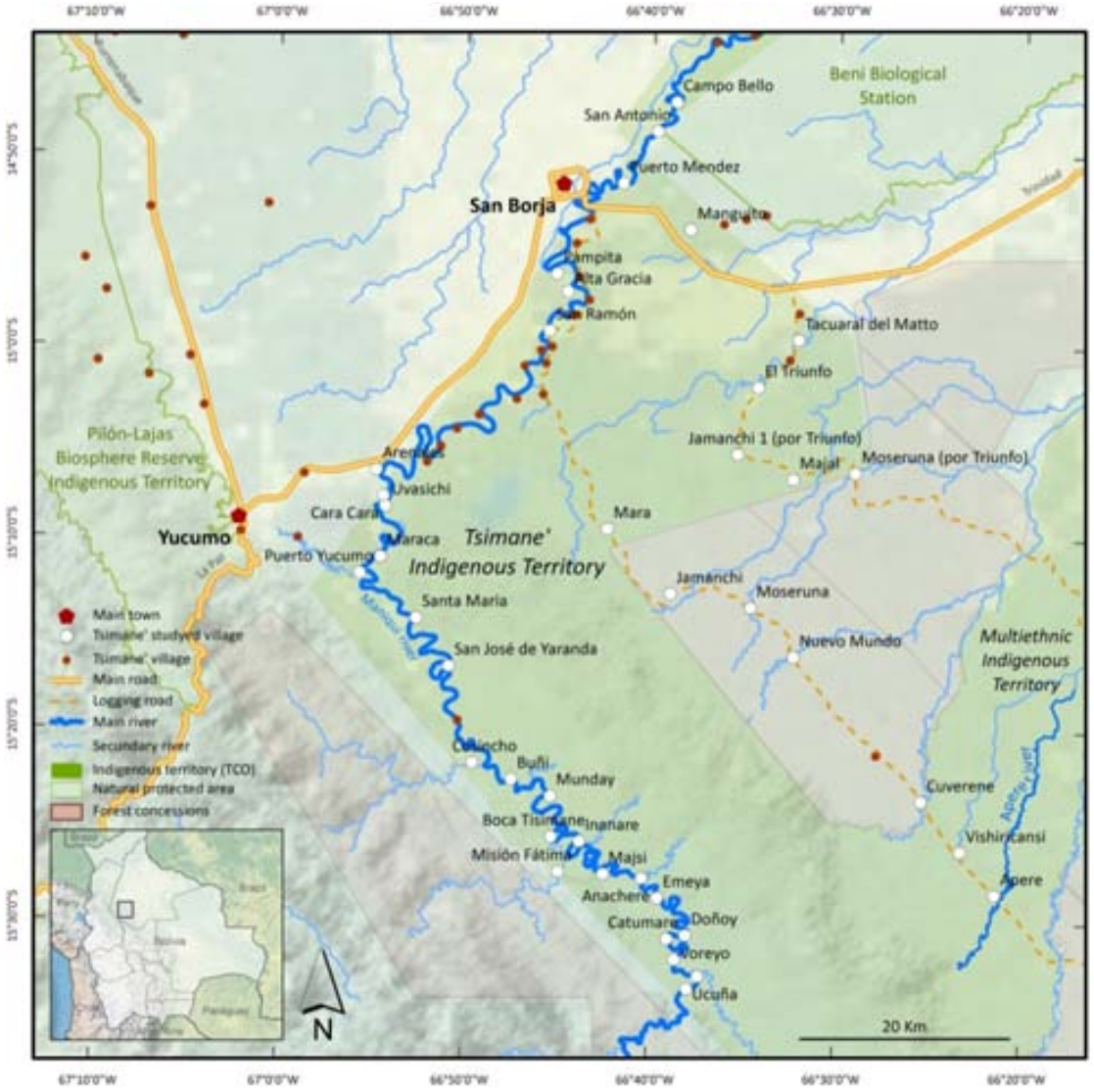

Figure 1. Map of the study area showing Tsimane' villages distribution and current land tenure system.

Regarding to social organization, most Tsimane' still practice cross-cousin marriage, meaning that a man weds the daughter of his mother's brother or that of his father's sister (Daillant 1994), despite a growing tendency for exogamous

unions in some villages close to towns. These variations between villages and between individuals from the same village create an interesting pattern in levels of acculturation (and market integration) that offer a unique opportunity to study the way the Tsimane' change and adapt their traditional practices and management of natural resources, namely, hunting and wildlife management.

The Tsimane' hunting practices

Hunting is a central activity for the Tsimane', not only for its importance in daily subsistence, but also for the socio-cultural representation it involves (Chicchon 1992; Apaza 2001; Huanca 2008). The consumption of wild meat continues to be the an important source of protein for most of the Tsimane' (complemented with fishing (Perez-Limache 2001; Zycherman 2012, unpublished)), but also a unique element of their livelihood strategy, embedded in their cultural identity, cosmologies, legends, and rituals. It is also one of the most important constituent for the happiness of the Tsimane' (Reyes-Garcí-a 2012).

Hunting is essentially a man activity but is has an important meaning for all the members of the Tsimane' society. Typically, hunters go harvesting during the day, entering deep in the forest in planned incursions. But night hunting can also occur, as well as opportunistic hunting in the horticultural plots or fallows that attract many animals (Chicchon 1992). Before a planned trip, men, usually join together to exchange impressions about the best locations for hunting and the presence of animals nearby. When they fill the chance to track abundant game, the family aligns on the trip. In these cases, the family often travels long distances and can be in the forest for several days. This is an opportunity to harvest large amounts of wild meat to feed the household and an excellent chance to teach the youngsters the most refined techniques of hunting, how to handle weapons, and let them know about stories of other hunters and the mythology surrounding hunting.

According to the Tsimane', the best hunting period, marked by the flowering of *o'ba* (*Chorisia speciosa*), occurs around May when animals are fattest (Huanca 1999). This is the perfect season to hunt some of the traditional favorite game species for the Tsimane' such as the spider monkey – *odo'* (*Ateles chamek*), or the

tufted capuchin – *oyoj* (*Cebus apella*), collared peccary – *quiti* (*Pecari tajacu*), red brocket deer – *ñej* (*Mazama americana*), and tapir – *shi'* (*Tapirus terrestres*). But for the Tsimane', most animals are edible, except, sloths, snakes, bats and jaguars, these last especially having a spiritual meaning.

The most common hunting technique is the tracking and stalking, in which hunters walk through the forest along a trail following fresh game tracks, or sounds, until they find the game prey. Another common hunting technique is to wait near a fruit tree or in claylick (natural areas with high clay concentrations in the soil, where often animals go for feed and obtain minerals that, when ingested, can reduce the effects of plant toxins, acidosis and intestinal infections in wildlife (Klaus & Schmid 1998)). Tsimane' choose these areas as they know that particular animals will go there for feeding or to mark their territory (Chicchon 1992). The traditional Tsimane' hunting instrument for excellence is the bow (*ijme')* and arrow (*coi'dye'*). Tsimane' have different types of arrows to hunt specific animals (Perez Diez 1983). Nevertheless, bow and arrows are becoming increasingly replaced by rifles and shotguns. Although, most men still manufacture their traditional instruments and some are particularly reputed for their handcraft skills, gunshots evidently improve efficiency and save time in hunting. A major problem for the use of shotguns is the acquisition of ammunitions in remote villages far from the market-town and more limited in the economic circuits of trade. In addition to bows and arrows and shotguns, traps are sporadically employed. Traps are particularly useful to capture rodents on agricultural plots or fallow sites. Dogs are also used and especially important in locating animals that live in burrows such as armadillos (e.g., *Dasypus* sp.) and some rodents, and to cornet animals that have been wounded (Chicchon 1992).

Besides these practical techniques indispensable to assure a good hunting, the fulfillment of hunting rituals and taboos are also believed to have a strong component in the success of the hunt. Traditionally, for the Tsimane', to break some taboos or to miss some of the hunting rituals could lead to the loss of hunting skills (Huanca 2008; Ringhofer 2010). For instance, when a successful hunter plans a trip some procedures most be carried out in advance. First, it is necessary to ask permission to the main spirit guardian of wildlife, *jäjäbä,* to send the adequate

number of preys and send them tamed, so the hunter can actually shoot the animal. The day before the hunt (and depending on the animals harvested also the days after), hunters must also follow a cultural practice, called *micdyidye'*. *Micdyi* means avoid or doing in moderation in the Tsimane' vocabulary, which relates to the prohibition or restriction of some daily practices. Specifically, according to the animal that the hunter aims to get, the hunter cannot consume some certain types of food. For example, eating hot peppers is forbidden before hunting tapirs. During *micdyidye'* hunters might also abstain from sexual relations. There are other cultural restrictions associated to hunting, as for example the fact that hunters should keep the animals bones and not eat their feet which is believed to prevent hunters for success in the next hunting excursion (Huanca 2008).

The Tsimane' also believe in the power of their medicines or *pinydye'* to improve their hunting abilities. For example, the Tsimane' use a substance called *isatrij*. The origin of this substance is not clear, as some authors argue that is extracted from the resin of the plant *o'yi* (*Manihot esculenta*) (Huanca 2008) whereas others state that is a plant just found in the mountains (Chicchon 1992). The most common use of this substance is to ingest it directly before going to hunt. A different way of using it is to combine it with *tsinki'*, the gall of eagle, capuchin monkey or even paca (*Agouti paca*), and ingest the mix or place it in the eyes or arms, so hunters become more skillful and attentive. These medicines are equally applied to dogs, so they become cunning hunters and do not let the prey escape (Chicchon 1992).

Until not long ago, all young Tsimane' boys used to be 'cured' with *piñidye* so they could become efficient hunters. The relatives performed a ritual which consisted in piercing the skin's arm with eagle's claw and scrub *isatrij* combined with the eagle gall and apply it in the eyes of the boys, so they become hunters as good as eagles. The ceremony used to be held during the southern cold winds season. After the ceremony, young boys could not bath for seven days (Chicchon 1992).

According to Huanca (2008), the Tsimane' used to have shamans or *cocojsi'*, which helped keeping the balance between the natural and the supernatural worlds. One of the most important roles of shamans was to mediate between hunters and

the animals' masters (*jäjäbä*, *caya'di* and *otyidye'*). The shaman would ask to the animal's master to provide animals for the families of his community, and at the same time, transmit to hunters the location and adequate quote of animals that the hunters could harvest (Huanca 2008). If these behaviors were not accomplished, game could become scarce. According to the words of an elder – "*jäjäbä would take all the animals from the forest*" and hunters or their families could get injured or fall ill. In fact, according to Huanca (1999) some hunters claim that the scarcity of game meat is related with the disappearance of the shamans. Moreover, the shamans used to say what specific practices follow before and after hunting. For example, if hunters killed a peccary, they had to practice *micdyidye'* for seven days in case it was a male, or nine days if it was a female. But, when they hunted a tapir, this ritual could continue for 14 days.

Until recently, most Tsimane' respected many of those traditional hunting practices. At present, the Tsimane' are progressively adopting new modes of subsistence that most certainly affect their traditional behavior and knowledge. The full understanding of the relations between the changes in the cultural traditional system and the way the Tsimane' manage their resources is vital to supply this society with tools that can help them becoming more resilient to face growing changes, as well as to improve the understanding of the development of indigenous societies towards the Western world. The changing hunting patterns of the Tsimane', along the variation of individual and community acculturation, in terms of the debate between the insurance of the indigenous livelihoods and wildlife conservation, will be discussed in the following chapters.

Goals and structure of the dissertation

In this dissertation, I study Tsimane' subsistence hunting along a gradient of acculturation from less to more acculturated villages. I also relate the previous factors with game availability on the territory of the same Tsimane' villages. This thesis has four specific aims:

1. to describe *a)* the composition and structure of the game community available in the Tsimane' territory, and *b)* the game harvest profile of the Tsimane' villages (chapter 1);
2. to understand how Tsimane' hunting pressure varies along a gradient of acculturation and wildlife availability (chapter 2);
3. to evaluate what sociocultural determinants relate to hunting behavior (chapter 3); and
4. to assess the attachment to traditional hunting norms and its implications into the game harvest and in communal game management (chapter 4).

The work presented within the scope of this thesis is a compilation of data collected between 2008 and 2010 and explored the year after. It encompasses a set of quantitative analyses accompanied by different theoretical discussions that allow the understanding of the impact of acculturation on hunting activity from different perspectives. I have structured this dissertation from a more ecological and general perspective of hunting patterns (chapters 1 and 2), to more social and specific individual aspects (chapters 3 and 4). The empirical analysis carried out in the first two chapters was made at the village level and aims to present a broader perspective to the hunting patterns related with different cultural and socioeconomic elements of the Tsimane' society. Thereafter, the final two chapters address more individual and specific questions related to the main theme of this thesis, the relationship between acculturation and hunting. Each chapter presented corresponds to a manuscript that will be submitted to Journal Citation Reports (JCR) journals in the near future. This justifies the following chapters' structure which –at times– repeats common sections with the introduction, such as the study area and the Tsimane' population descriptions. The specific outlines of the chapters are as follows:

Chapter 1 is as a basic introduction to the knowledge of the most important game species harvested by the Tsimane'. I first give a description of the composition and structure of the vertebrate community available in the areas surrounding the Tsimane' villages, to, thereafter, assess what environmental and geographic factors influence the distribution and relative abundances of these game species. I then

describe the composition and structure of the hunted vertebrate community. The general aim of the chapter is, on one hand, to evaluate the impact of subsistence hunting on the game available composition and structure, and on the other hand evaluate how the harvest profile is influenced by the available wildlife.

Chapter 2 targets the core discussion of the impact of acculturation on subsistence hunting and wildlife availability. It specifically analyzes the variation of hunting pressure along a continuum of villages' acculturation and with different levels of game availability. The chapter illustrates this point through adding a GIS component that provides a new methodological perspective used to assess hunting pressure. In the discussion, the chapter underlines the utility of this methodological approach in future wildlife conservation measures.

Chapter 3 goes into the individual level analysis (i.e. hunters' level) and explores the relation between acculturation and hunting behavior. From a set of acculturation proxies, this chapter explores which acculturation variables are strictly linked with the probability of engaging in hunting and with the amounts of game harvested (animals' number and biomass). In this chapter I also discuss the implications of acculturation in hunting activity and wildlife conservation.

Chapter 4 presents an empirical analysis that links changes in the hunting cultural beliefs system of the Tsimane' with wildlife conservation. From a set of traditional cultural norms based on beliefs, it assesses the maintenance of those cultural noms, and how they relate to the number and biomass of game harvested. This will help understanding the potential role of hunting cultural norms as informal institutions in the communal game management.

Finally I present a general **discussion** of the results of this research. In this final chapter, I integrate the main results of the four chapters of the thesis and provide a wider perspective of the implications of acculturation (and sometimes market integration) in the conservation of the Tsimane' livelihoods and wildlife. Also, I outline the policy implications of the work presented here and suggest future possible areas of research.

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CHAPTER 1

Game vertebrate composition and harvest in hunted forest sites in the Bolivian Amazon

Abstract

The Amazon (*sensu lato*) is among the most species-rich places in the world. Most of the large vertebrates present in these tropical rainforests are important in determining forest structure and plant diversity. They are also a significant source of food and income for many forest-dwellers. In this work, we present estimations of the composition and abundance of the game vertebrate community in the territory inhabited by Tsimane', a native group of hunter-gatherers in the Bolivian Amazon. We assess encounter rates for 21 game species, based on animal transects carried out around 40 villages. We analyzed game community composition and structure in villages along a gradient of forest cover and geographic remoteness. We used survey data to evaluate villages' game harvest profile. In the Tsimane' territory, game community composition and structure seem to respond to overhunting and habitat degradation. Results also suggest that overall species abundances increase with villages' isolation from market-towns. Data from harvest profile suggest that Tsimane' hunt according to game availability, except for some species such as spider monkey or white-lipped peccary, for which cultural preferences seem to prevail. Villages close to market-towns presented lower harvest rates than more isolated villages.

***Key words*:** habitat degradation; harvest profile; hunting pressure; indigenous peoples; Tsimane'; wildlife availability

Introduction

The Amazon tropical rainforest is among the most species-rich places in the world (Mittermeier et al. 2005) and among the regions with highest rates of ecosystems depletion (Davies et al. 2006; Asner et al. 2009; Peres et al. 2010). Over the last decades, activities such as hunting (Wilkie et al. 2011; Nasi et al. 2011), land clearing for agriculture or timber extraction (Asner et al. 2005), road construction (Wilkie et al. 2000), and the establishment of extractive industries such as oil exploitation (Orta-Martínez & Finer 2010) have put a large pressure on species and ecosystems in the Amazonian landscapes.

Subsistence hunting can lead to population decline or local extirpations. It can also dramatically alter the composition and size structure of vertebrate communities (Peres 2000a; Urquiza-Haas et al. 2011). Moreover, among game species, some medium and large mammals are especially important because they play an essential role in the maintenance of tropical rainforests structure and dynamics. They are essential for seed dispersal and seed predation (Wright et al. 2000; Peres & Palacios 2007; Brodie et al. 2009), constitute important preys for top predators (Estes et al. 2011), and exert an important physical control in herbivory patterns (Dirzo & Miranda 1991). Additionally, largest vertebrates also are the most threatened because they generate the highest value per unit of effort invested in hunting (Jerozolimski & Peres 2003). Some primate and ungulate species are especially ecologically vulnerable due to their low reproduction rates and low population densities (Jerozolimski & Peres 2003). Because the sustainable harvest of vertebrates could help retaining the value of Amazonian ecosystems (Redford 1992), understanding the patterns of vertebrate species composition, structure and abundance is an essential first step for any effort to assess the indirect effects of hunting on game species and overall biodiversity. Understanding these patterns is also important to predict the consequences of biodiversity loss for local livelihoods. However, and although the topic of subsistence hunting has generated a large body of literature, there exists only a reduced number of publications estimating game abundances, and those are limited to particular sites (e.g., Carrillo et al. 2000;

Escamilla et al. 2000; Lopes & Ferrari 2000; Cuarón 2001; Parry et al. 2007; Endo et al. 2010; Urquiza-Haas et al. 2011).

The territory nowadays inhabited by Tsimane', a native group of hunter-gatherers in lowland Bolivia, has been used as a hunting ground for centuries (Huanca 2008). Over the last decades, these lands have received the arrival of new actors (e.g., from loggers, pelt finders, ranchers, colonists) (Reyes-García et al. 2012a) that have increased the pressure on wildlife and on the overall biodiversity of the territory. Although the area is recognized as a repository of plant diversity (Killeen et al. 1993; Guèze et al. 2012), game abundance estimations are almost nonexistent, as in most parts of the Bolivian Amazon (Santivañez 2007). Indeed, we only know of one study evaluating the relative abundance of game vertebrate species at the Beni Biological Station (Herrera-MacBryde et al. 2000), a protected area that partly overlaps with the Tsimane' territory. Although informative, the study is limited in scope, as it only compared one Tsimane' village with an area not used for hunting, by quantifying animal sightings and tracks. Other studies have used data from hunting surveys to provide an indirect measure of wildlife conservation in the area (Chicchon 1992; Apaza 2001; Limache 2001; Wilkie & Godoy 2001; Apaza et al. 2002, 2003; Gutierrez 2005; Godoy et al. 2010), but without providing biological estimates of game abundance.

In this study, we present the first estimates of game vertebrate abundances in the Tsimane' territory. The specific goals of the article are (1) to describe the game vertebrate composition, structure and encounter rates in the Tsimane' territory, (2) to explore variations in composition, structure and encounter rates in villages along a gradient of remoteness and habitat degradation, and (3) to present the game harvest profile of the sampled villages. Our study includes results from animal transects in 40 Tsimane' villages. Sampled villages varied on their accessibility, size, and habitat degradation status, factors that may influence game composition and population abundances. So, our sample provides a realistic picture of the overall game composition on the Tsimane' territory.

Materials and methods

Study area

The Tsimane' territory is located between the foothills of the Andes and a wide area of the flooded Moxos savannas in the Beni region of the Bolivian Amazon. Elevation ranges between 150 m and 500 m upstream Maniqui River. The mean annual temperature is of 25.8°C (Navarro & Maldonado 2002) and the mean annual precipitation is of 1743 mm (Godoy et al. 2008). There is a four-month period of reduced precipitation -less than 100mm- from May to August characterized by the presence of episodic southern cold winds. Owing to a marked seasonality, most of the territory is covered with well-drained lowland forests with a high semi-deciduous species canopy reaching 40m, (Killeen et al. 1993). Vegetation is typical of lowland Amazonian forests but species richness is lower than in other parts of the Amazon (Killeen et al. 1993; Guèze et al. 2012). In the southwestern part of the territory, with higher altitudes, vegetation share floristic affinities with the transition Amazonian-Andean biogeographic regions, whereas in the northeast region, flooded savannas are predominant and some forest islands occur locally on higher terrains sharing affinities with the Brazilian-Paraná biogeographic region (Guèze et al. 2012). Previous studies indicate that, as in other neotropical rainforests (Peres 2000a), most game vertebrates present in this region are ungulates, primates, caviomorph rodents, cracids, tinamous, and tortoises (Chicchon 1992). However, we lack a detailed description of game species abundance and composition in the region.

The current estimated Tsimane' population is about 10 000 people, distributed on approximately 125 villages scattered along rivers and logging roads (Reyes-García et al. 2012b). The most important economic activities for the Tsimane' are hunting, fishing and slash-and-burn farming, being the sale of thatch palm and cash cropping of rice their primary sources of monetary income (Vadez et al. 2008). Hunting is a primordial activity for the Tsimane', since it continues to provide a vital source of food and protein and is at the core of the Tsimane' cultural identity (Chicchon 1992; Godoy et al. 2010). Among the Tsimane', excellence in hunting is a source of status for hunters and their families, allowing them to bound

with other members of the group through sharing and reciprocity. Hunting skills are also an observable feature that helps Tsimane' men to find a partner (Chicchon 1992; Gurven & von Rueden 2006). Nowadays, Tsimane' men regularly hunt with shotguns and, during short incursions, they are often accompanied by dogs that help them to track game preys. Traditional hunters, or any hunter lacking munitions, also use bow and arrows.

Sampling

Between March 2008 and July 2010, we collected information on 40 villages settled along the Maniqui River and two major logging roads (see Introduction – Fig. 1). We selected villages based on information from a recent census for this region (Reyes-García et al. 2012a). We only included villages established in *terra firme* lowland rainforest, and selected them to maximize variation in village-to-town distance (mean=57.86 km; SD=34.81 km). To conduct the study, we obtained previous consent from the *Gran Consejo Tsimane'*, the major Tsimane' political organization, and from all the study villages and participants. In villages with less than 40 households, we randomly selected ten households from a list provided by the highest-ranking authority of each village. In villages with ten or less households we surveyed all the present households, whereas in those with more than 40 households we surveys 25% of the village. In each selected household, we interviewed the male household head because traditionally all Tsimane' adult men were hunters and the main providers of wild meat for the entire household (Chicchon 1992). To capture seasonal variation, we had scheduled to visit each village a total of three times. Due to logistical constraints related to the remoteness of some villages, we could only visit twice 12 of the villages, and once 10 of them.

ANIMAL TRANSECTS

To assess the wildlife community available in the vicinity of each of the 40 sampled village, we conducted ten two-hours transects in each village (n=400 transects). Upon arrival to a village, we called for a communal meeting to which we invited all the hunters in the village. During the meeting, we asked hunters to

indicate the village major hunting paths and identify the type of habitat in which the path was settled. To capture the full spectrum of available game species, we then selected transects with different habitats along those paths. To minimize spatial autocorrelation in our data, and consequently overestimation of the wildlife community available, we tried to maximize the distance among transects. In each village, six of the hunting paths were surveyed during the morning (07:00 – 9:00 hours) and four during the evening (17:00 – 19:00). To capture seasonal variation on game availability we distributed transects assessment equally during our first two visits, roughly corresponding to the dry and the rainy season. The start of each transect was located at a minimum of 30 minutes walking distance from the village center (or school). Local hunters guided us along hunting trails and two Tsimane' trained monitors identified animal sightings or any indirect evidence (tracks, vocalizations, feces, or hairs), tracked them with GPS, and recorded the Tsimane' name of all species encountered. We only recorded species reported as hunted game in previous research among the Tsimane' (Chicchon 1992; Apaza 2001). Further details on transects characterization are given in Appendix II.

HUNTERS' SURVEYS

To assess game harvesting, we asked hunters to report information concerning their hunting trips during the two weeks previous to the day of the survey. Specifically, we recorded all the game harvested and -for each animal- its life stage, sex, and the hunting site. To capture seasonal variation on the hunting activity, the survey was repeated in the three different visits to the villages. We interviewed the same sample in each of the three visits, when available. In the first of our surveys, we also asked hunters to list their five most desirable game species.

Data analysis

AVAILABLE GAME COMMUNITY

For each species and village we estimated the average encounter rate (number of animal sights or tracks per kilometer). In the case of group-living species, such as primates, peccaries and coatis we accounted one group of sightings

or tracks as a single individual sighting. We used both direct sighting and track records as encounter measures along transects. To avoid self-replication or overestimation of species abundances, we excluded consecutive observations of the same species in space or next in time tracking (intervals of less than five minutes). To see variations according the geographic pattern, we also estimated encounter rates by villages' remoteness. To do so, we first classified villages in remote, medium and close by calculating a remoteness index that factors in the distance to the nearest market-town, plus the travel time.

To visualize the structure of the game community we classified game species into four biomass classes taking into account their body size distribution (adapted from body size classes given by Peres (2000a) and estimates of species body mass given by Myers et al. (2006)):

(1) Small species (<1 kg): night monkey (*Aotus azarae*) and squirrel monkey (*Saimiri boliviensis*);

(2) Medium species (1–5 kg): brown capuchin (*Cebus apella*), honey bear (*Potos flavus*), coati (*Nasua nasua*), agouti (*Dasyprocta punctata*), spix's guan (*Penelope jacquacu*), large tinamous (*Tinamus major*), curassow (*Mitu tuberosa*) and tortoises (*Geochelone* spp.);

(3) Large species (5–15 kg): howler monkeys (*Alouatta* spp.), spider monkey (*Ateles chamek*), collared anteater (*Tamandua tetradactyla*), paca (*Agouti paca*), and armadillos (*Dasypus* spp.); and

(4) Very large species (>15 kg): collared peccary (Pecari *tajacu*), white-lipped peccary (*Tayassu pecari*), red brocket deer (*Mazama americana*), tapir (*Tapirus terrestris*), capybara (*Hydrochoerus hydrochaeris*), and the edentantes giant armadillo (*Priodontes maximus*) and giant anteater (*Myrmecophaga tridactyla*).

We compared the game harvested number and biomass for each body size class and villages remoteness category using a Wilcoxon rank-sum test (Mann-Whitney). We used Redundancy Analysis (RDA), a constrained ordination technique, to analyze the overall composition and distribution of the vertebrate community in relation to environmental and geographic patterns (ter Braak &

Prentice 1988). Environmental variables included annual mean precipitation, and old-growth forest and early-growth/degraded forest cover area in each village. Annual mean precipitation was obtained from the WorldClim data set (http://www.worldclim.org). To estimate old-growth forest area and early-growth/degraded forests cover area, we used the best land cover classification of Landsat imagery from 2009 obtained by Paneque-Gálvez et al. (2011). We then applied a 5km circular buffer to the centre of each village surveyed. We used a 5 km buffer because, according to our previous work in the area, more than 60% of the hunting trips and all land transformations related to villages subsistence activities (i.e., agricultural plots) occur within this radius (Chapters 2 and 3; Cruz-Burga et al. 2012). We also included village population size to the RDA, because it is known that human density can have great impact on wildlife availability (Robinson & Redford 1991). For further details on environmental variables see Appendix I.

HARVEST GAME COMMUNITY

We described the total number and biomass of the animals harvested, as reported on the hunters' surveys. We also provided their status on the IUCN Red List. To assess the structure of the game harvested community we first classified species into the four body size classes previous described. To standardize village harvest rates, we then divided the total number and biomass of the animals captured by the number of visits made to each village. We finally plotted the standardized village harvest rate against villages' remoteness index. We compared the game harvested data among villages' remoteness categories, for each body size classes, using a Wilcoxon rank-sum test (Mann-Whitney).

We ran the Redundancy Analysis with CANOCO 4.5 software. Villages distance and land cover areas were estimated using ArcGis 10. All other statistical analyses were run with STATA 11.

Biases and limitations

The main potential bias of the present study relates to our method to estimate species encounter rates. We calculated species encounter rates as the

number of sightings or tracks of a certain species in a kilometer along a transect. Although we tried to avoid self-replication or overestimation by excluded observations bellowing to the same species that were contiguous in space or very close in time, our estimations might still be biased. For example, some authors only count the tracks of an animal crossing the transect as one sighting (Carrillo et al. 2000). However, although results presented here might overestimate game abundances when compared with previous works, especially terrestrial vertebrates whose estimation depends almost exclusively on tracks, those results show internal consistency when comparing across the different categories used in this study.

In addition to this bias, there is an important limitation to our methodology, related with the use of species encounter rates rather than game densities. We collected data on game availability along the villages' most common hunting paths, rather than using the usual line-transects approach (Peres 1999). We opted for this methodology to increase the sample size, since our visits to village ware limited to four days on average. Although we are aware that the estimation of game densities is an essential step to assess harvest sustainability, because estimations require a minimum of 40 sights per site (Buckland et al. 1993), most of the times it is not feasible in terms of effort sampling. Still, as one of the aims of our study was to compare game abundances along a village remoteness gradient, and since villages areas are relatively close to each other, we consider that the use of species encounter rate is more appropriated for such comparison.

Results

Available game community

COMPOSITION: On average, we walked 2.6 km of transects per village. Overall, in those transects we identified 30 animal species, of which we list records of 21 species of game vertebrates (Table 1.1). Collared peccary, brocket deer, paca, agouti and armadillos were tracked in every village, although their relative abundances per village varied considerably. We estimated an average encounter rate of 0.78 animals/km for collared peccary and of 2.45 animals/km for paca. Great tinamou

was present in 39 villages but presented a relatively low encounter rate (0.19 animals/km). Tortoises were sighted in only five villages with an average estimated encounter rate of 0.004 animals/km. White-lipped peccary and howler monkey that were just sighted in eight villages, also with relatively low encounter rates (0.02 and 0.01 animals/km respectively). The spider monkey, an endangered species (IUCN 2010) still hunted by the Tsimane', was not recorded during any transects.

Table 1.1. Encounter rate (and number of villages present) of each game vertebrate species assessed in 40 Tsimane' villages. Sampled villages were classified into three groups according to their remoteness to the closest market-town: remote (n=12), medium (n=14) and close (n=14).

Code	Vertebrate specie	English common name	**Average encounter rate** (animals / km)				
			Overall	Close	Medium	Remote	Group differences
	Ungulates						
Ptaj	*Pecari tajacu*	Collared peccary	0.78 (40)	0.74 (14)	0.79 (14)	0.8 (12)	nd
Mame	*Mazama americana*	Red brocket deer	1.86 (40)	1.25 (14)	2.35 (14)	1.99 (12)	a*** b* c***
Tpec	*Tayassu pecari*	White-lipped peccary	0.02 (8)	0.02 (3)	0.03 (5)	- (0)	b** c*
Tter	*Tapirus terrestris*	Tapir	0.19 (24)	0.1 (5)	0.23 (8)	0.24 (11)	c***
	Rodents						
Apac	*Agouti paca*	Paca	2.45 (40)	1.7 (14)	2.67 (14)	3.08 (12)	a*** c***
Dpun	*Dasyprocta punctata*	Agouti	1.55 (40)	1.54 (14)	1.55 (14)	1.57 (12)	nd
Hhyd	*Hydrochoerus hydrochaeris*	Capybara	0.02 (11)	0.03 (4)	0.01 (3)	0.02 (4)	nd
	Primates						
Cape	*Cebus apella*	Brown capuchin	0.02 (14)	0.01 (3)	0.03 (5)	0.03 (6)	c*
Alou	*Alouatta spp.*	Howler monkey	0.01 (8)	0.01 (1)	0.01 (4)	0.03 (3)	nd
Aaza	*Aotus azarae*	Azara's night monkey	0.06 (27)	0.04 (8)	0.09 (12)	0.05 (7)	a*
Sbol	*Saimiri boliviensis*	Squirrel monkey	0.03 (17)	0.03 (5)	0.03 (6)	0.02 (6)	nd
	Edentantes						
Ttet	*Tamandua tetradactyla*	Collared anteater	0.03 (18)	0.04 (7)	0.03 (6)	0.03 (5)	nd
Mtri	*Myrmecophaga tridactyla*	Giant anteater	0.01 (11)	0.01 (4)	0.02 (4)	0.01 (3)	nd
Dasy	*Dasypus* sp.	Armadillos	1.71	1.37	1.59	2.26	b* c***

			(40)	(14)	(14)	(12)	
Pmax	*Priodontes maximus*	Giant armadillo	0.07 (25)	0.04 (5)	0.06 (9)	0.12 (11)	b** c***
	Carnivores						
Nnas	*Nasua nasua*	Coati	0.1 (29)	0.08 (8)	0.13 (12)	0.08 (9)	a*
Pfla	*Potos flavus*	Honey bear	0.03 (15)	0.003 (1)	0.03 (6)	0.06 (8)	a*** c***
	Cracids						
Pjac	*Penelope jacquacu*	Spix's guan	0.09 (26)	0.04 (4)	0.11 (12)	0.1 (10)	a*** c***
Mtub	*Mitu tuberosa*	Razor-billed curassow	0.01 (9)	0.01 (2)	0.01 (4)	0.01 (3)	nd
	Tinamus						
Tmaj	*Tinamus major*	Great tinamou	0.19 (39)	0.17 (13)	0.19 (14)	0.22 (12)	c*
	Reptiles						
Geoc	*Geochelone sp.*	Tortoise	0.004 (5)	0.002 (1)	0.004 (2)	0.01 (2)	nd

Note: Differences assessed with Wilcoxon rank-sum test (Mann-Whitney) between: [a]close and medium villages, [b] medium and remote villages, and [c] close and remote villages. [nd] no significant differences and *, **, and *** statistically significant at $p< 0.1$, $p< 0.05$ and $p<0.01$, respectively.

Species encounter rates were generally higher in more remote villages than in medium or close to market-town villages. Largest differences were found between close and remote villages. Villages in the medium remoteness category resembled remote villages more than they resembled close to the market-town villages. White-lipped peccary was one exception to this result, and the only species we could not track in remote villages. For brocket deer the encounter rates were slightly higher in villages in the medium remoteness than in the other two categories. Small birds, such as *Ara* sp., were also sighted during the transects, as well as small mammals such as squirrels (*Sciurus* sp.) and porcupine (*Coendou prehensilis*), but due the low number of sights or tracks recorded and to their low contribution in terms of biomass to the overall community, we have not estimated their encounter rates, nor included them in the following analysis.

Area of old-growth forest varied considerably among villages, ranging from about 1.3 km^2 to almost 8 km^2, with an average of 5.8 km^2 (± 1.9). Early-growth/degraded forest area ranged even greatly, from 0.9 km^2 to 20.5 km^2, with an average area of 8.1 km^2 (± 6.4). The average annual mean precipitation estimated

for our 40 villages was of 1914 mm (± 123.3). Villages' size ranged from 3 to 95 households, with an average of 26.2 households (± 21.3).

The RDA for the available game community produced a significant model where all variables together explain 45% of the species composition and abundance (Table 1.2). The first axis explains almost the total variance of the available game data (34%) and displays a strong species correlation of about r=0.76. The three remaining axes together explain 9.9% of the total variance and show strong species correlation values.

Table 1.2. Results of the redundancy analysis (RDA) for available game species community and environmental variables in 40 Tsimane' villages.

Axes	**1**	**2**	**3**	**4**
Eigenvalues	0.34	0.08	0.01	0.009
Species-environment correlations	0.76	0.63	0.54	0.45
Cumulative percentage variance				
of species data	34.2	42.6	43.7	44.6
of species-environment relation	76.1	94.9	97.4	99.4
Sum of all canonical eigenvalues	0 .45			

The RDA biplot of Fig. 1.1 suggests that the old-growth forest has the largest influence in the distribution and relative abundance of most of the game species available at the community level. On the opposite side of the first axis, there are the early-growth/degraded forests not associated with species distribution and relative abundance, except for collared anteater (Ttet) and capybara (Hhyd). In fact, there is a gradient of forest cover, from areas with more early-growth/degraded forest to areas with more old-growth forest, which relates with villages distribution. Villages settled closer to market-town present higher areas of early-growth/degraded forest, whereas medium and remote villages have increased area of old-growth forest. Village size was negatively associated with game species presence. Overall, most species distribution was associated with the increase of old-growth forest cover. Villages in the medium remoteness category seem to have higher diversity of species and relative abundances than remote or close to mark-town villages.

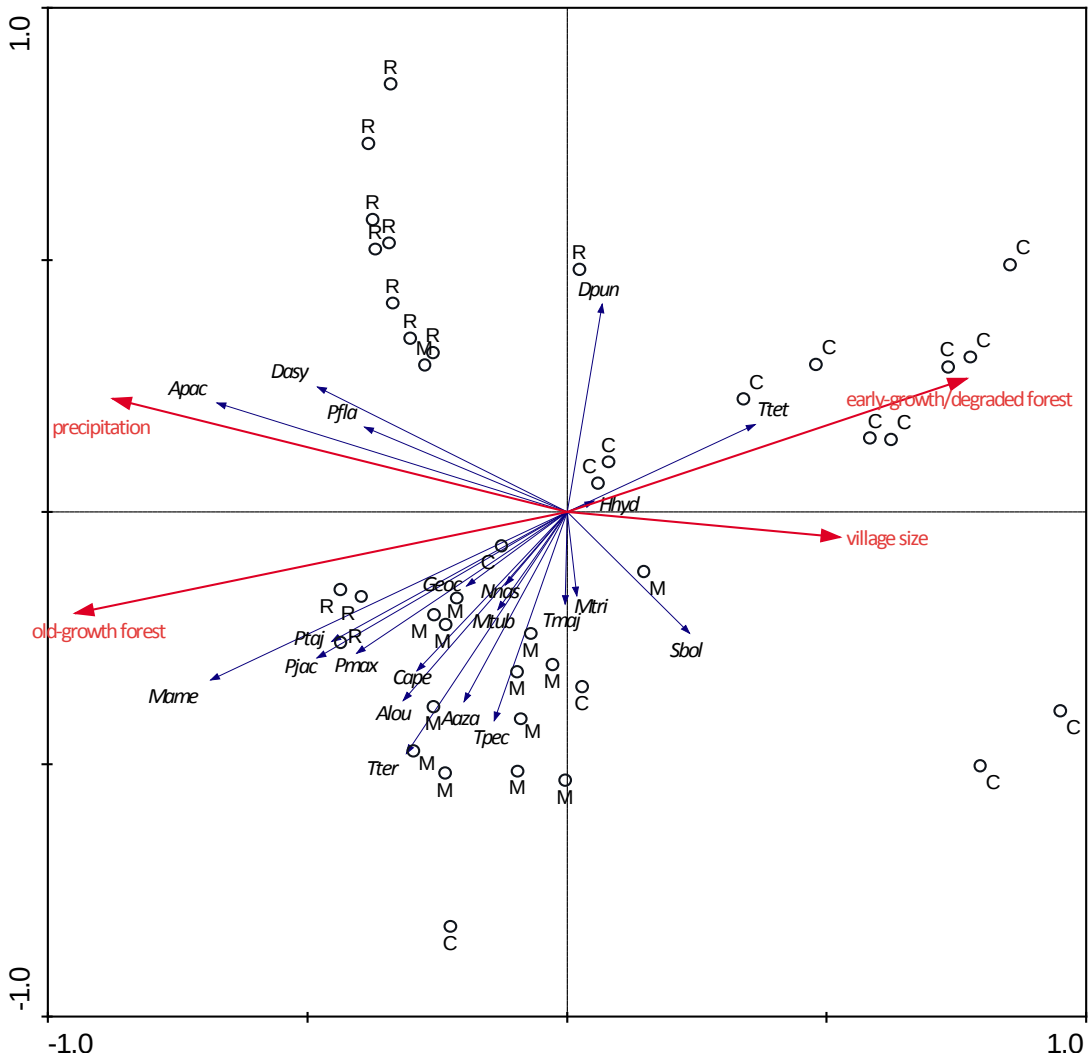

Figure 1.1. Biplot diagram of game species abundance estimates from animal transects in 40 Tsimane' villages classified according their remoteness to market-town: C – close, M – medium, R – remote. Game species labels combine the first letter from the genus name and three first letters from the species epithet (for name correspondence see table 1.1).

STRUCTURE: The encounter rate and biomass of species in different size classes varied across villages' remoteness (Fig. 1.2). In the three categories of villages' remoteness, the overall abundance of the game community was dominated by the two largest size classes, but encounter rates of those two classes were smaller at the close-to-town villages. Considering villages in the three remoteness categories, species in the large size category (5 – 15 kg) accounted for an average encounter rate of 4.2 animals/km, and, species in the very-large size category (> 15 kg) accounted for an average encounter rate of 2.9 animals/km. Remote and medium

remoteness villages presented the highest averages, with significant differences from the close-to-town villages. In the small body size class (<1 kg) and in the medium body size class (1 – 5 kg) no differences were found among remoteness categories. Regarding the biomass community structure, we found similar trends. Biomass estimations were dominated by large- and very large-bodied vertebrate species, especially in the medium and remote villages. The overall average of biomass for the four body size classes, from the smallest to the biggest was of 0.09, 4.3, 27.5, and 151.3 respectively.

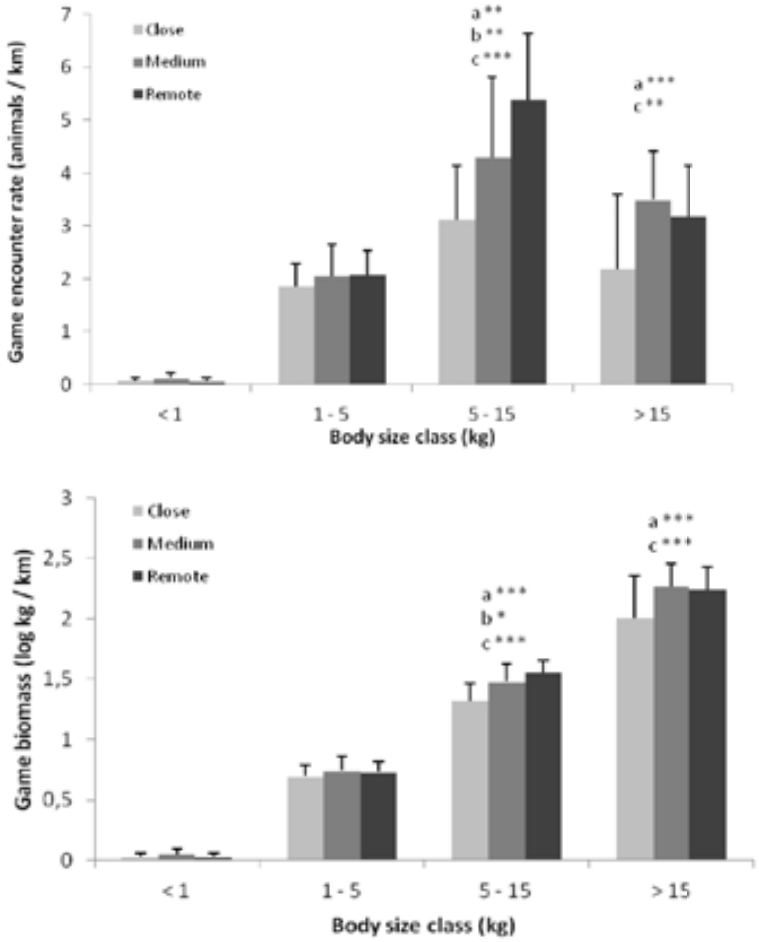

Figure 1.2. Encounter rate and biomass of game species according to their body size class, per village. Mean values (+ SD) are distributed with respect to the villages' remoteness categories: close, medium and remote. Differences assessed with Wilcoxon rank-sum test (Mann-Whitney) between: [a] close and medium villages, [b] medium and remote villages, and [c] close and remote villages. *, **, and *** statistically significant at p< 0.1, p< 0.05 and p<0.01, respectively.

Harvest game community

COMPOSITION: We identified 29 vertebrate species reportedly hunted by 347 Tsimane' hunters during 481 successful hunting trips (Table 1.3). The seven most hunted species –paca, collared peccary, coati, brown capuchin, red brocket deer, Spix's guan and howler monkey– represent about 70% of the total number of animals harvested. Tapir, red brocket deer, and collared peccary had the highest contributions in terms of biomass, representing about 70% of the total harvested biomass. According to the IUCN (2010) red list, spider monkey is classified as an endangered species, white-lipped peccary is considered near threatened, and tapir is a vulnerable species. Some species such as the giant anteater, giant armadillo, capybara, squirrel, porcupine and some small birds (i.e., *Ara* spp.) had very few records –less than five. The giant anteater and the giant armadillo are both considered vulnerable by the IUCN (2010) Red List.

Table 1.3. Number (and total biomass) of the animals harvested during 481 successful hunting trips with the corresponding IUCN Red List status (IUCN 2010). N = 816 animals recorded. Species with less than five records were excluded from the list. IUCN Red List categories: least concern (LC), near threatened (NT), vulnerable (VU), endangered species (EN), and data deficient (DD).

			Number (and biomass in kg) of animals			
Vertebrate specie	English common name	IUCN conservation status	Overall	Close	Medium	Remote
Ungulates						
Pecari tajacu	Collared peccary	LC	92 (1826)	22 (431.6)	43 (852.6)	27 (542.2)
Mazama americana	Red brocket deer	DD	71 (2908)	5 (227.5)	43 (1698.5)	23 (982)
Tayassu pecari	White-lipped peccary	NT	32 (704)	6 (132)	13 (286)	13 (286)
Tapirus terrestris	Tapir	VU	13 (2950)	2 (500)	2 (500)	9 (1950)
Rodents						
Agouti paca	Paca	LC	105 (861)	13 (101)	54 (454)	38 (306)
Dasyprocta punctata	Agouti	LC	14 (29.1)	5 (9.8)	9 (19.3)	-
Primates						
Cebus apella	Brown capuchin	LC	86 (212.8)	12 (30.3)	43 (107.3)	31 (75.2)
Alouatta spp.	Howler	-	56	13	17	26

	monkey		(362.3)	(83.3)	(112.37)	(166.6)
Aotus azarae	Azara's night monkey	LC	14 (16.6)	6 (6.7)	7 (8.6)	1 (1.23)
Saimiri boliviensis	Squirrel monkey	LC	25 (15.4)	13 (7.9)	11 (6.7)	1 (0.6)
Ateles chamek	Spider monkey	EN	16 (96)	4 (24)	4 (24)	8 (48)
Edentantes						
Tamandua tetradactyla	Collared anteater	LC	13 (55.8)	7 (29.7)	5 (22.5)	1 (3.6)
Dasypus sp.	Armadillos	-	19 (57)	8 (24)	7 (21)	4 (12)
Carnivores						
Nasua nasua	Coati	LC	91 (397.2)	27 (119.5)	29 (123.7)	35 (154)
Potos flavus	Honey bear	LC	26 (76)	-	15 (43)	11 (33)
Cracids						
Penelope jacquacu	Spix's guan	LC	70 (89.6)	9 (11.5)	40 (51.2)	21 (26.8)
Mitu tuberosa	Razor-billed curassow	LC	25 (76)	4 (12.2)	10 (30.6)	11 (33.6)
Tinamus						
Tinamus major	Great tinamou	LC	6 (6.2)	1 (1.03)	4 (4.12)	1 (1.03)
Reptiles						
Geochelone sp.	Tortoise	-	23 (141)	8 (46)	5 (30)	10 (65)

In general, most species presented higher harvest rates in the medium and remote villages than in the close-to-town villages. The agouti, collared anteater and armadillos represented exceptions, probably due the higher availability of more desirable game preys in those villages.

During our study, the Tsimane' reported that their most preferred species are the collared peccary, the red brocket deer, the brown capuchin, the howler monkey, and the coati. From our sample, the five species referred before appeared in 74%, 68%, 49%, 35% and 30% respectively of the lists of the five most desirable game species of the sampled hunters. These same species were also among the most hunted ones.

STRUCTURE: The overall vertebrate harvested community structure (Fig. 1.3) presented a different trend regarding the available game community structure (Fig.

1.1). Animals harvested were dominated by medium-bodied size species in all three village's remoteness categories. The overall average for the medium body size class was of 5.8 animals harvested, almost twice the average of very large species (3 animals), and twelve times higher the overall average of small species (0.5 animals). Close villages presented the highest contribution regarding the small body size class (< 1 kg), contrary to the pattern found in the remaining body size classes. However we have not found significant differences among remoteness categories in the small body class, as well as in the medium body size class (1 – 5 kg).

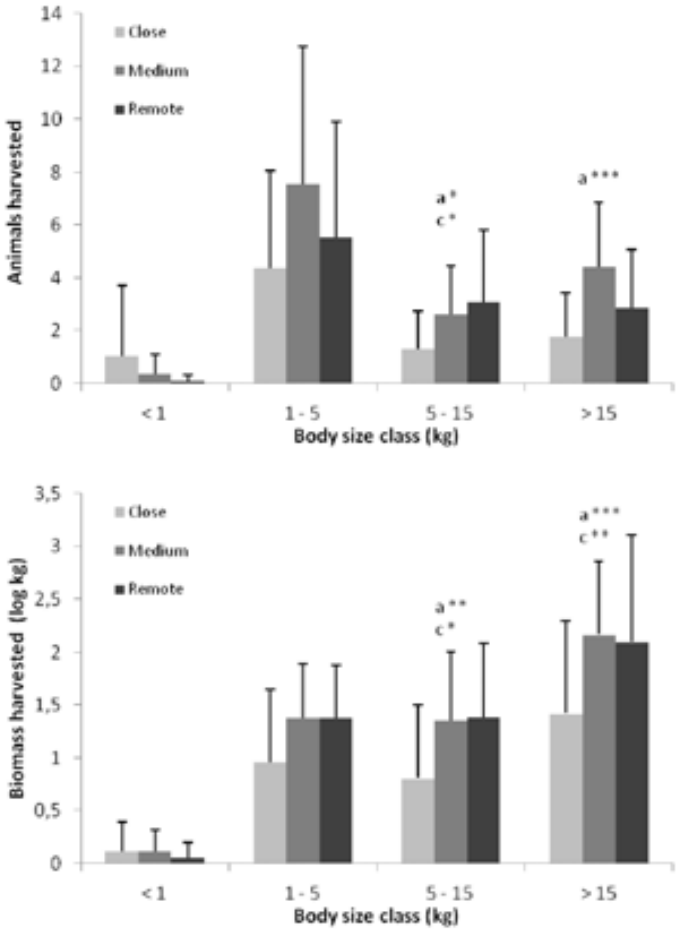

Figure 1.3. Number of animals and biomass harvested per village of game species according their body size class. Mean values (+ SD) are distributed with respect to the villages' remoteness categories: close, medium and remote. Differences assessed with Wilcoxon rank-sum test (Mann-Whitney) between: [a] close and medium villages, [b] medium and remote villages, and [c] close and remote villages.*, **, and *** statistically significant at $p< 0.1$, $p< 0.05$ and $p<0.01$, respectively.

On average, villages in the medium remoteness category harvested most animals from the very large (> 15 kg) body size class. Remote villages presented the highest average harvest at the large body size class (5 – 15 kg), and the close villages the lowest one. Regarding the biomass harvest profile, very large-bodied species represented the highest contribution in all three remoteness categories, with an average of 115 kg harvested per village. Large species had an overall harvest average of 18 kg/village, a one kg more than the overall average of the medium species class. The harvest of small species was on average of 0.3 kg. Finally, close-to-town villages presented lower significantly differences compared with the remaining village categories in the large and very large body size classes.

Discussion

This study represents the first series of line-transect surveys of game vertebrates (with a focus on medium- and large-bodied terrestrial vertebrates) in the Tsimane' territory. It also provides the first description of the hunting game profile among a large number of Tsimane' villages (32% of a total of about 125 known Tsimane' villages). The discussion will focus on the two main topics presented along this paper, available game community and game harvest profile, at the village level.

Available game community

Our results show two important findings that improve our knowledge about the available game community present in the Tsimane' territory. First, we found that the overall diversity of vertebrate game species was lower in the Tsimane' territory, than in other Amazonian forest sites. The finding was especially true for primates. And secondly, our data suggest that overall encounter rates seem to respond to hunting pressure and habitat degradation according to the geographical settlement pattern of the Tsimane' villages in regard to the distance and accessibility to the nearest market-town.

Regarding our first finding, we found that overall, the vertebrate fauna at all our study sites was less diverse, in terms of number of species, especially primates, than in other *terra firme* Amazonian forests subjected to hunting pressure (Peres 1997, 2000a; Lopes & Ferrari 2000; Endo et al. 2010). Differences in wildlife populations can hardly be attributed to single factors, as many environmental (e.g. climate, soil type) and anthropogenic variables (e.g. human density) may be interacting. So, in interpreting our finding, we highlight potential explanations for the differences found. First, the differences can be related to the marginal position of our study area in relation to the beginning of the Andean region, thus representing the distribution limit for most species (Emmons 1999; Mercado & Wallace 2010). And second, this difference may be due partly to the influence of subsistence hunting and habitat degradation observed in the area.

Regarding species abundances, a wider comparison with other studies in neotropical forest sites indicates that the encounter rates for some species in the Tsimane' territory are in fact within the range reported for other hunted and non-hunted forest sites (Carrillo et al. 2000; Lopes & Ferrari 2000; Cuarón 2001; Urquiza-Haas et al. 2011). However, encounter rates of game species such as for instance paca, brocket deer, collared peccary, and even tapir were fairly higher when compared more closely to sites that report high hunting pressure elsewhere. We attribute these differences to our methodological approach, as we referred before as a potential bias in our results. Species encounter rates assessed based on exclusively direct sightings, such as primates and cracid birds, fit on the range of values reported by other authors (Carrillo et al. 2000; Lopes & Ferrari 2000; Cuarón 2001; Parry et al. 2007; Urquiza-Haas et al. 2011), which suggests that our encounter rates for terrestrial vertebrates can be overestimated. Still, we reinforce that wildlife populations abundances depended of a myriad of environmental and anthropogenic factors, and that we are basing our comparisons in averages assessed in the surroundings of several villages.

Among the species with higher encounter rates, we found paca, brocket deer, and agouti. These species are reasonably resilient to hunting pressure (Peres 2001) and can be very tolerant to habitat modification, showing high densities in

secondary forests (Parry et al. 2007; Urquiza-Haas et al. 2011). On the opposite side, we could not find sights of spider-monkey; still we recorded the harvest of 16 individuals of this species. The spider monkey is one of the most vulnerable primates in the area, and one of the first species to disappear or became rare in areas of intensive hunting, habitat destruction, and fragmentation (Peres 1990, 2000a; Bodmer 1994). Besides, this specie was among the most prestigious game for Tsimane' hunters (Chicchon 1992), used to be included in traditional hunting rituals (Huanca 2008), and even used as medicine (Apaza et al. 2003). We also recorded low encounter rates for white-lipped peccary, another very prestigious species for Tsimane' hunters (Chicchon 1992). Curiously, we could no track sights of this species in remote communities. The low abundances of this species in the Tsimane' territory seems to be related to the boom of the pelt commercialization in the 1970s and the expansion of the logging activity in the area than to local subsistence demand. Indeed, this species has been greatly chased in the area for commercial purposes (Huanca 2008) to the extent that was given as locally extinct in some parts of the Tsimane' territory afterwards (Herrera-MacBryde et al. 2000). A possible explanation for having recorded tracks of white-lipped peccary in close and medium remoteness villages is that first, this species has high mobility and large home ranges (Fragoso 1998), so we cannot directly associate its records with its presence to a particular area. And secondly, this result can be related with the presence of the Beni Biological Station (EBB), a natural protected area created in 1982, and declared Biosphere Reserve by MAB-UNESCO in 1986, resulting from the overall biodiversity loss in the 1970s. This protected area is located at the northeast part of the Tsimane' territory, and overlaps with a reduced number of villages that are at the same time close to the San Borja market-town (see Introduction – Fig. 1). Therefore, the white-lipped peccary populations may have recovered, due the lack of extractive activities, except for the subsistence of few Tsimane' villages that are settled there. However, this hypothesis would be viable for the rest of the large-bodied game species. Still, we cannot test this hypothesis, because only one of our sampled villages is established in the EBB, and very close to the market-town of San Borja.

Our second finding relates to the environmental and geographic patterns found in species abundances. Results show that, in general, species abundances were higher in remote and medium remoteness villages than in close to the market-town villages. This was evident in species such as brocket deer, tapir, giant armadillo or honey bear, where we found significant differences among villages' remoteness categories. These results were supported by the structure game community analysis, where we also found significant differences among the two largest body size classes between villages' remoteness categories. This same trend was also verified in terms of biomass available. Bigger animals were more abundant in more remote than in close-to-town villages.

Finally, this environmental and geographic remoteness trend found in species abundances was confirmed by the RDA analysis, which suggests that species composition and distribution is markedly influenced by the cover of old-growth forest and villages' remoteness to market-town. A potential explanation for the overall distribution is that selective hunting and habitat degradation are impacting the composition and structure of vertebrate communities, but at different levels. Medium remoteness villages are the ones presenting intermediate levels of hunting pressure and forest disturbance, which seems to even enhance overall wildlife diversity and abundances by favoring more resilient and generalist species. Villages close to the market-town, and consequently more accessible and closer to main roads, suffer greatest impact of non-Tsimane' populations, including land clearing for agriculture or timber extraction (Paneque-Gálvez et al. 2011; Reyes-García et al. 2012b), which heavily impacts most of the wildlife populations.

Village game harvest profile

Results regarding the game harvest profile of the Tsimane' villages suggest two main hunting patterns. First, the overall hunting pattern for Tsimane' villages is associated to generalist game species whose abundance is higher in secondary forest. And secondly, villages close to market town seem to harvest less amounts of game than medium or remote villages.

Our results show that paca was the most harvested species, followed by collared peccary, coati, brown capuchin, and brocket deer. Most of these species are habitat generalists, with diurnal habits (except the brocket deer), presenting sometimes higher abundances in secondary forest sorrounding settlements than in primary forest (Peres 1993; Emmons 1999; Parry et al. 2007), which makes them easily accesible for hunting. Moreover, the collared pecarry, the coati, and the capuchin monkey are group species, witch makes them more visible, and therefore easier to hunting. However, the capuchin monkey presents low reproductive rates, thus being more vulnerable to population decrease than the other species. These results are in accordance with previous research that shows that a significant part of the biomass harvested by most of the indigenous societies in the Amazon is found in secondary forests or in forest-fallows mosaics sorrounding the settlements (Robinson & Bennett 2004). Secondary forests, in reasonably disturbed or fragmented areas, can support a high abundance of midsized and some large-bodied vertebrates compared with primary forests, such as rodents, ungulates, and even some primates (Gavin 2007; Parry et al. 2007), usually especies with rapidly reproducing rates, shorter longevities, and shorter generation times which make them less prone to overharvesting (Bodmer et al. 1997).

Nevertheless, when we look at the structure of community game profile, we found that Tsimane' hunters are harvesting mainly midsized animals. Although in absolut terms, paca –a large-bodied species- and collored peccary -a very large one- were the most hunted species, when standardized by the number of visits to villages, we found that the medium-bodied species (such as coati and brown capuchin monkey) provide the largest contributions in terms on number of animals harvested. Previous research suggest that subsistence hunters in Neotropical forests become less selective as local game populations decline, resulting in the disappearance of the most preferred species, which are generely large-bodied vertebrates, from community harvest profiles (Jerozolimski & Peres 2003). Still, when we compare the Tsimane' most prefered game species with their harvest profile, we find that the five most desirable species are among the most hunted ones. Yet, according to Chicchon (1992) in her work published a decade ago, the author referes that the most wanted species and prestigious for the Tsimane' were

the white-lipped peccary, collared peccary, tapir, brocket deer, and spider monkey. The change of favorite species can be associated with game scarcity, evident in the case of white-lipped peccary and spider monkey. Another evidence is the harvest of tapir, the species with the highest species-specific contribution in terms of biomass. Still it was harvested as much as the agouti or the night monkey, species whose interest in terms of meat taste or biomass amount is not very relevant.

Finally, regarding our second finding, we also found that close to market-town villages show lower harvest rates than villages in the medium and remote categories. Moreover, villages in the close category presented higher number of small species harvested than villages in the medium and remote categories. Although these differences were not statistically significant, this can be due to the low number of species -two species- accounted in this body size class. If large-bodied species are selectively killed whenever they are available, then their evident diminuishment in the close villages harvest profile or high consumption rates of small-bodied species, should be interpreted as further evidence of depletion of larger species. As we said before, villages close to market-town presented the highest population pressure and land clearence, which may be translated in a reduction of the most vulnerable or medium-and large-bodied species populations.

Conclusions

This study has found that the composition and distribution of game available seems to be responding mainly to hunting pressure and habitat degradation at different levels of intensity, a trend consistent with those found elsewhere in the Neotropics (e.g., Peres 2000a, 2000b). Moreover, the overall game harvest profile is consistent with the composition and abundance of the game community available, which means that the most hunted species are also the most abundant. An interesting evidence of this result is the apparent adaptability that Tsimane' hunters are presenting, by changing their favorite game species in response to game availability. However, we found exceptions for some game species to which cultural preferences seem to prevail. The harvest of spider monkey and white-lipped

peccary can be related to traditional preferences, since this species presented fairly low encounter rates, but continues to be harvest.

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CHAPTER 2

Does hunting pressure vary with acculturation? Insights from an Amazonian society

Abstract

While subsistence hunting in tropical rainforests contributes to food security, it also constitutes a major challenge to wildlife conservation. In this study, we explore the relation between hunting pressure and wildlife availability and different levels of acculturation among Tsimane' villages, a Bolivian Amazonian indigenous group. Between 2009 and 2010, we conducted a) interviews with hunters from 39 villages to estimate game harvested and b) game transects to estimate wildlife availability. We used GIS to provide a spatial representation of how hunting pressure and game availability vary along a continuum from less to more acculturated villages. Our multivariate analysis suggests that the diminishment of hunting pressure is associated to both changes in the traditional cultural system and wildlife scarcity. The methodology presented here can be a useful tool for the establishment of priority areas of conservation and for the control of the hunting activity itself. Understanding the links between changes in the indigenous traditional cultural system and game harvesting can help design approaches that simultaneously consider indigenous livelihood and wildlife conservation.

***Key words*:** conservation; game availability; GIS; indigenous peoples; Tsimane'

Introduction

Along with habitat loss and degradation, subsistence hunting is a major challenge to wildlife conservation in tropical rainforests. Forests that appear undamaged may in fact be heavily hunted resulting in unknown amounts of land containing significantly reduced densities of important game species (Redford 1992; Primack & Corlett 2005; Wilkie et al. 2011). Regardless of a large body of literature on subsistence hunting (Wilkie et al. 2011), the effects of hunting on biodiversity in neotropical rainforest regions continue to be a topic of concern for two main reasons. First, wildlife consumption continues to be vital as source of protein and income for indigenous peoples and many rural populations around the world (Robinson & Bennett 2000; Milner-Gulland et al. 2003; Brashares et al. 2004). And second, from a conservation biology perspective, hunting can have dramatic impacts on ecosystems, contributing to change forests composition and dynamics through the loss of ecological interactions (Peres & Palacios 2007), trophic meltdown (Estes et al. 2011), the decline of wildlife populations (Peres 2000) or species extinction (Redford 1992; Bodmer et al. 1997).

Due the significant overlap between indigenous territories and the world's remaining areas of high biodiversity (Toledo 2001; Maffi 2005; Pilgrim et al. 2009), indigenous peoples have found themselves at the center of a debate about how these environments should be used and managed (Redford & Stearman 1993; Peres & Zimmerman 2001; Chicchon 2009). Finding an appropriate balance between the local use and the conservation of game species is in the interest of both indigenous peoples and conservationists. Yet, finding such a balance is a very difficult task. While it is widely accepted that indigenous peoples had traditionally used and managed forest resources more sustainably than other groups (e.g. Smith and Wishnie, 2000), many authors argue that pressure on ecosystems and wildlife species might increase as indigenous societies undergo socioeconomic and cultural changes. Such changes include population growth, greater market access, increasingly sedentary settlement patterns, and changes in their belief systems (Stearman 2000; Jerozolimski & Peres 2003; Godoy et al. 2005; Suárez et al. 2009). For instance, in a study in the Brazilian Amazon, authors found a decreasing gradient in game availability from more preserved regions with isolated indigenous

people and difficult access to more connected regions, close to market areas with high density of villages and human population (Constantino et al. 2008). Likewise, research in the Manu National Park in Peru showed that changes in the current indigenous lifestyle –from dispersed settlements and bow hunting to permanent villages and modern hunting technology– clearly affected the preservation of species populations (Levi et al. 2009).

Among the processes that shape how indigenous peoples manage their natural resources in general and their hunting behavior in particular, the influence of acculturation has not been fully examined. Acculturation refers to the process by which a group progressively changes its cultural identity by gradually taking values and traits from other groups (Thomson & Hoffman-Goetz 2009). This definition does not include changes on economic situation such as wealth or income increase, so it allows us to differentiate the process of acculturation from market integration, a related but distinct process which involves the economic and monetary activities rather than cultural processes (Godoy et al. 2005). Nevertheless, we recognize that acculturation and market integration are processes often linked, and difficult to dissociate.

Two major gaps have been identified in the literature on acculturation and subsistence hunting. First, some authors argue that acculturation, like market integration, can ease access to new technologies (e.g. guns) and forms of transportation, which might result in an increased pressure on game species as hunters' efficiency improves (Lu 2007; Suárez et al. 2009; Godoy et al. 2010). For example, in a research among different ethnic groups in Serengeti, Mfunda and Røskaft (2010) found that people without education, who maintained a traditional way of life, were more involved in subsistence hunting than people with education who were mainly motivated by the monetary returns of hunting, which raises game offtake. Other authors argue that, as individuals become more acculturated, they start spending less time in their traditional activities, including subsistence hunting (Gross et al. 1979; Ringhofer 2010), especially when those activities do not provide cash income (Chicchon 1992; Reyes-García et al. 2007). The second major gap in the literature on acculturation and subsistence hunting is that often researchers have used hunting activity as a direct proxy from wildlife availability (Stearman McLean

1995; Mfunda & Røskaft 2010), assuming that changes in the first will have a direct effect on the second. But, to date, we lack a direct test of the association between acculturation, hunting activity, and wildlife availability.

In this paper we address those two gaps with data collected among the Tsimane', an indigenous society of the Bolivian Amazon. We first analyze the relations between acculturation and a) hunting pressure and b) wildlife availability. We then introduce direct measures of hunting pressure and wildlife abundances to assess the impact of acculturation in hunting behavior. We aim to provide a spatial representation of how hunting pressure and game availability vary along a continuum from less to more acculturated villages. Specifically, we test the two following hypothesis: 1) hunting pressure will be higher in less than in more acculturated villages, and 2) hunting pressure will be higher in villages with higher than with lower game availability.

Materials and methods

Study area

We conducted the study in the Tsimane' indigenous territory, located at the south of the Department of Beni, in the Bolivian Amazon (Fig. 2.1). The area spreads from the last foothills of the Andes to the east, reaching the edges of the Moxos savannas. Annual mean temperature in the area is of 25.8 °C, and annual mean rainfall is of 1743 mm (Godoy et al. 2008). The sampled villages were located in two indigenous territories, the Tsimane' *Territorio Comunitario de Origen* (TCO) and the Multiethnic TCO, and in a logging concession. Villages straddle along the Maniqui River, two logging roads, and the main road from San Borja to Yucumo, leading to La Paz. Vegetation around villages settled along road sites and near San Borja, in the northeast region of the Tsimane' territory, shares affinities with the Brazilian-Paraná biogeographic region, whereas vegetation surrounding villages settled along riverbanks, upstream the Maniqui River in the southwest part of the Tsimane' territory, is common of the transition Amazonian-Andean biogeographic regions (Guèze 2011).

Figure 2.1. Studied Tsimane' villages, Bolivian Amazon. Villages were classified according to the biogeographic region where they are settled in. NE villages belong to the Brazilian-Paraná region, whereas SW villages are established on the transition of Andean to Amazonian- regions.

THE TSIMANE' AND THEIR HUNTING HABITS

The Tsimane' are one of the largest indigenous groups inhabiting the old-growth forests of the Bolivian Amazon. Unofficial estimates the population at approximately 10 000 people, scattered along 125 villages (Reyes-García et al. 2012d). Tsimane' are traditional semi-nomadic hunter-gatherers, practicing slash-and-burn agriculture (Vadez et al. 2008). Hunting is not only part of their subsistence strategy but also an important feature of their cultural identity (Chicchon 1992; Huanca 2008).

Like many other indigenous groups in the Amazon, the Tsimane' are adapting to social and environmental conditions, which implies changes in their livelihood, as well as in their socioeconomic and belief systems (Godoy et al. 2005). Although the Tsimane' were first contacted during the times of the Spanish colony, contacts with outsiders intensified only during the 20th century (Reyes-García et al. 2012d). Nowadays, although part of the Tsimane' ancestral territory has been officially recognized as TCO, granting them exclusive use over land and resources, Tsimane' continue to suffer encroachments from outsiders, including illegal loggers, cattle ranchers, and newly arrived colonist farmers (Reyes-García et al. 2012b).

Different levels of contact with outsiders, allied with other historical and geographical factors (i.e. remoteness from main towns), have led to different levels of acculturation among Tsimane' individuals and villages. For instance, in remote areas, we can find villages without schools, where people are monolingual in Tsimane' language, practice traditional hunting and fishing with bow and arrow, and have limited contacts with outsiders through the bartering of rice and thatch palm for salt, sugar and other goodies. On the contrary, in areas closer to towns, we can find permanent villages with schools, where people typically speak Spanish and have access to cash income from wage labor in logging camps, cattle ranches, and in the homestead of colonist farmers, or from the sale of cash crops such as rice, plantains, maize, manioc, and fruits (Vadez, Reyes-Garcia, Huanca, & William R Leonard, 2008). In these villages, people generally no longer hold traditional beliefs and taboos and tend to adopt outsiders' behaviors and beliefs (including some conversions to the Catholic and Protestant religions).

Previous researchers have found that the Tsimane' report scarcity of wildlife when comparing present with past times (Godoy et al. 2010). Wildlife scarcity is locally explained by two main factors. First, the population of many game species decreased during the 1950s and 1970s because of the illegal commercialization of pelts and never recovered (Huanca, 1999). During those times, many Tsimane' were paid by local people to track animals (Huanca 2008). Species like the white-lipped peccary (*Tayassu pecari*) and the black caiman (*Melanosuchus niger*) were even given as local extinct in some areas of the Tsimane' territory (Herrera-MacBryde et al. 2000). Second, with the arrival of logging companies and cattle ranchers,

deforestation increased greatly. Moreover loggers and cattle ranchers became new competitors for hunting. Both factors lead, on one hand, to the movement of Tsimane' families in search of better hunting grounds (Huanca 1999; Bottazzi 2009), and on the other, to the loss of beliefs and taboos related to hunting. Thus, according to Huanca (2008) wildlife scarcity resulted in the hunting of game species that where prohibited before. All these changes might have resulted in unsustainable hunting of some species, as Chicchon (1992) reports, a situation that would be further aggravated with population growth.

Sampling and data collection

From March 2008 to July 2010, we visited 39 Tsimane' villages to collect data for this study. Previous to those visits, we obtained authorization from the *Gran Consejo Tsimane'*, the major institutional organization among the Tsimane', and during our visits we also obtained authorization from each village and individual participating in the study. Data were collected using methods from the social and natural sciences. We collected social data (acculturation and hunting pressure) from individual hunters and later aggregated the data at the village level. We collected ecological data (game availability) at the village level. Although we are aware that game availability would be better accounted at the landscape level, our estimates where conducted at the surroundings of villages' territory, where the main hunting activity occurs. We did so to link our social and ecological data at the village level.

We selected villages according to two criteria. First, to minimize variation on wildlife abundance due to the effects of different habitats, we only work in villages settled in *terra firme* forest. Second, to increase variation on village's level of acculturation, we selected villages settled at different distances to the town of San Borja. We based our village selection on information from previous works on the region (Reyes-García et al. 2012b) and in accordance with a participatory mapping project in the area (Reyes-García et al. 2012c). In each village, we selected ten of the male household heads to answer a questionnaire, except in the villages with less than 10 households, where we interviewed all the present male household heads, and in villages with more than 40 households where we selected 25% of the male

household heads. The households were randomly chosen from a list given by the highest-ranking authority of the village. To capture seasonal variation in hunting pressure and wildlife availability, we planned to visit all villages three times over the course of a year. However, we could not reach all villages the three times or not find all the initial respondents during the visits.

ACCULTURATION

During our first visit to a village, we collected socio-demographic information of hunters in the sample through a survey. In this work, we use two proxies of acculturation: years of schooling and number of times hunters traveled to the main market town (San Borja) during the month previously to the survey. We selected those two variables because previous work suggest that they are highly associated to the loss of indigenous identity (Sternberg et al. 2001; Godoy et al. 2005; Reyes-García et al. 2010).

HUNTING PRESSURE

To evaluate hunting pressure, we asked hunters about their hunting trips. Specifically, we asked about the Tsimane' name of any wild animal harvested in the two weeks prior to the day of the survey and the corresponding walking distances (in hours) from the village center to the kill site. The distance hunters travel to a hunting site is seen as an important indicator of a number of factors relating to hunting systems (Franzen 2006). Distance is often used as an approximation of the amount of effort that a hunter can or will invest in order to successfully forage (Smith 2008), which is also translated as an indicator of game availability (Haener et al. 2001), or hunting pressure (Hill et al. 1997; Read et al. 2010). In this sense, our measure of hunting pressure was assessed through the overlap of hunting kills, based on corresponding hunting distances. Such distances were converted to kilometers using an average rate of 2.26 Km per hour (Chicchon 1992). This survey was repeated in the three visits to a village with all the available hunters of our sample.

GAME AVAILABILITY

To estimate game availability, we conducted animal transects during the two first visits to each village. On the first visit, we gathered all the hunters from a village and asked them for the most common hunting paths used. We selected 10 two-hour transects in the vicinity of each village (n=390 transects). We visited six of the selected transects in the morning (07:00 – 9:00 hours) and four in the afternoon (17:00 – 19:00). The starting point of transects was located at a minimum of 30 min walking distance from the village center (or school). Local hunters guided us along hunting trails and two Tsimane' trained monitors identified the animal signs we found along transects by providing the Tsimane' name of the animal. We worked with local monitors because Tsimane' have a profound local knowledge on tracking animals (Chicchon 1992). We recorded information on animals' signs only for game species. We essentially identified mammal species of ungulates, rodents, primates, and carnivores, but also some birds, mainly cracids, and turtles, all of which are hunted by the Tsimane'. We tracked all the animal signs with GPS.

Data analysis

To control for habitat differences, and consequently game composition and availability, we first classified all villages according the biogeographic region where they are settled. These biogeographic regions match the settlement pattern of villages along the Maniqui River and villages settled along logging roads (see Fig. 2.1). Through the text, we refer to those two biogeographic regions as the NE region and SW region.

For data analyses, we used a single index of acculturation for two reasons. First, since we conducted the analysis at the village level and we only had 39 villages, by grouping our two variables in one index we increase our statistical power. Second, having one unique variable of acculturation enables the spatial representation of the data. We constructed the village acculturation index by averaging the sum of the two individual proxies: completed years of schooling and number of visits to market town. We previously standardized each variable by subtracting the mean from the original individual score and dividing it by the

standard deviation, so each variable had the same scale and weight in the acculturation index (Larsen & Marx 2006). This transformation results in negative and positive acculturation values, which correspond to the position of an individual (or village) below or above the zero distribution mean. Higher values in our index represent higher levels of acculturation.

To estimate hunting pressure, we buffered all the hunting kills using the correspondent walking distance (in km) to the hunter's village. We then intersected all the buffers and counted the number of overlapping polygons. The number of *overlaps* obtained was used as an index of the pressure exerted by the Tsimane' hunters and corresponds to the number of captures that occurred in the same space. To obtain a unique hunting pressure value per village we intersected the previews shape of the hunting pressure index with a buffer of 5 km of each village. We then averaged the hunting pressure exercised in the 5 km area to get a single value per village. We opted to get values of hunting pressure in 5 km around each village because more than 50% of the trips occurred in less than 5 km around the villages, and because further distances are accounted for in the estimated index, because overlap the nearest ones.

Our measure of game availability at the village level is partially supported by the fact that hunters tend to minimize travel costs (Parry et al. 2009), which means that most of the hunting trips are in areas close to villages, increasing game impact in these areas. For each transect we calculated the game encounter rate as the number of animal encounters per kilometer, and used the village average for further data analyses. To enable mapping game availability, we proceeded with the estimation of kernel densities using the GPS points (Worton 1989) collected during the animal transects. We used a circular search radius of 15 km (mean hunting distance plus standard deviation) in kernel density calculation. Once again we used the 5 km buffer to obtain the average values of kernel density per village.

Data analysis unfolded in three sequential phases. First, we used Pearson's correlations to evaluate the relations between *i)* hunting pressure and acculturation, *ii)* hunting pressure and game encounter rate, and *iii)* acculturation and game encounter rate. We also run a series of *t*-tests to assess differences in

means of the three variables between villages' settlement biogeographic regions. Second, to visually inspect the association between the three variables, we mapped both hunting pressure and game kernel density along the explanatory variable acculturation. Third, we estimated the effects of acculturation on village hunting pressure and game encounter rate using generalized linear model (GLM) regressions. We included village size (number of households), years of village settlement, village remoteness, and a dummy variable for village settlement region as controls in our model. Village remoteness was estimated factoring linear distances to the nearest market-town and cost of transportation (Reyes-García et al., 2012). We used ArcGIS 10 for GIS analyses, and STATA 11.1 for statistical analyses.

Results

We contacted 341 hunters of 39 villages and performed a total of 672 interviews. We inspected data on 487 hunting trips, which corresponds to 414 successful hunting trips and a total of 827 harvested vertebrate animals. The village acculturation level ranged from -2.36 to 5.36, averaged -0.05 (± 1.77). Mean hunting pressure in a 5 km buffer around villages was of 65.02 kills (± 21.17), with a minimum of 29.81 and a maximum of 89.71 kills. Average hunting distance from the villages' center to the hunting site was of 7.76 km (± 7.56). The mean value of animal signs encounters per km was of 10.04 (± 2.54), ranging between 4.65 and 14.99. This value represents on average the presence of 6.85 different species per transect (± 1.74).

Acculturation, hunting pressure, and game availability

Villages with lower levels of acculturation had higher hunting pressure than more acculturated villages (Person's r=-0.72, p<0.001, n=39). Also, hunting pressure was higher in areas with higher game encounter rate (Person's r=0.49, p=0.001). Finally, more acculturated villages presented lower game encounter rates (Person's r=-0.63, p<0.001). When analyzing villages by biogeographic region, we found that, first, the correlation coefficient between hunting pressure and acculturation increased slightly, being stronger among villages settled in the NE

region (Person's *r*=-0.79, p<0.001, n=18) than among villages in the SW region (Person's *r*=-0.73, p<0.001, n=21) (Fig. 2.2A).

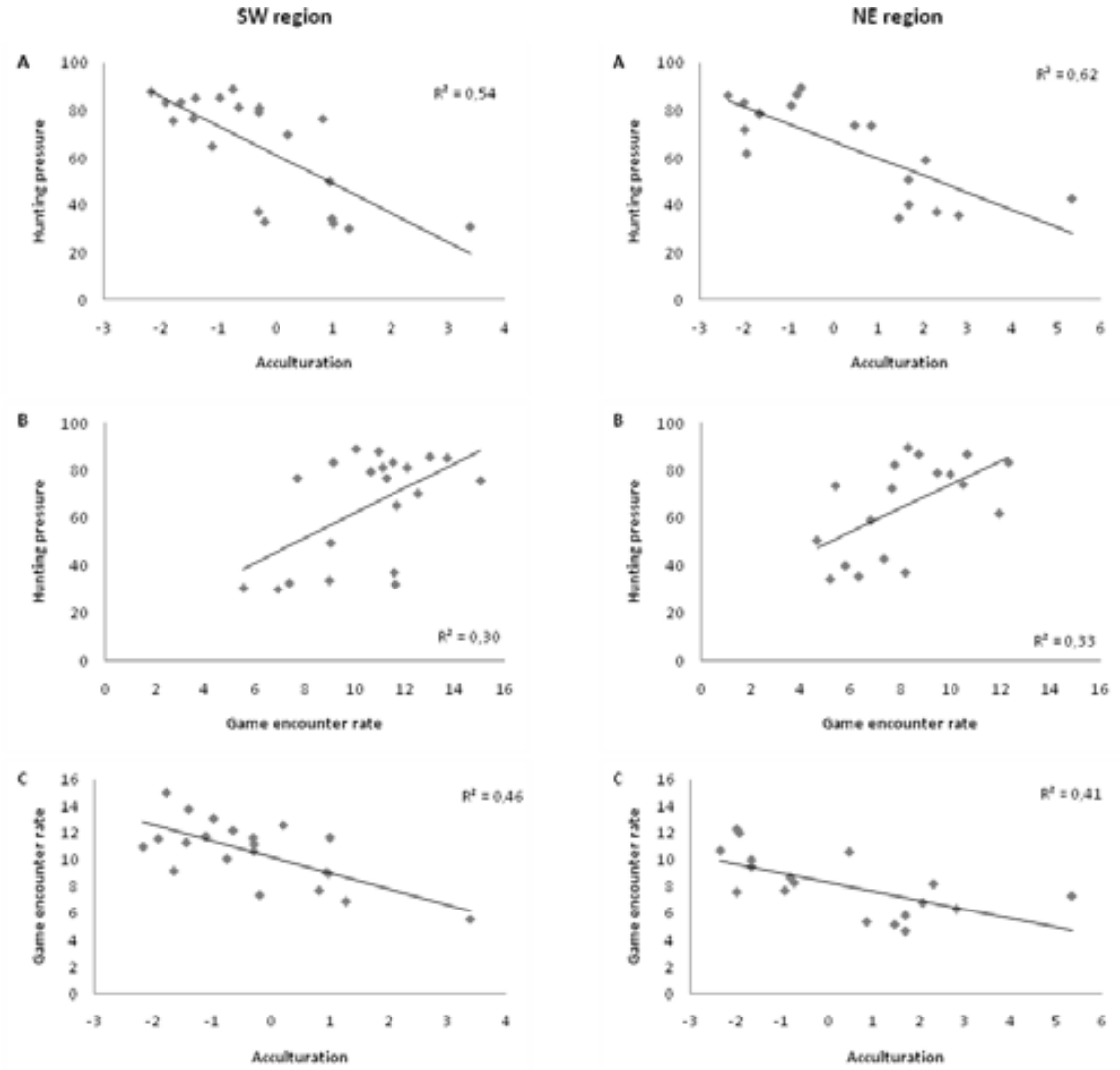

Figure 2.2. Relation between A) village hunting pressure and acculturation (given by the sum of years of schooling, and number of travels to the market town), B) village hunting pressure and game encounter rate (number of animals per km, estimated with transects), and C) village game encounter rate and acculturation. Results include data collected in the Bolivian Amazon: 21 villages were settled along riverbanks in the SW region and 18 villages were settled along logging roads and around main town, in the NE region.

Second, the correlation coefficient between hunting pressure and game encounter rate increased. Hunting pressure was strongly correlated with game encounter rate in villages settled in the NE region (Person's *r*=0.57, p=0.01) as well as in villages along the SW region (Person's *r*=0.54, p=0.01) (Fig. 2.2B). In fact, we found significant differences in the game encounter rate of villages settled in the NE

and the SW regions (paired *t*-test, *t*=-3.17, p<0.01). Last, the relation between game encounter rate and acculturation remained unchanged. Game encounter rate was highly correlated with acculturation among villages from the NE region (Person's *r*=-0.64, p=0.004) and in those settled in the SW part of the territory (Person's *r*=-0.68, p<0.001) (Fig. 2.2C).

Villages on the central line, along the Fátima logging road, showed low levels of acculturation compared with the rest of villages, especially the ones near the main road (Fig. 2.3). The visual examination of Fig. 2.3A suggests that hunting pressure increases with village-to-town access. The three areas with higher hunting pressure are 1) upstream Maniqui River, 2) south of Fatima's road, and 3) central area between the Fátima and the Triunfo logging roads. Within those three areas, hunting pressure was highest in areas close to villages' center and decreased in areas far from villages' center.

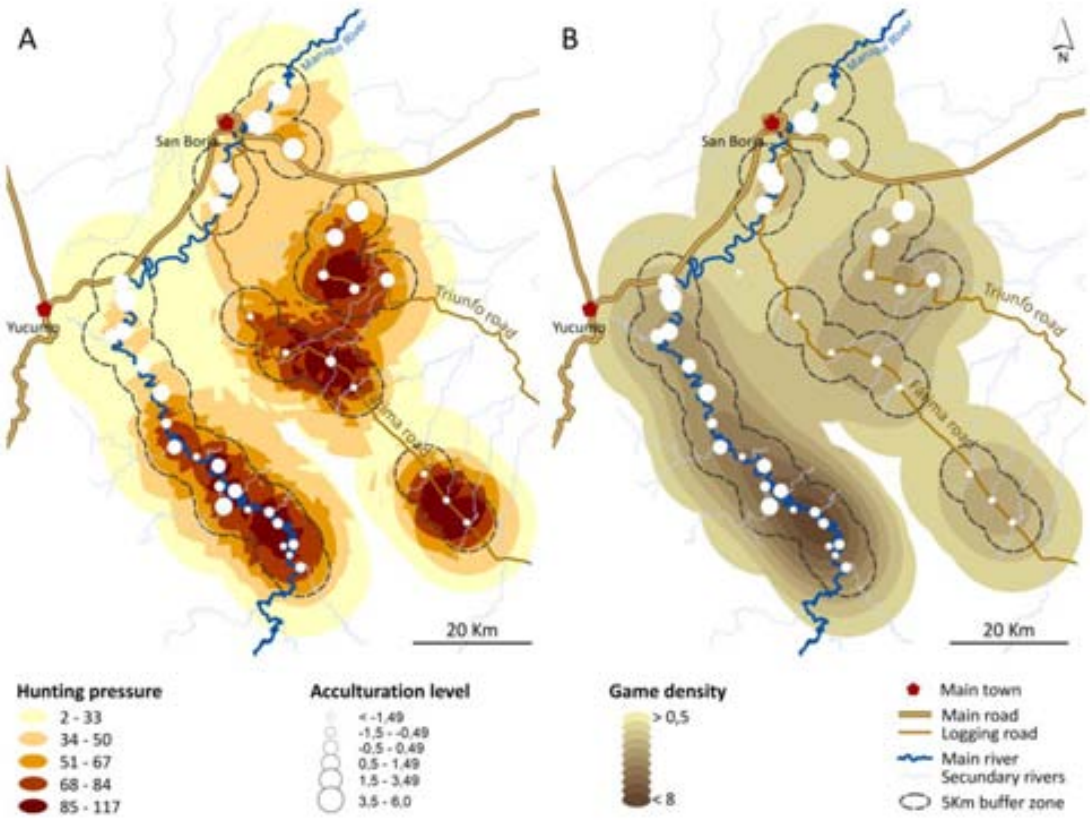

Figure 2.3. Spatial representation of the A) hunting pressure and B) game density, along with the acculturation values obtained for 39 Tsimane' villages, Bolivian Amazon. Values of hunting pressure correspond to the number of game kills occurred; game density, given by the number of animals per square kilometer, was assessed based on kernel's density estimation.

On Fig 2.3B, we found high game density in one of the three areas with high hunting pressure: upstream the Maniqui river. However, the pattern was different for the other two areas of high hunting pressure (i.e., the south Fátima road and the area between the Fátima and the Triunfo logging roads), where we did not find high game densities.

Table 2.1. Results from the GLM regressions of village acculturation and game encounter rate against hunting pressure.

	Hunting pressure	
	Model 1	Model 2
Explanatory variables		
Acculturation	-5.09*** (1.05)	-3.88*** (1.25)
Game encounter rate	2.06* (1.24)	2.82** (1.23)
Control variables		
Number of households	^	0.08 (0.10)
Years of settlement	^	-0.00 (0.01)
Remoteness	^	13.78*** (3.95)
Settlement region (SW region=1)	^	-17.46*** (5.60)
Constant	44.69*** (11.14)	35.86*** (12.18)
Observations	39	39
Log likelihood	-276.34	-276.33
AIC	14.32	14.53

Note: Values shown represent coefficient estimates with associated standard deviations in parentheses. Statistical significance level is given by *=p<0.1; **=p<0.05; ***=p<0.01. ^ Variable intentionally excluded.

We found a statistically significant and negative association between acculturation and hunting pressure in our two multivariate regression models (Table 2.1.): without (model 1) and with control variables (model 2). An increase of one-point of standard deviation in the village acculturation level was associated with a decrease of approximately five standard deviations in the hunting pressure ($p<0.001$) in model 1 and about four in model 2 ($p=0.002$). In other words, the increase in the level of village acculturation was associated with a reduction in the hunting pressure exerted around the village. Game encounter rate was also significant in both models. The increase in the presence of one animal per km was

associated with an increase of about two or three captures. Among the control variables, we found that village remoteness bore a positive and statistically significant association with hunting pressure. Hunters in more remote villages seemed to have performed more successful hunting trips than hunters in villages closer to towns. Finally, the region of village settlement also seemed to be associated with hunting pressure. Villages settled in the SW region apparently exerted more hunting pressure in the surrounding areas than villages in the NE region. Based on the Akaike Information Criterion (AIC), we considered both models identical, as the values of AIC are approximately the same.

Discussion

We start the discussion presenting two main caveats of the analyses presented here. We then discuss the three main findings of this work, before discussing the implications of this work for conservation.

Caveats

A first limitation in our study relates to the measure of game availability: animal transects. In this study, rather than using the usual line-transects approach (Peres 1999), we collected data on game availability along the villages' most common hunting paths. Two reasons justify our selection. First, sampling hunting paths allowed us to increase the sample size, since our visits to village was limited to four days on average. Second, sampling hunting paths provide a better representation of the hunting opportunities that Tsimane' hunters face than sampling line-transects, as Tsimane' usually walk along such paths during their hunting expeditions. However, we are aware that the choice of our measure might provide an underestimated measure of real game availability, thus making our results more conservative.

A second limitation of our study relates to our measure of hunting pressure. We defined hunting pressure as the number of successful game hunting kills occurred in a certain space at three points of time. However, hunters that go out for

hunting, but do not capture any game, also exert pressure. Moreover, since we could not visit all villages three times, and in each village not all the hunters were always available, we might have introduced some bias in our measure of hunting pressure. Thus, villages with greater sampling effort may translate in higher hunting pressure. Nevertheless, we consider that this methodology expresses the general hunting patterns occurring in the sampled area.

Acculturation, hunting pressure and game availability

Wildlife hunting continues to be an important subsistence activity for the Tsimane' population. Results from this study suggest that even in villages with high levels of acculturation and low game availability Tsimane' continue hunting. We explain the pervasive nature of hunting, not only as an important economic activity to supply the local diet, but also because of its cultural importance. According to previous studies, the Tsimane' are still a very autarkic society with part of the population remaining outside of the market economy (Godoy et al. 2010). This fridge of the Tsimane' society continues practicing foraging, hunting, and shifting cultivation as their main livelihood activities. Some of them do not practice any economic activity, a part from fishing, which provides them with alternatives to wild meat consumption. Furthermore, being a hunter is still an important aspect of Tsimane' identity (Huanca 2008). According to their cultural system, hunting is essential to achieve recognition and respect within the other members of the group, or even a way to find a partner (Chicchon 1992; Gurven & von Rueden 2006).

A second finding relates to the association between acculturation and hunting pressure. While many researchers argue that acculturation, as well as participation into the market economy, comes along with the adoption of new technologies and transport systems that would lead to major pressure on wildlife (Godoy et al. 2010), our results suggest that increasing acculturation decreases the amount of game harvested, which apparently seems to ease wildlife availability. A possible explanation for this finding relates to the opening of new economic opportunities. The acculturation process, and especially schooling, opens pathways to the non-indigenous world (Reyes-García et al. 2010) and leads to a shift of time

allocation from more traditional and subsistence activities to new ones (Gross et al. 1979; Ringhofer 2010). Unlike in other areas of the world (Nasi et al. 2008), the trade of wild meat is not a significant source of income for the Tsimane' (Godoy et al. 2010). There is no real market for bush meat in the area, and the illegal commercialization of pelts is almost inexistent due to national regulations. For these reasons, to obtain cash income more acculturated individuals have turned to activities such as wage labor or the intensification of cash-crops, which gives them the possibility to buy meat at local city markets. These new activities enlarge the range of social contacts of Tsimane' with outsiders and most probably change the way individuals perceive the cultural meaning of hunting and consumption of wild meat. Thereby, perhaps what before was an important identity element may progressively become to be an irrelevant sociocultural trait. Furthermore, areas surrounding towns or along the major communication axes (i.e., roads, main rivers) offer more opportunities to embrace on modern activities, as well as, educational possibilities. The gradient found between the villages hunting pressure, and acculturation is also related with this village remoteness pattern, which is intrinsically related with market access, as shown in Fig. 2.3 and Table 2.1.

Finally, the increased gradient from close to market-town to remote villages was also found in game availability. Villages settled far from the main market-town showed higher levels of game availability than villages close to it. This was especially true for the ones established in the SW region. Although the Tsimane' continue hunting all across their territory, hunting does not seem to be as profitable in areas close to town as in areas with increased species availability. Game scarcity might lead to abandonment of hunting activity, but in the case of the Tsimane' it rather seems to result in an adaptation to game availability. The fact that we recorded game harvesting in villages with low game densities (mainly in villages settled in the NE region) might indicate that hunters are no longer harvesting preferred large-bodied species –particularly more vulnerable- but most likely several small mammals and birds. This is a common pattern in overhunted areas or degraded habitats of the neotropical forests (Jerozolimski & Peres 2003), and may explain the high levels of hunting pressure in the NE region. In addition, game encounter rates were fairly low in the NE region. This result may be related to the

logging activity occurring in this area. Since the 1970s, logging companies started to operate across this area, one of the largest reserves of mahogany (*Swetenia macrophylla*) in South America (Reyes-García et al. 2012d). The intensification of timber extraction has most probably lead to overhunting and consequently, to the decline of some wildlife populations as well as to the degradation of ecosystems.

An interesting nuance of our study relates to causality. Although here we have explained wildlife availability as a consequence of acculturation, the association could be on the other direction. The wildlife scarcity observed and stated by many Tsimane' (Huanca 1999; Bottazzi 2009) might have boosted the process of acculturation and abandonment of hunting activity. However, due the complexity of these systems and the significant correlation between the factors in our analysis, we cannot state if the driving force behind the diminishment of hunting pressure is a change in the traditional cultural system or wildlife scarcity or, perhaps the result of both, as our multivariate analysis suggests.

A conservation perspective

In this article we provide insights to better understand the spatial patterns of hunting and game availability among villages from a native Amazonian indigenous society with varying levels of acculturation. Such contribution can help develop appropriate conservation strategies. This article also presents a major methodological contribution exploring the spatial representation of hunting patterns with geographic information systems (GIS). Some authors have mapped patterns of hunting trips or hunting areas sometimes using participatory mapping (e.g. Smith, 2003, 2008; Read et al., 2010), but to our knowledge, none has proxied hunting pressure by mapping the intensity of hunting activity and mapped game availability at the same time. The methodology we present in this work can be a useful tool for the establishment of priority areas of conservation and the hunting activity itself. Combined with other types of information such as, ecological variables, cultural preferences about game, it can be a helpful instrument in the assessment of the sustainability of hunting activities.

Conciliating biodiversity conservation with the well-being of indigenous peoples requires an integrated view. Although our results suggest a decrease in game pressure as a consequence of the acculturation process and the adaptation to new socioeconomic and environmental conditions, we must be careful when thinking in the near future approaches and conservation measures. The abandonment of traditional activities can be strictly linked with the loss of identity and cultural features, such as traditional ecological knowledge (Reyes-García et al. 2012a), a loss that can make indigenous peoples more vulnerable to changes. Additionally, although acculturation does not seem related to increase in hunting pressure, it could be related with the extraction of other resources that might indirectly affect wildlife availability, such as timber (Godoy et al. 2009). Therefore, one must be cautious when extrapolating the relation between acculturation and wildlife harvesting to other natural resources.

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CHAPTER 3

Does acculturation affect indigenous peoples' hunting behavior? Estimates from the Tsimane' in the Bolivian Amazon

Abstract

Wildlife hunting is an important economic activity that contributes to the subsistence of indigenous peoples and to the maintenance of their cultural identity. Changes in the indigenous way of life affect the way indigenous peoples manage ecosystems and resources around them, including wildlife populations. This paper explores the relation between acculturation, or loss of cultural identity, and hunting behavior among the Tsimane', an indigenous group in the Bolivian Amazon. We interviewed 347 hunters in 40 villages to estimate their level of acculturation and the amount of game they harvested. We used GLMs to assess the relations between three different proxies for acculturation (schooling, fluency in Spanish, and visits to market town) and 1) hunting activity, 2) number of game harvested, and 3) biomass of game harvested. We found a significant negative association between schooling and hunting activity and biomass of game harvested. We hypothesized that, although hunting greatly depends on game availability, it is also conditioned by cultural factors that impel or restrict hunters to engage in hunting. In that sense, our data suggest that schooling decreases both the probability of engaging in hunting and the returns provided by hunting. A potential pathway through which schooling affects returns to hunting relates to its effects on the acquisition of the knowledge and skills that make a proficient hunter.

***Key words*:** Bolivia; conservation; game harvest; rainforest; schooling; wildlife

Introduction

Of the known threats to the conservation of animal biodiversity in tropical forests, hunting is one of the most worldwide extensive, but also one of the most challenging to detect (Peres et al. 2006). Studies have demonstrated that when hunting overtakes the limit of sustainable harvest, it causes the decrease of animal populations and the extinction of large-bodied wildlife species (Milner-Gulland et al. 2003). Overhunting can also affect forest dynamics and composition (Peres 2000). Meanwhile, the negative effects of hunting on wildlife populations put in danger the livelihood of forest-dependent people (Bennett et al. 2007), as in many parts of the tropics the consumption of wild meat remains an important source of protein in human diets (Peres 2000; Jerozolimski & Peres 2003; Peres & Nascimento 2006; Gavin 2007; Ohl-Schacherer et al. 2007; Endo et al. 2010; Urquiza-Haas et al. 2011). Furthermore, researchers have highlighted that, in addition to their contribution to diet, hunting and wildlife consumption are important elements of indigenous peoples' identity. Hunting is often embedded in indigenous culture, cosmologies, legends, and rituals (Chicchon 1992; Bennett & Robinson 2000; Townsend 2000). In many indigenous societies, being a hunter is essential to achieve recognition and respect within the group (Chicchon 1992; Hawkes et al. 2001). It also offers a way to create social bounds with the members of the group, as hunted meat allows for sharing and reciprocity (Fortier 2001; Wiessner 2002).

Neotropical rainforests contain much of the world's wildlife diversity and are -at the same time- home to a diversity of indigenous peoples who have used and managed these ecosystems for many centuries (Redford & Stearman 1993; Redford & Sanderson 2000; Toledo 2001; Sunderlin et al. 2005). The growing concern over the loss of biodiversity in those areas has led to an intense debate about the role of indigenous peoples in wildlife conservation. Several researchers have highlighted that, despite the overlap between indigenous territories and areas of high biological diversity (Toledo 2001; Sunderlin et al. 2005), there is not necessarily a causal relationship between the two phenomena. Conservation of wildlife by native peoples may not be intentional, but rather a side effect of low population density, traditional hunting technology, and lack of external markets to impel high rates of game extraction (Hames 2007). If so, we would expect changes on the way

indigenous peoples' use and manage their natural resources as their traditional lifestyles change through processes such as acculturation, modernization, or simply as their population increases (Smith & Wishnie 2000; Godoy et al. 2005b).

Among the different processes that nowadays affect indigenous peoples' livelihoods, social scientists have highlighted acculturation as one of the most important (UNESCO 2008). Acculturation refers to the process of cultural change that happens when groups of individuals from different cultures come into continuous contact with one another leading to changes in the cultural patterns of either or both groups. Acculturation is not a linear course of action because it does not necessarily leads to assimilation and a loss of a person's ethnic identity (Thomson & Hoffman-Goetz 2009). However, it affects societies' livelihood and it can therefore affect the way indigenous peoples use natural resources (Byron 2003; Godoy et al. 2005b; Shen et al. 2012). For instance, a study among five different ethnic groups in the Ecuadorian Amazon showed that each additional year of education of the male household head, a standard proxy for acculturation, was associated with an increase of the agricultural area of 18% and 27% (Gray et al. 2008), most of which was devoted to cash-crops. Another study among different indigenous of the lowland Bolivia, showed that schooling was associated with the increase of income from wage labor (Godoy et al. 2005a), which implied changes in their indigenous people's traditional subsistence activities. Further, research suggest that as indigenous peoples acculturate, they also fail to follow their traditional institutions for resource management, which often results in a deterioration of common pool resources (Ostrom et al. 1999). Researchers also suggest that changes in livelihoods associated to acculturation ultimately result in a decrease of indigenous peoples traditional knowledge (Reyes-García et al. 2007b, 2012a), which in turn might also affect the way indigenous use and manage natural resources (Reyes-García et al. 2010b). However, despite the growing interest in the link between changes in indigenous peoples livelihood and the fate of the forest, the way in which acculturation impacts the hunting habits of indigenous peoples is still poorly understood.

In this article, we contribute to this body of research by analyzing how cultural changes in an indigenous society affect their hunting behavior. We define

hunting behavior as the act of engaging on hunting activities for subsistence instead of engaging in other traditional or non-traditional activities. Specifically, we examine the association between acculturation and (1) the probability that a person engages on hunting and (2) game harvested. For the empirical analysis, we use data collected in a foraging and farming society of native Amazonians in Bolivia, the Tsimane'. As -in the study area- acculturation is associated to the increase in time allocated to income generating economic activities (Ringhofer 2010), and as there is no specific market for bush meat (Chicchon 1992; Reyes-García et al. 2007b), we expect more acculturated individuals to engage on hunting less often than less acculturated individuals. We also expect that more acculturated individuals will have lower rates of game harvest, since their hunting skills may decrease as the time dedicated to the activity of hunting decreases.

Materials and methods

Study area

Our study was conducted in the Tsimane' indigenous territory. It included 40 villages settled along the Maniqui River and neighboring logging roads (see Introduction – Fig. 1), in the municipality of San Borja, Department of Beni, Bolivian Amazon. The study area is in the transition between the last foothills at the Eastern Andes to the lowland rainforest and the Moxos wet savannas. The climate is thermotropical with summer rains from October to April. The mean annual temperature is 25.8 °C, and the mean annual rainfall is 1743 mm (Godoy et al. 2008), with an approximately four-month dry season with less than 100 mm rainfall per month.

The Tsimane' territory is covered with different types of old-growth forest: the most spread is a lowland forest lacking some typical Amazonian species, due to the rather high seasonality of climate, including sporadic strong cold winds from the south during the dry season (Guèze et al. 2012). Most forests are *terra firme* forests, although some areas are covered with inundated or seasonally-flooded forests due to geomorphology and highly variable micro-topography (Killeen et al. 1993). In

this study, we focus on *terra firme* forests. These forests support about 30 game vertebrate species between mammals, birds, and reptiles. Most of the biomass with potential to be harvested is represented in the following species: paca (*Agouti paca*), coati (*Nasua nasua*), collared peccary (*Pecari tajacu*), red brocket deer (*Mazama americana*), white-lipped peccary (*Tayassu pecari*), brown capuchin (*Cebus paella*), howler monkey (*Alouatta* spp.) and tapir (*Tapirus terrestris*). There are also other vertebrate species like squirrel monkeys (*Saimiri boliviensis)*, armadillos (e.g. *Dasypus* sp., *Priodontes maximus*), anteaters (*Tamandua tetradactyla*, *Myrmecophaga tridactyla*), cracid birds (e.g., *Mitu tuberose*, *Tinamus major*), and tortoises (*Geochelone sp.)*, all of which are also hunted in this region. The spider monkey is classified as an endangered species, and the white-lipped peccary, considered near threatened by IUCN 2010, are among the favorite hunting species of the Tsimane' (Chicchon 1992).

THE TSIMANE' POPULATION

The Tsimane' live in approximately 125 villages scattered along the Maniqui and Apere rivers, the main road from Yucumo to Rurrenabaque, and some logging roads (Reyes-García et al. 2012c). Unofficial estimates set the current population in about 10 000 people. Despite frequent contacts with other sectors of the Bolivian society (i.e., Catholic and Protestant missionaries, traders, cattle ranchers, and loggers) over the last 60 years, the Tsimane' have maintained a distinctive cultural identity. However, in the last few years, with the growth of the Bolivian economy and the development of new infrastructures (e.g. roads) and new educational and health programs in the area, the Tsimane' have seen many changes in their traditional way of live (Reyes-García et al. 2012a), which contributed to a growing socioeconomic differentiation between Tsimane' living in different villages, but also between Tsimane' living within the same village. Few Tsimane' live in small villages (with 2 to 10 households) without schools and speak only Tsimane'. They forage and practice shifting cultivation and limit their contact with outsiders to bartering rice and thatch palm for salt, sugar and some tools. Most of them still practice hunting and fishing with bow and arrow, and hold to some hunting traditions and rituals, especially the older. But other Tsimane' live in large (10 to 50 or more

households), more accessible, permanent villages with schools. They typically speak Spanish and have more access to cash income from the sale of crops (rice, plantains, maize, manioc, and fruits), forest products (honey, firewood, and thatch palm), and wage labor in logging camps, cattle ranches, and in colonist farmers' homesteads (Vadez et al. 2008). In these villages, people usually hunt with gunshots and rifles and generally no longer hold traditional Tsimane' beliefs and taboos.

Sampling

We conducted research between March 2008 and July 2010. The study villages were selected based on a census in the study area (Reyes-García et al. 2012b) and distances to the main market town, San Borja. Upon arrival to each village, we interviewed the highest-ranking authority to ask information concerning the entire village, such as the number of households in the village, the name of the household heads, and the type of infrastructure present in the village. We randomly selected ten male household heads (hereafter hunters) in villages with less than 40 households in the list provided, except in villages with ten or less households, where we interviewed each male household head. In villages with more than 40 households, we sampled 25% of them. On average the villages visited had 25.8 households (± 21.3). We try to visit each village three times to capture seasonal variation on the hunting reports. We could visit only 12 of the villages twice and ten villages once. Additionally, due to the high mobility of the population, not all hunters interviewed during our first visit could be contacted on one or the two follow up visits. In sum, 23% of the hunters were interviewed three times and 63% of the hunters were enquired twice.

ASSESSING HUNTING BEHAVIOR

To estimate wildlife harvesting, hunters were interviewed about their hunting trips during the two weeks before the day of the interview. We asked about the characteristics of the hunting trips (duration, number of people participating, and hunting weapons utilized) and about the animals caught during each trip. For each kill, the following information was recorded: Tsimane' name, live stage

(juvenile or adult), sex (male or female), and estimated distance from the hunting site to the village center (in hours walking). We converted walking distances to kilometers at an average rate of 2.26 km per hour (Chicchon 1992). For each successful hunting trip we estimated the number of hunted animals and the corresponding biomass harvested by using published estimates of species body mass and live stage (Myers et al. 2006). During the interviews, we tried to identify duplication of information in multiple-party hunting expeditions by asking how many people had engaged in the hunting trip and by checking if hunting mates reported the same information. However, since it was not always feasible to identify all the participants and account for exact amounts of meat that goes to the hunter' household or to other's households, we assumed some intrinsic error in our measure and opted for working with gross estimations of hunting harvest. We repeated the same interview in the three visits to the villages.

ASSESSING ACCULTURATION

Acculturation and market integration are often parallel processes difficult to dissociate (Thomson & Hoffman-Goetz 2009), which led us to use three different measures to capture a global perspective and minor error interpretation on the evaluation of the hunters' level of acculturation (Godoy et al. 2005b; Lu 2007). First, we collected data on hunter's level of schooling and proficiency in Spanish (Bolivian national language), as those traits have been shown to be correlated with loss of indigenous cultural identity (Sternberg et al. 2001). We judged each participant's ability to speak Spanish and coded answers as 1 if the person spoke some Spanish and 0 if he spoke only Tsimane'. We also proxied individual acculturation level with recalls of the number of trips to the nearest market town during the month before the interview. This measure has also been used as a proxy for market integration (Godoy et al. 2005b), but we include it here because, in some indigenous societies, visits to market-town is associated with the acquisition of modern human capital (Morsello & Ruiz-Mallén 2012).

To assess the availability of wildlife, we defined ten transects of two hours each in the vicinity of each village (n=400 transects). Upon arrival to the village, we grouped the present hunters and asked them to identify the ten most common hunting paths in the village's territory. We set transects on those hunting paths. The start of a transect was located at 30 min walking distance from the village center (or school). Overall, we surveyed six of these hunting paths during the morning (07:00 – 9:00 hours) and four during the evening (17:00 – 19:00). Local hunters guided us along hunting trails and two Tsimane' trained monitors identified the animal signs we found along the transects by providing the Tsimane' name of the tracked animal. We opted for working with local monitors, because it is known that Tsimane' have a profound local knowledge on tracking animals due to their hunting skills (Chicchon 1992). Information on animals' signs was recorded only for game species. All the animal signs were tracked with GPS. For each village we estimated the average number of encounters and the corresponding biomass per kilometer. We only took into account individual sights, which mean that group-living species, such as primates, were probably underestimated. The biomass estimation, although simplistically, allows differentiating game availability among villages because combines information of encounter rate and body size.

Data analysis

We performed a reliability analysis using Chronbach alpha to see the internal consistence among our three acculturation proxies. To explore the relation between acculturation and hunting behavior we first ran a generalized linear model (GLM) with binomial family and Probit link function, using a binary variable of the hunting behavior as outcome variable and our three acculturation proxies and the two variables that express game availability as main explanatory variables. Our outcome variable is binary and reflects the inter-individual variation between observations when the hunter had engaged in at least one hunting trip during the two weeks previous to the interview and observations when the hunter had not. GLM included clustering by individual to relax the assumption that observations (i.e. hunting trips) are independent across an individual. To test the robustness of our model, we

repeated GLM by adding different socioeconomic variables, such as fishing activity, hunter's age (and age squared to control for possible nonlinearity), household size, household income in logarithms), hunting season, and village remoteness (see Table 3.1).

Second, we examined the association between a hunter's level of acculturation and 1) the number of animals hunted and 2) the biomass harvested, while controlling for game availability. To do so, we ran GLMs, with Poisson distributed error terms, logarithmical link function, and clustered observations by individuals. The sample used for this model included only observations in which the hunter had reportedly engaged in hunting trips during the two weeks previous to the interview. Once again we treated each hunting trip as an independent observation. We used the number of hunted animals and the biomass harvested per trip as outcome variables. We used the same robustness analysis as in the previous GLM. Statistical analyses were conducted using Stata 11.1 and GIS procedures using ArcGis 10.0.

Results

Tsimane' hunting patterns

We recorded 479 hunting trips conducted among 347 hunters with a total of 821 successful kills that occurred during 86% of the trips (412 successful hunting trips). Most of the hunting trips (68%) lasted one day or less. The rest (32%) lasted from two to nine days. Half of the interviewed hunters went alone on their hunting trips (51% of hunts). The reported kills were done mainly with shotguns (55%) or rifles (28%) and just a few were done with bow and arrows (15%). The remaining kills (2%) were done with dogs, *machetes*, or traps. On average, hunters walked about three hours (or an estimated distance of 6.53 km) from the village center to the kill site, with a maximum estimated distance up to of 50 km, corresponding to hunting incursions lasting several days. Almost 60% of the kills occurred within a range of 0.37 and 5 km from the village center, with only 1.26% of the kills occurring up to 50 km away.

Table 3.1. Definition and descriptive statistics of individual level variables used in the regressions.

Variable	Description	N	Mean	SD	Min	Max
Dependent variables						
Hunting activity	Dummy variable distinguishing between observations when hunters engaged in at least one hunting trip during the two weeks previous to the interview (=1) from observations without hunting activity (= 0)	1014	0.47	0.50	0	1
Animals harvested	Number of animals hunted per trip	479	1.71	1.37	0	6
Biomass harvested	Biomass harvested per trip, in kilograms	479	23.01	46.13	0	536.31
Explanatory variables						
Schooling	Maximum school grade attained by the hunter (ranges from 0 to 13)	347	1.93	2.69	0	13
Spanish	Dummy variable capturing the ability to speak some Spanish (=1)	347	0.93	0.24	0	1
Visits to market	Number of monthly travels to the market-town	347	1.09	1.25	0	7
Encounter rate	Average game encounter rate per kilometer, from the estimation of ten transects per village	40	9.42	2.57	4.65	14.99
Biomass	Average biomass of game available per kilometer, estimated based on the ten transects per village	40	199.09	107.16	52.26	471.63
Control variables						
Fishing	Dummy variable to capture whether the hunter went fishing during the two weeks previous to the interview (=1)	1014	0.89	0.31	0	1
Age	Hunter's age, in years (entered as age squared also in GLM to control for possible nonlinearity)	347	42.41	16.86	17	97
Household size	Number of people living in the household	347	6.11	2.94	1	18
Household income	Household income from the sale of rice since last harvest, in US dollars	347	71.97	11.37	0	1166
Dry season	Dummy variable that captures the season in which the survey was conducted (dry season = 1; rainy season = 0)	1014	0.79	0.41	0	1
Village remoteness	Remoteness index factoring village linear distance to the market-town plus the traveling cost (in time)	40	2.14	0.72	0.3	3.3

A total of 29 animal species were identified as hunting preys (see Chapter 1, Table 1.3). The seven most commonly hunted species – paca, collared peccary, coati, brown capuchin, red brocket deer, spix's guan, and howler monkey – comprised 70% of all the kills. The harvest of tapir, which provided a high contribution in terms of biomass (total of 2950 kg harvested), was relatively erratic (about 2% of the kills) compared with the harvest of collared peccary (11%) and with the harvest of red brocket deer (9%), two species that also provided high contributions in terms of biomass (1806 kg and 2953 kg respectively). The paca, which was the most commonly hunted species in terms of total number (13%), only contributed with a total of 870 kg of biomass. The white-lipped peccary was among the ten most hunted species representing 4% of the records. Tapir, giant armadillo, and giant anteater represented a total of about 2% of the total harvest. The spider monkey also represented almost 2% of the total harvested animals.

On average, hunters caught 1.7 preys per hunting trip. In about 41% of the trips, they captured just one prey and in 14% they captured nothing. The average biomass harvested per hunting trip was 23 kg (Table 3.1). Less than 2% of the trips showed harvesting of more than 100 kg of game, which in almost every case involved the hunting of a tapir, an incursion of several days, or even both.

Hunting behavior and acculturation

The Cronbach's alpha coefficient of our three proxies of acculturation was below the standard 0.80 (α=0.54), suggesting that each of those three variables capture different aspects of the process of acculturation. The average level of schooling was low (1.93). Thus, 46% of the hunters had no schooling, 35% had between 1 and 3 years of schooling, and just eight hunters (2%) had completed high school (13 years of schooling). Just 7% of the hunters in our sample reported to be monolingual in Tsimane'. On average, Tsimane' hunters travelled to the market-town approximately once a month. However, there is a large variation in these data, as about 63% of the respondents reported to have visited the market town less than once during the previous month, while 16% reported to have visited the market town at least twice a month during the same period. Regarding game availability,

the encounter rate per km did not show great variation among villages. However, the corresponding assessed biomass did: six villages presented less than 100 kg/km, whereas in four villages the average estimated biomass available was of more than 400kg/km.

Table 3.2. Results from Generalized Linear Models of acculturation against hunting behavior, without control variables (model 1) and with control variables included (model 2).

	Hunting behavior Hunting (1) / No hunting (0)	
	Model 1	Model 2
Acculturation		
Schooling	-0.08*** (0.02)	-0.09*** (0.02)
Spanish	-0.02 (0.17)	-0.21 (0.18)
Visits to market	0.02 (0.05)	0.04 (0.05)
Game availability		
Encounter rate	-0.07** (0.03)	-0.09*** (0.03)
Log biomass	0.69*** (0.13)	0.71*** (0.13)
Control variables		
Fishing	^	-0.08 (0.17)
Age	^	0.00 (0.02)
Age^2	^	-0.00 (0.00)
Household size	^	0.02 (0.02)
Log household income	^	0.04** (0.02)
Dry season	^	-0.12 (0.11)
Village remoteness	^	0.33*** (0.08)
Constant	-2.73*** (0.66)	-3.40*** (0.78)
Observations	1014	1014
AIC	1.32	1.30
Log pseudolikelihood	-661.96	-643.60

Note: GLM with binominal family and probit link function, include clustering by individuals. Robust standard errors in parenthesis. Game biomass available per km and household income entered as logarithms in the models.*, **, and *** statistically significant at p< 0.1, p< 0.05 and p<0.01, respectively. ^ Variable intentionally excluded from the analysis.

Results from Table 3.2 show a strong negative association between level of schooling and the probability that the person engaged in hunting, independently of whether we run the GLM with (model 2) or without control variables (model 1). Our two other proxies for acculturation, Spanish fluency and trips to the market town, bore no statistically significant association with hunting activity. On these same models, our two measures of game availability were significantly related to hunting

behavior. Game encounter showed a negative association with hunting behavior in both models, whereas the log biomass showed a positive association with hunting behavior. Regarding control variables, household income (in logs) and village remoteness showed a significant positive association with hunting behavior. According to the Akaike Information Criterion (AIC) both models are identical, which gives consistence to the significant association found.

Table 3.3. Results from Generalized Linear Models of the number of game animals and biomass (in kilograms) harvested by Tsimane' hunters.

	Animals harvested		**Biomass harvested (kg)**	
	Model 1	Model 2	Model 3	Model 4
Acculturation				
Schooling	-0.03 (0.02)	-0.03 (0.02)	-0.11*** (0.04)	-0.10** (0.04)
Spanish (some fluency)	-0.01 (0.14)	-0.03 (0.16)	-0.01 (0.26)	-0.08 (0.27)
Visits to market	0.09* (0.05)	0.08 (0.05)	0.19** (0.10)	0.20** (0. 09)
Game availability				
Encounter rate	-0.04* (0.02)	-0.03 (0.02)	-0.05 (0.06)	-0.06 (0.06)
Log biomass	0.23** (0.09)	0.20** (0.10)	0.41* (0.23)	0.41 (0.29)
Control variables				
Fishing	^	0.18 (0.14)	^	-0.19 (0.39)
Age	^	-0.02 (0.02)	^	-0.03 (0.03)
Age2	^	0.00 (0.00)	^	0.00 (0.00)
Household size	^	0.01 (0.02)	^	0.03 (0.03)
Log household income	^	0.02 (0.02)	^	-0.03 (0.03)
Dry season	^	0.09 (0.10)	^	0.06 (0.31)
Village remoteness	^	0.02 (0.08)	^	0.21 (0.14)
Constant	-0.35 (0.5)	-0.32 (0.65)	1.36 (1.06)	1.36 (1.43)
N	478	478	478	478
AIC	3.25	3.26	44.46	43.81
Log pseudolikelihood	-769.98	-766.11	-10619.39	-10457.64

Note: GLM with Poisson family and logarithmic link function, include clustering by individuals. Robust standard errors in parenthesis. Game biomass available per km and household income are entered as logarithms in the models. *, **, and *** statistically significant at p< 0.1, p< 0.05 and p<0.01, respectively. ^ Variable intentionally excluded from the analysis.

Results in Table 3.3 show that the number of animals hunted bore no association with any of the acculturation proxies here, with one exception. We

found a positive but weak association between the number of animals hunted and visits to market-town in our model without controls (model 1). When using biomass harvested, we found a negative association between the weight of harvested preys and hunters' schooling, and a positive association between the number of times a hunter traveled to the main market town and the biomass harvested (models 3 and 4). Both game availability variables were significantly associated with the number of animals harvested (model 1), but when including controls (model 2), game encounter rate was no longer significantly associated with the number of animals harvested. Regarding the association between game available and biomass harvested, we found that only biomass per km (in logs) was significantly associated to biomass harvested (model 3). None of the other control variables bore a significant association with any of our outcome variables in any of the models. The comparison of each pair of models according to their AIC suggests that these models are equivalent in terms of explained variance.

Discussion

Hunting is still a central economic activity for the Tsimane'. Hunting contributes to Tsimane' subsistence and to the sociocultural representation that surrounds their society (Chicchon 1992). Our results suggest that, although this activity is highly regulated by game availability, cultural factors that can be measured at the individual level also contribute to explain Tsimane' hunters' behavior. We will first discuss the relation between the different acculturation components and hunting behavior and after relate it with wildlife availability.

Our results show that the three acculturation components measured here relate in different ways to hunting behavior. From the several proxies of acculturation used, only level of schooling seems to be associated in a consistent way with a decrease of hunting activity. The association found between schooling and hunting activity was negative, implying that adult males with more formal education tend to engage less often in hunting than adult males with less formal education. This finding supports our initial hypothesis. But how might schooling

affect hunting behavior? We advance two non-exclusive potential explanations for the association found. First, several researchers have highlighted that schooling can undermine aspects of traditional culture (Sternberg et al. 2001; Zent 2001; Voeks & Leony 2004) as time and resources invested in schooling deflect from time and resources invested learning traditional activities (Sternberg et al. 2001). This might be particularly truth for the learning of complex skills such as hunting. For example, a study among the Tsimane' suggests that males who have not attended school only reach the maximum of hunting knowledge and skills at the age of 37 (Gurven et al. 2006). Furthermore, achieving proficiency in hunting involves the consistent practice of bow and arrow from the early ages as well as following expert hunters to learn tracking and pursuing animals (Chicchon 1992), so the necessary experience and body of knowledge and skills related to hunting can be achieved. If hunting requires such a significant time of learning to reach peak levels in performance, then it would be no surprise that time spent at school decreases the time individuals spend learning and practicing their hunting abilities with expert hunters from older generations, thus affecting their overall performance as hunters.

Our second explanation relates to the possibilities to participate in different economic activities offered by schooling. It has been argued that schooling allows individuals to learn and acquire new skills that will fundamentally shape their behavior, beliefs, and role in society, providing the endowments of human capital to enter modern occupations or compete for employment in the formal labor market (Haveman & Wolfe 1984). In the case of indigenous peoples, especially in highly autarkic economies such as the Tsimane', even low levels of schooling allow people to shift to new economic activities (Reyes-García et al. 2007a, 2010a). The high returns of schooling might explain why Tsimane' with some years of formal education decide to reduce their investments in traditional activities, such as hunting.

Differently from schooling, we did not find any relation between Tsimane' hunting behavior and Spanish fluency. We think that this might be due to the simplicity of the measure used. Our measure only distinguished between people who were completely monolingual and those who spoke some Tsimane'. As 92.6% of the hunters in the sample speak some Spanish, we probably do not have enough

variability in the Spanish variable to associate it with hunting behavior. Future studies should aim for a better measure of fluency in the national language to evaluate how different levels of Spanish fluency can influence the participation in different economic activities, such as hunting.

Finally, our results suggest that there is an association between our third proxy of acculturation, travel to the market-town, and biomass harvesting, although, visits to market-town bore no association with the probability of a hunter engaging in a hunting trip. A potential explanation for this association relates to the increase in hunting efficiency that hunters who visit the market town and can acquire ammunitions regularly can achieve. Previous research suggest that, when provided with firearms, hunters from indigenous societies can increase their offtake rates considerably, as compared with traditional hunting technology (Robinson & Redford 1991; Stearman 2000; Levi et al. 2009). For the Tsimane' the access to ammunitions at the villages is limited to traders visiting their villages. But those traders sell ammunitions at very high prices. For instance, the purchase of a box of bullets caliber 22 in some villages can cost almost ten times more than in the market-town, or can be exchange by a high number of thatch palms. Because buying ammunitions to traders implies such a high amount of work and time, hunters prefer to invest time visiting market-town where they can sell their non-timber products and crops to buy a variety of assets and market food.

One more result merits attention. The number of animals harvested bore no association with the proxies for acculturation used, except for a weak association with visits to market-town in one of the models. Most probably this result is related with game availability. In fact, we found a positive association between the logarithm of the biomass available per km and the number of animals harvested. In general, villages near market-town are the ones with greater pressures for natural resources and higher rates of deforestation and habitat destruction (Paneque-Gálvez et al. 2011; Reyes-García et al. 2012c). Those conditions translate into a decrease of wildlife, especially mid- and large-bodied mammal. Besides, villages closer to market-town, not only have greater access and new subsistence opportunities, but they were also the first villages in having schools and formal education plans implemented. Our results showed that hunters are most likely to be

active in areas with the most game available and were protein substitutes are difficult to get. The negative association between game encounter rate and hunting behavior (Table3.2) support this hypothesis. Usually, greater biomass availability is related with lower encounter rates, because large animals have in general lower population densities than smaller animals (Jerozolimski & Peres 2003; Robinson & Bennett 2004).

In sum, acculturation can have an impact on hunting behavior, but this impact is not straight forward. In the case of the Tsimane' society, schooling seem to decrease hunting activity, whereas visits to the market-town can increase hunting efficiency. Furthermore, it is worth noticing that findings presented here have to be taken with caution before attempting any generalization. As mentioned in the introduction, our main finding has to be understood in the Tsimane' context where, unlike in other societies, there is not a market for bushmeat. It would be plausible to hypothesize that, as some authors have noticed, where there is a market for bushmeat more acculturated people would hunt more, as the sale of bushmeat provide an important source of household income (Nasi et al. 2008; Mfunda & Røskaft 2010).

To date, Tsimane' lack a wildlife management project and no interest has been shown by the local governmental identities and the *Gran Consejo Tsimane'* to establish any wildlife conservation project. The only adaptation showed is the use of domestic animals, by a small number of households (Godoy et al. 2010). Tsimane' are in a critical situation, since their subsistence still relies heavily on wild meat consumption. Our results suggest that the Tsimane' seem to be abandoning hunting as they encounter a shortage of wildlife and, once having the necessary modern human capital, new economic opportunities present themselves. Nevertheless, gathering activities such as hunting will continue till it's feasible, putting in great danger wildlife and all the forest biodiversity. Community participatory management, controlled by effective wildlife policy, have proved in some cases the maintenance of wildlife populations viable and the livelihood of the local societies (Noss & Cuéllar 2001; Shepard et al. 2010).

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CHAPTER 4

The loss of cultural norms and its impact on communal game management. A case study among an indigenous society in the Bolivian Amazon

Abstract

Through the establishment of cultural norms and rules, indigenous societies have developed informal institutions that regulate the management of common pool resources. Researchers have argued that those management norms have often contributed to the sustainable use of common pool resources, and thus to ecological conservation. Such norms and rules are encoded in a myriad of expressions that range from conventions and taboos to spiritual beliefs. This paper examines traditional cultural norms related to hunting among the Tsimane', a group of hunter-horticulturalist in the Bolivian Amazon. We hypothesize that Tsimane' who follow traditional hunting norms might have lower harvest returns that those who do not follow them. We first examine the maintenance of traditional norms, and then examine the association between adherence to those hunting norms and game harvesting. We conducted research between 2008 and 2010 among Tsimane' hunters (n=298) from 39 communities. We collected data through structured interviews. Our results suggest that most Tsimane' hunters no longer follow traditional hunting norms. We found an inverted-U shape association between adherence to traditional hunting norms and the amount of wildlife harvested by individuals. For people with overall low cultural attachment, the higher their adherence to hunting norms the more biomass they harvested. Contrarily, for people with overall high cultural attachment, biomass harvested decreased with increasing adherence to hunting norms. Our results contribute to the body of research suggesting that informal institutions may contribute to the management of common pool resources in a sustainable way, since we show that the following of traditional hunting norms and values potentially help maintaining lower levels of game offtake.

Key words: Bolivian Amazon; cultural belief system; game harvest; hunting traditional attachment; Tsimane'

Introduction

For hunting purposes, wild game living in areas where several human groups co-exist can be considered a common pool resource (CPR). In the absence of regulations, i.e., in an open access scenario, hunting can led to species extinctions, as Hardin (1968) predicted in his seminal work and as several examples of local and regional extinctions from overhunting in the Amazonia suggest (Robinson & Redford 1991; Bodmer et al. 1997; Milner-Gulland et al. 2003; Nasi et al. 2011). Hunters acting in pure self-interests might preferentially pursue species that yield high returns, regardless of vulnerability to depletion (Hames & Vickers 1982; Alvard 1994; Peres 2000). But often, human societies have developed rules and institutions that regulate the management of those common pool resources. Thus, formal and informal regulations of hunting can might help prevent overhunting (Colding & Folke 2001; Bremner & Lu 2006). For instance, in the Ecuadorian Amazon, where wildlife harvest was leading to local depletion of several game species, a Kichwa community adopted several measures to regulate and improve sustainability of hunting (Sirén 2006). Such regulations included the return to some traditional practices (follow of old hunting rituals according to their traditional calendar) in order to protect particularly vulnerable species.

Research on the management of common pool resources, defined as the use and control of a common resource by a group of individuals through the collective action and share of property rights (Ostrom 1999; Berkes 2004), proposes that, over time, societies develop formal and informal institutions that allow them to manage those common pool resources in a socio-economically sustainable way (Ostrom 1990; Becker & Ostrom 1995; Ostrom et al. 1999; Colding & Folke 2001; Waylen et al. 2010). Formal institutions are often contained in written laws that guide how stakeholders or communities control, use, and management their resources (Pacheco 2008). Forest tenure regulations that indigenous societies have to follow are examples of such formal institutions. Informal institutions include cultural norms or rules, such as taboos or beliefs that determine human behavior towards the use and management of natural resources. For instance, Jones et al. (2008) suggest that the existence of strict taboos in Madagascar regarding the prohibition to harvest certain species offered a real protection to threatened

species, such as the lemur *Propithecus edwardsi* and the carnivore *Cryptoprocta ferox*. Similarly, da Silva et al. (2005) found that the Matsigenka, in the Peruvian Amazon, have restricted hunting seasons for certain monkeys with mythological or symbolic importance, such as the howler monkeys and spider monkeys. According to da Silva et al. (2005) the fact that Matsigenka believe that some game animals have vengeful spirits that might cause illness has also contributed to the viability of some game populations.

In this article, we use this framework to examine the association between traditional norms related to hunting and amount of wildlife harvested among the Tsimane', a hunter-horticulturalist society in the Bolivian Amazon. We consider traditional hunting norms or rules as an informal institution, since there is evidence that in some Amazonian cultures several traditional norms based on cultural beliefs and values can guide individuals' decisions on wildlife access and use, which may impact the availability of certain game species (Colding & Folke 2001). We use game harvesting as a proxy of the impact of hunting in wildlife conservation, although we are aware of the limitations of such an equation as many other factors (e.g., human density, use of modern hunting technology) might also play a determinant role in the abundance of wildlife populations. In the next sections, after documenting Tsimane' traditional hunting believes, we address the following questions: 1) to what extent do the Tsimane' continue following some of their traditional hunting norms or rules? and 2) does adherence to hunting norms predicts the amount of wildlife harvested by an individual? Following predictions from the theory of common pool resources (that would argue that informal institutions such as traditional hunting norms or rules help regulate natural resources management), we hypothesize that Tsimane' who are more detachment to traditional hunting norms would harvest larger amounts of game.

Materials and methods

Study area

The Tsimane' territory lies from the Andean piedmont to the vast planes of the savannas of Moxos, in the Bolivian Amazon, department of Beni (Reyes-García et al. 2012b). The climate of the region is thermotropical with summer rains from October to April. From May to August there is a period of reduced precipitation -less than 100mm- and the presence of episodic southern cold winds. The mean annual temperature is 25.8°C (Navarro & Maldonado 2002) and the mean annual rainfall is 1743 mm (Godoy et al. 2008). Most of the territory is covered with Amazonian lowland forests with a high semi-deciduous canopy reaching 40 m (Guèze 2011). Tsimane' communities are in general located in indigenous territories, the Tsimane' *Territorio Comunitario de Origen* (TCO) and the Multiethnic TCO, in logging concessions, or natural protected areas (Introduction – Fig. 1).

THE TSIMANE' AND THEIR SOCIAL ORGANIZATION

The Tsimane' are one of the largest ethnic groups in the lowlands of Bolivia (Censo Indígena 2001). Current unofficial estimates set their population to about 10,000 peoples, scattered along 125 communities (Reyes-García et al. 2012b). Their lands are owned collectively according to the different land tenures mentioned above. Tsimane' manage natural resources through a combination of local formal rules and informal norms. Communities lack formal territorial delimitation, but informal internal boundaries are known and they guide the establishment of households and agricultural plots. Likewise, households share common land and resources for hunting, fishing, and gathering of plants and fruits but have exclusive rights to their agricultural plots.

Still considered a very autarkic society (Godoy et al. 2010), the Tsimane' have started adopting modern ways of living that have gradually changed their cultural and socioeconomic system in recent years. The increasing numbers of contacts with other sectors of the Bolivian society, the economic development, the expansion of new infrastructures (e.g. roads) that open access to highland colonists and loggers, and the new educational and health programs in the area have been the main drivers of such changes. Nowadays, among the Tsimane' society there is

increasing variation in the levels of acculturation and integration into the market society. For example, some Tsimane' live in remote communities, where they maintain traditional subsistence practices such as hunting, fishing, foraging, and shifting agriculture (Vadez et al. 2008). They practice barter with traders who travel to their villages to obtain salt and some tools in exchange of thatch palm (*Geonoma deversa*) or rice. Other Tsimane' live in communities closer to communication axes, such as logging roads or market-towns, and have adopted new market-based economic activities, such as cash cropping or wage labor, usually for loggers or ranchers.

Tsimane' traditional social organization is also being gradually replaced by the legal national system of social organization. For much of Tsimane' known history, shamans (*cocojsi'*) held the highest status positions due to their ability to communicate with forest spirits and ancestors (Daillant 1994). They also played an important role on the guidance of communal decisions (Huanca 2006). Shamans disappeared among the Tsimane' for more than 20 years now, due in part to the longstanding influence of Catholic and Evangelical missionaries. In replacement, a new social hierarchy was officially established among the Tsimane' in 1989, year when the *Gran Consejo Tsimane'* -the political representative institution- was created. The Tsimane' now routinely appoint *corrigidores* or community leaders that participate in the *Gran Consejo Tsimane'*. Corregidores are responsible for channeling Tsimane' demands to the national society, but they often lack coercive authority within their villages.

THE TRADITIONAL HUNTING BELIEF SYSTEM

Tsimane' myths about forest animals demonstrate the importance of hunting in the Tsimane' culture (for further details see Huanca (2006, 2008)). The Tsimane' traditionally believed that forest animals and trees have master spirits that care for them, for example breeding, feeding, and herding their animals (Huanca 2006). A forest spirit, *jäbäbä*, is believed to be the shepherd of wild animals, who usually live in a spiritual space. The master spirit had the faculty of opening doors to let animals go to the physical world where the Tsimane' live and where they can hunt them. As mentioned, one of the important roles of the shaman in traditional Tsimane' society was to mediate between people and spirits. On the one side, the shaman was able to

assure successful hunting trips as he could ask the spirits to free the animals, and to send them tame, so it would be easy for the Tsimane' to hunt them. On the other side, the shaman was able to impose restrictions on the amount of game that the community could hunt, as he was able to restrict hunting activity (Huanca 2006).

There were also rules and practices hunters should follow to keep the balance between spirits and nature. For example, according to the oral tradition recorded by Huanca (2006, 2008), Tsimane' hunters had to pray to the animals' masters before going hunting. They also had to follow some restrictions (*micdyidye'*) that affected the time between hunting excursions. Moreover, they were only allowed to capture one animal of group species, such as the spider monkey (*Ateles chamek*) or the white-lipped peccary (*Tayassu pecari*), in each hunting trip. Not obeying to those rules would result in punishments of the hunters and their families. Such punishments could take the form of a sickness, or an accident in the forest sent by the master spirit of the species hunted. Punishments could also come on the form of game scarcity, as the master spirit could decide to stop '*sending*' game (Huanca 2008).

Another example of hunting restrictions imposed by the Tsimane' belief system relates to the prohibition of hunting around salt licks. Tsimane' tradition inhibits the hunt of peccaries around salt licks, especially during the afternoons (Huanca 2006). This rule may be related with the control of hunting pressure on certain game species and in areas where they knew there was more probability of overhunting.

Likewise, traditionally Tsimane' carefully kept the bones of wild animals and returned those bones to the forest by putting them in holes next to big trees, as an offering to the animals master and nature itself. Tsimane' beliefs state that if hunters do not return the bones to the forest, they would not succeed as hunters and wild animals would become scarce (Huanca 2006, 2008). Another example relates with the animal feet. Oral tradition affirms that if hunters leave the feet of wild animals in the place where they capture them, the master spirit would keep animals tamed, and hunting would be easier (Huanca 2008). Moreover, burying the animals' heads would also ensure the abundance of animals.

Oral tradition of the Tsimane' also refers to some hunting rituals that enhance the hunters' abilities (Huanca 2008). For instance, Tsimane' hunters drink or put in their eyes a traditional medicine –*piñidye*– that make them more astute and better at shooting their bows.

Data collection

SAMPLING: We worked in 39 Tsimane' villages over the course of 20 months of fieldwork, between 2008 and 2010. To conduct the work, we obtained previous consent from the *Gran Consejo Tsimane'* and from each village and individual participating in the study. We draw on data collected by a participatory mapping project ongoing at the time (Reyes-García et al. 2012a) to select villages.

We based our study on quantitative enquiry, using socioeconomic surveys and structured interviews with hunters. To select hunters, we randomly selected households of each community from a list previously given by the highest-ranking authority, and interviewed the male household heads to answer a questionnaire. We selected male household heads because traditionally they were all hunters and the formal providers of wild meat to the family (Chicchon 1992). In villages with less than 10 households, we interviewed all the present male household heads. In villages with more than 10 households and less than 40, we randomly selected 10 households. And in villages with more than 40 households, we surveyed 25% of the households. We visited each village three times. During our first visit, we collected background information on traditional practices. With that information we elaborated a survey to measure the adherence to hunting cultural norms. We conducted the hunting cultural norms questionnaire during our second and third visits to the communities. To control for seasonal variation in hunting, in each visit we applied a questionnaire to measure biomass of game harvested. The final sample used in the analysis corresponds to people from whom we had both measures of traditional hunting believes and game harvested.

GAME HARVESTED (outcome variable): We asked to each hunter about his hunting excursions on the two weeks prior to the day of the interview. We recorded data about the animals harvested, live stage (juvenile or adult) and sex. We repeated this

survey in our three visits to the villages with the same hunters, when present. For each individual, we estimated two outcome variables: (1) the average number of animals hunted per trip and (2) the average biomass harvested per trip, calculated based on published estimates of species body mass and live stage (Myers et al. 2006). We included individual observations even when there was no hunting activity reported.

HUNTING CULTURAL ATTACHMENT (explanatory variable): We created an index that captures hunter's self-reported adherence to Tsimane' hunting norms. The index was based on responses to five questions in which hunters were asked whether they regularly adhere to a set of hunting cultural norms or rules (Table 4.1). To construct the five questions we used previous ethnographic work (Chicchon 1992; Huanca 2008) and informal discussions with Tsimane' hunters on their traditional hunting belief system.

Table 4.1. Description of the questions used for measuring hunting cultural attachment at the individual level in 39 Tsimane' villages, Bolivian Amazon.

Norm	Question
1	Do you pray to the animals' master –*jäjäbä*– before going hunting?
2	Do you keep the bones of the animals harvested to return them to the forest?
3	Do you bury the feet of the captured animals?
4	Do you take *piñidye* (traditional medicine) before going hunting?
5	Do you bury the animals' head in the place of capture?

We coded each answer as 0 if the hunter reported to have completely abandoned the practice of the hunting norm, 1 if he sometimes practiced it, and 2 if he reported to continue practicing it on a regular basis. We created an individual score (hereafter, cultural attachment index) that captures hunter's adherence to traditional Tsimane' hunting norms by summing the answers to the five questions. The index ranges from 0 (if the hunter does not follow any of those norms) to 10 (if he stills follows them all). Higher values, therefore, represent larger cultural attachment to the Tsimane' traditional hunting belief system. Although none of the five questions are direct practices or taboos against hunting or against eating certain species, we opted to ask for those specific norms because we considered

that those questions were less sensitive than direct questions asking about taboos, we were certain that those practices were traditionally practiced among the Tsimane', and we assumed that the detachment to those practices is a good indicator of the detachment of more restrictive rules that involve less common practices.

SOCIOECONOMIC CHARACTERISTICS (control variables): We collected a set of data to use as control variables in our regression analysis. Control variables to our regression model included 1) standard socio-demographic variables, such as hunters age (and age squared to control for possible nonlinearity), household size, and overall individual hunting activity given by the number of hunting trips made in relation to the number of surveys the hunter responded, 2) standard proxies of acculturation, such as years of schooling, ability to speak Spanish (official national language) and the number of monthly travels to the market town, and 3) proxies for market integration as household income from the sale of rice from the previous year harvest (enter as logarithmic due non-linearity) and village remoteness. We judged each participant's ability to speak Spanish and coded answers as 0 if the person was monolingual in Tsimane' and 1 otherwise. We also estimated the village remoteness, given by its distance to the nearest market-town, plus travel cost. For the estimation of distance we used ArcGis 10.0.

Data analysis

First, to explore the relation between adherence to Tsimane' hunting traditional norms and amount of game harvested, we ran a series of Tobit regressions. One set of regressions included the average number of animals harvested per trip as outcome variable and our hunting cultural attachment index as main explanatory variable. The second set of regressions was the same than the first one except that it included biomass (in kg) harvested per trip as the outcome variable. For each of our outcome variables we ran two different models. The first model included only our explanatory variable -cultural attachment score- and its square term to control for nonlinear relation, plus a full set of dummy variables for communities to control for communities' attributes that remained fix during the

study period but that may affect household wildlife consumption (e.g. population size, habitat composition) and game availability. In the second model we added a full set of control variables that allow testing the robustness of our original model.

Secondly, to explore socioeconomic differences among hunters according to their attachment to hunting norms, we separated our sample in two groups: (*i*) non-believers, or the respondents with a score lower than three in the cultural attachment score (the mean inflection point of the curve resulting from the multivariate analysis, see Results section), and who do not follow the majority of hunting norms; and (*ii*) believers, or hunters with a cultural attachment score equal to or higher than 3, who mostly follow traditional norms. We then ran a set of t-tests to assess differences between groups, depending on their age, years of schooling, fluency on Spanish, number of travels to the market-town, the share of times they used bow and arrows for hunting, and the community of residency. For all statistical analysis we used Stata 11 for Windows.

Potential biases and limitations

The main limitation of our study relates to the nature of our questions regarding hunting cultural attachment. Although we tried to select non- sensitive questions, because we deal with believes that have strongly been attacked by Catholic and Protestant missionaries on the recent decades, there is a possibility that people might be reluctant when expressing their attachment to traditional beliefs. For instance, the fact that a hunter denies the practice of praying to the master of the animals can be seen as a way for him to integrate into the mainstream society. We tried to control this by working with a Tsimane' translator known in all villages, who had long experience in conducting surveys and who has collaborated with the Tsimane' Amazonian Panel Study (http://www.taps.org) since 2002, but we cannot be sure that this eliminated all reluctances.

Results

In Table 4.2, we present descriptive statistics of the variables used in the regression analyses. On average, our sample of Tsimane' hunters harvested about 14 kg of wild meat (±19.5) per hunting trip, with values ranging from 0 to about 113 kg/trip. This corresponds to about one animal (±1) captured per trip, although we also recorded 30 trips without capture and 3 trips with six preys. Overall, on 47% of the survey's respondents had gone on at least one hunting trip over the two weeks before the interview. From all the hunters, 26% did not report any hunting activity before our interviews, 20% had gone hunting every time we surveyed them, and about 41% had gone hunting at least half the times we interviewed them.

Table 4.2. Definition and descriptive statistics of the variables used in the analysis. Tsimane' hunters (n=298) from 39 villages in the Bolivian Amazon.

Variable	Description	Mean	Std.Dev.	Min	Max
Outcome variables					
Animals harvested	Number of animals captured per trip	0.92	1.03	0	6
Biomass harvested	Kilograms of game biomass harvested per trip	13.48	17.15	0	91.16
Explanatory variable					
Hunting cultural attachment	Index, given by the sum of the responses to the five questions on the adherence of hunting norms (Table 4.1). Values range from 0 (lowest attachment) to 10 (highest attachment)	1.82	1.86	0	10
Control variables					
Hunting activity	Proportion of hunting incursions in relation to the number of surveys	0.47	0.36	0	1
Age	Hunters' age	42	16.67	17	97
Schooling	Maximum years of formal education	1.83	2.5	0	13
Spanish	Ability to speak some Spanish	0.93	0.25	0	1
Visits to market town	Number of monthly travels to the market-town	0.96	1.2	0	7
Household size	Number of family members living in the household	6.1	2.95	1	18
Household income	Income from the sale of rice harvest for the year prior to the interview, in US dollars	69.93	126.75	0	1166
Community remoteness	Remoteness given by the community distance to the nearest market-town, plus its accessibility given by the travel cost in time	2.22	0.67	0.39	3.26

The mean value of our index of attachment to hunting norms was fairly low (1.82 ±1.86) within the scale we defined (0 to 10), suggesting that, overall, people in our sample seem to be fairly detached from the hunting norms asked on the interview. The standard deviation of responses to all the questions was also quite low, suggesting small variation among informants. Only 2 hunters (0.67%) fully practiced the five traditional hunting norms we asked for, whereas 34% of the respondents no longer practice any of those norms, and about 21% of the hunters seem to follow only one of the five traditional hunting norms. The descriptive statistic of the five questions on people's attachment to hunting norms is presented in Table 4.3. We found that about 27% of the respondents always practice any of the two hunting norms related to questions 2 and 3, whereas 17% of respondents just practice those same norms sometimes. For the remaining three questions (question 1, 4 and 5) the number of hunters that always follows those cultural norms dropped to an average of about 4% of the respondents, but the number of those who sometimes follow them raised slightly about 6%.

Table 4.3. Responses to the five questions used to estimate hunting cultural attachment, in number of hunters (and frequency). Answers given by respondents (n=298) were classified as 0 if never practiced the hunting norm, 1 if sometimes practiced it, and 2 if always practiced it.

Question		**Hunting norm practice**		
		Never (=0)	Sometimes (=1)	Always (=2)
1	Do you pray to the animals' master –*jäjäbä*– before going hunting?	258 (86)	19 (6.33)	23 (7.67)
2	Do you keep the bones of the animals harvested to return them to the forest?	176 (58.67)	47 (15.67)	77 (25.67)
3	Do you bury the feet of the captured animals?	162 (54)	56 (18.67)	82 (27.33)
4	Do you take *piñidye* (traditional medicine) before going hunting?	268 (89.33)	21 (7)	11 (3.67)
5	Do you bury the animals' head in the place of capture?	285 (95)	13 (4.33)	2 (0.67)

To give an intuitive description of how our index of hunting cultural attachment varies along biomass of wildlife harvested, we present a graphical distribution of the two variables (Fig. 4.1). In the left part of the graph we see that as attachment to hunting norms increase, so it does the amount of biomass harvested.

The increase, however, reached an inflexion point for a score of 5 in our scale of hunting cultural attachment. Beyond this point, an increase of the index seems to be associated with a decrease in biomass harvested.

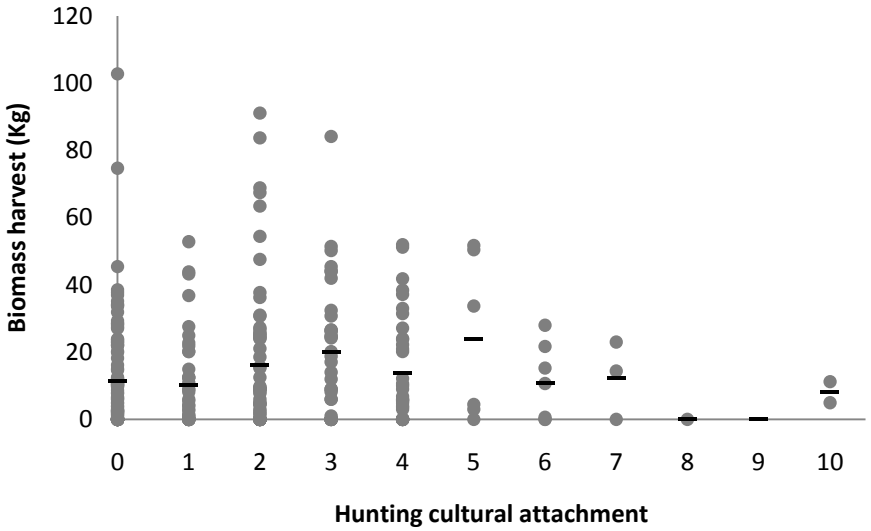

Figure 4.1. Variation of biomass of game harvested along the hunting cultural attachment index. Higher values represent higher hunting cultural attachment. Black lines represent the mean value for each belief.

Results of the multivariate analysis (Table 4.4) seem to confirm the non-linear relation observed in the graphical analysis. Thus the cultural attachment index was positively and significantly associated to the kilograms of biomass harvested by an individual, whereas the square term of the same index was associated in a negative and statistically significant way with the outcome variable (models 1 and 2). Taken together, the two coefficients suggest that the association between attachment to hunting norms and kilograms of biomass harvested resembles an inverted-U. This relation remains robust when we include control variables into the model (model 2). The coefficients found in model 1 or 2 imply that the relation between hunting cultural attachment and kilograms of biomass harvested follows different patterns. For those people with low levels of cultural attachment (i.e. between 0 and 3) we find a positive relation between the two variables: an increase of one point in our scale of attachment to hunting norms is associated to an increase of about 4 kg of biomass harvested. However, the direction of the association reaches a turning point at about 3 points (2.98) in our scale of

cultural attachment. Beyond this score the association becomes negative: an increase in one point in our scale of hunting cultural attachment is associated to a decrease of about 0.6 kg of biomass harvested.

We tested the same association using the average number of animals harvested per trip as outcome variable. We did not find any significant association with any of our explanatory variables in the model with (model 4), nor without controls (model 3).

Table 4.4. Tobit regressions of the biomass (kg) harvested (models 1 and 2) and the number of game animals (models 3 and 4) without and with control variables, in relation to the loss of traditional taboos of Tsimane' hunters (n=298).

	Biomass harvest (kg)		**Animals harvest**	
	Model 1	Model 2	Model 3	Model 4
Explanatory variables				
Hunting cultural attachment	3.662**	3.544**	-0.021	-0.03
	(1.628)	(1.583)	(0.094)	(0.095)
Hunting cultural attachment (square)	-0.584**	-0.593**	-0.003	-0.002
	(0.239)	(0.232)	(0.014)	(0.014)
Control variables				
Hunting activity	^	32.731***	^	1.194***
		(4.978)		(0.291)
Age	^	-0.405	^	-0.037
		(0.475)		(0.029)
Age (square)	^	0.004	^	0.000
		(0.005)		(0.000)
Schooling	^	-0.445	^	-0.011
		(0.652)		(0.038)
Spanish	^	0.024	^	0.143
		(5.51)		(0.335)
Visits market-town	^	1.153		-0.014
		(1.734)		(0.104)
Household size	^	0.713	^	0.053*
		(0.507)		(0.031)
Log household income	^	-0.039	^	0.016
		(0.503)		(0.03)
Community remoteness	^	-4.422	^	-2.396
		(28.745)		(1.578)
Constant	16.758**	16.355	1.838***	7.22*
	(7.384)	(70.295)	(0.43)	(4.295)
Log likelihood	-947.74	-921.04	-376.55	-364.28
Pseudo R^2	0.06	0.09	0.14	0.17

Note: All models include full set of dummy variables for communities. Robust standard errors in parenthesis. *, **, and *** statistically significant at p< 0.1, p< 0.05 and p<0.01, respectively. ^ Variable intentionally excluded from the analysis. For definition of variables see Table 4.2.

Overall, 209 (69%) hunters belong to the group of non-believers (cultural attachment index < 3), and 91 (31%) belong to the group of believers (index ≥ 3). Hunters belonging to each of the two groups differ in the number of times they used bow and arrow in their hunting incursions (p=0.06), the number of travels to the market-town (p=0.02), and in the village of residency (p=0.06). On average, the group of believers used more often bow and arrow (mean=2.36 ± 0.06), traveled less to market-town (mean=0.72 ± 0.1), and lived in more remote villages (mean=0.24 ± 0.04) than the non-believers group whose use of bow and arrow was more erratic (mean=0.15 ± 0.02), visited more often (mean=0.11 ± 0.09), and lived closest to market-town (mean=2.21 ± 0.04). Differences in Spanish fluency, household income, and village of residency were not significant between the two groups.

Discussion

Two important findings stand out from our work. First, our results suggest that few Tsimane' hunters are attached to the practice of those traditional hunting norms categorized in our study. And second, we found a non-linear association between the adherence of those hunting norms and the biomass of game harvested.

Our first important finding relates to Tsimane' low attachment to traditional hunting norms. The recent history of the Tsimane' provides an explanation for this finding. Specific changes that may have influenced the Tsimane' hunting belief system include the arrival of the Protestant missioners since the 1950s (Reyes-García et al. 2012b), the disappearance of shamans around the 1980s (Huanca 2006), the increased contact with outsiders in the last decades (Reyes-García et al. 2012a), and the reduction of game available in the area (Herrera-MacBryde et al. 2000; Huanca 2008). On the one side, the influence of the missionaries and the disappearance of the shamans have probably undermined Tsimane' traditional belief system and hunted related rituals. Missionaries were against the worship of nature masters, as well as against shamans and their social role and influence within the Tsimane' society. On the other side, the increased contact with, and

pressure of the mainstream Bolivian culture might have also undermined traditional beliefs that are on the basis of the hunting norms. For example, by observing non-Tsimane who did not fulfill their rituals, but were still successful and efficient hunters, the Tsimane' might have started abandoning and even stop believing in some of their cultural traditions. Furthermore, the decline of some of the most important game populations for the Tsimane' resultant of the pelt commercialization boom also seem to have impacted on their cultural system. According to Huanca (2008), during the pelt commercialization boom the Tsimane' started consuming the meat of species that were a taboo before. However, although cultural attachment to hunting norms seems to be decreasing, hunting itself continues to be a very important activity among the Tsimane'. As we referred before, only 26% of our sample reported not having engaged on hunting during the two weeks before the interview. Traditionally, hunting was important not only as a subsistence economic activity, but also as a cultural element central in the overall identity of the Tsimane' society. Nowadays, with the erosion of the hunting belief system and heritage, the distinctive feature of being a hunter might not be as important as before, and with it, social relations associated with this identity might also have changed.

Our second important finding relates to the association between the adherence to those hunting norms and the amount of biomass harvested. According to the theory of common pool resources, we had predicted an increase of game harvesting as the attachment to traditional norms and rules decreased. However, our results suggest an inverted-U shape association between hunting cultural attachment and the amount of game harvested. First, among the people who hold less to hunting norms (with values between 0 and 3 on our scale of cultural attachment) the higher the score, the more biomass of game harvested, thus contradicting our initial expectation. Second, among people with higher attachment to those hunting norms (with values equal or higher than 3 on our scale of traditional hunting attachment) the greater the attachment, the less biomass harvested, which supports our initial hypothesis. We provide two related explanations for this finding.

A plausible explanation for the finding regarding the first part of the curve is that people who do not adhere to hunting norms, no longer share traditional interests and understandings that can act beyond self-interest, and bring benefits to the community. Some authors advocate the importance of maintaining a cultural identity that is held collectively and that can be reflected on the effectiveness of common pool resources management (Mosimane & Breen 2012). Examples in common pool resources literature show that, where there is no trust to invest in collective activities, people tend to cause destruction through over-utilizing or under-investing in the maintenance of commonly owned resources (Becker & Ostrom 1995; Ostrom 1999; Berkes 2004). In the case of the Tsimane', increased contact and proximity with the mainstream culture might be eroding those informal institutions that contribute to a cultural identity, and at the same time, influence individual behaviors and communal subsistence patterns.

The finding identified in the second part of the curve supports expectations of the theory of common pool resources management. According to our results, attachment to the traditional belief system apparently impacts game harvest rates, potentially helping maintaining low levels of offtake. This finding essentially entails that the individual altruistic action has to be based on shared cultural norms towards the achievement of a common interest. In this case, the role of those informal institutions might embody the organizational endeavors of a group of individuals in the management of common pool resources for collective benefits.

Thus, although we do not know to what extend these traditional norms were efficient in maintaining wildlife populations, and that the work presented here does not provide a test of such link either, our results suggests that the breach of such norms or the erosion of informal institutions is affecting the individual hunting behavior and most probably the collective management of wildlife. Traditional hunting norms in some cases have proved to be more effective in ensuring the sustainable use of wildlife, than modern management techniques. In a society undergoing rapid cultural and socioeconomic transitions, such as the Tsimane' society, traditional cultural concepts should be accounted for future conservation measures, or at least for the preservation of the Tsimane' cultural heritage. Finally, we reinforce that this work is a fist approach to the assessment of informal

institutions among the Tsimane' culture and that the two hypothetical initial conclusions require further research to be fully understood. Furthermore, future research should also focus on the pathways and characteristics that allow individuals and communities to maintain those informal institutions that can improve the management of common pool resources, despite acculturation, integration to the market economies, and the pressure of encroachment from outsiders in their territory.

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GENERAL CONCLUSIONS

This dissertation analyzes Tsimane' subsistence hunting through an interdisciplinary approach based on empirical data from the social and the natural sciences. The dissertation brings insights on the links among acculturation, the livelihood of indigenous societies, and wildlife conservation. This work extends beyond traditional ecology and conservation biology approaches -species centered- to bring into the picture cultural and socioeconomic factors. As results from this work suggest, the approach is much needed as cultural and socioeconomic factors affect the hunting behavior and management of communal game of indigenous societies, and consequently wildlife abundance and diversity. Interestingly, I found that there is also a feedback loop, so changes in wildlife abundance and diversity revert in changes in cultural aspects. With the analysis presented here, I strive to strengthen a growing literature discussing the effects of acculturation in the way indigenous societies manage their natural resources, and at the same time contribute to the body of literature that advocates that community-based conservation can be a possible pathway to cultural and biological conservation (e.g., Ostrom 1990; Berkes 2004).

In the first chapter of this thesis, I have shown that the nowadays available game community identified along the Tsimane' territory seems to partially be the result of intensive hunting and habitat degradation. Those factors should be added to the list of other environmental (e.g., species limit distribution, climate) and anthropogenic factors (e.g., human demography, land clearance) that doubtless play an important role in shaping wildlife population distribution. My results show that, in the Tsimane' territory, game abundance increases from close to market-town villages' to more remote villages, a trend also observed in villages' harvest rate. I interpret this finding as meaning that villages close to the market-town show low game abundances and low levels of wildlife harvest, a situation mainly driven by the increased population pressure, better acessibility to outsiders, and higher cover area of early growth/degradated forest than in distant villages. Finally, the village hunting profiles presented here suggest that the Tsimane' are hunting according to game availability, except for some species that continue to be largely hunted despite their low abundance, possibly because traditional preferences for those species seem to prevail.

In the next two chapters, I analyze how acculturation affects hunting pressure at the village level (chapter 2) and individual hunting behavior of Tsimane' hunters (chapter 3). Although hunting greatly depends on game availability (as discussed in chapter 1), results from those two chapters suggest that increasing (village and individual) acculturation decreases the hunting activity as well as the final returns provided by hunting. A possible explanation for this finding relates to the opening of new economic opportunities that come with acculturation. The acculturation process not only involves the loss of traditional cultural values, but also the acquisition of other values and behaviors of the dominant society. In that sense, schooling might erode Tsimane' traditional values, but it also opens pathways which increase their endowments to enter in market-based occupations, such as wage labor. And as people engage in those new occupations, they reduce their hunting activity. In chapter 3, I introduced the use of GIS tools for the estimation of hunting pressure and for the spatial visualization of the variation of hunting pressure and game availability along the gradient of acculturation observed in the studied villages. I stress the utility of remote sensing and GIS tools as a

methodology that allows spatially-explicit planning for game monitoring. The use of GIS tools can help provide spatial assessment trough accounting for empirical cultural and economic data of local communities for developing future wildlife management strategies.

The last chapter focuses on hunters' attachment to traditional hunting norms and how the practice of those norms relates with communal game management. Results show that most Tsimane' hunters seem to be abandoning traditional norms associated to hunting, as well as the hunting practices derived from those norms. My work suggests that for people with overall low cultural attachment, the higher their adherence to hunting norms the more biomass they harvested. Contrarily, for people with overall high cultural attachment, biomass harvested decreased with increasing adherence to hunting norms. This non-linear patterns could be the result of the acculturation (and market integration) process, through the breaking of values, beliefs and norms. People who adhere less to traditional hunting norms (maximizing the amount of meat harvested), no longer share interests and understandings that can led them to act beyond self-interest, resulting in benefits to the community. Contrary, those who still adhere to hunting norms seem to share a cultural belief system towards the achievement of a common interest (sustainable harvesting).

Wildlife hunting continues to be an important subsistence activity for the Tsimane' society. However, the viability of wildlife populations in the Tsimane' territory are threatened. The current viability of wildlife populations in the Tsimane' territory has inherited the legacy of unsustainable harvest of wild meat in the past (Chicchon 1992), largely linked to the illegal pelt market and the increasing encroachment from outsiders into the Tsimane' territory (Huanca 2008; Bottazzi 2009; Reyes-García et al. 2012). Moreover, overharvesting has probably increased with growing access to hunting technology (i.e., rifles), growing demand due to human population growth, the enlargement of hunting grounds to remote areas by the opening of new roads (usually associated with the logging activity), and a lack of monitoring and management. All these factors coupled with the inexorable march of modernity, primarily through schooling, wage jobs, and trading opportunities are profoundly changing the Tsimane' traditional hunting lifestyle. As a consequence,

new individual hunting behaviors and management practices have been adapted to face the new endowments of modern life. As the Tsimane' become more acculturated, they seem to progressively abandon subsistence hunting and, at the same time, detach from their traditional indigenous hunting identity, cosmologies, and rituals. This converts hunting into a merely subsistence activity and not a crucial element of the Tsimane' culture. With changes in traditional cultural systems, changes in the social relations are also expected, as subsistence hunting among the Tsimane' used to serve as a mean to create social bounds and to achieve recognition and respect within the group (Chicchon 1992; Huanca 2008). Consequently, the loss of this cultural identity that traditionally was held collectively reflects on the effectiveness of communal game management for sustainable harvesting.

But although results from my work suggest that increasing acculturation seem to contribute to the diminishment of hunting activity, this does not directly translate in less pressure on wildlife, as the newly adopted market-based activities can have as large impact on wildlife as subsistence hunting. The transition to market-based economic activities can decrease Tsimane' forest dependency (e.g., if they engage in wage labor), but it also may derive into increasing dependency of other forest resources (e.g., sale of timber and non-timber forest products) or into agricultural intensification. In the first case, traditional ecological knowledge can be replaced by Western knowledge and the acquisition of new skills, which would make difficult the maintenance of the hunting identity and the possibility of future communal management. In the second case, the extraction of other forest resources causing habitat degradation or conversion to agriculture might indirectly affect game species populations, and the overall biodiversity of the area.

It is very difficult to devise policies targeting the factors that affect wildlife abundance in the Tsimane' territory (i.e., globalization forces, habitat degradation, etc.). But the one factor that could be subject to policy recommendations is wildlife management. In spite of its ecological, cultural, and nutritional importance, subsistence hunting is not regulated in any way in the Tsimane' territory. Nowadays, the Tsimane' lack any kind of wildlife (or any other resource) management programs something that is aggravated with the loss of their

traditional management rules. The Bolivian legal system acknowledges exclusivity of subsistence hunting within the *Territorios Comunitarios de Origen* (TCOs) to the indigenous peoples that inhabit them (*La Ley de Veda General e Indefinida Ratificada 1999*, DS 25458). Furthermore, the same law encourages the sustainable use of wildlife species based on the development of management plans. Tsimane' political organizations should take advantage of this legal framework to design a sustainability management for wildlife in their territory. Research suggests that successful sustainable management practices are in part intrinsically dependent on indigenous willingness to protect their lands and natural resources (Colchester 2000; Noss et al. 2004), so bringing the Tsimane' on board of the design of such a management plant could help in its successful implementation. I advocate that -in the case of the Tsimane'- a wildlife management project can not only support sustainable harvesting, but also built resilience among the Tsimane' society by providing a framework for the maintenance of their culture and traditional ecological knowledge. Such a plan could also provide economic and development opportunities through job creation or new learning and training opportunities.

Furthermore, due to the significant overlap between indigenous peoples lands and the world's biodiversity-rich areas (Toledo 2001; Sunderlin et al. 2005), future governance should reinforce biodiversity conservation measures through the protection of indigenous territories and land rights, so indigenous peoples can both benefit from and strengthen conservation in the lands they inhabit. It seems obvious that indigenous people's right to hunt should coexist with wildlife management. This way, participatory and community-based management may be an important and sustainable mean of resource use and a significant channel to promote dialogue between social scientists, ecologists, NGOs, and indigenous populations about conservation issues.

Future investigations can potentially include studies on traditional and local ecological knowledge. On one hand, it is important to understand how the acculturation process and the changes on the hunting patterns that Tsimane' are experiencing are affecting their traditional ecological knowledge, regarding hunting and the ecology of game species. On the other hand, having underlined the fact that some cultural norms are no longer followed by a majority of the hunters, it is

important to undergo a further step of investigation to explore whether local hunting knowledge can contribute as an effective tool for assessing conservation and game management strategies. For instance, future research should analyze if the knowledge of the Tsimane' on wildlife abundances and distribution may be important in the establishment of wildlife management programs.

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APPENDICES

Appendix 1. List of communities sampled and corresponding characteristics, along the Tsimane' territory, Bolivian Amazon.
BBE= Beni Biological Station; FC= Forest Concession; PL= Private Land; TCO= Territorio Comunitario de Origen (Indigenous Territory). [a] Estimations based on Landsat imagery for the year 2009, by applying a 5km circular buffer to the centre of each community; [b] Estimations obtained from Worldclim data set; [c] Spanish ability to talk evaluation, ranging from 0 to 2. 0 if the person only speaks Tsimane' and 2 if it is fluent in Spanish; [d] refers to the market-town presented in the nearest market town column; [e] Household income from the rice sale since last harvest; [f] In Bolivianos (US$1=7.2Bs).

Village	Land tenure	Old-growth forest[a] (km^2)	Early-growth /degraded forest[a] (km^2)	Annual mean precipitation[b] (mm)	Number of households	Average schooling (years)	Average Spanish ability[c]	Visits to market town[d]	Average income[e] (Bs[f])	Nearest market town	Linear distance[d] (Km)	travel time[d] (hours)	Travel cost[d] (Bs[f])
Alta Gracia	TCO	2.81	19.73	1738	22	2	1.3	3.1	1328	San Borja	10.41	2.5	5
Anachere	TCO	7.3	2.43	2028	16	0.45	0.63	0.74	84.16	Yucumo	52.13	26	7
Aperecito	TCO	7.59	2	2162	20	0.3	0.6	0.3	75.78	San Borja	82.26	26	5
Arenales	TCO	3.42	20.46	1816	43	2	1	2.1	2014	Yucumo	13.97	0.5	7
Boca Tsimane'	TCO	6.26	9.7	1979	7	2	1	0.25	412.5	Yucumo	43.08	17	7
Buñi	TCO	6.93	5.61	1950	10	0.16	1	0.6	100	Yucumo	36.46	13	7
Cachuela	TCO	6.69	7.3	1912	12	0.8	1	0.75	700	Yucumo	28.79	11	7
Campo Bello	BBE	2.68	13.61	1743	43	2.61	1.15	2.11	761.81	San Borja	13.37	4	0
Cara Cara	TCO	4.29	18.73	1823	13	4.1	1.1	2.48	1176	Yucumo	14.06	2	7
Catumare	TCO	7.29	2.68	2062	8	0	1	0.35	21	Yucumo	57.89	30	7
Cosincho	TCO	6.83	5.99	1931	48	2.33	1	0.82	568.62	Yucumo	32.68	12	7
Cuchisama	TCO	7.16	3.61	2091	24	0.45	0.81	0.7	173.88	Yucumo	62.55	34	7
Cuverene	TCO	7.53	1.8	2090	10	0.16	0.83	0.42	80	San Borja	68.77	24	5
Doñoy	TCO	7.23	2.98	2069	9	1.37	1.12	0.43	2.64	Yucumo	58.95	29	7
El Triunfo	TCO	5.71	9.5	1846	48	2.26	1.26	1.49	1748	San Borja	27.17	2.5	10
Emeiya	TCO	7.26	2.76	2042	11	1.1	0.9	0.86	241.25	Yucumo	54.52	27	7
Inanare	TCO	6.28	9.36	1991	12	2.36	1.09	0.31	299.56	Yucumo	45.32	18	7
Jamanchi (por Fátima)	FC	7.6	1.44	1915	13	0.69	1	0.31	162.28	San Borja	31.01	15	5

Village	Land tenure	Old-growth forest[a] (km^2)	Early-growth /degraded forest[a] (km^2)	Annual mean precipitation[b] (mm)	Number of households	Average schooling (years)	Average Spanish ability[c]	Visits to market town[d]	Average income[e] (Bs[f])	Nearest market town	Linear distance[d] (Km)	travel time[d] (hours)	Travel cost[d] (Bs[f])
Jamanchi 1 (por Triunfo)	TCO	7.15	3.23	1867	26	1	1	0.76	1337	San Borja	40.82	3.5	10
La Pampita	TCO	1.89	18.2	1726	19	2.63	1.27	3.09	364.28	San Borja	8.74	2	5
Majal	TCO	6.85	2	1894	27	1.3	1.1	0.64	434.89	San Borja	36.07	4.5	10
Majsi	TCO	6.68	6.99	2013	3	0.2	1	0.43	60	Yucumo	49.14	24	7
Manguito	TCO	2.79	10.28	1762	30	1.33	1.4	3.02	852.89	San Borja	13	2	10
Mara	TCO	7.71	0.88	1874	7	0.14	1	0.48	568.18	San Borja	33.54	10	5
Maraca	TCO	5.76	13.57	1848	14	2.63	1	1.32	197.05	Yucumo	14.16	5	7
Misión Fátima	TCO	6.17	11.05	1995	89	3.4	1.16	0.57	190.71	Yucumo	45.98	20	7
Moseruna (por Fátima)	FC	7.64	1.85	1942	9	1.75	1.12	0.38	452.5	San Borja	44.64	16	5
Moseruna (por Triunfo)	TCO	7.04	1.43	1903	13	1.89	1	1.43	1261	San Borja	39.59	5.5	10
Munday	TCO	7.02	4.53	1962	15	2.07	1.07	0.53	95.52	Yucumo	40.31	14	7
Nuevo Mundo	FC	7.67	1	1978	22	0.6	1.2	0.39	291.45	San Borja	50.69	19	5
Puerto Mendez	TCO	1.32	20.53	1701	30	4.9	1.45	3.74	1031	San Borja	5.71	2	5
Puerto Yucumo	TCO	6.18	10.69	1846	52	1.6	1.05	1	810	Yucumo	12.85	4	7
San António	PL	2.06	15.81	1730	60	2.68	1.5	1.96	650	San Borja	10.32	1	0
San José de Yaranda	TCO	6.81	6.15	1891	50	3.69	1.07	0.46	133.9	Yucumo	24.81	10	7
San Ramón	TCO	2.64	16.46	1758	17	1.79	1	2.45	1130	San Borja	14.26	3	5
Santa Maria	TCO	6.87	5.75	1868	30	2	1.12	0.58	296.15	Yucumo	19.66	8	7
Tacuaral del Matto	TCO	4.05	12.76	1838	95	3.3	1.1	1.84	1720	San Borja	27.19	2	10
Uvasichi	TCO	4.74	18.33	1824	33	3.2	1.1	0.9	220	Yucumo	14.13	1.5	7
Vishiricansi	TCO	7.73	0.9	2126	12	0	0.28	0.18	24.61	San Borja	74.85	24.5	5
Voreyo	TCO	7.21	3.25	2074	9	0.71	0.85	0.3	325	Yucumo	59.84	32	7

Appendix 2. Average values of animal transects for the 40 Tsimane' villages sampled, in the Bolivian Amazon.

Village	Location (UTM, 19S Easting)	Location (UTM, 19S Northing)	Average transect length (km)	Total km walked	Average species richeness	Average encounter rate (animals/km)	Average biomass (kg/km)
Alta Gracia	742787	8345701	1.44	14.44	12	8.15	102.85
Anachere	749774	8289220	2.24	22.42	15	14.76	229.2
Aperecito	783731	8287445	2.99	29.87	17	13.11	471.63
Arenales	724341	8328591	1.53	6.12	6	7.07	76.28
Boca Tsimane'	741247	8293636	2.03	16.24	11	11.75	171.94
Buñi	737256	8298742	1.8	16.16	11	14.91	236.01
Cachuela	732107	8304473	3.01	30.06	11	13.13	215.27
Campo Bello	753308	8363869	2.31	16.14	11	8.53	233.04
Cara Cara	725021	8326082	1.85	7.42	8	5.81	66.99
Catumare	752180	8283363	2.56	25.65	15	11.27	232.48
Cosincho	733501	8300358	2.5	25	12	13.35	271.09
Cuchisama	755151	8279748	2.67	26.69	15	12.13	248.67
Cuverene	776360	8295765	2.84	28.4	13	8.12	244.43
Doñoy	753969	8283671	2.63	26.3	14	13.66	182.19
El Triunfo	761112	8336376	3.14	31.37	13	6.25	199.36
Emeiya	751285	8287303	2.91	29.1	11	10.54	161.36
Inanare	743891	8292831	2.85	28.46	12	11.71	163.8
Jamanchi (por Fátima)	752601	8316564	2.95	29.48	17	10.28	266.67
Jamanchi 1 (por Triunfo)	759098	8329940	3.61	36.05	17	9.23	157.62
La Pampita	741738	8347388	1.06	10.6	10	7.27	106.7
Majal	764452	8327517	2.74	27.39	14	8.9	147.52
Majsi	746074	8289619	2.72	27.15	14	12.11	182.05
Manguito	753922	8351576	3.06	30.63	13	5.15	53.03
Mara	746520	8322788	2.65	23.84	17	12.51	433.23
Maraca	724710	8320235	1.99	19.9	12	9.32	190.56
Misión Fátima	741969	8290202	3.13	31.33	13	8.53	133.72
Moseruna (por Fátima)	760344	8315151	3.63	36.29	13	10.3	454.75
Moseruna (por Triunfo)	770084	8329096	2.91	29.15	20	11.29	459.87
Munday	741060	8297148	2.81	28.11	13	11.18	161.05
Nuevo Mundo	764289	8310629	2.87	28.74	17	10.27	286.11
Puerto Mendez	748142	8356067	1.39	11.15	9	7.25	52.26
Puerto Yucumo	722722	8319411	2.97	29.65	13	8.06	130.44
San António	751477	8361062	2.36	18.91	12	8.19	110.27
San José de Yaranda	731242	8309673	2.78	27.78	16	9.79	169.69
San Ramón	741014	8341913	2.96	29.62	10	5.63	93.62
Santa Maria	728116	8314297	2.45	24.51	13	12.25	183.98
Tacuaral del Matto	764990	8340924	2.76	27.59	10	7.54	99.62

Village	Location (UTM, 19S Easting)	Location (UTM, 19S Northing)	Average transect length (km)	Total km walked	Average species richeness	Average encounter rate (animals/km)	Average biomass (kg/km)
Uvasichi	725199	8325075	2.56	23	12	10.23	137.16
Vishiricansi	780241	8291260	3.07	30.68	17	11.06	299.8
Voreyo	753261	8281812	2.83	28.27	13	9.67	147.5

Appendix 3. Photographs of the main subsistence economic activities among the Tsimane'.

Hunting

Fishing

Slash-and-burn agriculture (chaco)


Thatch palm (*jatata*) production


Selective logging