Gendered Networks, Gendered Livelihoods
Fishing, Healing and Homegardening among the Tsimane', Bolivian Amazonia

Isabel Díaz Reviriego

Gendered Networks, Gendered Livelihoods

Fishing, Healing and Homegardening among the Tsimane', Bolivian Amazonia

Isabel Díaz Reviriego

Ph.D. Dissertation, Doctoral Programme in Environmental Science and Technology
Institut de Ciència i Tecnologia Ambientals (ICTA)
Universitat Autònoma de Barcelona (UAB)

Gendered Networks, Gendered Livelihoods

Fishing, Healing, and Homegardening among the Tsimane', Bolivian Amazonia

Ph.D. Dissertation

Isabel Díaz Reviriego

Doctoral Programme in
Environmental Science and Technology
Institut de Ciència i Tecnologia Ambientals (ICTA)
Universitat Autònoma de Barcelona (UAB)

December 2015

Dissertation Director
Victoria Reyes-García

Institut de Ciència i Tecnologia Ambientals (ICTA)
Universitat Autònoma de Barcelona
and
Institució Catalana de Recerca i Estudis Avançats
(ICREA)

Dissertation Co-director
José Luis Molina

Department of Social and Cultural Anthropology,
Universitat Autònoma de Barcelona

UAB Universitat Autònoma de Barcelona

icta

Cover and design: Ana Varela García

To Sascha

Acknowledgements

I am deeply grateful to the extensive network of persons who have helped or in any way been part of this learning process. This thesis is the result of many bits here and there shared with all of them. Although this thesis embodies the contributions of these and countless other people I alone am responsible for any omissions or mistakes.

In particular, I am indebted to the Tsimane' for their willingness to participate in this research and for sharing their time and knowledge. They have taught me so much more than I could possibly write in a thesis. Living with them has been a unique lifetime experience that have broadened my horizon and inspired me in every possible way. *Yoshoropaij mi'in chätidye!*

I would like to express my profound gratitude to my supervisors. Dr. Victoria Reyes-García and Dr. José Luis Molina. Viki, your unconditional and enthusiastic support over the past four years has been essential in every phase of this research. I do really admire your level of self-discipline and commitment; you have been always *there* when I needed, even if you were physically thousand of kilometers away. José Luis, I am very grateful for your patience and support in helping me to understand the "social networks" step by step. I also would like to thank Judith Wickham, from the *Servei de llengües* of the UAB, for the *acompanyament de redacció de tesis* in the last phase of this process.

I am thankful to Dr.Raj Puri for receiving me as a visiting training fellow at the Center for Biocultural Diversity Studies at Kent University. There, I worked with Professor Patricia Howard whose guidance and critical perspectives have been particularly instrumental in helping me writing this dissertation. Patricia, you have been my *unofficial* supervisor and I am really glad for that. From my stay in Kent I also would like to express thanks to Clive, Boana, and Nico for their hospitality and friendship, *hartelijk bedankt!*

En Bolivia, quiero agradecer a Dr. Mónica Moraes, Directora del Instituto de Ecología de la Universidad Mayor de San Andrés, y a Dr. Rosa Isela, Directora del Herbario Nacional de Bolivia, por el apoyo institucional que me prestaron para poder desarrollar esta investigación. El soporte logístico de Tomás Huanca y Ester Conde del Centro Boliviano de Investigación y Desarrollo Socio-Integral (CBIDSI) fueron esenciales para poder realizar el trabajo de campo. Igualmente agradecer al Gran Consejo Tsimane' por apoyar esta investigación, en especial a Cándido Neri, Presidente del Consejo durante mi estancia en Bolivia.

En esta aventura, una persona clave ha sido Álvaro, amigo y compañero de investigación. Álvaro, tu alegría, positiva actitud y compañía fueron cruciales durante el trabajo de campo que incluyó desde motores rotos, dengue y todo tipo de enfermedades, momentos de humor -y también de estrés y frustración-, largos días de viaje en canoa y, sobre todo, grandes experiencias de vida. Tu apoyo sigue ahí, cada día, en cada viaje, en cada mail, en cada paso ¡Millones de gracias!, Marta, gracias por tu sabiduría y valentía, por tu determinación. Fuiste mis ojos, manos y pies en el campo. Trabajar junto a una mujer tsimane' como tú ha sido una

de las experiencias más enriquecedoras de mi estancia en Bolivia. Paulino, tu larga experiencia y profesionalidad como asistente y traductor fueron fundamentales para acercarme a todas y cada una de las personas en las comunidades, *yoshoropaij*! Quiero también agradecer a Consuelo, Óscar, Sandra, Vicente, Viqui, Lara y Giuliana por su trabajo y entusiasmo. Y a Juan Pablo, Alan, Asher y Kelly por el tiempo compartido en San Borja.

One of the major lessons learnt in these years has been teamwork. I am very much grateful to the *LEKipo* members; we have been a great team! *Merci beaucoup* Sandrine, Romain and Max, *kiitos paljon* Aili, *terima kasih* Tezza. It has been very encouraging to share with you a friendly, constructive, and warm atmosphere of collaboration and enlightening discussions, which has also expanded beyond our professional life.

Quiero agradecer también a todas las compañeras y compañeros de ICTA, en especial a las y los *LASEGians*, por el tiempo compartido entre pasillos y almuerzos.

A mis amigxs de aquí y allá.

En Madrid - y por medio Mundo- Lucía, Elisa y Cayetana, mis confidentes, mi inspiración y brújula. Gracias por estar *SIEMPRE*. Por crecer juntas. También a Clara, Patri, Javi, Belén, Almu, Nando, Jorge y Carlos, mi *Erasmus family*. Gracias por los encuentros y reencuentros, por estos diez años compartidos!

En Barcelona, a *Vanguards*: Marta, Vero, Marina, Maria, Marien, Arnim, Gael, Elena, Aleix, Christian, Helena, Sara, Pau… por construir un refugio de apoyo mutuo, cariño y diversión. Os llevaría conmigo… a todos los rincones del Planeta! a André, Masha, Hyerim, Rafa, Caterina… y toda la larga lista de inquilinxs de Bonavista, por ser el rincón gastronómico internacional del barrio, y en especial a Ana, por la amistad que surgió desde el primer día que nos conocimos y por construirla y cuidarla cada día. Por haber hecho posible que esta tesis brille con luz propia.

En India, gracias a la hospitalidad de la familia Vadez-Reyes por abrirme su hogar y por enseñarme un trocito de Hyderabad.

Ich bedanke mich bei meiner Familie und meinen Freunden in Deutschland, die mich während meiner Zeit in Dresden so sehr unterstützt haben.

Quiero destacar el apoyo incondicional de mi familia, en especial de mis padres. Agradecerle a mi padre por contagiarme su curiosidad y pasión por la naturaleza. A mi madre por su generosidad y su bondad, por cuidarme; por cuidar a todas las personas a su alrededor. Y sobre todo, a ambos, por enseñarme a disfrutar del día a día, de la vida sencilla. A mi hermana y mi hermano, porque con tan sólo un *silbidito*, siempre están para lo que necesite. Y a mis sobrinas Alicia, Daniela, Inés y Celia por darnos luz y alegría.

Finalmente, agradecerle infinitamente a Sascha, mi compañero, por su apoyo cotidiano y su paciencia. Por haber sido la mayor fuente de inspiración, armonía y cuidados detrás de cada paso del camino de esta tesis, aquí y allá. *Yu maje mi.*

Abstract

The central question that motivates this dissertation is how and to what extend do social relations, particularly gender relations, shape local environmental knowledge and subsistence practices of people in small-scale societies. Specifically, I sought to comprehend the gendered relations associated with the intracultural diversity of local environmental knowledge and practices in the context of global environmental and economic change. The study is grounded in the discipline of ethnoecology, but also incorporates insights from social network analysis and gender studies in biodiversity management and conservation.

The case of the Tsimane' forager-horticulturalists from Bolivian Amazonia was empirically analyzed. In particular, I focused on Tsimane' knowledge and practices related to fishing, medicinal plants and homegardening. The specific objectives of the thesis are: 1) to assess the diversity and redundancy of medicinal plant knowledge within Tsimane' ethnomedicinal system through a gender lens; 2) to explore the role of social exchange networks in medicinal plant richness maintained in homegardens and in the medicinal plant knowledge distribution among gardeners; 3) to describe potential patterns of fishing knowledge transmission in relation to the influence of fishers' knowledge, as perceived by other people; and 4) to ascertain the interrelations among gender division of labor, access and use of fishing techniques and grounds, and local ecologies in freshwater resource use. Data were collected during 18 months of fieldwork in two villages of the Tsimane' Territory integrating both quantitative and qualitative methods.

Tsimane' knowledge and practices regarding medicinal plants and fishing are gendered. Tsimane' women hold a wider range of knowledge about medicinal plant uses than men, probably as they are the principal caregivers and health custodians at a household and community level. Likewise, Tsimane' women and men target different fish species influenced by the gendered division of labor and the access to fishing techniques and fishing grounds. Irrespective from the location, men tend to target the larger and culturally regarded fish species. Further findings show that an individuals' location in a social network can provide both possibilities and constraints for accessing resources and knowledge through other people in the network. Thus, more central gardeners in exchange networks - typically women - maintain higher richness of medicinal plants in their homegardens, as they have more access to medicinal planting material and associated knowledge. Similarly, a fisher's position in the fishing network is associated to fishing abilities. Tsimane' men are more prominent in fishing networks and have higher perceived knowledge. Overall, results of this thesis suggest that Tsimane' gender relations shape the access to, use of, and knowledge about natural resources, and therefore, women's and men's local environmental knowledge.

Findings from this thesis advance the understanding of how local practices and environmental knowledge diversity arises in a dynamic context with a fresh interdisciplinary perspective that relies on social networks analysis. This thesis emphasizes the importance of addressing gender relations in the quest to explain intracultural knowledge diversity. The

more relevant contribution of my approach is the innovative manner of assessing people's gendered practices and knowledge in the light of the social structure in which they are embedded. Therefore, from the perspective adopted here, gendered knowledge and practices are the product of 1) women's and men's social relationships among them and towards the local environment they in which dwell and 2) their positions in the social networks. These findings are important for comprehending the broader social processes that occur in small-scale indigenous societies which are increasingly integrated into the market economy and national societies, and the potential impacts of these processes in their wellbeing and sovereignty.

Resumen

La pregunta central que motiva esta tesis es cómo y en qué medida las relaciones sociales, en particular las relaciones de género, dan forma a el conocimiento local ambiental y a las prácticas de subsistencia en las sociedades de pequeña escala. En concreto, he tratado de comprender las relaciones de género asociadas a la diversidad intracultural de prácticas y conocimiento ambiental local en el contexto de cambio ambiental y económico global. Este estudio se realizó desde la perspectiva de la etnoecología, pero también incorpora métodos de análisis de redes sociales y de estudios de género en la gestión y la conservación de la biodiversidad.

El caso de la sociedad Tsimane' de recolectores y horticultores de la Amazonia boliviana se analizado empíricamente. En particular, me centré en los conocimientos y prácticas Tsimane' relacionados con la pesca, las plantas medicinales y los huertos. Los objetivos específicos de la tesis son: 1) evaluar la diversidad y la redundancia de los conocimientos de plantas medicinales en el sistema etnomedicinal Tsimane' desde una perspectiva de género; 2) explorar el papel de las redes de intercambio social en la riqueza de plantas medicinales mantenidas en los huertos y en la distribución del conocimiento de plantas medicinales entre los/las horticultores; 3) describir potenciales vías de transmisión de los conocimientos de pesca en relación a la influencia del conocimiento de los pescadores, según la percepción de otras personas; y 4) determinar las interrelaciones entre la división genérica del trabajo, el acceso y uso de técnicas de pesca y zonas de pesca, y la ecología local, en el uso de recursos de agua dulce. Los datos fueron recogidos durante 18 meses de trabajo de campo en dos comunidades del Territorio Tsimane' incluyendo métodos cuantitativos y cualitativos.

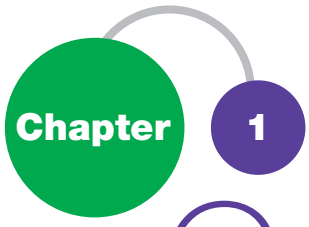
Los conocimientos y prácticas Tsimane' acerca de las plantas medicinales y la pesca están determinadas por el género. Las mujeres Tsimane' conocen una gama más amplia de usos de las plantas medicinales con respecto a los hombres, probablemente, porque son las principales cuidadoras y guardianas de la salud en los hogares y en la comunidad. Igualmente, mujeres y hombres Tsimane' pescan diferentes especies influenciados por la división genérica del trabajo, el acceso a las técnicas de pesca y a las zonas de pesca. Independientemente de la ubicación, los hombres tienden a pescar las especies más grandes y culturalmente más valoradas. Otros hallazgos muestran que la posición de una persona en una red social puede proporcionarle tanto posibilidades como limitaciones para el acceso a los recursos y a los conocimientos a través de otras personas en la red. Por lo tanto, los horticultores más centrales en las redes de intercambio - típicamente las mujeres - mantienen una mayor riqueza de plantas medicinales en sus huertos, ya que tienen más acceso a material de propagación y el conocimiento asociado. Del mismo modo, la posición de un pescador en la red de pesca se asocia a sus habilidades de pesca. Los hombres Tsimane' más prominentes en las redes de pesca son los percibidos como mejores pescadores. En general, los resultados de esta tesis sugieren que las relaciones de género Tsimane' dan forma al acceso, uso y conocimiento de los recursos naturales, y por lo tanto, al conocimiento ambiental local de las mujeres y de los hombres.

Estos hallazgos avanzan la comprensión de cómo la diversidad prácticas y conocimiento ambiental local surge en un contexto dinámico con una perspectiva interdisciplinaria basada en el análisis de redes sociales. Esta tesis hace hincapié en la importancia de abordar las relaciones de género para explicar la diversidad intracultural de conocimientos. La aportación más relevante de mi enfoque es la manera innovadora de evaluación de las prácticas y el conocimiento de género a través de la estructura social en la que las personas están inmersas. Por lo tanto, desde la perspectiva adoptada aquí, los conocimientos y prácticas de género son el producto de 1) las relaciones sociales entre mujeres y hombres y hacia el medio ambiente en el que habitan y 2) sus posiciones en las redes sociales. Estos hallazgos son importantes para la comprensión de procesos sociales más amplios que se producen en las sociedades indígenas de pequeña escala, cada vez más integradas en la economía de mercado y en las sociedades nacionales, así como los potenciales impactos de estos procesos en su bienestar y soberanía.

Table of contents

List of figures

List of tables



General introduction

Chapter 1
General introduction

1. Motivation and aim

Social relations define people's access to, use of, knowledge about and control over biodiversity and natural resources, thus, influencing their interests and management practices. The central question that motivates this dissertation is to ascertain how and to what extent do social relations, particularly gender relations, shape subsistence practices and environmental knowledge of women and men in subsistence-based societies.

Only a few decades ago, the attention to the practices and knowledge of indigenous and peasant peoples was mostly confined to the academic field of cognitive anthropology (Conklin 1954; Frake 1962; Berlin 1973; Hunn 1977, 1989), the significance of these knowledge systems being mostly neglected elsewhere (Zent and Maffi 2010; Reyes-García 2015a). It was not until the 1990's when other scholarly disciplines, policymakers, and activists "rediscovered" the practical value of traditional, indigenous or local environmental knowledge systems[1]. Since then, local environmental knowledge has been acknowledged for enhancing biodiversity at a landscape level, as well as for contributing to natural resource management and conservation (Inglis 1993; Gadgil et al. 1993; Berkes et al. 2000; Gavin et al. 2015). Local environmental knowledge has also been recognized as a tool for the design of alternatives to top-down development interventions (Sillitoe 1998, 2000; Bicker et al. 2000). Researchers have also highlighted the role of local knowledge in improving indigenous livelihoods and wellbeing (Mcdade et al. 2007; Reyes-García et al. *in press*) and as a means for self-determination and political empowerment (Posey and Dutfield 1996; Posey 1999). Local environmental knowledge is also considered the *repository* for maintaining biocultural memory (Nazarea 2006; Toledo and Barrera-Bassols 2008) as well as a source for building resilience in social-ecological systems (Ceuterick et al. 2011; Gómez-Baggethun et al. 2012; Reyes-García et al. 2014).

[1] There is ongoing debate on the most appropriate term to identify and define these complex bodies of cultural knowledge in relation to the environment (see for example Ellen and Harris 2005). Some of the most commonly used terms are folk knowledge (Atran et al. 2002), indigenous knowledge (Gadgil et al. 1993; Ohmagari and Berkes 1997), traditional ecological knowledge (Berkes et al. 2000; Gómez-Baggethun et al. 2012; Gómez-Baggethun and Reyes-García 2013), local ecological knowledge (Davis and Wagner 2003; Pilgrim 2006), or local environmental knowledge. As this research addresses the knowledge system of an indigenous society (that self- identify as such) from an ethnoecological perspective and the way they perceive, use, and manage natural resources, I mostly refer to local environmental knowledge and ethnobiological knowledge interchangeably through the text.

The "rediscovery" of local knowledge systems has been accompanied with a rising awareness of the threats for its preservation, which consequently led to a plethora of studies that focused on describing and examining how knowledge is transmitted and distributed in different cultures and across knowledge domains. The approach of most of these studies has mainly been on individual socio-demographic characteristics of knowledge holders to explain knowledge distribution, largely overlooking the role of social relations in shaping the knowledge that people hold.

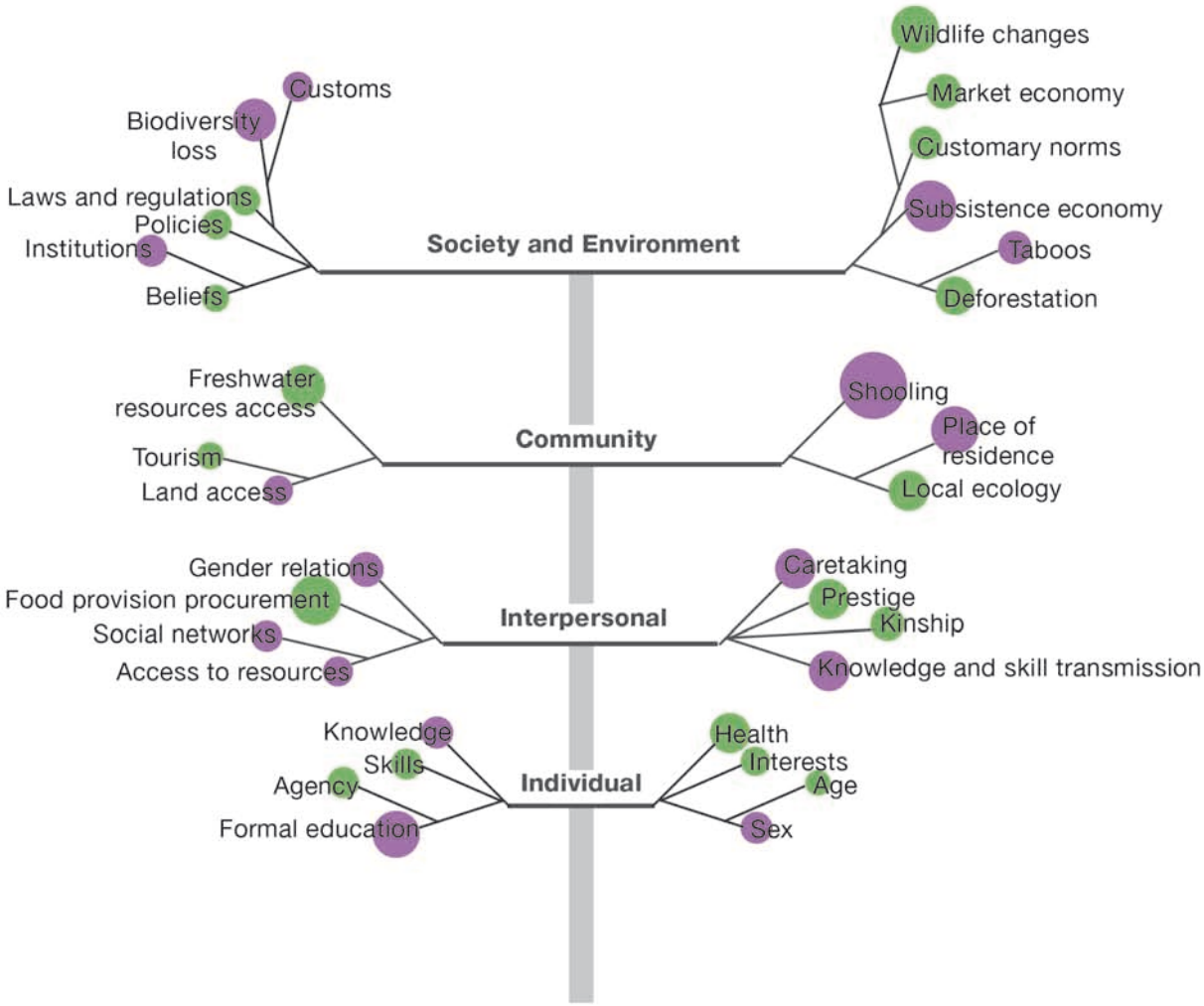
Our current understanding of local environmental knowledge systems depicts them as threatened and eroding, but – at the same time – as dynamic and adaptive (Reyes-García 2015a). Thus, on the one hand, researchers have looked at the driving factors of local knowledge erosion, including schooling, changes in land use, integration into the market economy, loss of access to resources because of conservation policies, to name several (Godoy et al. 2005; Gómez-Baggetun et al. 2010; McCarter and Gavin 2011; Paneque-Gálvez et al. 2013; Ruíz-Mallén and Corbera 2013; Reyes-García 2015a). On the other hand, researchers have also started to recognize that the focus on the *erosion* of local knowledge lies on the on the premise that knowledge is static, timeless or even decontextualized. Notwithstanding the relevance of assessing the loss of local knowledge, researchers have started to analyzing knowledge as situated, complex, adaptive, and dynamic (Ellen et al. 2005; Mathez-Stiefel et al. 2012; Gómez-Baggethun and Reyes-García 2013).

On the basis of these premises, two main motivations guide and interconnect my research interests in this dissertation:

1. To understand the dynamic social aspects that shape the intracultural diversity of local environmental knowledge and practices, going beyond the analysis of individual socio-demographic characteristics, and
2. To assess how social relations, namely gender relations, shape differences and similarities both between and within women's and men's practices and environmental knowledge, and their interplay.

This thesis presents a multifaceted study of fishing and medicinal plants practices and knowledge of Tsimane' people in Amazonian Bolivia. The aim of this thesis is to advance the understanding of the set of social relations defining women's and men's subsistence activities and their access to, use of, and knowledge about natural resources. In Figure 1, I show different sets of factors potentially influencing fishing and medicinal plants practices and knowledge among the Tsimane'. In this research, I largely focus on the *interpersonal and societal* and level for explaining individual's practices and knowledge over the role of individual's interests, curiosity, and agency in the process of learning, acquiring knowledge and practicing different activities.

Figure 1. Factors potentially influencing medicinal plants and fishing practices and knowledge among the Tsimane'.



This chapter presents the background of the thesis. I first introduce the more relevant aspects of the theoretical frameworks that guided the study, followed by the research strategy, the analytical approach, and the research objectives. The chapter concludes with the outline of the thesis.

2. Theoretical framework

This research was designed from the perspective of ethnoecology, the scientific interdisciplinary field that explores the relationships between humans and the natural world. Ethnoecology emphasizes the role of cognition in framing behavior in so far as people's localized activities are guided by the knowledge, beliefs and values they share with the social system members they interact with (Nazarea 1999, Gragson and Blount 1999). Within this field, and in order to develop a framework for investigating the set of social relationships influencing women's and men's practices and knowledge in Tsimane' Amazonian communities, I draw on empirical and theoretical insights from cultural evolution theory,

social network theory and methods, as well as gender studies in biodiversity management and conservation. In this section, I briefly present the essential concepts integrated in this study and particular epistemological considerations.

2.1 Cultural evolution theory

Scholars aiming at understanding human behavior and cultural change have borrowed concepts and methods from evolutionary theory to explain how beliefs, knowledge, customs, skills, attitudes, and languages, among others, are socially transmitted (Richerson and Boyd 2005; Mesoudi 2011). Drawing on Darwin's postulates of biological evolution (i.e. variation between individuals' characteristics, competition for resources, and inheritance of biological traits from the parental cohort) cultural evolution theorists enrich the human evolutionary theory by sustaining that human evolution is not only the result of biological evolution, rather the result of a complex process of dual inheritance, in other words, the co-evolution of genes and culture. Different than genes, culture is transmitted by social processes.

Several evolutionary approaches to cultural change have been built upon the pioneer work of Cavalli-Sforza and Feldman (1981) on cultural knowledge transmission. These authors proposed an adaptation of the genetical-transmission and developed a mathematical theory for explaining the transmission of cultural traits, later refined by Hewlett and Cavalli-Sforza (1986). In this model, cultural transmission is defined as "a process of social reproduction in which a culture's technological knowledge, behavior patterns, and cosmological beliefs are communicated and acquired" (Cavalli-Sforza and Feldman 1981: 922).

The pathways for cultural knowledge transmission described in Cavalli-Sforza and Feldman (1981) model are 1) from parents to children (vertical), 2) among peers or individuals of the same age (horizontal), and 3) from non-parental members of older generations to members of younger generations (oblique). Vertical transmission is the most "conservative" mode of transmission, as it limits innovations and enhances cultural continuity (McElreath and Strimling 2008). Horizontal modes of transmission can favor a rapid spread of cultural traits to others and intracultural variation of knowledge can be high. Within the path of one-to-many (oblique transmission), communication is highly efficient and therefore changes in knowledge may occur rapidly; also cultural traits can be transmitted both along multiple pathways or limited to one or another (Cavalli-Sforza and Feldman 1981). Both horizontal and oblique transmissions may be highly adaptive in rapidly changing environments. Researchers have tested the relevance of these different pathways of knowledge transmission in diverse domains, including foraging techniques (Hewlett and Cavalli-Sforza 1986; Ohmagari and Berkes 1997) and ethnobotanical knowledge (Lozada et al. 2006; Reyes-García et al. 2009; Mathez-Stiefel and Vandebroek 2012). Reyes-García et al. (*in press*) have proposed that these pathways have a differing importance through a person's life. Vertical knowledge transmission might be most important during early childhood and looses preeminence towards horizontal and oblique transmission as people aged. This multi-stage learning model of cultural learning emphasizes the complexity and diversity of cultural transmission pathways over the life span (Reyes-García et al. 2015b; see also Gallois 2015).

Richerson and Boyd (2005) have also argued that, in the process of social learning, people select from alternative sets of skills, ideas, beliefs, and values (cultural variants) to which they are exposed in the course of daily life. These authors proposed three possible biases that affect knowledge transmission: content bias, conformist bias, and prestige bias. Although the selection of cultural variants might be based on content (e.g., some variants might be easier to learn than others), people also have a predisposition to adopt those variants that occur more frequently (conformist bias) or that are exhibited by successful or prestigious individuals (prestige bias) (Henrich and Gil-White 2001; Richerson and Boyd 2005).

In this research, I integrate insights from the prestige bias model (Henrich and Gil-White 2001; Richerson and Boyd 2005) to explore the effect of being perceived as knowledgeable or with high status in subsistence activities (i.e. fishing and homegardening) on knowledge transmission and distribution patterns. To do so, I employ social networks analysis.

2.2 Social networks theory and methods

While cultural evolution theorists attempt to explain the mechanisms that account for the long-term transmission of cultural knowledge, researchers ranging from various disciplines such as anthropology, psychology, environmental sciences, and agronomy are interested in the contemporary processes that drive cultural knowledge transmission, its potential pathways, and the changes that can likely alter this process, e.g. knowledge loss and hybridization. In the quest to address cultural knowledge transmission, scholars have started to use social networks theory and methods. In this thesis, I pursue this latter approach of applying social networks analysis to explore the potential contemporary pathways of knowledge transmission that might define knowledge distribution among the Tsimane'.

More that three decades age, Boster's (1985, 1986) seminal work showed the relationship between variation in knowledge, social relations and transmission processes among the Aguaruna in Peru, where the knowledge of manioc varieties was patterned according to social identity and individual's opportunities to learn. More recently, Casagrande (2002) also has highlighted the contribution of social and situational factors to the uneven distribution of cultural knowledge. Thus, intracultural knowledge variation cannot be fully understood without paying attention to the social relations that allow and favor its transmission.

Drawing on this body of knowledge, researchers have recently found in social network analysis a quantitative analytical tool that can potentially help to understand and trace the pathways of knowledge transmission. Social networks are defined as a set of actors and their relations, thus, network analysis focuses on the relations among actors and not just on actors and their individual attributes (Hanneman and Ridle 2005). Besides individual characteristics or attributes (such as age, sex, ethnicity, income, and education), the social network approach put the emphasis on social relationships among individuals for explaining social phenomena. The "actors" in social networks, also known as "nodes", can be either collectivities or individuals.

Social network analysis builds upon graph theory concepts, matrices mathematical operations, and graphical representations for describing and quantifying social structure

properties, as well as for visualizing the networks (Wasserman and Faust 1994). Social network analysis also draws on psychological theories, such as social comparison theory, that focuses on the tendency of individuals to compare themselves to people with whom they have things in common. One important aspect of this theory is the principle of *homophily*, or the tendency of individuals to associate with people who are similar to themselves. *Homophily* in social networks has been suggested as a concept to approach the study of the social relations that influence, create, and maintain gender differences. This perspective emphasizes that what is considered as masculine and feminine is the product of the social relations in which women and men are embedded, thus their preferences and attitudes are determined by their social relationships (Smith-Lovin and McPherson 1993). The argument is that very initial small differences in the types of networks and experiences of boys and girls lead to men and women occupying very different social worlds (Smith-Lovin and McPherson 1993; McPherson et al. 2001).

Other theories and hypothesis have been also developed within the social network analysis discipline (see Kilduff and Tsai 2003; Borgatti et al. 2009; McCarty and Molina 2014, for overviews on different theoretical concerns guiding social network analysis). For example, Granovetter's (1983) strength of weak ties theory emphasizes the significant role of *weak ties* or acquaintances' relations compared with *strong ties* or well known people for the flow and access to new/different information in a social structure. Burt (2004) developed the concept of the *structural hole*, or the opportunity for individuals to act as bridges in otherwise unconnected groups within an organization, and in doing so, improving their social capital. I draw on these theoretical approaches to elucidate some of my findings in chapters 4 and 5.

There are two primary types of social networks analysis: whole networks or sociocentric networks and personal networks or egocentric networks. In this research, I use a whole network approach that focuses on the interactions of actors within a bounded space and aims at collecting data about each member of the bounded group and their interactions with all other members (see chapter 4 and 5). Interactions can be measured at different levels, specifically: node level (individual), dyad level (pairwise relations), and network level (aggregations of dyad and node measurements) (Borgatti el at. 2013). Node centrality, or the structural importance of a node in a network, is the most widely used node level measure (McCarty and Molina 2014). Central nodes may be prominent, or influential, or gatekeepers, or having control, visibility, prestige and power, but not as inherent properties of centrality, but rather as potential consequences of centrality (Borgatti et al. 2013).

A growing body of interdisciplinary research has started to apply social network analysis to answer questions on the factors that account for local environmental knowledge transmission and variation. For example, researchers have use social networks analysis to study cultural transmission of knowledge (Haselmair et al. 2014) or links between individuals' centrality in a network and knowledge distribution (Hopkins 2011; Calvet-Mir et al. 2012; Reyes-García et al. 2013) showing that individual's network position at least partly predicts their knowledge, where people with higher centrality measures tend to hold more knowledge than less central people. Knowledge transmission of management practices in

agroforestry and fisheries has also been explored with a social network approach (Atran et al. 2002; Marney et al. 2007; Crona and Bodin 2006, 2010; Crona and Hubacek 2010).

Another very prolific area of research applying social network analysis methods is the agrobiodiversity field. There are increasing evidences that cultural diversity, social differentiation, gender relations, and agrobiodiversity management are intertwined (Howard 2003, 2006a; Reyes-García et al. 2010; Leclerc and d'Eeckenbrugge 2011; Labeyrie et al. 2013), which highlights the importance of understanding the social context of plant materials' exchanges (i.e. seeds, stems, among others) as well as the cultural selection of plants and germplasm for agrobiodiversity conservation *in situ* (Ban and Coomes 2004; Coomes 2010; Ellen and Platten 2011; Pautasso et al. 2013; Coomes et al. 2015). Social network analysis has proved to be a powerful tool for monitoring seeds and crop varieties flows among farmers and gardeners (Subedi et al. 2003; Calvet-Mir et al. 2012; Reyes-García et al. 2013; Kawa et al. 2013; Poudel et al. 2015). These studies have shown that social networks can both facilitate and constrain seeds and crop varietal distribution.

Overall, the fundamental axiom of social network analysis is that social structure matters (Borgatti et al. 2009). In this dissertation, social network analysis is applied to explore individuals' opportunities and constraints in practicing different subsistence activities and in acquiring related cultural knowledge, which may partly be determined by their position within the network; thus, depending on the social structure.

2.3 Gender studies in biodiversity management and conservation

Gender is a critical analytical variable throughout this thesis, as an essentially relational variable that shapes social organization and the practices assigned, expected, and undertaken by women and men in their daily life. Gender relations cause and reinforce the transmission of environmental knowledge by defining with whom may women and men interact.

In this research, I use the terms sex - to refer to the individual level or biological differences between women and men - and the term gender - to refer to the interpersonal level or sociocultural differences between them. I employ these terms to locate women's and men's differences and interplay on their dependence on, use of, and knowledge of resources, in social norms and material conditions (Agarwal 1992, 2009). Nevertheless, I do acknowledge that the complexity of interactions between gender and environment are also shaped and constrained by the intersection of gender with other identities such as those along racial, ethnic, class, or caste; and that 'bounded' categories of "women" and "men" are imperfect (Banerjee and Mayerfeld 2007). I also recognize the existence of multiple non-dichotomous identities that much more accurately reflect the true diversity of human genders, although the thorough treatment of the multiplicity of gender identities is beyond the scope of this research. That said, I employ a binary view of the terms sex and gender, because despite problematic, I consider they are useful analytical categories to study the Tsimane' social organization and gender relations within the context of my study (see section 4 in chapter 2).

In ethnobiological research, the work of Howard (2003) and Pfeiffer and Butz (2005) on the importance of gender relations in biodiversity management and conservation and in

assessing variation in practices and knowledge, were pioneers in their systematic and thorough insights to the field. Howard (2003) highlighted the shortcomings and potential distorted results of research overlooking gendered knowledge, understood as "the knowledge which is held either by men or by women" (Howard 2003:22), particularly when men informants are taken as representatives of the knowledge (or practices) of the entire cultures. Three potential errors are related to gender-blind research: *omission*, when women's knowledge is not studied; *unreliability*, when the informants selected are not well or partially informed leading to an improper identification and characterization of uses and knowledge of plants; and *interpretation*, when people-biodiversity relations are misunderstood as a result of neglecting critical gender relations (Howard 2003, 2006b). Pffeifer and Butz (2005) also provided a detailed account on the factors underlying gender-based spatial and temporal variation in ecosystem exposure and knowledge in rural societies worldwide. Several factors that contribute to gendered differences in wild food harvesting, biodiversity and agrobiodiversity maintenance, natural resource management, as well as the transmission of secular customs and the conservation of sacred. Those factors include stereotypes or sex-based assumptions that overlook plurality of knowledge and practices within communities, and the disregard of distinctions between access, use and knowledge - when informants selected are just owners of for example land and not users - which also have implications for the gendered biodiversity and ecosystems management. Purposive sampling and approaches that assume cultural homogeneity are also potential sources of gender bias that can lead to fuzzy conclusions. Overall, these factors interact at different scales resulting in gendered knowledge regarding species (Lope-Alzina 2007; Carr 2008), plant and animal parts (Howard and Nabanoga 2007), as well as spatial, temporal and encounter rate variations (Turner 2003; Makalle 2012). Kothari's (2003) also brought the idea towards questioning the influence of micro and macro level of power relations in order to understand variations in knowledge, and the need to explore the power-knowledge web of relations.

Feminist political ecology is another discipline of inquiry about gender and environment issues that has inspired some aspects of this work. Feminist political ecology aims at understanding and interpreting gendered local experiences in the context of global processes of environmental and economic change (Rocheleau et al. 1996). Leach's (1994, 2006) people-oriented approach to conservation also places gender relations and the way in which women and men gain access to, and use and manage resources to the center of the analysis of forest resource use. She claims that women's forest resource use cannot be fully understood in isolation, what is, by focusing exclusively on women's experiences and therefore obscuring gender relations. Leach and colleagues also introduce the concept of "environmental entitlements", which focuses on intracommunity dynamics and informal institutions in community-base resource management, where different actors positioned differently in power relations have diverse and contested priorities and claims over resources (Leach et al. 1999). Other scholars have also claimed a multi-scale frame and an integrated social and ecological perspective to examine the links among local phenomena and regional and global processes (see Paulson 2003; Cote and Nightingale 2011; Nightingale 2015). From these studies, the two particular areas from which I draw in this work are the themes related to gendered knowledge and gendered customary access and management of

biodiversity and natural resources (Rocheleau et al. 1996). I have purposely encouraged both Tsimane' women and men to participate in this research in an attempt to better understand their interplay in daily practices which may lead to a gendered access to, use of, and knowledge about medicinal plants and fishing resources.

2.4 Epistemological considerations

It has been argued that all knowledges are anchored in particular cultural and socioeconomic contexts, what has been term as situated knowledges (Haraway 1988; Agrawal 1995). Within ethnoecology, Nazarea (1999) claims that ethnoecologists that aim to understand the interface between cognition and action should turn the attention to the lenses and latitudes that shape and frame these interconnections, as situated knowledges, as *views from a point.* She further mantains that the historical and political underpinnings of the representational and directive aspects of culture cannot be ignored, nor turn away from issues of distribution access, and power that shape knowledge systems and the resulting practices (Nazarea 1999: 9). Ellen (2004) refering to science as a knowledge sytem, also discusses that since science is dependent on cultural constructs to determine shared knowledge, and is conducted by sentient persons with values and social differences in intersubjective space, it will always only be *sufficiently precise*, but for all that a remarkably reliable model of the world (Ellen 2004: 444). On the basis these arguments about the situated nature of knowledge, I consider essential to specify the point from where my view arises in this thesis as a white female researcher trying to understand environmental knowledge, practices, and gender relations among people from a completely different cultural background.

Regarding epistemological considerations on the anthropological analyses of gender politics in Amazonia, Lorrain (2001) identifies two potential biases stemming from Western political philosophy and anthropological traditions: the hierarchy bias and the equality bias. On the hierarchy bias would lie in ethnocentric and ideological equality-blind judgements about gender relations that are mistakenly consider inegalitarian (Overing1986 cited as cited by Lorrain). On the other side, an equality bias can lead also to erroneous view of the same gender relations as egalitarian (Lorrain 2002). Drawing on Rivière (1984) she also argues that these perspectives are largely a function of the analytical levels that researchers chose, for example, sames sex (or same age) relationships might be egalitarian, whereas those with opposite sex (or diffrent age) might be hyerarchical. I draw on her ideas to situate my position in this dissertation regarding the analysis of gendered practices and knowledge among the Tsimane'.

The most detailed gender analysis to date among the Tsimane' was provide by Ellis (1996). She analyzed gender relations among the Tsimane' essentially from an equality bias point of view. Drawing on Overing (1986) critique to the hierarchy bias, she claims that the complementarity and interdependence of gender division of labor among the Tsimane' represent an "extreme case of gender equality and informality within Amazonia (Ellis 1996: 165) (see section 4 in chapter 2). Lorrain (2001), in contrast, argues that this egalitarian view for an economic system where men are the main meat and fish providers, and where the differential food consumption – specifically fish and meat - between households in everyday

life are overwhelmingly associated to flaws in male, rather than female, productive activities is, to a some extend, biased. She explains that female tasks in this sense (preparation of meat and its distribution) depends on previous male inputs, however, no male tasks required previous female input, which is why flaws in male productive tasks can have such an important impact (Lorrain 2001:269). Going back to the Tsimane', and two decades after Ellis study, some other researchers have already claim the emerging inequalities among Tsimane' women and men (Godoy et al. 2007; Zycherman 2013). I therefore position this work within the *hierarchy bias* epistemological interpretation of Tsimane' gendered practices and knowledge.

3. Research strategy and analytical approach

This thesis has been developed within a larger five-year research project entitled "The adaptive nature of culture: a cross-cultural analysis of the returns of Local Environmental Knowledge in three indigenous societies" aimed at empirically testing a pathway through which cultural knowledge might enhance human adaptive strategy: the individual returns to culturally evolved and environment-specific knowledge. A Starting Grant of the European Research Council (FP7-261971-LEK) funded the project, lead by Dr. Victoria Reyes-García. Therefore, data used in this thesis result from a cooperative effort of a gender-balanced team consisting of two PhD students and six local assistants and translators that lived and worked in two Tsimane' villages for 18 months. Data collection was authorized by the political representative organization of the Tsimane', the *Gran Consejo Tsimane',* in adherence with the International Society of Ethnobiology Code of Ethics (2006). All the people that participated in the study did so of their own free will and with full prior informed consent (FPIC).

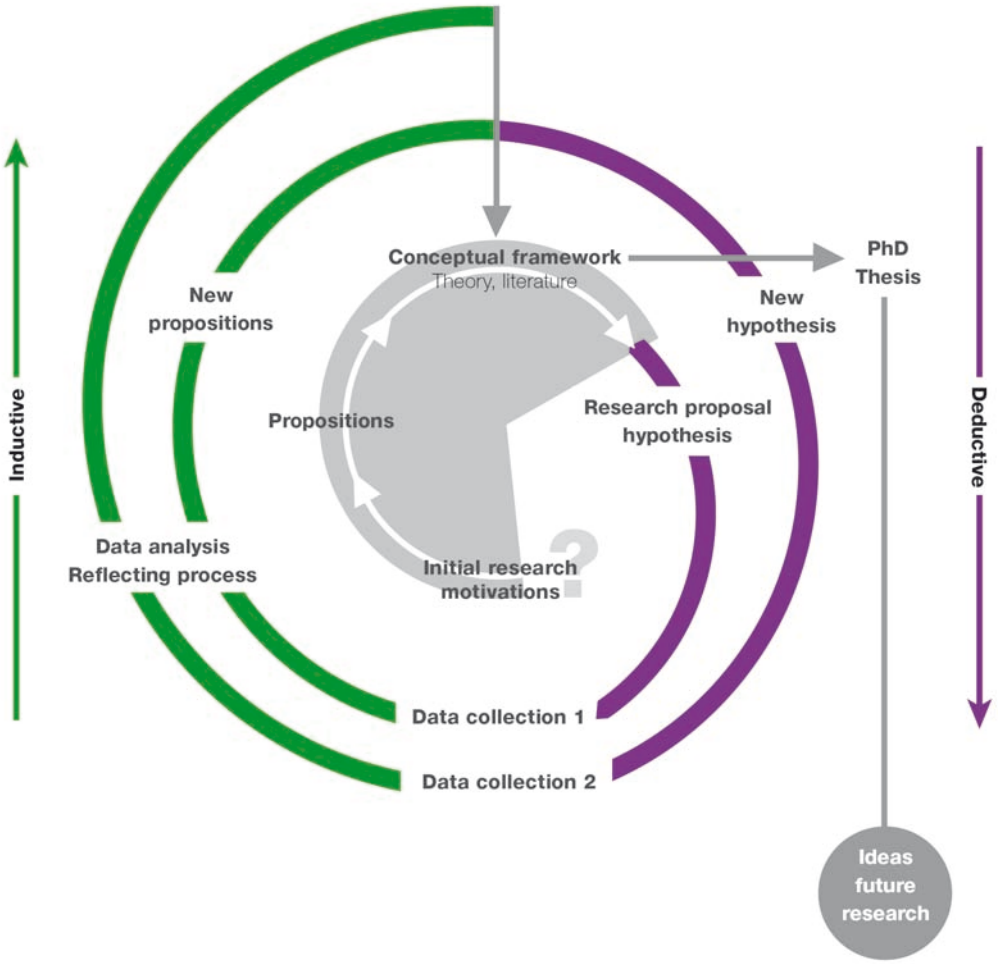
To develop this thesis I have combined two research strategies in constant loop and feedback, in a self-reflective and iterative learning process. Based on the research wheel metaphor (Rudestam and Newton 2015), I illustrate the research process of this thesis in Figure 2.

A primary phase of fieldwork (January-May 2012) was mostly devoted to obtain the agreement and FPIC to live in the villages, to learn Tsimane' language, to build trust with the people, and to adapt to live in a Tsimane' village. In this primary phase, I shared daily life in the villages and participated in different activities, such as trips to the forest to gather medicinal plants and wild edibles, fishing, or harvesting. I also collected census data, medicinal plants free-listings, and semi-structured interviews, as well as organized focus groups. After the initial phase in the villages, I analyzed some of the data and prepared the protocols for the second round of data collection. Also, after spending some months in the field, I decided to complement my original focus on medicinal plants with data regarding other domains of knowledge, specifically fishing and homegardening.

During the secondary phase of fieldwork (July 2012-August 2013), I collected homegarden inventories and conducted interviews, fishing ratings. I also collected a panel of

data about subsistence activities and social networks. A detailed account on each of these methods is provided in the following empirical chapters. Once fieldwork was finished, I cleaned and prepared data for analysis. I have analyzed, revised the theoretical and conceptual framework and wrote this thesis from September 2013 to December 2015.

Figure 2 Research analytical approach based on the research wheel metaphor (Rudestam and Newton 2015).



3.1 Research objectives

The purpose of this thesis is advancing the understanding of the set of social relationships, particularly gender relations, that define that define women's and men's subsistence practices and local environmental knowledge. The following specific objectives permitted the operationalization of this general aim, serving as a guide for the empirical research conducted among the Tsimane', in the Bolivian Amazonia, related to fishing and medicinal plants, as well as medicinal plant presence in homegardens.

1. To assess diversity and redundancy of knowledge in Tsimane' ethnomedicinal system through a gender lens (chapter 3).
2. To explore the role of social networks in explaining 1) medicinal plant richness in homegardens and 2) medicinal plant knowledge distribution among gardeners (chapter 4).
3. To describe potential pathways for the transmission of fishing knowledge in relation to fishers' knowledge as perceived by others in this process (chapter 5).
4. To ascertain the interrelations among 1) gendered division of labor, 2) technology use, and 3) local ecologies, in freshwater resource use, specifically on fish species extraction (chapter 6).

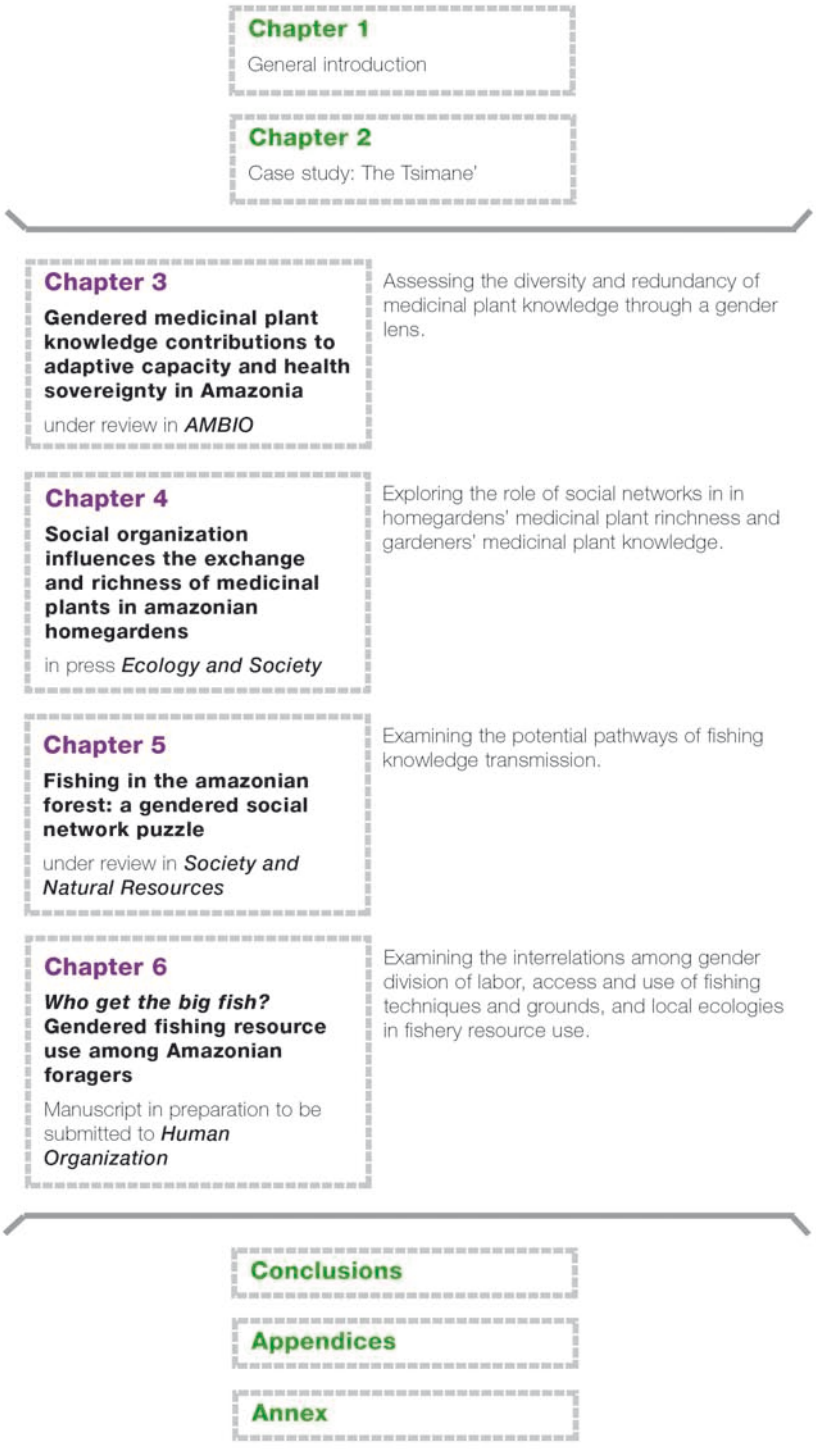
Each objective has been developed in a research paper, presented as the core of this thesis in four different chapters (see below).

4. Thesis Outline

This dissertation is organized in seven chapters (Figure 3). Following this general introduction, I provide a brief overview of the case study (chapter 2). Then, I present a compilation of four empirical research chapters in the format of scientific articles (chapters 3, 4, 5, and 6). These empirical chapters present some similarities, specifically in the description of the study area and the methodological approach. I have preserved each chapter in its original article format in order to maintain their respective internal cohesion, even if the reader finds some duplicated information between chapters. Finally, a comprehensive conclusion (chapter 7) provides an overview of the main theoretical and methodological learnings and practical implications of this research. It also suggests potential areas for future research. Further contents are compiled in three Appendices, providing methodological details for some of the chapters. I also present an Annex with a list of publications that I have co-authored during my PhD and the outreach efforts.

At the time of delivering this dissertation, the first article (chapter 3) is under review in AMBIO, the second article (chapter 4) is *in press* in Ecology and Society, the third article (chapter 5) is under review in Society and Natural Resources, and the fourth article (chapter 6) is a manuscript in preparation to be submitted to Human Organization. The following paragraphs provide an overview of the thesis articulation and summarize the four research chapters.

Figure 3. Structure of the thesis.



Chapter 2 provides a brief overview of the historical, biogeographical and sociocultural background of the Tsimane' forager-horticulturalists from Bolivian Amazonia, the empirical case that I analyze in the following chapters.

Chapter 3 presents a conceptual framework to assess diversity and redundancy of knowledge within ethnomedicinal knowledge systems. I partially evaluate how this framework operates in a particular empirical situation using the case of medicinal plant knowledge among lay Tsimane'. Through this chapter, I argue that research on indigenous health and medicinal plant knowledge should pay careful attention to women's knowledge I also discuss that Tsimane' ethnomedicinal knowledge and medical systems's adaptive capacity may rely on the use of medicinal plants as the primary source of healing or as an alternative to, or in combination with, biomedical options at a practical level.

Chapter 4 explores the influence that exchanges of medicinal plant material and knowledge through social networks might have for medicinal plant diversity in Tsimane' homegardens. I explore whether social organization patterns the exchange of medicinal plant knowledge and/or medicinal plant material employing a social network analysis approach. I argue that the understanding of the factors that pattern general species diversity in tropical homegardens, and medicinal plant diversity in particular, can help policy makers, health providers, and local communities to better understand how to promote and preserve medicinal plants *in situ.* This way, medicinal plants can continue to provide locally accessible, culturally appropriate, and economically affordable health care options for people with scarce access to biomedical healthcare systems.

Chapter 5 tests whether people's choice of fishing partners is related to fishers' perceived fishing knowledge. I focus on gendered social interactions and apply social network analysis. I argue that a network approach is useful for exploring local environmental knowledge transmission and distribution as it broadens our understanding of how the different social structures that derive from a particular cultural and economic context shape the opportunities and constraints that social relations impose on knowledge transmission, and on the use of natural resources.

Chapter 6 addresses the interrelation of 1) gender relations and division of labor 2) access to and use of fishing techniques and fishing grounds, and 3) local ecologies. I argue that gendered fishing resources use, livelihood strategies and ecological conditions in the study villages are intertwined. Where differing and changing livelihood strategies due to integration in the market economy might influence the fluidity of gender roles and labor, increasing women's labor and involvement in fishing.

Chapter 7 draws the main conclusions based on the four empirical chapters presented. For that purpose, I reflect on the theoretical and methodological contributions of this research. I also discuss about the practical implications of the research findings, to finalize with a reflection on the limitations of the approach and recommending areas for future research.

Finally, the Appendices provide further details on several aspects of the research methodology: Appendix 1 provides a list with the correspondence of medicinal plant

vernacular names with scientific names from the chapter 3; Appendix 2 contains a list of species inventoried in homegardens in two Tsimane' villages in chapter 4; Appendix 3 summarize the fish species reported in chapter 6. The Annex provides a list of publications that I have co-authored during my PhD and the outreach efforts.

5. References

Agarwal, B. 1992. Gender and environment debate: lessons from India. *Feminist Studies* 18(1): 119-158.

Agarwal, B. 2009. Gender and forest conservation: the impact of women's participation in community forest governance. *Ecological Economics* 68: 2785-2799.

Agrawal, A. 1995. Dismantling the divide tetween indigenous and scientific knowledge. *Development and Change* 26(3): 413-439.

Atran, S., D. Medin, N. Ross, E. Lynch, V. Vapnarsky, E. U. Ek', J.Coley, C.Timura, and M. Baran. 2002. Folkecology, cultural epidemiology, and the spirit of the commons. A garden experiment in the Maya lowlands 1991-2001. *Current Anthropology* 43(3):421-450.

Ban, N., and O.T. Coomes. 2004. Home gardens in Amazonian Peru: diversity and exchange of planting material. *Geographical Review* 94 (3): 348-368.

Banerjee, D., and M. M. Bell. 2007. Ecogender: locating gender in environmental social science. *Society and Natural Resources* 20 (1): 3–19.

Berkes, F., J. Colding, and C. Folke. 2000. Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications* 10(5): 1251–1262.

Berlin, B.C. 1973. Folk systematics in relation to biological classification and nomenclature. *Annual Review of Ecology, Evolution and Systematics* 4: 259-271

Bicker, A., P. Sillitoe, and J. Pottier. 2000. *Development and Local Knowledge*. Routledge. New York

Borgatti, S. P., A. Mehra, D. J Brass, and G. Labianca. 2009. Network analysis in the social sciences. *Science* 323: 892–895.

Borgatti, S. P., M.G. Everett, and J. C. Johnson. 2013. *Analizing Social Networks.* Sage Publications UK.

Boster J.S. 1985. Requiem for the omniscient informant: there's life in the old girl yet. In: J. Dougherty (ed.). *Directions in Cognitive Anthropology*, pp 177-198. University of Illinois Press, Champaign, Illinois.

Boster, J. S., F. C. Lees, and F. Tierson. 1986. Exchange of varieties and information between Aguaruna manioc cultivators. *American Anthropologist* 88(2): 428–436.

Burt, R.S. 2004. 2004. Structural holes and good ideas. *American Journal of Sociology* 110: 349–399.

Calvet-Mir, L., M. Calvet-Mir, J.L. Molina, and V. Reyes-García. 2012. Seed exchange as an agrobiodiversity conservation mechanism: a case study in Vall Fosca, Catalan Pyrenees, Iberian Peninsula. *Ecology and Society* 17(1):29.

Carr, E. R. 2008. Men's crops and women's crops: the importance of gender to the understanding of agricultural and development outcomes in Ghana's Central Region. *World Development* 36 (5): 900–915.

Casagrande, D.G. 2002. Ecology, Cognition, and Cultural Transmission of Tzeltal Maya Medicinal Plant Knowledge. PhD Thesis. University of Georgia.

Cavalli-Sforza, L.L., and M.W. Feldman. 1981. *Cultural transmission and evolution: A quantitative approach*. Princeton N.J: Princeton University Press.

Ceuterick, M., I., Vandebroek, and A. Pieroni. 2011. Resilience of Andean urban ethnobotanies: a comparison of medicinal plant use among Bolivian and Peruvian migrants in the United Kingdom and in their countries of origin. *Journal of Ethnopharmacology* 136:27-54.

Conklin, H. 1954. The Relation of Hanunuo Culture to the Plant World. PhD Thesis. Yale University.

Coomes, O.T. 2010. Of stakes, stems, and cuttings: the importance of local seed systems in traditional Amazonian societies. *The Professional Geographer* 62(3): 323-334.

Coomes, O. T., S. J. McGuire, E. Garine, S. Caillon, D. McKey, E. Demeulenaere, D. Jarvis, et al. 2015. Farmer seed networks make a limited contribution to agriculture? Four common misconceptions. Food Policy 56:41-50.

Pautasso, M., G. Aistara, A. Barnaud, S. Caillon, P. Clouvel, O. Coomes, M. Delêtre, et al. 2013. Seed exchange networks for agrobiodiversity conservation. A review. *Agronomy for Sustainable Development* 33(1): 151–175.

Cote, M., and A.J. Nightingale. 2011. Resilience Thinking Meets Social Theory: Situating Change in Socio-ecological Systems (SES) *Research. Progress in Human Geography* 36(4):475–89.

Crona, B., and Ö Bodin. 2006. What you know is who you know? Communication patterns among resource users as a prerequisite for co-management. *Ecology and Society* 11(2): 7.

Davis, A., and J. R. Wagner. 2003. Who Knows ? On the importance of identifying "experts" when researching local ecological knowledge. *Human Ecology* 31(3): 463-489.

Ellen, R. 2004. From ethno-science to science, or what the indigenous knowledge debate tells us about how scientists define their project. *Journal of Cognition and Culture* 4 (3): 409–450.

Ellen, R., P. Parkes, and A. Bicker (eds). 2005. *Indigenous Environmental Knowledge and Its Transformations: Critical Anthropological Perspectives*. Harwood: The Neatherlands.

Ellen. R., and H. Harris. 2005. Introduction. In: Ellen, R., P. Parkes, and A. Bicker (eds) *Indigenous environmental knowledge and its transformations* pp 1-34. Harwood, Amsterdam,The Netherlands.

Ellen, R., and S. Platten 2011. The social life of seeds: the role of networks of relationships in the dispersal and cultural selection of plant germplasm. *Journal of the Royal. Anthropological Institute*. 17: 563–584.

Frake, C. 1962. Cultural Ecology and Ethnography. *American Anthropologist* 64(1): 53-59.

Gadgil, M., F. Berkes, and C. Folke. 1993. Indigenous knowledge for biodiversity conservation. *Ambio* 22(2-3): 151-156.

Gallois, S. 2015. Dynamics of Local Ecological Knowledge. A Case Study among the Baka Children from Southeastern Cameroon. PhD Thesis. Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona.

Gavin, M.C., J. McCarter, A. Mead, F. Berkes, J.R. Stepp, D. Peterson, and R. Tang. 2015. Defining biocultural approaches to conservation. *Trends in Ecology and Evolution* 30(3): 140-145.

Gómez-Baggethun, E., and V. Reyes-García. 2013. Reinterpreting change in traditional ecological knowledge. *Human Ecology* 41(4): 643-647.

Gómez-Baggethun, E., S. Mingorría, V. Reyes-García, L. Calvet, and C. Montes. 2010. Traditional ecological knowledge trends in the transition to a market economy: Empirical study in the Donana Natural Areas. *Conservation Biology* 24(3): 721–729.

Gómez-Baggethun, E., V. Reyes-García, P. Olsson, and C. Montes. 2012. Traditional ecological knowledge and community resilience to environmental extremes. A case study in Doñana, SW Spain. *Global Environmental Change* 22:640-650.

Gragson, T. L., and B. G. Blount. *Ethnoecology: Knowledge, Resources and Rights.* University of Georgia Press, Athens.

Granoveter, M. 1983. The strength of weak ties: a network theory revisited. *Sociological Theory* 1: 201-233.

Hanneman, R. A., and M. Riddle. 2005. *Introduction to Social Network Methods*. University of California, Riverside (published in digital form at http://faculty.ucr.edu/~hanneman/).

Haraway, D. 1988. Situated knowledges: the science question in feminism and the privilege of partial perspectives. *Feminist Studies* 14(3): 575-599.

Haselmair, R., H. Pirker, E. Kuhn, and C. R. Vogl. 2014. Personal networks: a tool for gaining insight into the transmission of knowledge about food and medicinal plants among Tyrolean (Austrian) migrants in Australia, Brazil and Peru. *Journal of Ethnobiology and Ethnomedicine* 10(1): 1.

Henrich, J., and F. Gil-White. 2001. The evolution of prestige. Freely conferred deference as a mechanism for enhancing the benefits of cultural transmission. *Evolution and Human Behavior* 22:165−196.

Hewlett, B. S., and L. L. Cavalli-Sforza. 1986. Cultural transmission among Aka pygmies. *American Anthropologist* 88(4): 922–934.

Hopkins, A. 2011. Use of network centrality measures to explain individual levels of herbal remedy cultural competence among the Yucatec Maya in Tabi, Mexico. *Field Methods* 23(3): 307-328.

Howard, P.L. 2003. *Women and plants: gender relations in biodiversity management and conservation*. London: Zed books.

Howard, P.L. 2006a. Gender and social dynamics in swidden and homegardens in Latin America. In: Kumar B.M. and Nair P.K.R. (eds), *Tropical Homegardens: A Time-tested Example of Sustainable Agroforestry*. Springer Science, Dordrecht, The Netherlands.

Howard, P.L. 2006b. Gender bias in ethnobotany: proposals and evidence of a distorted science and promises of a brighter future. Distinguished Economic Botanist Lecture, Kew Gardens. https://www.academia.edu/163864/Gender_Bias_in_Ethnobotany_Propositions_and_Evidence_of_a_Distorted_Science_and_Promises_of_a_Brighter_Future.

Howard, P.L., and G. Nabanoga. 2007. Are there customary rights to plants? An inquiry among the Baganda (Uganda), with special attention to gender. *World Development* 35(9): 1542–1563.

Hunn, E.S. 1977. *Tzeltal Folk Zoology: The Classification Discontinuities in Nature*. Academic Press, New York, United States.

Hunn, E.S. 1989. Ethnoecology: The Relevance of Cognitive Anthropology for Human Ecology. In: Freilich M (ed) *The Relevance of Culture*. Bergin and Garvey, New York, United States.

Inglis, J. (ed) *Traditional Ecological Knowledge: Concepts and Cases*. International Program on Traditional Ecological Knowledge and International Development Research Centre. Canada.

International Society of Ethnobiology.2006. ISE Code of Ethics (with 2008 additions). Online: http://ethnobiology.net/code-of-ethics/

Kawa, N. C., C. McCarty, and C. R. Clement. 2013. Manioc varietal diversity, social networks, and distribution constraints in rural Amazonia. *Current Anthropology* 54(6): 764–770.

Kilduff, M., and W. Tsai. 2003. Is there social network theory? A critical examination of theoretical foundations In: Kilduff, M., and W. Tsai (eds) *Social networks and Organizations.* Thousand Oaks, CA: SAGE.

Kothari, B. 2003. The invisible Queen in the plant kingdom: gender perspectives in medical ethnobotany. In *Women and plants: gender relations in biodiversity management and conservation,* ed. Howard, P*, pp*.London: Zed books.

Labeyrie, V., R. Bernard, and C. Leclerc. 2014. How social organization shapes crop diversity: an ecological anthropology approach among Tharaka farmers of Mount Kenya. *Agriculture and Human Values* 31(1):97–107.

Leach, M. 1994. *Rainforest Relations. Gender and Resource Use by the Mende Gola, Sierra Leone*. Edinburgh University Press: International African Institute, London.

Leach, M. 2006. Gender and the environment: traps and opportunities. *Development in Practice* 2(1):12-22.

Leach, M., R.Mearns, and I. Scoones. 1999. Environmental entitlements: dynamics and institutions in community-based natural resource management. *World Development* 27(2): 245-247.

Leclerc, C., and G. Coppens d'Eeckenbrugge. 2012. Social organization of crop genetic diversity. The G x E x S interaction model. *Diversity* 4(1): 1–32.

Lope-Alzina, D.G. 2007. Gendered production spaces and crop varietal selection: case study in Yucatán, Mexico. *Singapore Journal of Tropical Geography* 28(1): 31-38.

Lorrain, C. 2001. The hierarchy and the equality bias: epistemological considerations in the analysis of gender. In: M.M. Rival and N.L. Whitehead, *Beyond the Visible and the Material: The Amerindianization of the Society in the Work of Peter Rivière*. Oxford University Press, New York.

Marney, I.E., B. H. Erickson, Q. S. James, and V. R Timmer. 2007. Transfer of knowledge on agroforestry management practices : the structure of farmer advice networks. *Ecology and Society* 12 (2): 32.

Makalle, A. M.P. 2012. Gender relations in environmental entitlements: case of coastal natural resources in Tanzania.*Environment and Natural Resources Research* 2 (4)

Mathez-Stiefel, S. L, and I. Vandebroek. 2012. Distribution and transmission of medicinal plant knowledge in the Andean highlands: A case study from Peru and Bolivia. *Evidence-based Complementary and Alternative Medicine*. ID 959285, 18 pp.

McCarter, J., and M.C. Gavin. 2011. Perceptions of the value of traditional ecological knowledge to formal school curricula: Opportunities and challenges from Malekula Island, Vanuatu. *Journal of Ethnobiology and Ethnomedicine* 7:38.

McCarty, C., and J.L. Molina. 2014. Social network analysis. In: *Bernard H.R., and Clarence, C.G. (eds) Handbook of Methods in Cultural Anthropology.* Rowman and Littlefield, UK.

McDade, T., V. Reyes-García, W. Leonard, S. Tanner, and T. Huanca. 2007. Maternal ethnobotanical knowledge is associated with multiple measures of child health in the Bolivian Amazon. *Proceedings of the National Academy of Sciences of the United States of America* 104:6134−6139.

McElreath, R., and P. Strimling. 2008. When natural selection favors imitation of parents. *Current Anthropology* 49: 307–316

McPherson, M., L. Smith-Lovin, and J. M. Cook. 2001. Birds of a feather : homophily in social networks. *Annual Review of Sociology* 27: 415–444.

Mesoudi, A. 2011. *Cultural Evolution: How Darwinian Theory Can Explain Human Culture and Synthesize the Social Sciences*. University of Chicago Press.

Nazarea, V.D. 2006. Local knowledge and memory in biodiversity conservation. *Annual Review of Anthropology* 35:317–35.

Nazarea, V.D.1999. Ethnoecology: Situated Knowledge/Located lives. University Arizona Press, Tucson.

Nightingale, A. 2011. Bounding difference: intersectionality and the material production of gender, caste, class and environment in Nepal. *Geoforum* 42(2):156-182.

Nightingale, A. 2015. Challenging the romance with resilience: communities, scale, and climate change. In: W. Harcourt and I.L. Nelson (eds) *Practising Feminist Political Ecologies: Moving beyond the 'Green Economy* 182–208. London: Zed Books.

Ohmagari, K., and F. Berkes. 1997. Transmission of indigenous knowledge and bush skills among the western James Bay Cree women of Subarctic Canada. *Human Ecology* 25: 197–222.

Overing, J. 1986. Men control women? The catch 22 in the analysis of gender. *International Journal of Moral and Social Studies* 1(2): 135-156.

Paneque-Gálvez, J., J. F. Masa, M. Guèze , A. C. Luz , M. J. Macía, M. Orta-Martínez, J. Pino, and V. Reyes-García. Land tenure and forest cover change. The case of southwestern Beni, Bolivian Amazon, 1986–2009. *Applied Geography* 43:113-116.

Paulson, S. 2003. Gendered practices and landscapes in the Andes: the shape of asymmetrical exchanges. *Human Organization* 62(3):242-254.

Pfeiffer, J.M., and R.J. Butz. 2005. Assesing cultural and ecological variation in ethnobiological research: the importance of gender. *Journal of Ethnobiology* 25(2): 240-278.

Piland R. 1991. Traditional Tsimane' Agriculture and its Relationship to Soils of the Beni Biosphere Reserve, Bolivia. M.A. thesis, University of Florida.

Pilgrim, S. 2006. A Cross-Cultural Study into Local Ecological Knowledge. PhD Thesis. University of Essex.

Posey, D. 1999. *Cultural and Spiritual Values of Biodiversity*. Intermediate Technology Publications, London.

Posey, D.A., and G. Dutfield. 1996. *Beyond Intellectual Property: Toward Traditional Resource Rights for Indigenous Peoples and Local Communities*. Ottowa: International Development Research Centre.

Poudel, D., B. Sthapit, and P. Shrestha. 2015. An Analysis of Social Seed Network and Its Contribution to On-Farm Conservation of Crop Genetic Diversity in Nepal. *International Journal of Biodiversity* 1-13.

Reyes-García, V. 2015a. The values of traditional ecological knowledge. In: Martínez-Alier, J., and R. Muradian (eds) *Handbook of Ecological Economics*. Edward Eldgar, UK.

Reyes-García, V., E. Kightley, I. Ruiz-Mallen, N. Fuentes-Pelaez, K. Demps, T. Huanca, et al. 2010a. Schooling and local ecological knowledge: Do they complement or substitute each other? *International Journal of Educational Development* 30:305-13.

Reyes-García, V., J. L. Molina, L. Calvet-Mir, L. Aceituno-Mata, J. J. Lastra, R. Ontillera, M. Parada, M. Pardo-de-Santayana, M. Rigat, J. Vallès, and T. Garnatje. 2013. "Tertius gaudens": germplasm exchange networks and agroecological knowledge among home gardeners in the Iberian Peninsula. *Journal of Ethnobiology and Ethnomedicine* 9(1): 53-62.

Reyes-García, V., L. Aceituno-Matab, L. Calvet-Mir, T. Garnatje, E. Gómez-Baggethun, J. J. Lastra, R. Ontillera, M. Parada, M. Rigat, J. Vallès, S. Vila, M. Pardo-de-Santayana. 2014. Resilience of traditional knowledge systems : The case of agricultural knowledge in home gardens of the Iberian Peninsula. Global Environmental Change 24: 223-231.

Reyes-García, V., R. Godoy, V. Vadez, L. Apaza, E. Byron, T. Huanca, W.R. Leonard, E. Pérez, and D. Wilkie. 2003. Ethnobotanical knowledge shared widely among Tsimane' Amerindians, Bolivia. *Science* 299 (5613): 1707.

Reyes-García, V., S. Gallois, K. Demps. *In press*. A multi-stage learning model for cultural transmission: Evidence from three indigenous societies. In: Hewlett B. and Terashima H. (eds) *Social Learning and Innovation in contemporary Hunter-Gatherers: Evolutionary and Ethnographic Perspectives*. Springer.

Reyes-García, V., S. Vila, L. Aceituno-Mata, L. Calvet-Mir, T. Garnatje, A. Jesch, J.J. Lastra, M. Parada, M. Rigat, J. Vallès, and M. Pardo-de-Santayana. 2010. Gendered homegardens: a study in three mountain areas of the Iberian Peninsula. *Economic Botany* 64(3): 235-247.

Reyes-García,V., M. Guèze, I. Díaz-Reviriego, R. Duda, A. Fernandez-Llamazares, S. Gallois, L. Napitupulu, O. Martí, and A. Pyhälä. *In press*. The adaptive nature of culture . A cross-culturalanalysis of the returns of local environmental knowledge in three indigenous societies. *CurrentAnthropology*.

Richerson, P.J., and R. Boyd. 2005. Not by genes alone how culture transformed human evolution. Chicago: Chicago University Press.

Rocheleau D., B. Thomas-Slayter, and E. Wangari. 1996. *Feminist Political Ecology: Global Issues and Local Experiences*. London and New York: Routledge.

Rudestam, K. E, and R.R. Newton. 2015. *Surviving Your Dissertation: a Comprehensive Guide to Content and Process* (4th ed). California: Sage Publications.

Ruiz-Mallén, I., and E. Corbera. 2013. Traditional ecological knowledge for adaptive community-based biodiversity conservation: Exploring causality and trade- offs. *Ecology and Society* 18(4): 12.

Sillitoe, P. 1998. The development of indigenous knowledge. A new applied anthropology. *Current Anthropology* 39(2): 229-252.

Sillitoe, P. 2000. Let them at cake: indigenous knowledge, science and the 'poorest of the poor'. *Current Anthropology* 16(6): 3-7.

Smith-Lovin, L., and J. M. McPherson. 1993. You are who you know: a network approach to gender. In: *Theory on Gender, Feminism on Theory*, ed. P. England. New York: Gruyter.

Subedi, A., P. Chaudhary, B. Baniya, R. Rana, R.,Tiwari, D. Rijal, B. Sthapit, and D. Jarvis. 2003. Who maintains crop genetic diversity and how? Implications for on-farm conservation and utilization. *Culture Agriculture* 25: 41–50.

Toledo, V., and N. Barrera-Bassols. *La Memoria Biocultural*. Icaria editorial, Barcelona.

Turner, N. 2003. Passing on the news: women's work, traditional knowledge and plant resource management in indigenous societies of north-western north America. In: P.L Howard (ed) *Women and Plants: Gender Relations in Biodiversity Management and Conservation* 133–149. Zed Books: London.

Wasserman, S., and K. Faust. 1994. *Social Network Analysis: Methods and Applications. Structural Analysis in the Social Sciences.* New York: Cambridge University Press.

Zent, S., and L. Maffi. 2010. Final Report on Indicator No. 2: Methodology for Developing a Vitality Index of Traditional Environmental Knowledge (VITEK) for the Project " Global Indicators of the Status and Trends of Linguistic Diversity and Traditional Knowledge.

Chapter 2

Case study: The Tsimane'

Chapter 2
Case study: The Tsimane'

This chapter provides an overview of the biogeographical setting in which the Tsimane' currently dwell, the most decisive historical and political events which have affected them and their territory, their socio-cultural background, a description of their principal economic activities, and a brief account of their mythology and cosmovision.

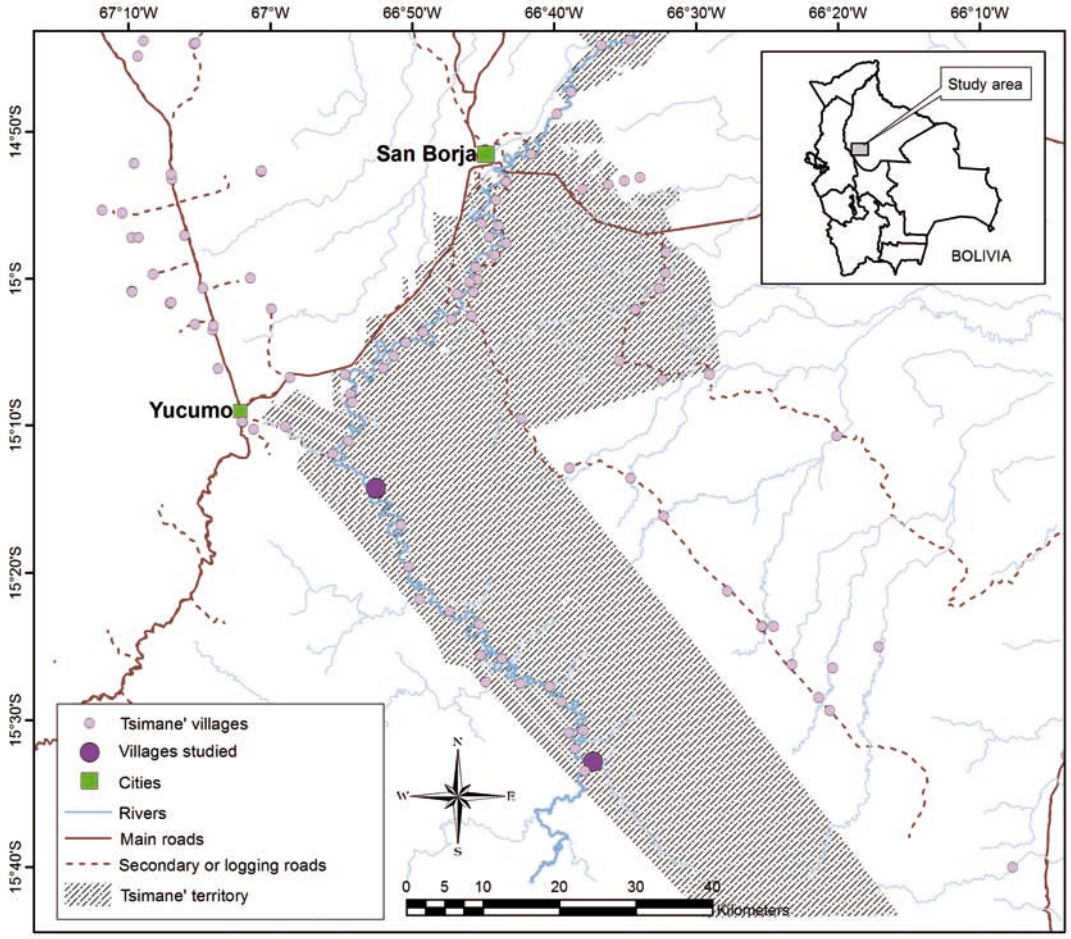
1. Biogeographical setting of contemporary Tsimane'

There are about 125 Tsimane' villages, distributed among several types of tenure regimes, 85 are in indigenous territories, 36 in protected areas, 4 in logging concessions, and 15 in private lands (Reyes-García et al. 2014). Some of these villages have a dual status i.e., that of both protected area and indigenous territory. In this thesis I focus on two villages within the Tsimane' Indigenous Territory, a large territory of approximately 392.220 hectares in the south-western (14º 10'- 15º 40' S, 66º 20'- 67º 20' W) department of Beni in the Bolivian Amazonian, which comprises about 55 villages (see Figure 4). The villages studied are relatively isolated, which does not necessarily imply great geographical distance from urban areas, as a mere 32 km and 122 km separate the villages from the closest town, San Borja (Luz 2012). It has more to do with general accessibility, as transport is restricted to the river and it takes a one-day or a three-day journey by canoe to reach the selected villages.

Geographically the study area lies between the foothills of the Andes and the flooded pampas of Moxos, with broadly two forest types: *terra firme* Amazonian lowland forest and at higher altitudes montane forest, for example, in the southwestern hills (Guèze 2011). The area shelters a rich biological diversity. Top canopy species include deciduous species such as *Hura crepitans*, *Swietenia macrophylla*, and *Terminalia oblonga*. Other common tree species are *Pseudolmedia laevis* and the palms *Bactris gasipaes* and Jessenia bataua (Guèze 2011). These forests support about 30 game vertebrate species, including *Mazama americana, Pecari tajacu, Agouti paca, Cebus paella,* and *Dasypus sp.* (Luz 2012).

The Maniqui River, which winds its way around the outskirts of the municipal town of San Borja, can be considered the very heart of the Tsimane' territory. It is along the banks of this river and its numerous tributaries that most Tsimane' communities are found (Ringhofer 2010). Freshwater fish are represented by *Prochilodus nigricans,* especially abundant in the Maniqui River, and other large-bodied catfishes as *Pseudoplatystoma fasciatum, Paulicea luetken,* and *Salminus maxillosus*. These three large-bodied species can reach up to one meter in length and play important ecological as well as economic roles in the study area by structuring aquatic foodwebs and providing highly regarded and culturally meaningful food resources for the Tsimane'.

Figure 4. Map of the study area



The climate seasonality of the region is strong: there is a dry and relatively cold winter between May and November, marked by occasional cold spells or *surazos* - mostly between May and July, and a wet and humid summer between December and April. Average annual rainfall ranges between 1.870 and 2.550 mm (CIDDEBENI 2002) and average annual temperature in the main town of the area, San Borja, 25.8 ºC (Navarro and Maldonado 2002).

2. Historical and political context

Early sporadic encounters between the Tsimane' and missionaries began in the 17th century. Some references to the Tsimane' people can be also found in the writings of explorers who travelled through the Amazonian rainforest at the beginning of the 20th century (Nordenskiöld 1924; Pauly 1928; Mètraux 1942). The general message conveyed by this early literature is that, up until the late 1930s, the Tsimane' managed to maintain a traditional and self-sufficient lifestyle, but their interactions with Bolivian society have steadily increased since the 1940s (Reyes-García et al. 2014). Some authors believe that Tsimane' success in resisting the established missions until the 1950s lies in their traditional social organization. The lack of a centralized figure and the organization of settlements into small semi-nomadic kin family units, as well as their extensive use of natural resources probably enabled them to move

easily and may have prevented them from staying in one place for a long time and their sedentarization in permanent missions (Chicchón 1992; Ellis 1996; Huanca 2006). The most thorough account on the historical and political events regarding the Tsimane' lands is provided in the work of Reyes-García et al. (2014) summarized as a historical timeline in Table 1.

The Tsimane' succeeded at resisting the missions until the 1950s, when the Catholic Redentorists and the Protestant New Tribes missionaries managed to establish missions in the area inhabited by the Tsimane'. Huanca (2006) compiled Tsimane' oral history, which identifies this period as turbulent, characterized by explosive epidemics, acts of aggression, and impositions of new social norms, social control and cultural violence including sexual harassment. Once Catholic and Protestant missions became permanently established in the territory for Christian indoctrination, the missionaries approach to the Tsimane' was different. While the Catholics attempted to promote economic development, health care and indoctrination, the Protestants emphasized the translation of the Bible into the Tsimane' language and additionally provided humanitarian aid. The missions influenced Tsimane' society significantly, for example, by undermining and eroding the role of *cocojsi* (traditional religious and health leader or shamans), and also discouraging the practices of polygamy and, to some extent, the use of medicinal plants (Huanca 2006).

In the same decade, other profound political changes took place in Bolivia, including social and political reforms associated with the 1952 Revolution and the subsequent 1953 land reform. The government endorsed the expansion of schooling and gave the responsibility for schooling remote lowland native Amazonian populations to Protestant missionaries (Castro-Mantilla 1997). The missionaries mostly trained young Tsimane' men, who later became teachers and political leaders (Reyes-García 2010).

After the rubber boom and with the opening of a road to the region in 1975, the arrival in the area first of ranchers and, afterwards, of colonists and loggers, also had a profound effect on Tsimane' territory and lifestyle. For example, the government promoted the resettlement of highland peoples (Aymara and Quechua) in the lowlands. This process of colonization affected the Tsimane' in different ways: in some cases, colonists used Tsimane' as labor for cattle ranching and logging; in other cases, the settling of colonists, armed with legal land tittles obtained in the capital city of La Paz, forced Tsimane' communities to move closer to rivers, away from the new roads (Reyes-García 2001).

Table 1. Historical and political events of the Tsimane' Territory

Period	Phase	Year	Key historical and political events	References
17th Century until 1952	Indigenous territories as marginal lands and the arrival of Missions,	1621	The Franciscan priest Gregorio de Bolívar provides the first known reference to the Tsimane'	Chicchón (1992), Daillant (2003)
		1693	Foundation of the Mission San Francisco de Borja	Métraux (1948)
		1805	Foundation of two small missions with the Tsimane' villages along the Maniqui river	Pérez Díez (1983)
		1860s	Violent confrontations: Tsimane' resistance to settle in missions	Daillant (2003), Huanca (2008)
		1910s	Arrival of new migrants to the area (mostly attracted by the rubber economy)	Paneque-Gálvez et al. (2014)
		1930s	Some Tsimane' start working as ranch laborers, becoming entangled in the debt-peonage system	Martínez-Rodríguez (2003)
		1950s	Arrival of the first traders to the Tsimane' Territory: expansion of debt-peonage systems	Riester (1993), Huanca (2008)
1952- 1980s	Forest frontiers expansion	1952	National Revolution in Bolivia: huge migration waves to the Bolivian lowlands	Pacheco et al. (2010)
		1957	Establishment of the Catholic Fátima mission and arrival of the Protestant New Tribes Mission	Huanca (1999)
		1970s	Illegal logging operations in the Chimane Forest (largest mahogany reserve in South America)	Jones 1980
		1975	Road opened between San Borja and Trinidad	Botazzi 2008
		1979	Road opened between Rurrenabaque and Yucumo: rapid increase of permanent migration	
		1980s	Land conflicts force many Tsimane' families to migrate to the Maniqui and Quiquibey rivers	
		1982	Creation of the Beni Biological Station (135,000 ha) in the lower section of the Maniqui river	Paneque-Gálvez et al. (2013)
1985-1994	Indigenous people's political awakening	1989	Creation of the *Gran Consejo Tsimane'* (GCT), political organization representing the Tsimane'	Reyes-García et al. (2014b)
		1990	March for Territory and Dignity: claims for indigenous territorial rights	Jones (1993)
			The Tsimane' are granted a communal land of ca. 400,000 ha: Tsimane' Indigenous Territory	Reyes-García et al. (2014b)
		1990s	The Tsimane' living in Pilón Lajas, TIM and TIPNIS are also granted territorial rights	
1994-2005	Neoliberal multicultural reforms	1994	Popular participation law: decentralization and recognition of indigenous authorities	Chumacero (2011)
		1996	Agrarian Reform Law: TCOs are created and the land titling process (*saneamiento*) starts	Assies and Salman (2000)
			Forestry Law: logging concessions are regularised and given priority over TCOs	Hunnisett (1996), Pacheco (2007)
			The opening up of a logging road destroys an important Tsimane' petroglyph site	Daillant (1997)
		1999	National halt of the land titling process (including Tsimane' Territory) due to land conflicts	Martínez (2000)
		2000	March for Lands, Territories and Natural Resources: claims to accelerate the titling process	INRA (2005)
2005-2015	Indigenous autonomies in the Plurinational State of Bolivia	2005	Election of Evo Morales as the first indigenous Bolivian president	Reyes-García et al. (2014)
		2006	Agrarian Reform Law: provisions for the acceleration of indigenous land titling	Chumacero (2011)
		2007	National Development Plan with the goal of reducing social inequality in Bolivia	Pacheco et al. (2010)
		2009	New Bolivian Constitution: more political rights and autonomy to indigenous peoples	Reyes-García et al. (2014)
		2010	TCOs are reconverted to TIOCs (Indigenous Originary Peasant Territories)	
			Jorge Añes becomes the first Tsimane' major of San Borja: enforcing local Tsimane' governance	
		2015	The Tsimane' land titling process is yet to be concluded (GCT aiming to recover logging concessions)	

Logging has been one of the critical economic forces promoting drastic transformations in the area inhabited by the Tsimane'. During the 1970's logging firms moved into the Tsimane' forests looking for precious woods, such as *Swetenia macrophylla* (mahogany), *Cedrela odorata* (cedar), and *Amburana seaerensis* (oak). The logging business has had ambiguous effects on the Tsimane'. On the one hand, logging companies benefited Tsimane' leaders by paying a percentage of their profit to the Tsimane' Council (see below), which allowed the functioning of the organization until the end of 1990s, when the logging business declined. On the other hand, these same companies were especially abusive with the Tsimane' living in formerly isolated forest communities, and even used violence to force them to work (Reyes-García 2001). Likewise, river traders and colonists were also abusive towards the Tsimane'. In summary, Tsimane' relations with outsiders since the beginning of the 20th century have been increasing in intensity, but have often also resulted in conflict.

Missionaries from the Protestant New Tribes had a firm attitude against the abusive system commonly practiced by the river traders and colonists. This brought the missionaries into confrontation with ranchers, loggers, and other traditionally powerful groups in the region, leading to the promotion and support of the founding of the *Gran Consejo Tsimane'* (CGT) in 1989, the first political representative institution of the Tsimane'. The CGT also fueled Tsimane' political awakening. In the 1990s, Tsimane' land rights were legally recognized by a Supreme Decree that assigned them an area that was named the Tsimane' Indigenous Territory. Later, the Tsimane' and other lowland ethnic groups were also granted land rights for other areas traditionally inhabited by them, such as the Pilón Lajas Biosphere Reserve, the Multiethnic Indigenous Territory (TIM by its initials in Spanish), and the Indigenous Territory and National Park Isiboro-Sécure (TIPNIS).

Anthropologists and researchers of different disciplines have also been working either with Tsimane' or in the Territory they inhabit since the end of the 1990s. Two major international research projects have been doing long-term research with the Tsimane': the Tsimane' Amazonian Panel Study (TAPS) and the Tsimane' Health and Life History Project. The TAPS research project ran between 2002-2010 and aimed to assess the effects of trade and market exposure on well-being and on the use of natural resources. The Tsimane' Health and Life History Project is another, which has been working with the Tsimane' since 2001, and which seeks to understand the impacts of ecology and evolution on the shaping of the human life course. Both research projects combine research with collaborative development initiatives and medical attention, which have had some impact on Tsimane' lifestyle. For example, the TAPS project in collaboration with a local NGO (*Centro Boliviano de Investigación y Desarrollo Socio Integral*- CBIDSI), undertook participatory mapping of the Tsimane' Indigenous territory in which traditional forest uses were mapped (Reyes-García et al. 2012a). The maps resulting from this project have been used by Tsimane' leaders to support their claims to land titles. The Life History Project collaborates with the local hospital in San Borja by providing Tsimane' translators to help health professional to communicate with monolingual Tsimane'and also provides full assistance to Tsimane' people in emergencies, including the relocation to other hospitals in Bolivia in severe cases. It is worth mentioning that Tsimane' people sometimes do not understand researchers'

interests in their daily life and feel exhausted by answering the "weird" questions that anthropologists have been asking for so many years.

Other national and international non-governmental organisations (NGOs) have also worked in the area on issues like conservation, productive projects, and health assistance. Several NGOs have launched projects to promote the direct sale of thatch palm (jatata) by the Tsimane', with the aim of avoiding the unjust system of debt peonage in which they become indebted to the traders who act as intermediaries for the commercialization of thatch palm panes in the market towns, so the Tsimane' could also receive higher economic benefits for their thatch panes production. For example, while in 2013 a thatch palm pane was sold for up to 15 bolivianos (2.19 US$) in Santa Cruz, the main city in Bolivian lowlands, the price in the village barely reached 6 bolivianos (0.88 US$) (Fernández-Llamazares et al. *in press*). However, to date, all these projects have largely failed, partly due to the powerful thatch of the thacht palm lobby in the local government (Rioja 1999). In recent years, some Tsimane' individuals have also attempted to commercialize thatch palm panes on their own, but nonetheless most continue to rely heavily on intermediaries who pay them poorly for their work and sell the products in the market at much higher prices (Fernández-Llamazares et al. *in press*).

Conservationists also played an important role in the region in the late 1990s by supporting indigenous peoples as allies in conservation, pushing the Bolivian government to endorse the co-administration of protected areas which included the participation of indigenous peoples (Bottazzi, 2008). In that sense, the establishment of areas in the Bolivian lowlands for environmental protection with the dual status of indigenous territories and protected areas helped the Tsimane' to control the advancement of logging and colonization. One example is the Tsimane'-Mosetene Indigenous Territory and Pilón-Lajas Biosphere Reserve. The Tsimane' have also been included as park rangers in the Beni Biological Station. However while some consider the inclusion of indigenous peoples in the management of protected areas to be a recognition of their rights, it could also be argued that before such legislation indigenous peoples had the *de facto* total management of those resources, which became partially controlled by the National Service of Protected Areas and foreign NGOs after establishment of protected areas (Reyes-García et al. 2014). In other words, including indigenous peoples in the management of protected areas only partly gives them their management roles back.

The election of Evo Morales as the first indigenous president of Bolivia (2005) and the adoption of the new Constitution of the Plurinational State of Bolivia (2009), which includes a rather complex notion of territorial autonomy for indigenous groups, renewed efforts to address indigenous demands for self-governance and territory. This had some concrete implications at a local level. Thus, in 2010, Jorge Añez, the President of the GCT at that time, was elected mayor of the town of San Borja, giving even stronger political influence to the Tsimane' at the local and regional levels and contributing to the defense of the Tsimane' Territory against land-grabbers and settlers.

3. Subsistence and economic activities

The majority of contemporary Tsimane' are forager-horticulturalists who rely on farming, fishing, hunting and the collection of wild edibles for subsistence. They also barter and sell agricultural products, thatch palm and timber as primary sources of income. However, there is a great deal of variation among individuals, households and communities in level of engagement in subsistence activities versus cash-generating activities. The villages included as empirical case studies in this dissertation are largely subsistence oriented.

Tsimane' agricultural systems have been the focus of various studies (Piland 1991; Huanca 1999; Vadez 2004) (see Figure 6.a seasonal calendar in chapter 6). Agriculture was until recently practiced for subsistence, but in the last two decades it has also become increasingly commercially oriented, since the selling of plantain and rice is one of the main sources of income for many Tsimane' households. Tsimane' agriculture consists of cultivated fallow plots, which are the source of staples and cash crops, and of homegardens. In cultivated plots, Tsimane' practice slash and burn agriculture. Previous research suggest that the Tsimane' maintain a rich agroecological diversity in their fields: among other crops, 30 cassava varieties, 10 plantain varieties, 8 maize varieties, and 13 rice varieties have been documented (Piland 1991; Vadez and Fernández-Llamazares 2014). Tsimane' homegardens have received scant attention in agricultural studies so far. In this thesis, I focus on homegardens (chapter 4) as the source of medicinal plants, fruit trees, and other useful species some of which provide dyes, fibres, and fish poisons. Minor crops and plants typically grown in homegardens are important both because they can represent up to 11% of the total value of food consumption in some Tsimane' villages (Reyes-García 2001), but also because of their direct relation to other values, as a source of useful plants for treating primary health complaints and for the conservation of genetic resources (e.g. seeds).

The Tsimane' also raise domesticated animals such as pigs and chickens and occasionally also ducks, goats, and cattle. Generally, the husbandry of animals is not particularly active; animals are allowed to forage freely in and around the households and the villages. Domestic animals are often consumed within the household, but they are also often sold or bartered when Tsimane' travel to town and are in need of cash. Cattle ranching is a very recent activity for the Tsimane' and considered to be a symbol of wealth, since it resembles the practices of the cattle ranchers in the region.

Hunting is not just a major source of protein for the Tsimane' but also an important cultural practice (Chicchon 1992; Huanca 2006; Luz 2012). Hunting is practiced all year round. However, Tsimane' consider the best time for hunting to start in May, as at animals are at their fattest at this time of the year. While commonly thought as an activity taken up by men, it is not uncommon for women and children to hunt for small game using dogs and machetes.

Fishing is also practiced all year round, with peaks during fish migration (April to May) and in the dry season (August to November). Men, women and children regularly employ a number of differing fishing techniques to catch a diversity of fish species. Fish provide the

single most important source of protein for Tsimane' households (Perez 2001; Zycherman 2013). A detailed account of fishing activities is provided in chapters 5 and 6.

The Tsimane' rely upon forest resources for edibles, medicinal plants, fish poisons, firewood, and construction materials, among others products (Reyes-García 2001). Seasonally available fruits are an important source of caloric intake, especially for children, and are appreciated because of their sweet taste (Aiello 2013). Forest plants are also an essential source of traditional medical resources, which are used to relieve headaches, diarrhea, infertility and burns (see chapter 3 for a detailed account of medicinal plant use). The Tsimane' have been shown to have a great deal of ethnobotanical knowledge (Reyes-García et al. 2003). Having this knowledge seems to have positive effects on household's health profile. For example, the study by McDade et al. (2007) showed that as a mother's level of ethnobotanical knowledge is associated with better child health, arguably, because caring work and healthcare is mostly a female responsibility.

Finally, the extraction of non-timber forest products, especially the thatch palm (*Geonoma deversa*) harvesting, and logging are important sources of income in the villages studied. In many households, the thatch palm trade is the primary source of income throughout the year for women and men, and sometimes even for children (Martínez Cantero 2012). More common than cash payment, a system of debt peonage is established between merchants who visit Tsimane' people living in remote villages, whereby consumer goods such as oil, soap, fishing hooks and line, batteries, and medicines are purchased or bartered in exchange for woven thatch palm panels (Martínez Cantero 2012). It is through the trading of thatch palm that the Tsimane' of these more isolated villages are principally involved in the market economy. Logging is mostly a source of income for men, and sometimes for women who work in logging camps as cooks. Tsimane' people generally used to work for legal or illegal loggers receiving wages or goods as payment. More recently, some Tsimane' are also starting to log by themselves through a credit-payment system with merchants in nearby towns, from whom they buy chainsaws and pay back with timber. Through the period of this research, I have observed how this is chaning the Tsimane' way of organizing logging activities. Rather than work as labor for non-Tsimane' loggers, some men in the villages obtained loans to buy chainsaws from merchants in the city. These Tsimane' men subcontract other men in the village to help them log. Most of these subcontracts are within the kinship network, i.e. brothers or brothers-in-law, creating new relations of patronage within villages.

4. Social and cultural background

Estimated according to a general census recording people over 15 years of age who self-identified as Tsimane', the Tsimane' number between 10,000 and 14,000 people. The average population growth rate is high, about 4.2%, between 2001 and 2013 (Reyes-García et al. 2014; Undurraga et al. 2014).

Like other indigenous groups in Amazonia, Tsimane' society is endogamic and unions generally follow a cross-cousin Dravidian kinship system, where an individual may marry his

or her mother's brother's daughter or son, or their father's sister's son or daughter (Daillant 2003). Although this is the culturally preferred union arrangement, some couples do not follow this system and marry other people. This happens more commonly among Tsimane' living in urban centers or in the periphery. However, it is still uncommon to go against the cross-cousin system and people who transgress this norm are usually stigmatized. There is no marriage ceremony and unions are defined by the cohabitation and relatively stable relationship of a couple. There are no forced unions, and Tsimane' women can decide among potential spouses (Daillant 2003). Post marital residence is generally matrilocal until the first child is born.

The household is the main unit for production, consumption and social reproduction. Tsimane' preferably live in nuclear family dwellings in the vicinity of other kin households of extended families within a village. Ringhofer (2010) describes Tsimane' sociability as follows:

> *To the outside observer, the everyday social world of the Tsimane' seems to strike a balance between periods of dispersed nuclear family living, aggregation in extended family networks, and community life. Yet it is the household that provides the heart of Tsimane' sociability. Though providing for a single unit, the household is strongly embedded in a larger social setting that includes extended family networks as well as an attenuated network of friends, neighbors and other actors constituting life in the community* (Ringhofer 2010:75).

Ethnographic references depict the cultural importance of *sòbaqui,* or visiting kindred networks, including both temporary and frequent visits to family members living in the same or neighboring villages and long-term visits to more distant relatives (Ellis 1996). Those visits serve to maintain social relations as well as to establish new ones, as for example, when an adult woman takes her family to visit her brother so the children can get to know their cross-cousins, potential marriage partners (Reyes-García 2012b). Social relations have been suggested as a central and defining feature of wellbeing among the Tsimane', constituting a dense web of social support (Reyes-García 2012b).

Gender relations are one of the central axes and driving forces of Tsimane' social life and division of labor. Ethnographers have describe how the complementary roles of women and men are the means of nurturing appropriate and desirable sociality (Ellis 1996). Drawing on the previous work of Overing (1984) and McCallum (1989) Ellis describes the function of food and manioc beer production, distribution and consumption in creating differing forms of sociality, based on sharing and reciprocity. In her view, neither men nor women among the Tsimane' are endowed with special recognition or position in their respective roles (Ellis 1996:137). She writes:

> *A consideration of Tsimane gender relations and the way in which they organize relations of production and consumption and, in turn, create differing forms of sociality leads to an understanding of gender equality amongst the*

> *Tsimanes. I aim to illustrate that although persons and their productive activities are gendered, such a process in no way infers an associated hierarchy of values. Neither male nor female work is perceived as lying at the periphery or center of Tsimane social life. Both are essential for appropriate social living and their intertwining complementarity is crucial as part of the processual achievement of this* (Ellis 1996:144).

Ellis allusion to the complementarity of women's and men's practices refers to the procurement and distribution of food. Women and men have particular roles, but their responsibilities are intricately connected. The provision of meat and fish is a male responsibility which depends on hunting and fishing ability. Thus, men's abilities condition their role as food providers for the household, and also for sharing with the extended family. The responsibility of females, in turn, is to distribute the meat, to prepare and cook the food, and to produce manioc beer (*shocdye*).

Recent work on the changing value associated with food among the Tsimane' suggests that despite the fact that food procurement, production and distribution continue to moderate gender roles and responsibilities, the methods of production are shifting as Tsimane' livelihoods strategies are changing (Zycherman 2013). For example, the expansion of plantain fields for cash has reduced the production of manioc, thus plantains have replaced manioc as the key ingredient in *shocdye.* This change is significant in symbolic terms. Among the Tsimane' there has always been a special relationship between females and manioc beer; women's status depends on the quality and sweetness of the beer they produce, which is associated to the quality of their saliva, which, in turn, is considered a gift from the gods to women. In this sense, women had an essential role in the creation and maintenance of social life (Riester 1976, Huanca 2006). Plantains, however, have different properties, producing a sweet beer with no need to masticate the plantains during preparation. Therefore, women cannot be valued for by their ability and quality of saliva for beer production. Men are also spending less time hunting and more time in logging and agriculture. As a consequence of these shifts, meat is nowadays mostly commonly bought, especially in the villages closer to market towns. Thus, Tsimane' women and men are able to adapt their responsibilities and division of labor to the new circumstances (Zycherman 2013) and to maintain their respective gender roles. According to Huanca (1999) the cultural need for this complementary division of labor may be the reason why Tsimane' widows are uncommon. Tsimane' men and women do not stay alone after their spouses die. A widow usually moves to her sister's house, while a widower may move in with his wife's sister or another female relative

Another defining social feature of the Tsimane' stressed by Daillant (2003) is the idea that there is non-hierarchical organization among the Tsimane', in which only the *cocojsi,* due to their healing powers and their ability to communicate with all kinds of natural spirits, would have had a higher hierarchical standing within the larger social setting. Lack of hierarchical organization does not mean, however, that there are no sources of status and prestige. Elders, including women, were considered a source of knowledge for younger Tsimane' and to the present day have a higher social standing than younger members of the community. The

respect individuals evoke is not static but changes within a person's life cycle. Village members who excel in one productive activity or another tend to enjoy an overall higher social standing than others. Others are known for their sharp wit, astuteness or wisdom. All these attributes equally infer a certain sense of social acceptance and status (Ringhofer 2010; Aiello 2013).

Although formal leaders seem to have been largely absent in traditional Tsimane' society - with the exception of the cocojsi - today, some new forms of hierarchies associated with leadership have started to appear. For example, the need to acquire legal title to land and to relate to the wider Bolivian society pushed the Tsimane' to elect community leaders, locally called *corregidores,* who are usually young men who speak Spanish. The *corregidores* are gaining more importance in local organization and thereby eroding the traditional leadership of community elders (Reyes-García et al. 2008). A good example of the recent social stratification within the group is the *Gran Consejo Tsimane'* whose board members are men, with occasional women representatives in charge of the "gender" portfolio. Members of the GCT, who were trained under the auspices of the New Tribes Mission, are nowadays a socioeconomic elite. Generally they live in the urban center, having access to modern goods and services which allow them to distinguish themselves from the rest of the Tsimane' (Byron 2003). Likewise in villages with schools, teachers enjoy a privileged status and authority over other village members, often based on their educational accomplishments, their Spanish language abilities, and their secure source of income.

Reyes-García et al. (2008) also suggest that in rapidly transforming rural societies, political positions, such as those that some Tsimane' hold, might begin to overshadow cultural knowledge as a determinant of prestige, which is nowadays associated with formally educated young men whose main social role is to represent Tsimane' interest to outsiders. Byron (2003) also points out that the new organization of power and wealth - *corregidores* and GCT - almost always marginalizes women in village decision-making processes. Women's lack of formal education and competence in Spanish, as well as the mobility required of representatives, keep Tsimane' women outside political arenas (Melgar 2009; Fernández-Llamazares et al. 2014). Nonetheless, compared with other indigenous societies, Tsimane' women can be seen as 'better off' because of their central role in village social life (Melgar 2009).

Finally, although the Tsimane' have been shown to be one of the societies least integrated into the market economy (Henrich et al. 2010), the recent acceleration of this process seem to be rapidly changing changing traditional values, as some studies have suggested (Reyes-García et al. 2008; Zycherman 2013).

5. Mythology and cosmovision

Tsimane' ways of interaction with nature and with each other are mostly dictated by strongly embedded traditions based on their own cosmology and cosmogony, passed down from older generations through oral tradition. Myths, rituals and taboos help to direct the interaction of Tsimane' people with their natural environment as they legitimise relationships and provide regulatory rules for resource use, as well as for the cultural sphere of the forest and its use (Ringhofer 2010). Traditionally, Tsimane' spirituality was animistic, believing in spirits own the river, the forest or animals (Riester 1976). Although there is a strong Christian influence today, the belief in these 'owners' of nature is still apparent in a syncretice form, mostly in the more isolated villages.

Cultural anthropologists have produced a rich body of literature on supernatural meanings in Tsimane' oral tradition (Riester 1976; Ellis 1996; Huanca 2006). Huanca (2006) describes the *A'mo* or tree owners. For example, the Tsimane' say that the owner of the tree called *Titij* (*Ficus insipida*) is a spirit who provides medicine. There are also animal masters who regulate fish availability. *I'dojore*' is a benevolent fish owner who provides fish to the Tsimane'. For example, the upriver migration of fish is interpreted as a sign of *I'dojore'* being at work. In contrast, *O'pito'* (rainbow) is a harmful owner who monopolizes fish without sharing them, causing fear and distrust. *O'pito'* can also make people sick, specifically when people overfish and leave a lot of fish to die and rot, *O'pito'* gets furious and bewitches people who pass nearby, causing them to fall sick.

6. References

Aiello, M.O. 2013. The Children of the Tsimane': Exploring How Children Create and Negotiate Health Outcomes. PhD Thesis. Northwestern University.

Byron, E. M. 2003. Market Integration and Health: The Impact of Markets and Acculturation on the Self-Perceived Morbidity, Diet, and Nutritional Status of the Tsimane' Amerindians of Lowland Bolivia. University of Florida, United States.

Bottazzi, P. 2008. Linking 'socio-' and 'bio-' diversity: the stakes of indigenous and non-indigenous co-management in the Bolivian lowlands. In: Galvin, M., Haller, T. (eds.) *People, Protected Areas and Global Change: Participatory Conservation in Latin America, Africa, Asia and Europe, Perspectives of the Swiss National Centre of Competence in Research (NCCR) NortheSouth*. Geo-graphica Bernensia, Bern, pp. 81-110.

Calvet-Mir, L., V. Reyes-García, and S.Tanner. 2008. Is there a divide between local medicinal knowledge and Western medicine? A case study among native Amazonians in Bolivia. *Journal of ethnobiology and ethnomedicine* 4:18.

Castello, L., G. David, L. Mcgrath, L. Hess, M. T. Coe, P. Lefebvre, P. Petry, M. N. Macedo, V.F. Renó, and C.C. Arantes. 2013. The vulnerability of Amazon freshwater ecosystems. *Conservation Letters* 6 (4): 217-229.

Castro-Mantilla, M. D. 1997. La viva voz de las tribus: El trabajo del ILV en Bolivia, 1954-1980. La Paz, Bolivia: Ministerio de Desarrollo Sostenible y Planificacion, Vice Ministerio de Asuntos Indigenas y Pueblos Originarios.

Chicchon, A. 1992. Chimane Reource Use and Market Involvement in the Beni Biosphere Reserve, Bolivia. PhD Thesis. University of Florida, United States.

CIDDEBENI. 2002. Diagnóstico del distrito municipal indígena Chimane, proyecto: Apoyo a la formulación del plan distrital de desarrollo indígena. Trinidad: CIDDEBENI.

Daillant, I. 2003. Sens dessus dessous: organisation sociale et spatiale des chimane d'Amazonie bolivienne. Nanterre: Société d'ethnologie.

Ellis, R. 1996. A Taste for Movement: An Exploration of the Social Ethics of the Tsimanes of Lowland Bolivia. PhD Thesis. St. Andrews University, Scotland.

Fernández-Llamazares, Á., I. Díaz-Reviriego, M. Guèze, M. Cabeza, A. Pyhälä, and V. Reyes-García. *In press*. Local perceptions as a guide for the sustainable management of natural resources: empirical evidence from a small-scale society in Bolivian Amazonia. Ecology and Society.

Fernández-Llamazares, Á., I. Díaz-Reviriego, and I.V. Sánchez. 2014. Las voces del cambio: percepciones de una sociedad ante el proceso de cambio. In: V. Reyes-García and T. Huanca (eds) *Cambio global, cambio local. La sociedad Tsimane' ante la globalización*, Barcelona: Icaria.

Gragson, T.L. 1992. Fishing the waters of Amazonia: Native subsistence economies in a tropical rain forest. *American Anthropologist* 94(2): 428–440.

Godoy, R., V. Reyes-García, V. Vadez, W. R. Leonard, and E. Byron. 2007. How well do foragers protect food consumption? Panel evidence from a native Amazonian society in Bolivia. *Human Ecology* 35 (6): 723–32.

Guèze, M. 2011. Evaluation of Tree Diversity and Utilization: the Role of Acculturation. A case study in the Bolivian Amazon. PhD Thesis. Institut de Ciència i Tecnología Ambientals, Universitat Autònoma de Barcelona.

Henrich, J., J. Ensminger, R. McElreath, A. Barr, C. Barret, A. Bolyanatz, et al. 2010. Markets, religion, community size and the evolutio of fairness and punishment. *Science* 327 (5972):1480-1484.

Henrich, J., and J. Broesch. 2011. On the nature of cultural transmission networks: evidence from Fijian villages for adaptive learning biases. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences* 366(1567):1139–1148.

Huanca, T. 1999. Tsimane ' Indigenous Knowledge , Swidden Fallow Management , and Conservation. PhD Thesis. University of Florida, United States.

Huanca, T. 2006. Tsimane' oral tradition, landscape and identity in tropical forest. La Paz: Imprenta Wangui.

Luz, A.C. 2012. The Role of Acculturation in Indigenous Peoples Hunting patterns and Wildlife Distribution. The case of the Tsimane' in the Bolivian Amazon. PhD Thesis. Autonomous University of Barcelona, Spain.

Martínez Cantero, S. 2012. Economía y Pueblo T'simán: Las relaciones sociales que se tejen con la jatata. Cambios en su economía. Undergraduate Thesis. Sevilla University, Spain.

McCallum, C. 1989 Gender, Personhood and Social Organization amongst the Cashinahua of Western Amazonia. Ph.D Thesis, London School of Economics. United Kingdom.

McDade, T .W., V. Reyes-García, P. Blackinton, S. Tanner, T. Huanca, and W. R. Leonard. 2007. Ethnobotanical knowledge is associated with indices of child health in the Bolivian Amazon. *Proceedings of the National Academy of Sciences of the United States of America* 104 (15): 6134–39.

Melgar, Tania. 2009. *Detrás Del Cristal Con Que Se Mira : Mujeres Chimane, órdenes normativos e interlegalidad*. Instituto de la Mujer, Beni. Bolivia.

Métraux, A. 1942. *The Native Tribes of Eastern Bolivia and Western Mato Grosso* (vol 134). United States Government Printing Office, Washington DC, United States.

Navarro, G., and M.Maldonado. 2002. Geografía Ecológica de Bolivia: Vegetación y Ambientes Acuáticos. Cochabamba, Bolivia.

Nordenskiöld, E. 1924 Exploraciones y Aventuras en Suramérica. APCOB, Apoyo para el Oaks, CA: SAGE.

Overing, J. 1984. Dualism as an expression of fifference and danger: Marriage exchange and reciprocity among the Piaroa of Venezuela. In: Kensinger (ed) *Marriage Practices in Lowland South America*. Urbana. University of Illinois Press.

Pauly, A. 1928. Ensayo de etnografía Americana. Viajes y exploraciones. Casa Jacobo Peuser, Buenos Aires, Argentina.

Pérez-Limache, E. 2001. Uso de la Ictiofauna entre los Tsimane'. BS Thesis. Universidad Nacional Mayor de San Andrés, Bolivia.

Piland R. 1991. Traditional Tsimane' Agriculture and Its Relationship to Soils of the Beni. Master Thesis. University of Florida, United States.

Reyes-García, V. 2001. Indigenous People, Ethnobotanical Knowledge, and Market Economy. A Case Study of the Tsimane' Amerindians in Lowland Bolivia. PhD Thesis. University of Florida, United States.

Reyes-García, V., R. Godoy, V. Vadez, L. Apaza, E. Byron, T. Huanca, and W. R. Leonard .2003. Ethnobotanical knowledge shared widely among Tsimane' Amerindians, Bolivia. *Science* 299: 60208.

Reyes-García, V., J.L. Molina, J. Broesch, L. Calvet, T. Huanca, J. Saus, S. Tanner, W. R. Leonard, and T.W. McDade. 2008. Do the aged and knowledgeable men enjoy more prestige? A Test of predictions from the prestige-bias model of cultural transmission. *Evolution and Human Behavior* 29 (4): 275–81.

Reyes-Garcia,V., E. Kightley, I. Ruiz-Mallen, N. Fuentes-Pelaez, K. Demps, T. Huanca, and M.R. Martínez-Rodriguez. 2010. Schooling and local ecological knowledge: Do they complement or substitute each other? *International Journal of Educational Development* 30:305-13.

Reyes-García, V., M. Orta-Martínez, M. Guèze, A. C., Luz, J. Paneque-Gálvez, M. J. Macía, J. Pino, and TAPS Bolivian Study Team 2012a. Does participatory mapping increase conflict? A randomized evaluation in the Bolivian Amazon. *Applied Geography* 34:650–658.

Reyes-García. 2012b. Happiness in the Amazon. Folk explanations of happiness in a hunter-horticulturalist society in the Bolivian Amazon. In: H. Gelina and G. Davey (eds) *Happiness across cultures. Views of happiness and quality of life in Non-Western cultures*. Springer, London.

Reyes-García, V., J. Paneque-Gálvez, P. Bottazzi, A.C. Luz, M. Guèze, M.J. Macía, M. Orta, and P. Pacheco. 2014. Indigenous land reconfiguration and fragmented institutions : a historical political ecology of Tsimane ' lands (Bolivian Amazon). *Journal of Rural Studies* 34: 282–91.

Riester, J. 1976. *En Busca de la Loma Santa*. La Paz: Los Amigos del Libro.

Riester, J. 1978. *Canción y Producción en la Vida de un Pueblo Indígena: Los Chimane, Tribu de la Selva Oriental*. La Paz: Los Amigos del Libro.

Rioja, G. 1999. The jatata project: The pilot experience of Chimane empowerment. In: Sustainable Harvest and Marketing of Rain Forest Products, eds. M. J. Plotkin and L. M. Famolare, 192–196. Washington D.C.: Island Press.

Ringhofer, Lisa. 2010. *Fishing, Foraging and Farming in the Bolivian Amazon. On a Local Society in Transition.* Dordrecht: Springer Netherlands.

Salo, M., A. Sirén, and R. Kalliola. 2013. Fishing in and fishing out the Amazon. In: *Diagnosing Wild Species Harvest*. Resource use and conservation. Academic Press.

Tanner, S., and A. Rosinger. 2014. Salud y nutrición: perfil y cambio. In: V. Reyes-García and T. Huanca (eds) *Cambio global, cambio local. La sociedad Tsimane' ante la globalización*, Barcelona: Icaria.

Undurraga, E.A, Z, Cruz-Burga, and R. Godoy. 2014. Demografía y territorialidad del la población Tsimane' actual. In: V. Reyes-García and T. Huanca (eds) *Cambio global, cambio local. La sociedad Tsimane' ante la globalización*. Barcelona: Icaria.

Vadez, V., and Á. Fernández-Llamazares. 2014. De la agricultural a la comercialización. In: V. Reyes-García and T. Huanca (eds) *Cambio global, cambio local. La sociedad Tsimane' ante la globalización*. Barcelona: Icaria.

Zycherman, A. 2013. The Changing Value of Food: Localizing Modernity among the Tsimané Indians of Lowland Bolivia. PhD Thesis. Columbia University, United States.

Chapter 3

Gendered medicinal plant knowledge contributions to adaptive capacity and health sovereignty in Amazonia

Chapter 3

Gendered medicinal plant knowledge contributions to adaptive capacity and health sovereignty in Amazonia[2]

Abstract

Ethnomedicinal systems are key elements of social-ecological systems, providing culturally appropriate and locally accessible health care options, especially for populations with scarce access to biomedicine. The resilience of ethnomedicinal systems generally rests on two pillars: high plant species diversity and a robust local knowledge system, both threatened by local and global environmental change. To understand local knowledge systems' adaptive capacity to a changing environment, gendered knowledge must be addressed. In this paper, we first present a conceptual framework to guide the assessment of diversity and redundancy of knowledge in ethnomedicinal systems through a gender lens. Then, we partially examine this framework with a case study of medicinal plant knowledge amongst lay Tsimane' of Bolivian Amazonia. Our results suggest that Tsimane' medicinal plant knowledge is gendered and that the frequency of reported ailments and the redundancy of knowledge used to treat them are positively associated. We discuss the implications of knowledge diversity and redundancy within a local knowledge system for resilience, adaptive capacity, and health sovereignty.

Keywords

Ethnomedicine; gendered knowledge; global environmental change; intracultural knowledge variation; knowledge diversity; Tsimane'.

[2] Díaz-Reviriego, I., Á. Fernández-Llamazares, M. Salpeteur, P.L. Howard, and V. Reyes-García. Gendered medicinal plant knowledge contributions to adaptive capacity and health sovereignty in Amazonia. *Under review* in *AMBIO*, Special Issue: gender perspective in resilience and adaptation to global change research.

1. Introduction

Ethnomedicinal systems, which generally rely on high species diversity and local knowledge, are critical to the resilience and adaptive capacity of many indigenous peoples and rural communities. Resilience refers to "the capacity of a social-ecological system to absorb recurrent disturbances so as to retain essential structures, processes and feedbacks" (Adger et al. 2005:1036), whereas adaptive capacity refers to "the preconditions necessary to enable adaptation, including social and physical elements, and the ability to mobilize these elements" (Nelson et al. 2007:397). Ethnomedicinal systems are key elements to many indigenous and rural social-ecological systems, as they provide locally accessible, culturally appropriate, and economically affordable health care options, especially for populations with scarce access to biomedicine. High species diversity is a pillar of a resilient ethnomedicinal system, as it provides a wide spectrum of chemical components that can be applied to a wide range of illnesses and to a diversity of people (e.g. infants, elderly, pregnant women). High species diversity also permits functional redundancy, which is considered as a key attribute of resilient social-ecological systems, since more than one species can be used for a given illness, so that, if a particular species becomes unavailable, others may be a substitute (Kassam et al. 2010). Local knowledge systems constitute the other pillar of ethnomedicinal systems and are complex and dynamic; people's ability to generate, transform, accommodate, transmit and apply local knowledge in an integrative fashion is critical to the resilience of such systems (Ellen et al. 2005; Mathez-Stiefel et al. 2012).

Local knowledge is socially acquired through intergenerational transmission and through peers of similar ages (Cavalli-Sforza and Feldman1981) when people engage with one another and with their biophysical environments (Lauer and Aswani, 2009). Consequently, local knowledge cannot be evenly distributed. Diversity of knowledge partly arises from specialization: for example, shamans, herbalists, and midwives hold different bodies of knowledge, which also differs from lay knowledge. Knowledge varies, for example, according to people's differential access to species and to the related knowledge about these species, to their care giving and healing responsibilities, their interests in medicinal plants and healing, and the health concerns of the people they treat. Knowledge diversity also originates from the division of specific tasks and responsibilities socially attributed to different social groups. Researchers who study intracultural knowledge distribution and transmission, know that gender relations - the socially constructed and culturally learned behaviors ascribed to women and men within a particular culture – are highly significant (e.g., Rocheleau et al. 1996; Pfeiffer and Butz 2005). Researchers have also argued that gendered knowledge -or that which is held by women or men but not by both - is context-specific and depends not only on the gender division of labor and use of space, but as well is embedded in cosmologies, beliefs, and norms about appropriate behaviors and the social power accorded to each sex (Howard 2003). It is as complex as the relations produced by the intersection of gender and environment with other racial, ethnic, caste, and class divisions (Banerjee and Bell 2007; Carr 2008).

Attention to gendered knowledge is also required to understand how global environmental change (GEC) affects ethnomedicinal systems. Ethnomedicinal systems are particularly vulnerable to the impacts of GEC, as changes in the vegetation and floristic composition may directly influence the availability and use of medicinal plants (Hanazaki et al. 2013). Changes in the social-ecological context lead to adaptive and maladaptive changes in ethnomedicinal systems (Byg et al. 2010; Giovannini et al. 2011). Recognizing the gendered nature of knowledge provides better insights into local adaptation GEC and, since the challenges and vulnerabilities posed by GEC are not gender-neutral, specific attention must be given to impacts on women's knowledge and access to plant resources.

The aim of this paper is twofold. We first present a conceptual framework to assess diversity and redundancy of knowledge within ethnomedicinal knowledge systems. Then, we partially assess how this framework operates in a particular empirical situation using a case study of medicinal plant knowledge amongst lay Tsimane' of the Bolivian Amazonia.

1.1 Does knowledge diversity contribute to the resilience of knowledge system?

While researchers have long realized that knowledge is unequally distributed within communities and that there are patterns to this knowledge distribution, they have rarely discussed the implications of knowledge diversity, or the differences in the knowledge held by different people**,** for adaptive capacity and for knowledge systems resilience. Only recently, some have argued that differentiated knowledge may be an asset for adaptation to changing social and ecological conditions. Ruelle and Kassam (2010) studied plant knowledge among Standing Rock Nation elders in the United States, and found that elders hold knowledge about different plants and also different knowledge about the same plants. Differences are linked in part to variations in species' use and spatial distribution, and harvesting strategies. Knowledge diversity allows the knowledge system to store more potential options for coping with change, which may improve knowledge system resilience and hence communities' adaptive capacity in response to change.

In order to shed light on the potential mechanisms through which diversity within knowledge systems may enhance adaptive capacity and resilience, we depart from the ecological concept of *functional diversity,* which refers to the number of functionally different groups of species that influence an ecosystem's performance. We put forth the concept of *functional knowledge diversity* to refer to the number of functionally different types of knowledge (e.g., knowledge held by shamans, that held by other healers, lay people's knowledge) that affect the performance of knowledge systems. Similar to the ecological concept of 'functional types', or the set of species that have similar effects on specific ecosystem processes and dynamics (Gitay and Noble 1997), we put forth the concept *functional knowledge type,* or the set of species knowledge that has a similar function in the knowledge system. In a specific ethnomedicinal plant knowledge system, functional knowledge type refers to the knowledge of a set of medicinal plants that have the same function (i.e. use or therapeutic category): that is, all of the plants that are known and used to treat the same ailment. The same plant species can belong to different functional knowledge

types simultaneously when it is used to treat different ailments. Thus, the concept of functional knowledge types serves to assess people's ability to use different medicinal plants to treat health afflictions identified within one system.

1.2 Does knowledge redundancy enhance knowledge system resilience?

The concept of *ecological redundancy* means that there is more than one species that can perform the same function or functions in a given ecosystem (Walker 1992). So, if one species disappears, functionally redundant species provide the capacity to either resist change or bounce back after disturbance (resilience). Drawing on the concept of ecological redundancy, Alburquerque and Oliveira (2007) proposed a model of utilitarian redundancy in local medical systems. They argue that such redundancy is important because it may reduce the potential impacts of overharvesting on particular species and may allow the functions of the system to be maintained when a given species is over-harvested, ensuring system resilience. The measure of redundancy they propose aims to identify and quantify the relation between species richness (i.e., those medicinal plants species that are known) and their function within the ethnomedicinal system (i.e., uses or therapeutic categories according to the local illness classification system). This model assumes that, when treating any given ailment, people have preferences for some plants over others but when preferred species are unavailable, other species can substitute. The assumption dovetails with some research that reports that people use substitute species only when preferred species are absent (Santoro et al. 2015). However, other research shows that, in such circumstances, people may instead recur to biomedical resources (Ferreira Junior's et al. 2011).

Following Alburquerque and Oliveira's utilitarian redundancy model (2007), we add the concept of *functional knowledge redundancy*, defined as the overlap in species knowledge within functional knowledge types. In an ethnomedicinal knowledge system, this refers to the number of species that are used to treat the same ailment. Such redundancy could arise either different plant species are used to treat the same illness or different parts of the same species are used or different means of preparation. Usually it is species diversity that provides the basis. Functional knowledge redundancy may arise from people's differential access to plant species and the related knowledge as well as from patterns of knowledge transmission; different people may develop diverse and overlapping (redundant) knowledge to treat the same ailments, contributing to knowledge redundancy and diversity.

In this paper, we argue that functional knowledge diversity in ethnomedicinal knowledge systems is likely to be expressed in relation to specialized and lay knowledge. Furthermore, within functional knowledge types, gendered knowledge may increase the knowledge diversity that helps communities cope with a changing environment and thus influences the resilience of the ethnomedicinal system.

2. Tsimane' medicinal knowledge and health: vulnerability in the face of global change

We worked in villages within the Tsimane' Territory in the Department of Beni, Bolivian Amazonia. The Tsimane' are a group of forager-horticulturalists who succeeded in resisting Catholic and Protestant proselytism throughout the 1950s. The Protestant New Tribes Mission profoundly influenced Tsimane' culture through schooling and the provision of basic biomedical services. In the late 1980s, the missionaries also supported the foundation of a political organization, the *Gran Consejo Tsimane'*. Contact with merchants, loggers, and anthropologists, among others, have also affected Tsimane' culture in diverse ways. On average, Tsimane' adults have completed about two years of formal schooling (Reyes-García et al. 2010) and some 78% of women and 55% of men only speak the Tsimane' language (Undurraga et al. 2014). Even though the government has expanded primary health care services to rural areas over the past decade, access to biomedical healthcare is very limited, especially for those living far from towns.

The Tsimane' are increasingly integrated into the regional economy, mostly through sales of thatch palm, rice, and plantains in towns or to traders who visit their villages and through wage labor, where men work for local loggers and ranchers. Nevertheless, Tsimane' livelihoods and healthcare are still highly self-sufficient and dependent on local forest resources. This dependence on forest resources is threatened by rapid ecosystem change in their Territory, which increases vulnerability and challenges their adaptive capacity (Fernández-Llamazares et al. 2015). For example, research has documented increased landscape fragmentation and deforestation, that reduces the diversity and abundance of wildlife, affecting the Tsimane's food security (Luz 2013; Zycherman 2013), with potentially serious health implications.

Broader cultural changes have also occurred among the Tsimane'. Traditionally, the *cocojsi'* (shaman) had a very important role mediating between humans and spiritual beings. Now, only a few elders know how to administer certain traditional remedies against sorcery, and people sometimes refer to them as *cocojsi'* (Huanca 2014). These practices persist mostly in more remote villages, where people attribute illness and death to sorcery. In general, lay Tsimane' typically use medicinal plants to treat illnesses (Reyes-García et al. 2005), but ethnobotanical knowledge is changing as they adapt to economic, social, political, and environmental change, where knowledge loss is more acute for men than for women, and for people living in villages that are closer to towns compared with those living in remote villages (Reyes-García et al. 2013).

Research amongst the Tsimane' shows a high prevalence of influenza, respiratory problems and gastrointestinal afflictions, as well as tuberculosis and cutaneous leishmaniasis (Tanner 2005). Calvet-Mir et al. (2008) found that the Tsimane' often use a combination of ethnomedicine and pharmaceuticals to treat illness, thus presenting an example of medical pluralism (Tanner and Rosinger 2014).

3. Methods

We applied a mixed methods approach throughout 18 consecutive months of fieldwork (January 2012-August 2013). We collected data to assess 1) medicinal plant knowledge, 2) ailments suffered and remedies used, 3) the distribution of medicinal plant knowledge and redundancies in the knowledge used to treat these ailments, and 4) perceptions of the division of healing and caretaking responsibilities.

We obtained consent to carry out the research from the *Gran Consejo Tsimane'*. Subsequently, a community meeting was held in two villages (V1 and V2) along the Maniqui River (see chapter 2, Figure 2.a) to inform and explain the project to villagers and to determine the willingness of men and women aged 16 years and older to participate. To minimize the risks of a potential source of gender bias in data collection, we trained a team of male and female assistants and translators (see Morgen 1989 in Pffeifer and Butz 2005).

3.1 Qualitative methods

Qualitative data were collected through participant observation, for example, in medicinal plant foraging expeditions and remedy preparation. In the first months of fieldwork, 12 semi-structured interviews were conducted on Tsimane' healing system – e.g. we asked about the most common health concerns in the area, and how informants responded to those complaints. Three focus groups discussions were also carried out with two groups of ten and four women, and one group of seven men, to address perceptions and socio-cultural norms around access to and control over medicinal plants and pharmaceuticals, and gendered behaviors and responsibilities regarding health care giving. All this information helped contextualize the research and interpret the results.

3.2 Quantitative methods

Quantitative methods were used to 1) identify plants with medicinal uses (free-listings), 2) assess medicinal knowledge distribution, diversity, and redundancy (free-listings and a knowledge survey) and 3) determine health ailments suffered by the Tsimane' and the treatments used (health survey).

3.2.1 *Assessing the intracultural diversity of medicinal plant knowledge*

We use free-listings to identify plants with medicinal uses. We interviewed a sample of 20 women and 20 men aged 16-91 (mean=47 years) in each study village, asking informants to list all of the medicinal plants they knew. We then asked the informants to list all of the ailments that could be potentially treated with each plant listed, the parts used, and the methods of preparation.

We used free-listings to assess the differences in knowledge by sex and age groups (<25, ≥25<50, ≥50 years), using similarity-based statistics. We estimated the weight of the sex and

age variables in explaining the overall variations in knowledge, using schooling level and monolingualism in the local language as references. Following Salpeteur et al. (2015), we used the Jaccard index to build separate distance matrices from each data set. We then applied a Between-class Correspondence Analysis (BCA) and a permutational multivariate ANOVA on the distance matrices, using the packages ade4 (Chessel et al. 2004) and vegan (Oksanen et al. 2014) in the R software (R Development Core Team 2011).

With results from the first 20 free-listings, we designed a medicinal knowledge survey (available at: http://icta.uab.cat/Etnoecologia/Docs/[423]-lektests.pdf) that was applied to a sample of 63 women and 58 men aged 16-91 years (mean=37), consisting of structured questions about 16 medicinal plants. To develop the survey, we first calculated the salience of each plant according to its occurrence and position in free-listings (Thompson and Zhang 2006) and then created three salience groups. We then randomly selected three plants from the high and low salience groups, and four plants from the medium salience group. Women and men's free-listings were analyzed separately, and three more plants listed only by women and three listed only by men were selected. To administer the survey, local assistants read the vernacular names of the selected plants and asked informants whether they knew the plant and, if so, to list up to three different symptoms or ailments that could be treated with it. Informants were also asked their age, educational level, fluency in Spanish, and whether they had ever been attended in a hospital setting.

The following variables where then constructed for each respondent: number of plants known, number of illnesses treated with the plants known and average number of uses per medicinal plant known. We examined the distribution of these variables with a Kolmogorov-Smirnov test and compared the values of such variables by sex and age groups with a t-test of mean comparisons, according to the distribution of the variables.

3.2.2 *Exploring medicinal plant knowledge redundancy*

To explore redundancy in Tsimane' medicinal plant knowledge, we collected self-reported morbidity data using a health survey. The survey was administered up to six times over the course of 12 months to a sample of 106 women and 89 men aged 16-91 (mean= 34 years). Adults (≥16 yrs) self-reported information and mothers (or the adult in charge in case of the mother's absence) reported on their children's health. We asked about the ailments suffered in the two weeks prior to the interview and the treatments used. We classified treatments as 1) traditional (medicinal plants or others), 2) biomedical, or 3) mixed (a combination of traditional and biomedical treatments).

We then evaluated the potential correspondences between data collected through the free-listings, the knowledge survey, and the health survey. Ailments or uses reported in the health survey were used as a proxy to refer to functional knowledge types. Specifically, we constructed a matrix in which each row corresponds to the set of medicinal plants within a functional knowledge type. Through the columns in this matrix, we mapped out the association between i) the most frequently reported ailments in the health survey (columns A

and B), and ii) the number and names of plants that women and men listed as remedies for such ailments (columns C-H), an indicator of functional knowledge redundancy. We calculated Spearman correlations between frequency of reported ailments and functional knowledge redundancy within functional knowledge types for women and men.

Plants voucher specimens were not collected for this study. Vernacular names given by informants were recorded and linked to botanical genera based on previous ethnobotanical research in the area; therefore, the decision to associate a local name with a scientific species name was made only when a single member of the genus was known to be equivalent to the vernacular name reported. Vernacular names are used throughout the text; see correspondence to botanical genera in Appendix 1.

4. Results

4.1 Contextualizing Tsimane' healing practices

Focus group discussions provided a clear picture of Tsimane' health caregiving behavior. Men and women alike attribute caregiving to women and recognize some elder women as midwives, who number roughly one per extended family or clan in the village:

> *We are the ones who take care of the family. When our children are sick we take care. Also some older women know how to help with labor, they know plants but also they use injections. We sometimes gather medicinal plants, and sometimes we ask our men to bring them, they also know where to find them. (Women, 28-78, V1, April 2012).*

Both women and men noted that they seek advice and treatment from the *cocojsi* (shaman) when they perceive that their health problem is a result of *farajtacdye'* (sorcery) or *därä'cansi* (forest beings), as those conditions are beyond the scope of lay plant remedies and biomedicine. Focus groups participants also said that they know how to use *corpa*, a traditional Andean healing technique involving the use of mineral salts that has been assimilated by the Tsimane'. In the remote villages, traders traveling on the Maniqui River year-round bring medical supplies and trade or barter pharmaceuticals in exchange for forest or agricultural products. Mobile health campaigners also visit the villages. As one informant stated, there are several sources of biomedicine:

> *The doctor comes once a year; this year he has not come yet. He does check-ups; he uses medicines, but not medicinal plants. Medicines are expensive. When I have palm thatch I barter it for medicines with the merchant, but they are expensive. (Man, 33, V1, April 2012).*

Pharmacies in local towns are also sources of biomedical treatments. San Borja Hospital and other medical facilities are located in or near urbanized areas, but treatments are costly and most Tsimane' cannot afford them.

Results from the semi-structured interviews indicate that the Tsimane' differentiate common afflictions as strong (*fersi*) and mild (*oyayas*), as well as supernatural health complaints cause by bewitchment. They combine medicinal plants, pharmaceuticals, and shamanic rituals to treat their health problems:

> *When my son catches a cold I use medicinal plants, also to treat his scabies. If we feel very weak we can also go to the hospital. There, doctors can cure leishmaniasis but they cannot cure us if we got bewitched in the forest. Then we have to go to the cocojsi. (Woman, 44, V2, May 2012).*

The Tsimane' perceive that they are bewitched because they experience a different typology of pain. They say that they can become bewitched when going to the forest or working in their agricultural fields. They describe how this feels,

> *When I feel like something is biting me inside, like spines inside my flesh, then I go to the cocojsi, he knows how to take them out. (Man, 37, V1, April 2012).*

4.2 Intracultural variation and diversity of medicinal plant knowledge

A total of 78 medicinal plants were listed by at least two people in the free-listings (Appendix 1). Some of the plants were reported to have only one medicinal use, but others, i.e. *ere'*, *saute* and *tamtac*', had up to six different uses. Informants reported using a total of nine different plants parts, eight means of preparation, and seven means of application. The most frequently reported part used was bark (40% of the uses), followed by leaves (≈18%) and roots (≈18%). The high frequency of root use is due to women's common use of *saute* (ginger) and *buisi* for contraception. The most frequently reported means of preparation was boiling (50%). Women reported rubbing on the skin as a means of application in 13% of the cases, and men reported making poultices in about 10% of the cases.

Results from the Between-class Correspondence Analysis (BCA) show differences by sex in relation to uses, parts, and means of preparation. In all three cases, the analysis shows that men's and women's answers were significantly different (uses $p<0.1$; parts $p<0.05$; preparations $p<0.01$). The one-dimension projection of the variability in answers shows that the two groups are clearly separated in the three cases (Figure 5). The permutational multivariate ANOVA shows that, when introducing other factors in the analysis (age, education and monolingualism), the sex of the informant explains about three percent of the total measured variation in knowledge of uses, parts, and means of preparation, while the other factors are not significant (Table 2).

Figure 5. Projections in a one-dimension space of the variability of knowledge reported in free-listings regarding medicinal plants uses, parts, and preparation means. Points represent individuals, purple: women, green: men.

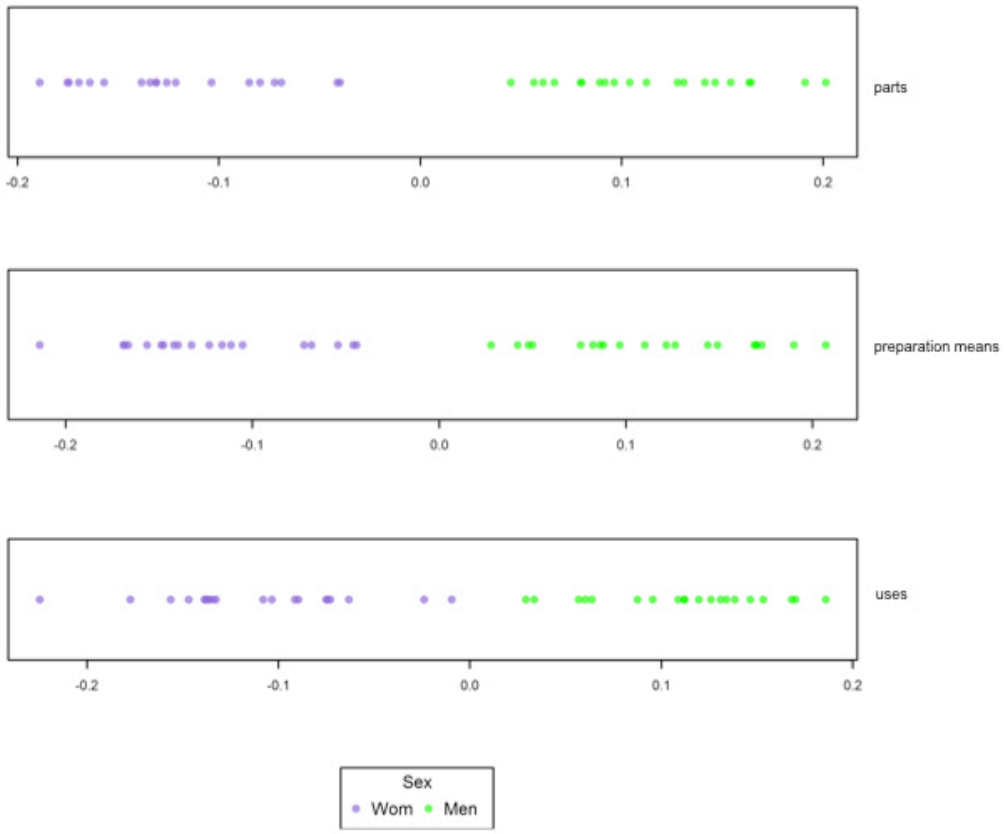


Table 2. Results of the permutational multivariate analysis of variance used to discriminate the weight of each variable (sex, age, schooling level and monolingualism) in explaining the observed variations and similarities in medicinal plant knowledge of medicinal plants useful parts, preparations means, and uses.

	Permutational Anova		
Variables	*R^2 value with significance level*		
	parts	preparations	uses
sex	0.03472 **	0.03348 **	0.02870 *
age	0.04998	0.05012	0.05301
schooling level	0.02767	0.02983	0.02697
monolingualism	0.02382	0.02631	0.02870

Note: p-values * ,**, and *** significant at the 0.1, 0.05 and 0.01 level

A close examination of the free-listings data suggests that gendered differences refer both to the quantity of knowledge and the substance of knowledge. For example, although women and men generally agreed on the most commonly reported medicinal uses, only women reported medicinal reproductive health uses (e.g. fertility, labor, and contraception), and uses related to childhood ailments such as chickenpox. Only men reported medicinal uses related to the gallbladder (Table 3).

Results from the knowledge survey help to better illustrate the differences found with BCA for the free-listings, indicating gendered variation in the ability to name medicinal uses for 16 selected plants species ($p<0.1$) (Table 4). Women knew more medicinal uses ($p<0.05$) and more uses per plant ($p<0.05$) than men (Figure 6). From the various age-sex categories, young men (≤25 years of age) reported fewer medicinal plants and fewer medicinal uses per plant than people in any other age category ($p<0.05$), whereas older women (>50 years of age) reported more medicinal plants and uses (Table 4).

Figure 6. Results from knowledge survey. Comparison of box-plot distributions of a) the number of ailments a person can treat using medicinal plants, and b) average number of uses known by medicinal plant known.

a)

b)

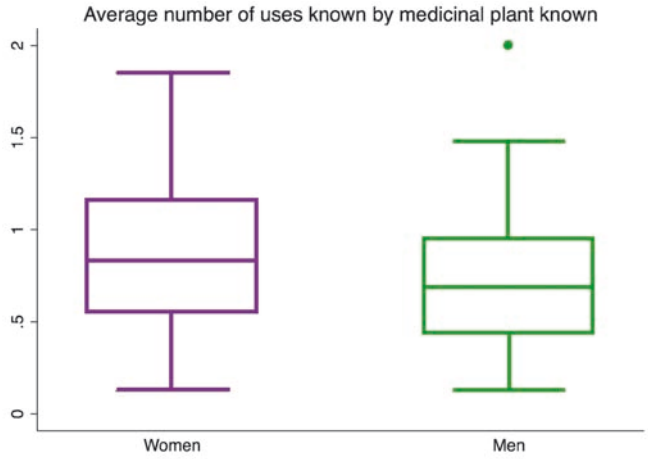


Table 3. Women and men answers to knowledge survey by plant

	Women				Men			
Vernacular name	**Number of ♀ that give a medicinal use**	**Number of ailments that can be treated**	**Most common ailments that can be treated with the plant**	**Specific ailments that can be treated with the plant cited by ♀**	**Number of ♂ that give a medicinal use**	**Number of ailments that can be treated**	**Most common ailments that can be treated with the plant**	**Specific ailments that can be treated with the plant cited by ♂**
vambason	44	15	stomach pain,diarrhea	menstruation	44	16	diarrhea back pain	gallbladder
macha	25	13	back pain flu	post labor	25	12	back pain muscle ache	scabies
buisi	57	15	stomach ache menstruation	muscle ache contraception	40	14	stomach pain	
parta	6	5	diarrhea back pain		10	7	diarrhea stomach pain	flu
cravu	24	11	flu diarrhea	labor	26	10	flu tooth ache	
jamo'tarara	22	8	leishmaniasis fungus	fertility muscle ache	17	5	leishmaniasis fungus	
punuvacdyes	24	11	infected sore (boil) muscle ache	muscle ache	19	10	infected sore (boil) muscle ache	
que'tsejtse	18	5	muscle ache		15	8	muscle ache	
tyi'mujmure	37	12	infected sore (boil) fever	fever diarrhea	30	13	infected sore (boil) fever	
yavitus	20	13	muscle ache dizziness	menstruation	12	10	muscle ache infected sore (boil)	
arara'	51	8	fungus muscle ache		52	9	fungus muscle ache	
banana	23	8	bullet ant sting muscle ache	stomach pain	15	7	bullet ant sting muscle ache	
ñetas	30	12	muscle ache	chickenpox to gain weight	20	14	stomach pain	menstruation
marva	58	19	wasp sting labor	menstruation scabies pre-labor	41	14	wasp sting cuts	
mature	55	17	fungus labor	babies weeping	48	19	fungus tooth ache	
tson'sonty	26	12	leishmaniasis fungus		33	9	leishmaniasis fungus	

Table 4. Results of statistical analyses (t-test) of women's and men's knowledge of medicinal plants from the knowledge survey.

Variables		Definition	Total	Women	Men	p-value
Number of plants known		Nº of plants with a medicinal use (from 0 to 16)	7.61 (2.21)	7.95(2.98)	7.25(2.83)	0.09*
Number of different illness (uses)		Nº of different illnesses treated with the selected plants	7.42(2.95)	7.92(2.93)	6.8782.90)	0.02**
Average number of uses		Average nº of uses known per medicinal plant recognized	0.81(0.39)	0.87(0.40)	0.74(0.38)	0.03**
By age groups						
Number of plants known	<25		6.26(2.13)	6.78(2.27)	5.6(1.80)	0.05*
	>25<50		8.12(2.87)	8.39(2.88)	7.84(2.87)	0.22
	>50		8.23(3.50)	8.64(3.93)	7.82(3.16)	0.30
Number of different illness (uses)	<25		6.35(2.37)	6.89(2.40)	5.67(2.22)	0.07
	>25<50		7.94(3.09)	8.24(3.16)	7.63(3.03)	0.21
	>50		7.55(3.04)	8.73(2.80)	6.36(2.91)	0.03**
Average number of uses	<25		0.65(0.36)	0.74(0.39)	0.54(0.28)	0.05**
	>25<50		0.86(0.40)	0.89(0.41)	0.83(0.40)	0.26
	>50		0.90(0.38)	1.03(0.36)	0.78(0.37)	0.06

4.3 Use of ethnomedicine and biomedicine in the treatment of ailments

Some 47% of women and 37% of men reported to have been ill in the two weeks prior to the survey. A total of 38 different ailments were reported, where different people reported 22 (Table 5, column A). The most commonly reported ailments were colds, coughs, diarrhea, body or muscle ache, and fever (Table 5, column B). When asked about the treatments used for the ailment, in 24% of the cases both women and men reported not to have done anything, whereas in 34% of the occurrences traditional medicine was used. Women used biomedicine

for 29% of the ailments they reported and men used it in 20% of the instances. Women used a combination of traditional and biomedicines for 13% of the instances, whereas men used a combination in 20% of the instances. When parents were asked about the treatments administered to children, they did not apply a treatment in 18% of the cases, used traditional medicine in 26%, biomedicine in 39%, and a combination of both in 16% of the instances. Biomedicines used included pills (e.g., aspirin, diclofenaco or paracetamol), creams and ointments, vitamins, and antibiotics.

4.4 Knowledge redundancy within functional knowledge types

In spite of certain exceptions, we observe a greater redundancy among medicinal plants used for the ailments that were most frequently reported in the health survey - e.g. colds, diarrhea, and aches (Table 5, columns A to D). Overall, we found a correlation between the frequency of illnesses reported and the redundancy of medicinal plants used to treat them (women's Spearman *rho*= 0.68 p<0,001; men's Spearman *rho*=0.61 p<0, 05). Functional knowledge redundancy was similar for women and men, except for headaches, where women reported knowing more plants (greater redundancy). Despite similar levels of redundancy within functional knowledge types (sets of plants listed by ailment), there were differences by sex (see Table 5, columns E to H). For example, both sexes reported 17 plants for treating body aches, but women listed *tam tac'*, *rovodyes*, and *punucvadyes* more frequently, whereas men listed *saute* and *morifi* more frequently; only women reported *vambason* and *arara'*, whereas *mashaty* and *potona* were reported only by men. Fever and back pain (sometimes describe as body pain) presented exceptions with *low* redundancy. For example, while fever was the second most frequently reported ailment, only three plants were free-listed as remedies (although three more species were reported health survey). It may be that, as a very specific symptom, it is treated with fewer plants in comparison with ailments such as colds, which may include a diverse topology of symptoms. We also observed that fever is commonly treated with pharmaceuticals. The use of an alternative treatment could, therefore, explain lower plant knowledge redundancy.

Women and men agreed more about the least frequently reported ailments both in terms of the total number of species reported and those reported within functional knowledge types. They named the same plants for bewitchment, eye ailments, intestinal parasites and skin conditions, which may indicate that knowledge for this ailments is widely shared or that, when only a single or a few species are effective, this is more generally known. For example, *tyi'* was the only plant used to treat general skin problems, and to protect newborns' skin. There was also agreement the about the two species used against bewitchment (*conojfoto* and *cos'*), which is an important local concern. Some of the afflictions reported in the health survey (e.g., chickenpox, post-labor) were not mentioned in the free-listings (i.e., no plants were named to treat these conditions).

Table 5. Information on ailments reported and plants reported to treat them in the health survey as well as knowledge of medicinal plants reported that could be used to treat them in free-listings (FL) and knowledge survey. Each row corresponds to the set of medicinal plants within a functional knowledge type (use). Columns C to H used as indicators of functional knowledge redundancy.

A	B	C	D	E	F	G	H	I	J	K
Ailments	**Report frequency**	**Number of plants reported by ♀ in FL as treatment**	**Number of plants reported by ♂ in FL as treatment**	**Most frequent reported plants by ♀ in FL as treatment**	**Most frequent reported plants by ♂ in FL as treatment**	**Plants reported just by ♀**	**Plants reported just by ♂**	**Most frequent reported plants in FL as treatment (>10% total sample)**	**Plants reported to be employed in health survey to treat the ailment**	**Knowledge survey results (reported by >10% total sample)**
Cold	211	18	16	ere', shepi	shepi, chorecho	coti, cravu	ashashaj	shepi, ere', chorecho	shepi, ere' ashashaj, saute, chorecho	cravu, mature
Fever	62	2	3	shepi	bejqui, viyucure		bejqui viyucure		viyucure, cos' shepi'is, shepi, ashashaj	tyimujmure
Cough	41	6	7	tamtac, saute	tamtac, saute		shepi'is	saute, tamtac	shepi, ere', tamtac	
Backpain	33	3	3	vambason	macha	vambason	macha			vambason, macha, arara'
Diarrhea	32	16	16	oveto', vambason	oveto', chura'			oveto, bätin, chura'	tamtac, tyi, oveto	vambason, buisi
Headache	30	7	2	saute,shepi, rovocdyes, viyujcure, vujnare	chito', ufjare	saute,shepi, rovocdyes, viyujcure, vujnare			seviria, vayori, chorecho, Tamtac, shepi, chij	
Body ache	27	17	17	tamtac, rovocdyes, punuvacdyes	morifi, saute	vambason	arara', mashaty, potona	tamtac, morifi, punuvacdyes	chorecho, saute, ere', millo/corpa, titij, conojfoto, arara'	que'setjet ,arara' buisi, punuvacdyes, ,ñetas
Stomach pain	16	8	10		tamtac, oveto'	tamtac, saute	ujfare, vijsi	tamtac	vambason, tamtac,	vambason,buisi,ñetas

A	B	C	D	E	F	G	H	I	J	K
Ailments	**Report frequency**	**Number of plants reported by ♀ in FL as treatment**	**Number of plants reported by ♂ in FL as treatment**	**Most frequent reported plants by ♀ in FL as treatment**	**Most frequent reported plants by ♂ in FL as treatment**	**Plants reported just by ♀**	**Plants reported just by ♂**	**Most frequent reported plants in FL as treatment (>10% total sample)**	**Plants reported to be employed in health survey to treat the ailment**	**Knowledge survey results (reported by >10% total sample)**
Fungus	11	9	12	tamtac, saute, conojfoto	saute, tamtac		jämecatidye, undye, uruuru	saute tamtac	arara', cos'	arara',marva,mature,tsonsoj
Chickenpox	11	-	-						momoch, conojfoto	
Anemia	9	-	-						yän	
Vomit	5	-	-						not specify	
Skin	4	1	1	tyi'	tyi'				cos'	
Bewitchment	4	2	2	conojfoto, yän	conojfoto, yän				conojfoto, yän,	
Intestinal parasites	3	1	1	titij	titij					buisi
Eye complaint	3	1	1	cajin'si	cajin'si					
Toothache	3	-	-						shepi	mature
Boil/skin Sore	2	1	2	titij	mojmosh		mojmosh			punuvacdyes,tymujmure
Injury	2	2	4	yantes	Ijmeme, itsi	shiveñi	yantes	ijmeme, itsi	vashi	
Knee pain	2	-	-						tamtac	
Post partum	2	-	-						macha	buisi
Hemorrhage	2	-	-							

continuation Table 5

5. Discussion

We propose a conceptual framework focusing on the potential for medicinal plant knowledge to sustain the functionality and adapt to the dynamics of the ethnomedicinal system undergoing social and ecological change. We partly empirically examined this conceptual framework using Tsimane' medicinal plant knowledge. Our study has three main empirical results: a) among lay Tsimane', medicinal plant knowledge is widely shared but gendered; b) there is a positive association between the frequency of reported illnesses and functional knowledge redundancy within the set of plants used to treat them; and c) at a practical level, women and men used medicinal plants or traditional treatments in the same proportion for the ailments reported, but women used more biomedical treatments and men use more a combination of biomedicine and traditional medicine.

Previous research showed that Tsimane' ethnobotanical knowledge is widely shared (Reyes-García et al. 2003). However, our first result suggests that there are gendered differences in medicinal plant knowledge. This diversity seems to reside in women's greater knowledge of medicinal uses associated with reproductive and pediatric ailments, which accords with other research showing a positive association between maternal ethnobotanical knowledge and children's health (McDade et al. 2007).

Researchers have considered the implications of intracultural knowledge distribution for the resilience and adaptive capacity of knowledge systems. Some argue that - from a probabilistic perspective - a normal distribution of knowledge in an ethnomedicinal system may reduce its vulnerability to disturbances (Ferreira Junior et al. 2013; Santoro et al. 2015). For example, if only one person holds specialist knowledge and passes away before this knowledge is transmitted, this knowledge is lost. But is such knowledge is more widely distributed it is less likely to disappear. It has also been claimed that knowledge diversity may contributes to adaptability in the long-term (Ruelle and Kassam 2011). For example, with climate change, a diversity of knowledge about species and their distribution and abundance may offer options for coping with variation in seasonality. Here we argue that knowledge diversity may make significant contributions to adaptive capacity beyond the household level – i.e. at community level (see Reyes-García et al. *in press*). As principal caregivers and health custodians at a household and community level, Tsimane' women share the benefits emerging from their more diverse knowledge with rest of their society.

The second important finding is that, overall, there is a greater medicinal plant knowledge redundancy for the most frequently reported ailments. This knowledge redundancy may offer a variety of options for treating such ailments. However, there are a few exceptions, such as fever, a specific symptom often treated with pharmaceuticals, which may in part explain lower plant knowledge redundancy.

Despite finding similar degrees of redundancy in numbers of medicinal plants that treat frequent complaints, gendered knowledge and preferences are also evident, which contributes to redundancy within the knowledge system. There is greater agreement between the sexes with respect to treatments for some of the least frequently reported ailments. The lower

knowledge redundancy regarding medicinal plants used to treat bewitchment or sorcery, might also suggest that such treatments are more often part of the shamanic or specialized domain of knowledge.

Finally, our study also indicates that Tsimane' women and men use plant traditional treatments slightly more often than biomedical or combined treatments. More women reported using biomedicine and more men used a combination of the two. Mothers reported a considerably higher use of biomedicines to treat their children. As principal caregivers, women might hold not only more knowledge of medicinal plants but also more knowledge about biomedicine. As our qualitative results suggest, the Tsimane' find pharmaceuticals to be more effective for certain health problems, and say that some medicinal plants are difficult to find in the villages and can only be found in the distant forest. This could also lead women, who usually have fewer opportunities to go to the forest, to use more biomedicines.

Health and medicinal knowledge research in disciplines such as anthropology and ethnobiology have suffered from a 'professional bias' (Kothari 2003, Gold and Clapp 2011) and has mostly focused on the knowledge and practices of specialists (i.e., shamans, healers), positions that in many cultures are often held mainly by men, thus neglecting women's medicinal knowledge and access to the different treatments available. However, many common health concerns are largely treated at household level (Wayland 2001, Finerman and Sackett 2003) where mainly laywomen are responsible. The variety of treatment options and the diverse knowledge associated with them also contributes to health sovereignty (Kassam et al. 2010), as it enables individuals to opt for treatments that they consider appropriate. The adaptive capacity of communities' knowledge and medical systems may rely on the use of medicinal plants as the primary source of healing or as an alternative to, or in combination with, biomedical options at a practical level.

6. Conclusion

The conceptual framework provided in this paper to assess knowledge diversity and redundancy within local knowledge systems may be useful for researchers who seek to evaluate adaptive capacity and resilience, especially of ethnomedicinal knowledge systems. Beyond medicinal plant knowledge redundancy and its effect on knowledge system functionality, future research would benefit substantially from an evaluation of the distribution and availability of medicinal plant species in the study area. Future research should also pay attention to the complexity in the treatments, e.g., the use of combinations of medicinal plants, and of medicinal plants with other traditional remedies, to treat illness. The data collected to evaluate knowledge redundancy only considered the use of individual plants while, in practice, the Tsimane' employ mixed remedies, thus medicinal knowledge redundancy may have been underestimated. Furthermore, as human adaptation to change emerges from heterogeneous processes, it would be helpful to carry out research that focuses not only on the content of knowledge, but as well on the context of its production, capturing the recursive relationship between knowledge and agency as mediated by power, culture, and history within adaptive dynamics (Leach 2008; Cote and Nightingale 2011). This would allow

a more nuanced understanding of the ethnomedicinal knowledge system's functionality and adaptive capacity.

7. References

Adger, W. N., T. Hughes, C. Folke, S. R. Carpenter, and J. Rockstrom. 2005. Social- ecological resilience to coastal disasters. *Science* 309 (5737):1036–1039.

Alburquerque, U.P., and R.F. Oliveira. 2007. Is the use-impact on native caatinga species in Brazil reduce by the high species richness of medicinal plants? *Journal of Ethnopharmacology* 113:156-170.

Banerjee, D., and M. M. Bell. 2007. Ecogender: locating gender in environmental social science. *Society and Natural Resources* 20 (1): 3–19.

Byg, A., J. Salick, and W. Law. 2010. Medicinal plant knowledge among lay people in five Eastern Tibet villages. *Human Ecology* 38(2): 177–191.

Calvet-Mir, L., V. Reyes-García, and S. Tanner. 2008. Is there a divide between local medicinal knowledge and Western medicine? a case study among native Amazonians in Bolivia. *Journal of Ethnobiology and Ethnomedicine* 4:18.

Carr, E. R. 2008. Men's crops and women's crops: the importance of gender to the understanding of agricultural and development outcomes in Ghana's Central Region. *World Development* 36 (5): 900–915.

Cavalli-Sforza, L.L., and M.W. Feldman. 1981. *Cultural transmission and evolution: A quantitative approach*. Princeton N.J: Princeton University Press.

Chessel, D., A. Dufour, and J. Thioulouse. 2004. The ade4 package I. One-table methods. *R News* 4: 5-10.

Cote, M., and A.J. Nightingale. 2011. Resilience Thinking Meets Social Theory: Situating Change in Socio-ecological Systems (SES) *Research. Progress in Human Geography* 36(4):475–89.

Ellen, R., P. Parkes, and A. Bicker, eds. 2005. *Indigenous Environmental Knowledge and Its Transformations: Critical Anthropological Perspectives*. The Neatherlands: Harwood.

Ellis, R. 1996. A taste for movement: an exploration of the social ethics of the Tsimanes of lowland Bolivia. PhD Thesis. St. Andrews University, Scotland.

Fernández-Llamazares, Á., I. Díaz-Reviriego, A.C. Luz, M. Cabeza, A. Pyhälä, and V. Reyes-García. 2015. Rapid ecosystem change challenges the adaptive capacity of Local Environmental Knowledge. *Global Environmental Change* 31: 272-284.

Ferreira Junior, W.S., A.H. Ladio, and U.P. Alburquerque. 2011. Resilience and adaptation in the use of medicinal plants with suspected anti-inflmamatory activity in the Brazilian Northeast. *Journal of Ethnopharmacology* 138:238-252.

Ferreira Júnior, W.S., F.R. Santoro, A.L. Borba, A.H. Ladio, and U.P. Albuquerque. 2013. The role of individuals in the resilience of local medical systems based on the use of medicinal plants – a hypothesis. *Ethnobiology and Conservation* 2(1):1-10.

Finerman, R., and R. Sackett. 2003. Using Home Gardens to Decipher Health and Healing in the Andes. *Medical Anthropology Quarterly* 17 (4): 459–482.

Giovannini, P., V. Reyes-García, A. Waldstein, and M. Heinrich, 2011. Do pharmaceuticals displace local knowledge and use of medicinal plants? Estimates from a cross-sectional study in a rural indigenous community, Mexico. *Social Science and Medicine* 72(6): 928-936.

Gitay, H., and I.R. Noble. 1997. What are plant functional types and how should we seek them? In *Plant Functional Types*, ed. Smith, T.M., H.H. Shugart, and F.I. Woodward, 3–19, Cambridge University Press.

Gold, C., and R. Clapp. 2011. Lay Healing, Medicinal Plants, and Indigenous Healthscapes in Highland Peru. *Latin America Research Review* 46(3):93-111.

Hanazaki, N., D.F. Herbst, S.Marques, and I. Vandebroek. 2013. Evidence of the shifting baseline syndrome in ethnobotanical research. *Journal of Ethnobiology and Ethnomedicine* 9:75.

Howard, P.L. 2003. *Women and plants: gender relations in biodiversity management and conservation*. London: Zed books.

Huanca, T. 2014. La cosmovisión Tsimane' tradicional en un contexto global. In *Cambio global, cambio local. La sociedad Tsimane' antes la globalización*, ed. V. Reyes-García, and T. Huanca. Barcelona: Icaria.

Kassam, K.A., M. Karamkhudoeva, M. Ruelle, and M. Baumflek. 2010. Medicinal plant use and health sovereignty: Findings from the Tajik and Afghan Pamirs. *Human Ecology* 38(6):817–829.

Kothari, B. 2003. The invisible Queen in the plant kingdom: gender perspectives in medical ethnobotany. In *Women and plants: gender relations in biodiversity management and conservation,* ed. Howard, P*, pp*.London: Zed books.

Lauer, S., and S. Aswani. 2007. Indigenous Ecological Knowledge as Situated Practices: Understanding Fishers' Knowledge in the Western Solomon Islands. *American Anthropologist* 11(3): 317-329.

Leach, M. 2008. Re-framing resilience: A symposium report. STEPS Working Paper 13. Brighton: STEPS Centre.

Luz, A.C. 2013. The Role of Acculturation in Indigenous People's Hunting Patterns: Implications for Wildlife Conservation. The Case of the Tsimane' in the Bolivian Amazon. Ph.D. Thesis. Spain: Universitat Autònoma de Barcelona.

Mathez-Stiefel, S.L., R. Brandt, S. Lachmuth, and S. Rist. 2012. Are the Young Less Knowledgeable? Local Knowledge of Natural Remedies and Its Transformations in the Andean Highlands. *Human Ecology* 40:909-930.

McDade, T., V. Reyes-García, W. Leonard, S. Tanner, and T. Huanca. 2007. Maternal ethnobotanical knowledge is associated with multiple measures of child health in the Bolivian Amazon. *Proceedings of the National Academy of Sciences of the United States of America* 104:6134−6139.

Nelson, D. R., W. N. Adger, and K. Brown, 2007. Adaptation to Environmental Change: Contributions of a Resilience Framework. *Annual Review of Environment and Resources* 32:395-419.

Oksanen, J., F. Blanchet, R. Kindt, P. Legendre, P.R. Minchin, B. O'Hara, G.L. Simpson, P. Solymos, H.H. Stevens, and H. Wagner. 2014. vegan: Community Ecology Package . R package version *2.0-10*. http://cran.r-project.org/package=vegan.

Pfeiffer, J.M., and R.J. Butz. 2005. Assesing cultural and ecological variation in ethnobiological research: the importance of gender. *Journal of Ethnobiology* 25(2): 240-278.

R Development Core Team. 2011. *R:* A Language and Environment for Statistical Ccomputing. Vienna, Austria : the R Foundation for Statistical Computing.

Reyes-García V., M. Gueze, A. C. Luz, M. Macia, M. Orta-Martínez, J. Paneque-Gálvez, J. Pino, and X. Rubio-Campillo. 2013. Evidence of traditional knowledge loss among a contemporary indigenous society. *Evolution and Human Behaviour* 34: 249-257.

Reyes-García, V., R. Godoy,V. Vadez, L. Apaza, E. Byron, T. Huanca, W. R. Leonard, E. Pérez, et al. 2003. Ethnobotanical knowledge shared widely among Tsimane' Amerindians, Bolivia. *Science* 299: 5613-1707.

Reyes-García, V., Vadez, T. Huanca, W.R. Leonard, and D. Wilkie. 2005. Knowledge and Consumption of Wild Plants: A comparative study in two Tsimane' villages in the Bolivian Amazon. *Ethnobotany research and applications* 3:201-207.

Reyes-García. V, E. Kightley, I. Ruiz-Mallén**,** N. Fuentes-Pelaez, K. Demps, T. Huanca, M.R. Martínez-Rodríguez. 2010. Schooling and local environmental knowledge: Do they complement or substitute each other? *International Journal of Educational Development* 30(3):305-313.

Rocheleau D., B. Thomas-Slayter, and E. Wangari. 1996. *Feminist Political Ecology: Global Issues and Local Experiences*. London and New York: Routledge.

Ruelle, M.L., and K.A. Kassam. 2011. Diversity of Plant Knowledge as an Adaptive Asset: A Case Study with Standing Rock Elders. *Economic Botany* 65(3):295-307.

Salpeteur M., H. Patel, A. Balbo, X. Rubio-Campillo, M. Madella, P. Ajithprasad, and V. Reyes-Garcia. 2015. When Knowledge Follows Blood. Kin Groups and the Distribution of Traditional Ecological Knowledge in a Community of Semi-nomadic Pastoralists. *Current Anthropology* 56(3) : 471-483.

Santoro F.R, W.S. Ferreira Júnior, TAdS. Araújo, A.H. Ladio, and U.P. Albuquerque. 2015. Does Plant Species Richness Guarantee the Resilience of Local Medical Systems? A Perspective from Utilitarian Redundancy. *PLoS ONE* 10(3).

Tanner, S. 2005. A Population in Transition: Health, Culture Change, and Intestinal Parasitism among the Tsimane' of Lowland Bolivia. PhD Thesis .Michigan: University of Michigan.

Tanner, S., and A. Rosinger. 2014. Salud y nutrición: perfil y cambio. In *Cambio global, cambio local. La sociedad Tsimane' antes la globalización*, ed. V. Reyes-García and T. Huanca. Barcelona: Icaria.

Thompson, E.C, and J. Zhang. 2006. Cultural Salience: Measures Using Free-List Data. *Field Methods* 18(4):398-412

Undurraga, E.A, Z, Cruz-Burga, and R. Godoy. 2014. Demografía y territorialidad del la población Tsimane' actual. In: *Cambio global, cambio local. La sociedad Tsimane' antes la globalizació,* ed. V. Reyes-García, and T. Huanca. Barcelona: Icaria.

Walker, B.H. 1992. Biodiversity and Ecological Redundancy. Conservation biology 6(1):18–23.

Wayland, C. 2001. Gendering Local Knowledge: Medicinal Plant Use and Primary Health Care in the Amazon. *Medical Anthropology Quarterly* 15 (2): 171–188.

Zycherman, A. 2013. The changing value of food: localizing modernity among the Tsimané Indians of lowland Bolivia. PhD Thesis. Columbia University.

Chapter 4

Social organization influences the exchange and richness of medicinal plants in Amazonian homegardens

Chapter 4

Social organization influences the exchange and richness of medicinal plants in Amazonian homegardens[3]

Abstract

Medicinal plants provide indigenous and peasant communities worldwide with means to meet their health needs. Homegardens often act as medicine cabinets providing easily accessible medicinal plants for household needs. Social structure and social exchanges have been proposed as factors influencing the species diversity that people maintain in their homegardens. Here, we assess the association between the exchange of medicinal knowledge and plant material and medicinal plant richness in homegardens. Using Tsimane' Amazonian homegardens as a case study, we explore whether social organization shapes exchanges of medicinal plant knowledge and/or medicinal plant material. We also use network centrality measures to evaluate people's location and performance in medicinal plant knowledge and plant material exchange networks. Our results suggest that social organization, specifically kinship and gender relations, influences medicinal plant exchange patterns significantly. Homegardens' total and medicinal plant richness are related to gardeners' centrality in the networks, where people with greater centrality maintain greater plant richness. Thus, together with agroecological conditions, social relations among gardeners and the culturally-specific social structure seem to be important determinants of plant richness in homegardens. Understanding which factors pattern general species diversity in tropical homegardens, and medicinal plant diversity in particular, can help policy makers, health providers, and local communities to better understand how to promote and preserve medicinal plants *in situ.* Biocultural approaches that are also gender sensitive offer a culturally appropriate means to reduce the global and local loss of both biological and cultural diversity.

Keywords

Exchange networks; gender; plant diversity; social network analysis; tropical homegardens; Tsimane'.

[3] Díaz-Reviriego, I., L. González-Segura, Á Fernández-Llamazares, P.L. Howard, J.L. Molina, and V.Reyes-García. Social organization influences the exchange and richness of medicinal plants in Amazonian homegardens. *In press* in *Ecology&Society.* Special Issue: Networking the Environment. Social Network Analysis in natural resource management and local ecological knowledge studies.

1. Introduction

Medicinal plants provide locally accessible, culturally appropriate, and economically affordable health care options for people with scarce access to biomedical healthcare systems. Indeed, most indigenous and peasant communities meet their primary health care needs through the use of medicinal plants. While some medicinal plants are obtained from the wild, many are also obtained - both for household consumption and for sale - from agricultural fields and homegardens (e.g. Bernholt et al. 2009, Aceituno-Mata 2010, Thomas and van Damme 2010, Yang et al. 2014). Especially, tropical homegardens support high species diversity and help communities to meet health needs, constituting *in situ* germplasm banks, biodiversity reservoirs, and medicine cabinets (Finerman and Sackett 2003, Huai and Hamilton 2009).

1.1 Diversity in homegardens

Tropical homegardens are renowned for their typically high levels of biological diversity. This species diversity is the result of gardeners' meticulous selection and management, which is aimed at providing products they consider to be important to subsistence and livelihoods (Nair and Kumar 2006). Homegarden diversity partly depends on climatic conditions, altitude, size and age of the garden, remoteness from urban centers, and village size, among other factors (Wezel and Bender 2003, Kehlenbeck and Maass 2004, Wezel and Ohl 2005, Rao and Rao 2006). Furthermore, socio-cultural and economic characteristics of gardeners are important for explaining plant diversity in homegardens. For example, Howard (2006) showed that, in Latin American homegardens, the division of labor, knowledge, access to garden resources, and degree of commoditization help to explain the structure, composition, and functions of homegardens. The sex of the gardener and the gendered distribution of gardening tasks are related to diversity in homegardens in the Iberian Peninsula (Reyes-García et al. 2010) where, despite being smaller and closer to the dwelling, gardens managed mainly by women have greater species diversity per unit area compared with those mainly manage by men. In Peruvian Amazonian gardens, differences in homegarden diversity are related to ethnicity (Uranina, mestizos and Achuar) in terms of species richness, homegarden composition, and the presence of medicinal plants, where some medicinal species are exclusively cultivated by one or another ethic group (Perrault-Archambault and Coomes 2008). Finerman and Sackett (2003) have also observed that, in the Ecuadorian Andes, where gardens are managed by women and are largely devoted to medicinal plant production, species composition reflects household demographics (e.g. age, composition) and stage in the life cycle (e.g. reproductive status) as well as specific health needs of individuals in the household.

Homegarden diversity is also strongly influenced by access to and exchange of planting material (seeds, stakes, stems, and cuttings) (Aguilar-Støen et al. 2009, Coomes 2010), which are critical for developing and maintaining plant diversity. Peoples' movements and migratory patterns are typically accompanied by flows of seeds and plants, which modify, enrich, and diversify migrants' homegardens (Voeks 2004; Kujawska and Pardo-de-Santayana 2015). For

example, in a study of planting material exchange networks among indigenous peoples in the Peruvian Amazon, Lerch (1999) found a positive association between plant diversity in homegardens and households' frequency of plant exchanges; Ban and Coomes (2004) found similar results in the same region. However, the exchange of homegarden planting material is usually contained within certain social networks. Most exchanges occur between kin, relatives, close friends, and neighbors (Buchmann 2009; Aguilar-Støen et al. 2009), predominately between women (Boster 1985, Sereni Murrieta and Winklerprins 2003, Lope-Alzina and Howard 2012).

1.2 Navigating social exchange through social network analysis

Only recently have researchers begun to apply social network analysis (SNA) to investigate the exchange of homegarden products (goods and planting materials) and the related knowledge. Calvet-Mir et al. (2012) explored the seed exchange network in homegardens in the Catalan Pyrenees and evaluated its contribution to agrobiodiversity conservation. They found that people who were mentioned more often in seed exchange networks and who had a higher level of intermediation conserved more local landraces and had more knowledge of such varieties compared with people who were less central in the network. In a similar study among gardeners in the Iberian Peninsula, Reyes-García et al. (2013) found that the number of contacts that an individual had in the germplasm exchange network was positively associated with their agroecological knowledge. Lope-Alzina (2014) reported that, among members of a Yucatec-Maya community in Mexico, homegardens are the main source of exchanged planting material. They found that, despite strong market participation, gift-giving continues to be the predominant form of exchange, with most gifts coming from homegardens and with most exchanges occurring between women in kinship-based networks. Elderly women at the top of the hierarchy within their own kin networks were the most outstanding givers.

Social network analysis has also been used to explore medicinal plant knowledge transmission pathways. For example, Hopkins' (2011) study among Yucatec-Maya in Mexico suggests that an individual's knowledge of herbal medicines is positively associated with that individual's structural position within the herbal remedy network. Other researchers have assessed selective learning biases in cultural transmission pathways through social network modeling. Henrich and Broesch (2011) asked Fijian villagers about who they would go to for advice if they have a question about how to use medicinal plants. Their results suggest that, being knowledgeable, older, and a woman, and lacking formal education, increase the chances of being selected as model for learning about medicinal plants. In summary, findings from previous research suggest 1) that the individual structural position in social networks is associated with medicinal plant knowledge, and 2) that kinship, sex, and cultural learning pathways shape social networks.

In this study, we seek to contribute to these lines of research by assessing the influence that the exchange of medicinal knowledge and plant material through social networks have for medicinal plant diversity in Tsimane' Amazonian homegardens. We explore whether social organization (i.e. kinship, gender relations and the division of labor and tasks in gardening)

patterns the exchange of medicinal plant knowledge and/or medicinal plant material. We use network centrality measures to evaluate people's location and performance in knowledge and plant material exchange networks, hypothesizing that people with higher centrality in the knowledge/plant material network maintain a higher diversity of medicinal plants in their homegarden.

2. Methods

Our research was carried out among Tsimane' forager-horticulturalists in the Amazonian lowland forest of Beni Department, Bolivia. We selected two villages located along the Maniqui River, within the Tsimane' Indigenous Territory. Although both villages are relatively isolated and self-sufficient, they differ in their degree of isolation. One village is closer to the market town (it can be reached after a one-day canoe trip) whereas the other is farther from the town (it can only be reached after a three-day canoe trip) (see Chapter 2, Figure 2.1).

Social organization in Tsimane' villages is largely kinship based, where most Tsimane' practice cross-cousin marriage (Daillant 2003), and residence is commonly matrilocal (couples live with or near the wife's parents). Traditionally, the Tsimane's semi-nomadic settlements were small, consisting of clusters of two to three extended family households that were often considerable distances apart (Chiccón 1992, Ellis 1996). The influence of Protestant missionaries and the introduction of formal education in the mid-20th century fostered the settlement and confluence of different clans or clusters around schools. Today, the Tsimane' still change residence very frequently, even within villages, moving closer to their agricultural plots in the harvest season and to rivers in the dry season, when fish are plentiful.

In these villages, livelihoods are mostly subsistence-oriented and depend on foraging and swidden agriculture. Besides having swidden plots located at varying distances from the household, the Tsimane' cultivate and manage a diversity of species in homegardens. While there are many and diverse ways to define homegardens (see e.g. Nair and Kumar 2006), we use a concept that coincides well with the type of land use practiced by the Tsimane': "the peridomestic area belonging to the household where members plant and/or tend useful plants" (Perrault-Archambault and Coomes 2008). Frequently used or common medicinal plants are found in homegardens together with fruit trees, cotton, and chili pepper (Reyes-García et al. 2003, Reyes-García et al. 2005).

Since their access to biomedical health care is very limited, medicinal plants provide the Tsimane' with locally accessible and socio-culturally relevant options for treating health complaints. Ailments are firstly treated in the household, where women are the principle healers (Chiccón 1992). However, both women and men cultivate plants in the area around their houses. Quite interestingly, the Tsimane' recognize customary ownership of these medicinal plants and have detailed knowledge of such rights (see also Howard and Nabanoga 2006). In the Tsimane's customary usufruct tenure system, gardens belong to the families who

originally established them (e.g. former residents). Abandoned gardens are usually reoccupied by the families that previously abandoned them or by their closest relatives, who obtain permission from the previous occupants to use them (Piland 2000). When a family member dies, to get rid of bad spirits and avoid visits by the deceased's spirit, the Tsimane' move to another location (Chicchón 1992); the garden that remains behind is left intact (Piland 2000).

2.1 Data collection

The first and third authors lived in the area for 18 months (January 2012- November 2013) allowing them to actively observe as well as participate and interact with the Tsimane' while gardening. Different tasks were performed with some of the informants; for example, we accompanied them while gathering products from their gardens, and helped with tasks such as planting and weeding.

Between August and December 2012, individual inventories were made of all plants in homegardens that were planted or managed by household heads. A total of 86 informants were interviewed (46 women and 40 men), which represented about 80% of all household heads. Of these, 55 lived in the village closer to town village and 31 lived in the farther village. Each informant was asked individually to show the plants kept in the garden, and to provide their vernacular or common names and uses. Uses were classified into four categories: food, medicine, artisanal (including plants use for making bags, carpets, and bows and arrows), and others (including fish poisoning, ornamental, and construction uses). A given plant could fall into more than one category (e.g. a plant with both food and medicinal uses). When the informants indicated a plant with medicinal uses, they were asked about the ailments it was used to treat.

Social network data were compiled through individual interviews. We used recall methods that employed a set of name generators to collect network data in relation to knowledge (e.g. information and advice about medicinal plants) and plant material (propagates, seeds, plants) exchange (hereinafter medicinal plant exchange networks) (Table 6). The names collected were limited to people who reside within the village, as a boundary for a whole network analytical approach. In addition to data on social relations, we collected demographic data on each informant, including sex, age (in years), kinship relations, years of residence in the village and years residing in the household. Because some informants in each village were not members of a village clan (e.g. the teacher and his wife, who are Tsimane' from another village but reside in the studied village), these were considered as a separate clan for the descriptive analysis (clans 5 and 9) and were not taken into account in statistical analysis.

We also assessed the medicinal plant knowledge of garden managers. To do so, we first asked 20 men and women from both villages to free-list the medicinal plants they knew, in order to design a knowledge survey that consisted of structured questions regarding some 16 medicinal plants, which were chosen according to their frequency and position in the free-listing or their 'salience' (Thompson and Zhang 2006). We created three salience groups by randomly selecting the three species with the highest and lowest salience, and four species with medium salience. Additionally, we analyzed women's and men's free-listings separately

and selected three more species that were listed only by women and three listed only by men. During the knowledge survey (available at http://icta.uab.cat/Etnoecologia/Docs/[423]-lektests.pdf), local assistants read out the vernacular names of the selected medicinal plants, asking gardeners whether they knew the plant and, if so, to list up to three different medicinal uses for that plant. The average number of uses known per known species was used to assess individuals' medicinal plant knowledge.

Table 6. Name generating questions used to elicit information on knowledge and medicinal plant material exchange social networks in homegardens in two Tsimane' villages.

Network	Question asked (name generator)
Medicinal plant knowledge network	Q1: Could you tell me the names of anyone who has ever given you advice about medicinal plants?
	Q2: Could you list the name of people to whom you have ever given advice about medicinal plants?
Medicinal plant material exchange network	Q3: Could you list the names of people who gave you medicinal plants for your homegarden?
	Q4: Could you list the names of people to whom you have ever given medicinal plant material or remedies from your homegarden?
	Q5: While doing the inventory, for each medicinal plant the informants showed us, we asked: Has someone given you this plant? If so, Could you tell me the name of the person who gave you this plant?

2.2 Data Analysis

We use richness as a proxy for diversity in homegardens, i.e. the number of different species inventoried per informant's garden. The richness of plant species in homegardens was measured for each informant using inventory data. Total richness is the number of distinct species (including those with medicinal, food, artisanal and other uses) inventoried per informant garden. Medicinal plant richness is the number of distinct plant species with medicinal use(s) inventoried by informant garden.

We recorded the vernacular names given by interviewees (Hanazaki et al. 2000, Perrault-Archambault and Coomes 2008), and then identified their scientific equivalents using previous ethnobotanical studies in the area (see Appendix 1), and assigned codes to calculate richness. For example, the local names *seviria* and *vira' vira'* are synonyms that refer to a single botanical species, *Cymbopogon citratus*, so the same code was assigned to both vernacular names to avoid double counting. When it was not possible to link vernacular names to botanical nomenclature since this information was not available, we assigned unique codes to all of the vernacular names given by informants. This might lead to the over-estimation of species richness as some of these vernacular names probably refer to the same species. Also, it might have led us to under-estimate the actual number of species since a

single vernacular name may refer to different species, which has been called "hidden diversity" (Cavalcanti and Alburquerque 2013). We described the overall composition of homegardens by village, clan, sex of the gardener, and age groups. To this end, kinship data was used to assign informants to one of nine different clans identified, and informants were also classified into one of four age groups (younger or equal to 25, 26-35, 36-45, and > 45 years).

2.2.1 *Social network analysis*

Using information on social exchange networks, we built a whole network matrix and calculated a set of graph-based measures (McCarty and Molina 2014) for each village (group level) and informant (individual level). Information was treated as undirected and analyzed with UCINET6-Netdraw for Windows. Nominations elicited with a multiple name generator approach were aggregated in a single file by village, since we consider that planting material often flows together with the associated knowledge - in other words, when people give/receive planting material, they typically also give/receive explanations on how to grow and use the species (Reyes-García et al. 2013). For each village exchange network, we calculated 1) size, or number of people in the network; 2) density, or the proportion of existing connections in the network relative to the maximum possible number of connections (from 0 to 1); 3) centralization, or tendency for a few people to centralize the existing connections (expressed as a percentage); and 4) reciprocity, or the extent of reciprocated ties. We calculated three centrality measures for each person in the network (Wasserman and Faust 1994, Freeman 1977,1979): 1) degree, or number of people with whom a person is directly connected; 2) betweenness or the extent to which a given person (ego) appears in the path connecting other people in the network; and 3) egobetweeness, or the number of people connected to each other only through the ego, a measure that captures the importance of a person in her or his personal network. In order to capture the existence of a relation regardless the direction of the nomination, data were treated as undirected.

To explore the effect of clan membership, sex, and age of the gardener on exchanges of knowledge and plant material, we calculated an External-Internal index (E-I index) (Krackhardt and Stern 1988). The E-I index is proposed as follows:

$$E - I\ index = \frac{EL - IL}{EL + IL}$$

where

EL= number of external exchanges of medicinal knowledge and plant material
EI= number of internal exchanges of medicinal knowledge and plant material

Therefore, given a partition of a network into a number of mutually exclusive groups (here, clans, sex, or age groups), the E-I index evaluates the relation between external and internal exchanges (relative homophily, or people's tendency to relate to others who are similar to themselves, leading to preferential exchanges within groups). The value of the E-I index can range from -1 (in which all ties are within the group) to 1 (all ties are external to the group): the index equal zero when a group has the same number of internal and external ties. A permutation test (n=5000) was performed to assess whether the network E-I index was significantly different than expected.

2.2.2 *Statistical analysis*

To estimate the association between medicinal plant richness managed by an informant and informants' centrality measures, we ran a Poisson multivariate regression, which is adequate for count data. We first tested whether degree centrality was associated with medicinal plant richness while controlling for additional factors that research suggests affect diversity in homegarden. Specifically, controls in our regression include: village or residence, clan membership, sex, age (in years), and age squared (Age2), (to control for non-linearity in the relation between age and medicinal knowledge, as cognitive ability might decrease among elders), years of residence in the village (to control for mobility), years residing in the same house (as a proxy for homegarden age), and, individuals' medicinal plant knowledge. We use STATA 13 for Mac for the statistical analysis.

3. Results

3.1 Richness in Tsimane' homegardens

A total of 111 plants were inventoried in this study, 45 of which were used as medicines. The total richness in gardens in the two villages is relatively high and evenly distributed, with 86 and 83 plants encountered in the closer and more isolated villages, respectively. Food was the most common use reported followed by medicinal, artisanal and other uses. Figure 7 illustrates the distribution of the number of plants inventoried and the corresponding uses reported by village, clan, and sex-age groups. On average, a resident of the closer-to-town village maintained 11.58 (SD=8.53) plants, including 1.90 (SD= 2.27) with medicinal uses. In the farther village, an informant on average maintained 13.67 (SD=7.49) plants, 3.54 (SD=2.87) of those with medicinal uses.

In the closer village, women maintained 2.75 (SD=2.58) medicinal plants and men 0.96 (SD=1.39). One woman had 12 medicinal plants in her homegarden, but 17 informants (30.90%) had none (12 of whom were men). A similar pattern was found in the farther village, where women also maintained more medicinal plants in homegardens (4.29; SD=3.07) compared with men (2.64; SD=2.37), and five informants had none (16 %), three of whom were men. The species most frequently found plants in homegardens were citruses, such as orange (*Citrus sinensis*) and grapefruit (*Citrus paradisi*), along with peach palm

(*Bactris gasipaes*), mango (*Magnifera indica*), and cotton (*Gosipyum barbadense*) – the latter was almost exclusively planted by women. The medicinal plants most frequently found in homegardens were ginger (*Zingiber officinale*), tobacco (*Nicotina tabacum)* and garlic weed (*Petiveria alliacea)*. Of the total number of times that medicine was reported as a use, 15% were used for treating common flu, 10% for general pain, 10% for fungal infections of the skin, and five percent each for diarrhea and stomach afflictions, injuries, wasps' stings and skin parasites.

3.2 Structure of medicinal knowledge and plant material exchange networks

There were 48 gardeners involved in medicinal plant exchange networks in the village closer to town and 37 in the farther village (Figure 8). These networks were characterized by low density (0.034 in the closer village and 0.063 in the farther village), low centralization indexes (8.08% vs. 6.28%) and low reciprocity (0.0317 vs. 0.109), meaning that connections in the networks are relatively low and not reciprocal. Overall, both networks show asymmetry and hierarchy, meaning that some people have many more connections than others.

Figure 7. Richness of plants in different use categories inventoried by village (A closer to town, B more isolated); clans (C: clans 1 to 5, closer to town village; clans 6 to 9 farther village), and sex-age groups (D: women left side, men right side).

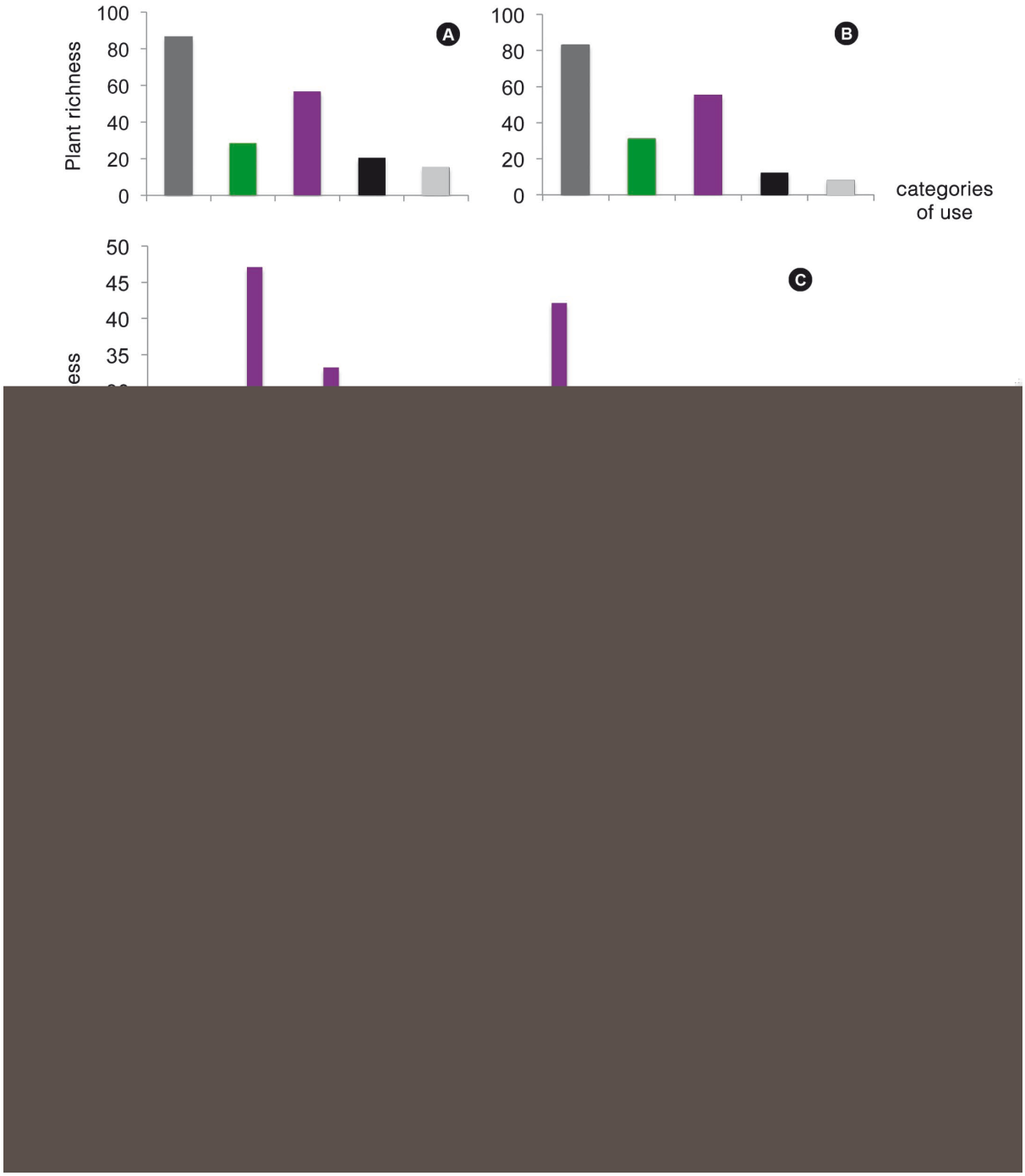
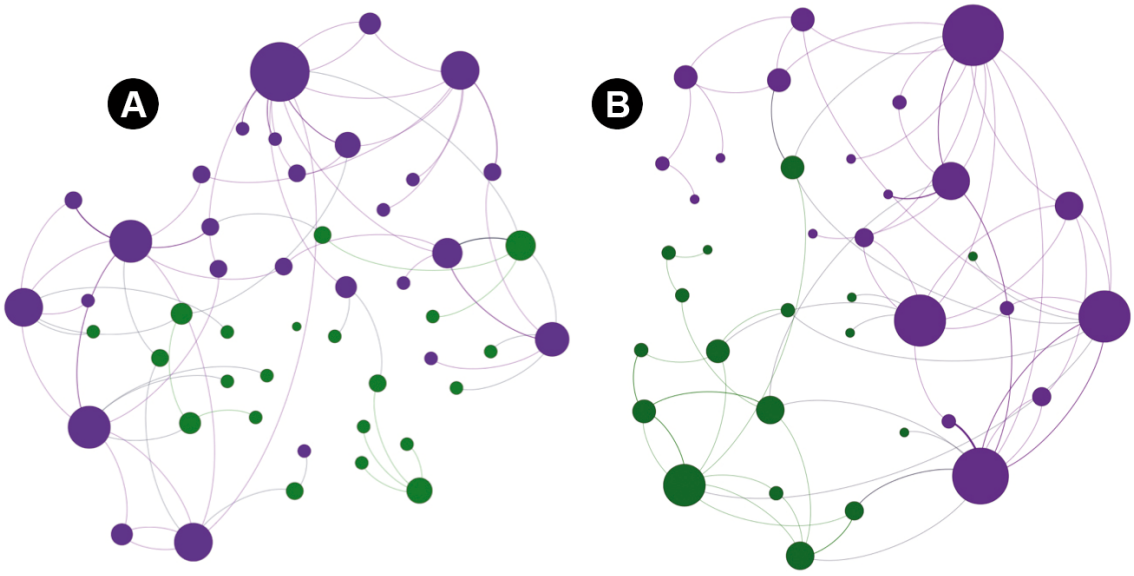
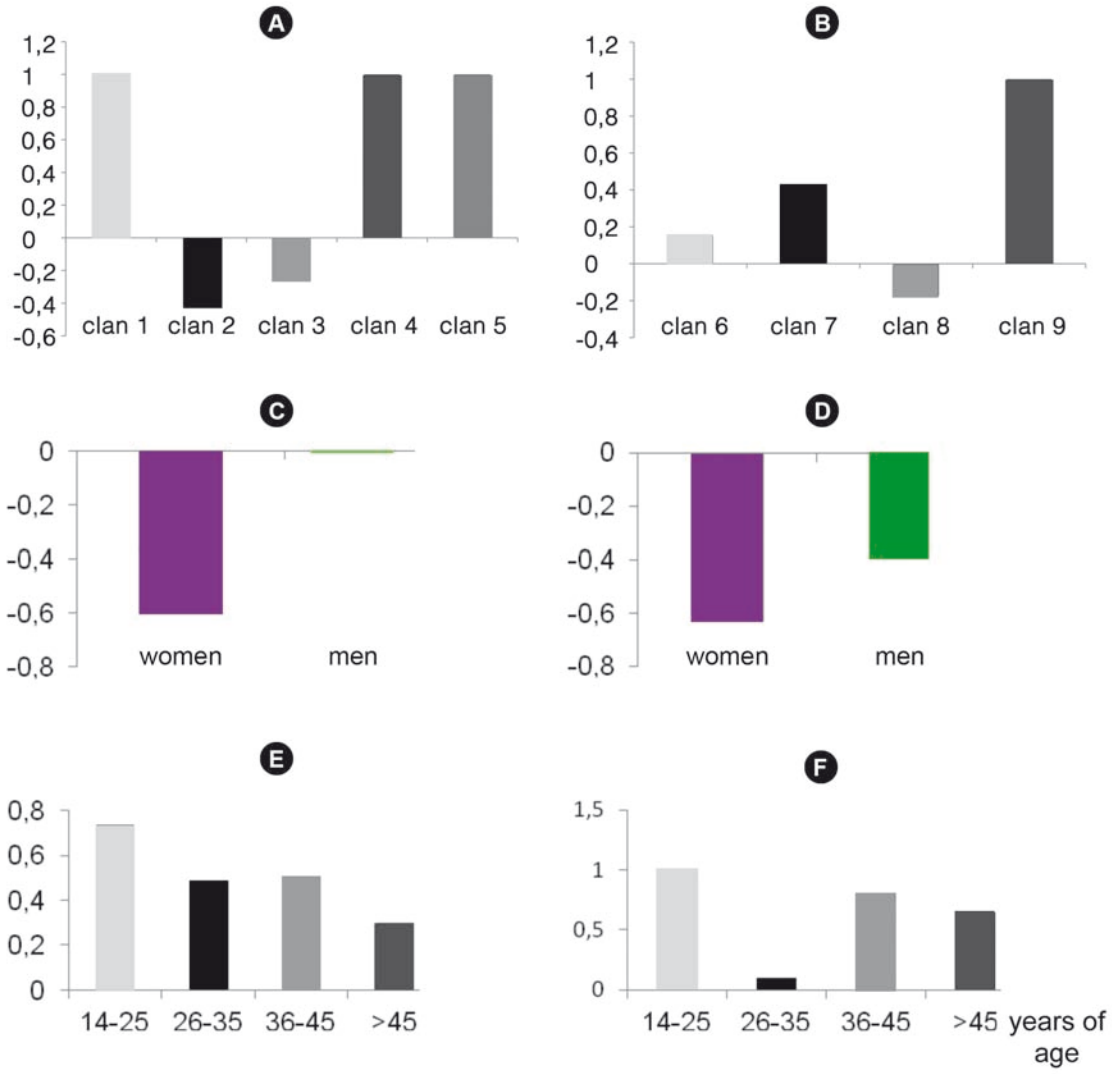


Figure 8. Medicinal plant knowledge and exchange networks (undirected) by village: A) closer to town village and B) farther village. Nodes color shows sex of the person (women: purple; men: green). Nodes size shows degree centrality.



We found different patterns in the exchanges of medicinal knowledge and plant material between E-I indexes calculated by clan membership and sex, but not by age groups (Figure 9). When grouping by clan membership, larger clans (2, 3, and 8) tended to have more exchanges within the same clan, whereas, smaller clans (1, 4, 6, and 7) had mostly external exchanges. The permutation tests revealed statistically significant differences for the E-I indexes between clans for the closer village ($p < 0.05$), meaning that different clans had dissimilar exchange patterns. Sex groups presented homophily, with most exchanges occurring within the same-sex group; this difference was significant for both villages ($p<0.05$). Most exchanges occurred outside of the age group, and differences among E-I indexes for age groups were not statistically significant.

Figure 9. Graphic representation of E-I indexes by clans (A, B,); sex (C, D); and age-groups (E, F). Figures on the left-hand side correspond to village closer to town, and right-hand side to farther village. E-I index evaluates the relationship between external and internal exchanges, ranging from -1 (all ties within the group) to 1(all ties external to the group); if the ties are divided equally, the index will equal zero.



3.3 Centrality measures

On average, centrality measures were higher in the farther village and for women. The average degree values were 2.96 (SD= 2.90) and 4.17 (SD=2.48) for women in the closer and farther villages, respectively, and 1.15 (SD=1.36) and 3.35 (SD=3.12) for men, indicating that women exchanged (gave or received) medicinal plants with more people compared with men (Figure 9). The average value for betweenness centrality followed a similar pattern, with women in both villages having a similar value (mean= 80.70, SD=127.56 in the closer village; mean= 81.59, SD=76.50 in the farther village), meaning that, on average, each woman connected 80 pairs of otherwise unconnected informants. There was high variation in this variable, indicating that some women had a much more pronounced centralizing role in the

network than others. Average betweenness values were lower for men (closer village 27.30, SD=56.99; farther 39.84, SD=184.02). Betweenness displayed greater variation for men than for women, suggesting greater variation in men's bridging role, particularly in the farther village. Similarly, the average value of the variable egobetweenness was considerably higher for women (closer village 5.78, SD=10.98; farther 8.17, SD=9.59) compared with men (closer village 0.82, SD=1.94; farther village 6.71, SD=12.38) although, again, men's egobetweenness displayed greater variation than women's.

Table 7. Definition and descriptive statistics for variables used in multivariate analysis

Variable	Definition	N	Mean	SD	Min	Max
Outcome variables						
Medicinal richness	Total number of different medicinal plants inventoried in a homegarden	86	2.5	2.611062	0	12
Total Richness	Total number of different plants inventoried in a homegarden	86	12.33721	8.189822	2	39
Explanatory variables						
Degree	Number of people with whom a person is directly connected	86	4.184989	2.83004	1	11
Betweenness	Grade of intermediation among people where each person is directly and indirectly connected	86	94.01606	111.9947	0	585.767
Egobetwenness	Grade of intermediation among people where each person is directly connected	86	8.90222	11.74843	0	50

Continuation next page

Variable	Definition	N	Mean	SD	Min	Max
Controls						
Age	Age of the person, in years	85	39.27	16.62	14	88
Age2	Age squared term to control for non-linearity in the relation of age with richness in homegardens	85	1815	1687.38	196	7744
Medicinal knowledge	Average number of medicinal uses known per plant known from a knowledge survey consisting in 16 medicinal plants	80	0.87	0.41	0.125	2
Years in household	Number of years a person lived in the in the same household	81	6.69	7.09	0.1	25
Years in village	Number of years that the person lived in the village	79	23.24	13.50	1	66
		N	%			
Closer village	Village of residence					
	closer to town	55				
	isolated	31				
Clan	Clan membership					
	1	8	9.30			
	2	17	19.77			
	3	22	25.58			
	4	6	6.98			
	5	2	2.33			
	6	11	12.79			
	7	7	8.14			
	8	11	12.79			
	9	2	2.33			
Male	Dummy variable that captures the sex of the person, (1=man, 0=woman)					
	women	46	53.49			
	men	40	46.51			

3.4 Medicinal plant richness in homegardens and centrality in the exchange network

We analyzed the link between informants' medicinal richness in homegardens and informants' locations in the medicinal plant exchange networks (assessed through centrality measures). Degree centrality, which measures the number of people with whom a person is directly connected, has a statistically significant relation with medicinal richness in homegardens. The association is robust for all regressions. Across all models, the variable male displays a greater and more consistent association with medicinal plant richness, suggesting that women have a prominent role in these networks.

In model [A], we tested the association between a person's degree centrality and the richness of medicinal plants species that they maintain in their homegarden, controlling for village, sex, and age (Table 8). Results indicate that a person's degree centrality has a positive and statistically significant association with medicinal plant richness (coef = 0.122; p=0.000). In other words, the higher the number of connections that a person has in the exchange networks, the higher the richness of medicinal plants the person maintains in her/his homegarden. The statistical significance of the "closer village" dummy variable (coef=0.454; p=0.004) denotes that informants in the closer village have higher medicinal richness compared with informants in the farther village. Results also indicate that women have higher homegarden medicinal richness than men (coef= -0.621; p=0.000), and that people with greater medicinal plant knowledge (coef=0.502; p=0.008) tend to maintain greater medicinal species richness in their homegardens. Age, however, was not significantly associated with homegarden medicinal richness.

Model [B] resembles model [A], except that instead of village, we used a set of dummies to control for clan membership. As in the previous model, we found that degree centrality is associated with greater medicinal richness in homegardens (coef=0.127; p=0.000). Compared with people in clan 6, people in clans 2,3,4 and 8 have less homegarden medicinal richness and people in clan 1and 7 have more (see Table 8).

In model [C], we excluded the variables age and age squared (not significant in previous models) and added the number of years a person has resided in the household. As in the two previous models, we found that degree centrality is associated with higher medicinal plant richness (coef= 0.126; p=0.000). In this model, the variable male (coef=-0.641; p=0.000) and years residing in the household (coef=0.032; p=0.003) are associated with medicinal richness, which suggests that women who have had gardens for longer periods also have more medicinal plants in their gardens.

In our final model [D], we controlled for the years residing in the village. Again, we found a positive and statistically significant association between degree centrality and richness (coef=0.136; p=0.000). As in previous models, the variable man is also significantly associated with richness as is years residing in the village, meaning that people who have longer residency in the same village maintain more medicinal plant richness in their homegardens.

Table 8. Poisson multivariable regressions between informant's medicinal plant richness in homegardens and individual centrality measures.

			Medicinal plant richness	
Model	**[A]**	**[B]**	**[C]**	**[D]**
Number of observations (n)	80	80	76	74
Explanatory variable				
Degree	0.122 (0.024)***	0.127 (0.026)***	0.126 (0.025)***	0.136 (0.030)***
Control variables				
Village	0.454 (0.156)***	^	^	^
Clan (omitted clan 6)				
1	^	0.187 (0.326)	-0.234 (0.353)	0.035 (0.340)
2	^	-0.068 (0.214)	-0.195 (0.216)	-0.424 (0.265)
3	^	-0.447 (0.240)*	-0.075 (0.245)***	-0.637 (0.256)**
4	^	-1.012 (0.533)*	-1.107 (0.534)**	-0.956 (0.538)*
7	^	0.389 (0.208)*	0.095 (0.240)	0.225 (0.213)
8	^	-0.011 (0.313)	-0.295 (0.376)	-0.252 (0.317)
Man	-0.621(0.160)***	-0.626 (0.161)***	-0.641 (0.168)***	-0.472 (0.168)***
Age	0.029 (0.022)	0.029 (0.023)	^	^
Age2	-0.000 (0.000)	-0.000 (0.000)	^	^
Medicinal knowledge	0.502 (0.188)***	0.390 (0.203)*	0.290 (0.204)	0.079 (0.221)
Years in household	^	^	0.032 (0.011)***	^
Years in village	^	^	^	0.015 (0.005)***
R^2	0.22	0.25	0.25	0.25

† For definition of variables see Table 7. Robust standard errors in parenthesis. * ,**, and *** significant at the 10%, 5% and 1% level. ^ variable intentionally omitted. Model C, core model used in robustness analysis.

Table 9. Robustness analysis

	[a]	[b]	[c]	[d]
	Medicinal plant richness	**Medicinal plant richness**	**Total richness**	**Tobit regression**
Number of observations (n)	76	76	76	76
Explanatory variables				
Degree	^	^	0.092 (0.012)***	0.457 (0.112)***
Betweenness	0.002 (0.000)***	^	^	^
Egobetweenness	^	0.023 (0.006)***	^	^
Control variables				
Clan (omitted clan 6)				
1	-0.570 (0.339)*	-.0404 (0.344)	0.446 (0.147)***	-0.422 (1.257)
2	-0.334 (0.215)	-0.166 (0.218)	0.339 (0.097)***	-0.104 (0.856)
3	-1.028 (0.252)***	-0.797(0.243)**	-0.311(0.111)**	-1.596 (0.849)*
4	-1.419 (0.524)***	-1.289 (0.529)	-0.457(0.203)**	-1.753 (1.310)
7	0.069 (0.243)	0.218 (0.242)	0.199 (0.120)*	0.691 (1.053)
8	-0.344 (0.374)	-0.241 (0.378)	0.079 (0.165)	-0.820 (1.289)
Male	-0.676 (0.170)***	-0.739 (0.165)***	-0.346 (0.072)***	-1.631 (0.581)***
Medicinal knowledge	0.330 (0.205)	0.295 (0.204)	0.274 (0.089)***	0.731 (0.746)
Years in household	0.037 (0.011)***	0.032 (0.011)***	0.006 (0.005)	0.088 (0.042)**
R^2	0.22	0.22	0.33	0.13

† For definition of variables see Table 7. Robust standard errors in parenthesis. * ,**, and *** significant at the 10%, 5% and 1% level. ^ variable intentionally omitted.

We tested the robustness of the findings by running a set of variations of our best model (Table 8, model C; R^2= 0.25). In our two first robustness tests (see Table 9, models [a] and [b]) we changed the explanatory variable using betweenness centrality and egobetweenness instead of degree centrality. In the third robustness model ([c]), we changed the outcome variable to total richness and kept the same controls as in the Model C. The last robustness model ([d]) explored the possible effect of having censoring in the data (18 people did not have any medicinal plants) by fitting a Tobit multivariate regression rather than a Poisson multivariate regression model. Results from the robustness analysis confirm that other centrality measures are also associated with medicinal richness. Robustness analysis also suggests that the variable degree centrality has a positive association with total richness in homegardens (coef=0.092; p=0.000). Finally, the association between degree centrality and richness is also maintained when running a Tobit multivariate regression model (coef=0.457; p=0.000). In summary, results suggest that the associations found in Table 9 are robust to changes in the specification model.

4. Discussion

In this work, we aimed to assess the influence that medicinal plant exchanges through social networks have for homegarden medicinal plant richness by applying social network analysis methods. Our results suggest that Tsimane' social organization, specifically kinship and gender relations, influences medicinal plant exchange patterns significantly. Our findings also show that people who are more central in the network (i.e. who hold higher centrality measures) maintained greater medicinal plant richness, as well as total richness, in their homegardens. Women also maintain a higher richness of medicinal plants in their homegardens than men.

Previous studies suggest that social organization shapes the pattern of social exchanges in small-scales societies affecting, for example, crop diversity (Leclerc and D'Eeckenbrugge 2012, Labeyrie et al. 2013) and local ecological knowledge (Salpeteur et al. 2015). Researchers have also argued that planting material exchanges are by no means 'free-flowing' (Coomes and Ban 2004) but, rather, are usually confined to kinship networks (Buchmann 2009; Aguilar-Støen et al. 2009) in which women often have a prominent role (Boster, 1985; Sereni Murrieta and Winklerprins 2003). As has been shown elsewhere (Coomes and Ban 2004) it is possible that this pattern also increases the opportunities to access new planting material for homegardens. For example, among the Achuar in the Peruvian Amazon, planting material, such as seeds or cuttings, moves mostly through matrilineal kin networks, particularly from female-to-female (Perrault-Archambault and Coomes 2008). For the Achuar, gardening is traditionally a woman's responsibility and, as in other Amazonian societies, high agrobiodiversity in gardens confers prestige to its owners (Descola 1986 as cited in, Perrault-Archambault and Coomes 2008).

Our results support these previous studies, showing that exchange of knowledge and plant material exchanges among the Tsimane' are not random, but embedded within networks based on kinship and gender relations. Results suggest that networks are gendered, presenting

homophily, where women performance is prominent. Tsimane' social organization can then help to explain our findings. It is mostly based on kinship and, within a village, extended families' households are spatially clustered. Socializing among the Tsimane' consists of visits, which are an essential means to maintain close relations. Visiting usually occurs between same-sex kin and affines (Ellis 1996), which would facilitate exchanges among members of the same sex and clan, and also explain why is it that larger kin groups tend to have more exchanges. Tsimane' women are considered as the main health custodians who are responsible for meeting the health needs of their families in the first instance (Chiccón 1992). Gardening also seems to be also primarily a women's domain, a productive role that is related to their duties as caregivers in the domestic sphere. Women are prominent garden managers across the Latin American region (see Howard 2006 for a review), which is also related to the maintenance of traditional communal social relations, community food security, and health (Lope-Alzina 2014, Finerman and Sackett 2003). Homegardening provides women with an opportunity to engage in subsistence production that does not violate gendered norms about men's responsibilities in the productive sphere (e.g. as 'principle providers') or about women's 'domesticity', offering women sources of authority, autonomy, and status, and a place where they can develop specialized knowledge and provide visible means of recognition according to their cultural roles (Howard 2006, Lope-Alzina and Howard 2012). Homegardens are also considered as arenas for sociality and experimentation and are a source of pride and self-esteem for women (Heckler 2004). The Tsimane' do not seem to deviate from this pattern.

Locations in a social network provide both possibilities and constraints for accessing resources and knowledge through other people in the network (Calvet-Mir et al. 2012; Kawa et al. 2013), given that, in each particular situation, networks can either support or constrain access to these people. Access to other people's planting material is important for developing and maintaining diversity in homegardens (Coomes 2010). In this study, network centrality seems to be associated with a person's performance in medicinal plant exchange networks, as people with higher centrality in the network also maintain higher medicinal plant richness in their homegardens. Compared with men, women are more central in the exchange networks, a finding that fits well with women's prominent role as main garden managers. The gendered networks, in which women have higher centrality measures, may indicate that they have more access to medicinal planting material and associated knowledge. Other factors, such as the number of years that a garden has been tended by its owner and the number of years that a person has resided in the same village, also explain medicinal plant richness in Tsimane' homegardens.

We would like to end by acknowledge the potential shortcomings of our interpretations since our data capture only a snapshot of network structure at a single point in time which, to be valid, assumes that network structures are stable (Howison et al. 2011). Data were also limited in that they were only collected on exchanges that occurred within the same village; exchanges with Tsimane' residing in other villages were not considered, and nor were exchanges with non-Tsimane' (i.e. with merchants and researchers). This limits the breadth

and thus explanatory power of our results, since social networks are dynamic and are embedded within networks at higher local and regional scales.

5. Conclusion

This research suggests that social network analysis is an appropriate and useful tool for tracing the uneven flow of homegarden medicinal planting material and knowledge among the Tsimane'. Homegarden medicinal plant richness and total plant species richness are related to gardeners' centrality in the exchange networks, meaning that people with greater centrality maintain greater richness. As women generally hold higher centrality, they also maintain greater richness than men. Similarly, the number of years the garden has been tended and the number of years a person has resided in the same village are positively related with greater medicinal plant and total plant species richness. This study also shows that social organization, specifically around kinship and gender, influence medicinal plant knowledge and planting material exchange patterns significantly, highlighting that, together with agroecological conditions, social relations among gardeners and the culturally specific social structure are important determinants of plant species diversity in homegardens. This suggests that agrodiversity and culture are closely interrelated (Howard 2006, Leclerc and D'Eeckenbrugge 2012).

Understanding which factors pattern general species diversity in tropical homegardens, and medicinal plant diversity in particular, can help policy makers, health providers, and local communities to better understand how to promote and preserve medicinal plants *in situ,* so that they can continue to provide locally accessible, culturally appropriate, and economically affordable health care options for people with scarce access to biomedical healthcare systems. Such understandings promote the use of gender sensitive biocultural approaches which offer a culturally appropriate means to reduce the global and local loss of both biological and cultural diversity.

6. References

Aceituno-Mata, L. 2010. Estudio Etnobotánico y Agroecológico de la Sierra Norte de Madrid. PhD Thesis. Universidad Autónoma de Madrid, Madrid.

Aguilar-Støen, M., S. R. Moe, and S. L. Camargo-Ricalde. 2009. Home gardens sustain crop diversity and improve farm resilience in Candelaria Loxicha, Oaxaca, Mexico. *Human Ecology* 37: 55–77.

Ban, N., and O.T. Coomes. 2004. Home gardens in Amazonian Peru: diversity and exchange of planting material. *Geographical Review* 94 (3): 348-368.

Bernholt, H., K. Kehlenbeck, J. Gebauer, and A. Buerkert. 2009. Plant species richness and diversity in urban and peri-urban gardens of Niamey, Niger. *Agroforestry Systems* 77(3):159-179.

Boster J.S. 1985. Requiem for the omniscient informant: there's life in the old girl yet. In: J. Dougherty (ed.). *Directions in Cognitive Anthropology*, pp 177-198. University of Illinois Press, Champaign, Illinois.

Buchmann, C. 2009. Cuban home gardens and their role in social-ecological resilience. *Human Ecology* 37:705-721.

Calvet-Mir, L., M. Calvet-Mir, J.L. Molina, and V. Reyes-García. 2012. Seed exchange as an agrobiodiversity conservation mechanism: a case study in Vall Fosca, Catalan Pyrenees, Iberian Peninsula. *Ecology and Society* 17(1):29.

Cavalcanti, D.R., and U.P, Albuquerque. 2013. The "hidden diversity" of medicinal plants in northeastern Brazil: diagnosis and prospects for conservation and biological prospecting. *Evidence-based Complementary and Alternative Medicine.* Article ID 102714, 29pp.

Chicchón A. 1992. Chimane Resource Use and Market Involvement in the Beni Biosphere Reserve, Bolivia. PhD Thesis. University of Florida, Gainesville

Coomes, O.T. 2010. Of stakes, stems, and cuttings: the importance of local seed systems in traditional Amazonian societies. *The Professional Geographer* 62(3): 323-334.

Coomes, O.T., and N. Ban. 2004. Cultivated plant species diversity in home gardens of an Amazonian peasant village in Northeastern Peru. *Economic Botany* 58:420-434.

Daillant, I. 2003. Sens Dessus Dessous: Organisation Sociale et Spatiale des Chimane d'Amazonie Bolivienne. Recherches amèricaines 6. *Société d'ethnologie*, Nanterre.

Ellis, R. 1996. A Taste for Movement: An Exploration of the Social Ethics of the Tsimane' of Lowland Bolivia. PhD Thesis. St. Andrews University, Scotland.

Finerman, R., and R. Sackett. 2003. Using home gardens to decipher health and healing in the Andes. *Medical Anthropology Quarterly* 17(4): 459-482.

Freeman, L. C. 1977.A set of measures of centrality based on betweenness. *Sociometry* 40: 35-41.

Freeman, L. C. 1979. Centrality in social networks: conceptual clarification. *Social Networks* 1(3): 215-239.

Hanazaki, N., J. Y. Tamashiro, H. F. Leitao–Filho, and A. Begossi. 2000. Diversity of plant uses in two Caiçara communities from the Atlantic Forest coast, Brazil. *Biodiversity and Conservation* 9(5):597–615

Heckler, S. L. 2004. Cultivating sociality: aesthetic factors in the composition and function of Piaroa homegardens. *Journal of Ethnobiology* 24(2): 203-232.

Henrich, J., and J. Broesch. 2011. On the nature of cultural transmission networks: evidence from Fijian villages for adaptive learning biases. Philosophical Transactions of the Royal Society B: Biological Sciences 366(1577):1139-1148.

Hopkins, A. 2011. Use of network centrality measures to explain individual levels of herbal remedy cultural competence among the Yucatec Maya in Tabi, Mexico. *Field Methods* 23(3): 307-328.

Howard, P.L. 2006. Gender and social dynamics in swidden and homegardens in Latin America. In: Kumar B.M. and Nair P.K.R. (eds), *Tropical Homegardens: A Time-tested Example of Sustainable Agroforestry*. Springer Science, Dordrecht, The Netherlands.

Howard, P.L., and G. Nabanoga. 2007. Are there customary rights to plants? An inquiry among the Baganda (Uganda), with special attention to gender. *World Development* 35(9):1542–1563.

Howison, J., A. Wiggings, and K. Crowston. 2011. Validity issues in the use of social network analysis with digital trace data Validity issues in the use of social network analysis with digital trace data. Journal of the Association for Information Systems 12(12): 767-797.

Huai, H., and A. Hamilton, 2009. Characteristics and functions of traditional homegardens: a review**.** *Frontiers of Biology in China* 4(2): 151–157.

Kawa, N. C., C. McCarty, and C. R. Clement. 2013. Manioc varietal diversity, social networks, and distribution constraints in rural Amazonia. *Current Anthropology* 54(6): 764–770.

Kehlenbeck, K., and B.L. Maass. 2004. Crop diversity and classification of homegardens in Central Sulawesi, Indonesia. *Agroforestry Systems* 63(1): 53-62.

Krackhardt, D., and R.N. Stern .1988. Informal networks and organizational crises: an experimental simulation. *Social Psychology Quarterly* 51(2): 123-140

Kujawska, M., and M. Pardo-de-Santayana. 2015. Management of medicinally useful plants by European migrants in South America. *Journal of Ethnopharmacology* 172: 347-355.

Labeyrie, V., R. Bernard, and C. Leclerc. 2014. How social organization shapes crop diversity: an ecological anthropology approach among Tharaka farmers of Mount Kenya. *Agriculture and Human Values* 31(1):97–107

Leclerc, C., and G. Coppens d'Eeckenbrugge. 2012. Social organization of crop genetic diversity. The G x E x S interaction model. *Diversity* 4(1): 1–32.

Lerch, N. C. 1999. Home Gardens, Cultivated Plant Diversity, and Exchange of Planting Material in the Pacaya-Samira National Reserve Area, Northeastern Peruvian Amazon. Unpublished M.A. Thesis. McGill University, Montreal.

Lope-Alzina, D. G. 2014. Una red comunal de acceso a alimentos: el huerto familiar como principal proveedor de productos para intercambio en una comunidad Maya-Yucateca. *Revista Gaia Scientia* ,Volume Especial Populações Tradicionais: 199-215.

Lope-Alzina, D. G., and P.L. Howard. 2012. The structure, composition, and functions of homegardens: focus on the Yucatán Peninsula. *Etnoecológica* 9(1):17-41.

McCarty, C., and J.L. Molina. 2014. Social network analysis. In: *Bernard H.R., and Clarence, C.G. (eds) Handbook of Methods in Cultural Anthropology.* Rowman and Littlefield, UK.

Nair, P.K.R., and B.M. Kumar. 2006. *Tropical Homegardens: A Time-tested example of Sustainable Agroforestry*. Springer Science, Dordrecht, The Netherlands.

Perrault-Archambault, M. and O.T. Coomes. 2008. Distribution of agrobiodiversity in home gardens along the Corrientes River, Peruvian Amazon. Economic Botany 62(2):109-126.

Piland, R. 2000. Agricultura Tsimane' y su relación con la conservación en la Reserva de la Biosfera Estación Biológica del Beni, Bolivia. *In: Biodiversidad, Conservación y Manejo en la Región de la Reserva de la Biosfera Estación Biológica del Beni, Bolivia,* pp 329-344. United States of America. United States of America. SI/MAB Series No. 4, Washington, DC.

Rao, M.R., and R.B. Rao. 2006. Medicinal plants in tropical homegardens. In: Kumar B.M. and Nair P.K.R. (eds)*, Tropical Homegardens: A Time-tested Example of Sustainable Agroforestry*. Springer Science, Dordrecht, The Neatherlands.

Reyes-García, V., J. L. Molina, L. Calvet-Mir, L. Aceituno-Mata, J. J. Lastra, R. Ontillera, M. Parada, M. Pardo-de-Santayana, M. Rigat, J. Vallès, and T. Garnatje. 2013. "Tertius gaudens": germplasm exchange networks and agroecological knowledge among home gardeners in the Iberian Peninsula. *Journal of Ethnobiology and Ethnomedicine* 9(1): 53-62.

Reyes-García, V., R. Godoy, V. Vadez, L. Apaza, E. Byron, T. Huanca, W.R. Leonard, E. Pérez, and D. Wilkie. 2003. Ethnobotanical knowledge shared widely among Tsimane' Amerindians, Bolivia. *Science* 299 (5613): 1707.

Reyes-García, V., S. Vila, L. Aceituno-Mata, L. Calvet-Mir, T. Garnatje, A. Jesch, J.J. Lastra, M. Parada, M. Rigat, J. Vallès, and M. Pardo-de-Santayana. 2010. Gendered homegardens: a study in three mountain areas of the Iberian Peninsula. *Economic Botany* 64(3):235-247.

Reyes-García, V., V. Vadez, T. Huanca, W.R. Leonard, and D. Wilkie. 2005. Knowledge and consumption of wild plants: a comparative study in two Tsimane' villages in the Bolivian Amazon. *Ethnobotany Research and Applications* 3:201-207.

Salpeteur M., H. Patel, A. Balbo, X. Rubio-Campillo, M. Madella, P. Ajithprasad, and V. Reyes-García. 2015. When knowledge follows blood kin groups and the distribution of traditional ecological knowledge in a community of semi-nomadic pastoralists, Gujarat (India). *Current Anthropology* 56(3): 471-483.

Sereni Murrieta, R.S., and A. Winklerprins. 2003. Flowers of water: homegardens and gender roles in a riverine caboclo community in the lower Amazon, Brazil. *Culture & Agriculture* 25(1): 35-47.

Thomas, E., and P. Van Damme. 2010. Plant use and management in homegardens and swiddens: evidence from the Bolivian Amazon. *Agroforestry Systems* 80(1): 131-152.

Thompson, E.C., and J. Zhang. 2006. Comparative cultural salience: measures using free-list data. *Field Methods* 18(4):398-412

Voeks, R. A. 2004.Disturbance pharmacopoeias: medicine and myth from the humid tropics. *Annals of the Association of American Geographers* 94(4): 868–888

Wasserman, S., and K. Faust. 1994. *Social Network Analysis: Methods and Applications* Vol.8. Cambridge University Press, Cambridge.

Wezel, A., and J. Ohl. 2005. Does remoteness from urban centres influence plant diversity in homegardens and swidden fields?: a case study from the Matsiguenka in the Amazonian rainforest of Peru. *Agroforestry Systems* 65(3): 241-251.

Wezel, A., and S. Bender. 2003. Plant species diversity of home-gardens of Cuba and its significance for household food supply. *Agroforestry Systems* 57(1): 39-49.

Yang, Lixin., S. Ahmed, J.R. Stepp, K. Mi, K., Zhao, Y. Ma, J., Liang, D., Pei, S., Huai, H., Xu, G., A. C. Hamilton., Yang, Z., and D. Xue. 2014. Comparative homegarden medical ethnobotany of Naxi healers and farmers in Northwestern Yunnan, China. *Journal of Ethnobiology and Ethnomedicine* 10(1): 6.

Chapter 5

Fishing in the Amazonian forest: a gendered social network puzzle

Chapter 5

Fishing in the Amazonian forest: a gendered social network puzzle[4]

Abstract

We explore cultural transmission of fishing knowledge drawing from research on intracultural variation in ethnobiological knowledge and the pathways for knowledge transmission using social network analysis. Ethnographic and quantitative methods were employed during 18 months of fieldwork among the Tsimane' in the Bolivian Amazonia to assess fishers' perceived knowledge and to characterize fishing networks. We employed a fishing rating, as a proxy for fishing perceived knowledge, to investigate whether people's choice of fishing partners was related to this rating. Logistic regressions were performed to determine the association between the fishers' ratings and their socio-demographic identities, fishing routines, and network centrality measures. We found a positive association between fishers' ratings and centrality in networks; association that is more striking for women than for men. We propose that a network approach broadens understanding of the influence of gender on intracultural knowledge transmission and distribution as well as natural resource access and use.

Keywords

Cultural transmission; gender; intracultural knowledge variation; prestige-bias; status; Tsimane'.

[4] Díaz-Reviriego, I., Á Fernández-Llamazares, P.L. Howard, J.L. Molina, and V. Reyes-García. Fishing in the Amazonian forest: a gendered social network puzzle. *Submitted* to *Society&Natural Resources*.

1. Introduction

Ethnobiological knowledge is rooted in particular places, where people acquire this type of knowledge largely through cultural transmission and practical engagement in daily life (Ellen 2004). In his seminal study on the knowledge of manioc varieties among the Aguaruna in Peru, Boster (1985) found that ethnobiological knowledge is not evenly distributed and that intracultural diversity in knowledge is patterned. The gender division of labor, an individual's age, expertise, and membership in kin and residential groups were important in shaping knowledge distribution. He argued that individuals' learning capacity depends on their motivation, ability, and opportunities to learn, where the social relations within which they are embedded can present opportunities as well as constraints for knowledge transmission (Boster 1986). Thus, Boster's findings highlighted the importance of social relations for understanding the transmission processes that cause intracultural knowledge variation.

Much subsequent research on ethnobiological knowledge systems has explored how the identities of knowledge holders shape knowledge distribution, where individual identities are defined, among others, by age (Begossi et al. 2002), formal education (Zarger 2002), market participation (Reyes-García et al. 2005), and sex (Voeks 2007). For example, elders and those with less formal education or market participation may hold greater ethnobiological knowledge. However, research that is confined to exploring variation according to socio-demographic identities often overlooks the importance of social interactions (social relations) for explaining intracultural knowledge variation and how this is shape by cultural transmission.

1.1 Cultural knowledge transmission through social networks

Cultural evolution theory has attempted to discern different pathways through which knowledge is transmitted, developing models of cultural transmission (Cavalli-Sforza and Feldman 1981) and testing these for different domains, such as foraging techniques or ethnobotanical knowledge (Hewlett and Cavalli-Sforza 1986; Reyes-García et al. 2009). Richerson and Boyd (2005), for example, argue that, in the process of social learning, people select from alternative sets of skills, ideas, beliefs, and values (cultural variants) to which they are exposed in the course of daily life. Although the selection of cultural variants might be based on content (e.g., some variants might be easier to learn than others), people also have a predisposition to adopt those variants that occur more frequently or that are exhibited by successful or prestigious individuals, i.e., those with high social status, where these traits depend on the social relations of a specific community.

Similar insights have arisen from a completely different body of research based on social network analysis (SNA), a tool associated with social network theory (Borgatti et al. 2009). SNA is employed to determine how the connections between individuals in a social structure affect their abilities to access information or other resources. People who have more centrality in the network (are more connected with other people) appear to have more opportunities to accumulate and control information, which in turn may increase their influence. Burt (1992), for example, argues that those who connect otherwise disconnected people (acting as

'brokers') have greater control over information flows. In general, individuals' positions in social networks define, to some extent, their ability to perform in the social structure in which they are embedded.

Recently, researchers have begun to use this quantitative approach to explore the role that social networks play in knowledge transmission and distribution. (Haselmair et al. 2014)) explored the significance of social networks in food and medicinal plant knowledge transmission among migrants, whereas (Hopkins 2011; Calvet-Mir et al. 2012)) examined the links between individuals' positions in a network and their knowledge of medicinal plants and agrobiodiversity, respectively. Henrich and Broesch's (2011) study of cultural transmission networks among Fijian villagers showed evidences of the importance of selective learning biases in knowledge transmission, where people are biased to learn from others perceived as more successful or knowledgeable about fishing, medicinal plants, and yam growing. Kawa et al. (2013) also found that the distribution of *perceived* knowledge in a culture can be related more to an individual's status (e.g. resource endowment, visible performance) rather than to their *objective* knowledge; a person (or household) with higher status may be more central to a network, but may not necessarily be more knowledgeable from an etic point of view. Overall, results from this body of research suggest that an individual's network position at least partly predicts their knowledge and skills and that cultural transmission networks are influence by learning biases.

1.2 Cultural knowledge is gendered

Research shows that gender relations strongly affect natural resource access, use, and knowledge (e.g., Rocheleau et al. 1996; Howard 2003; Pfeiffer and Butz 2005). In this study, gender[1] is understood as the socially constructed and culturally learned behavior ascribed to women and men within a particular culture. Gender relations are embedded in cosmologies, beliefs, and norms about appropriate behaviors and social power accorded to each sex (Howard 2003). Gender is a relational identity that conditions how women and men interact with people of the same and opposite sex, as well as with their environments, and that is reflected in power relations, the division of labor, use of space, and access to, use and knowledge of natural resources (e.g., Howard and Nabanoga 2007; Kelkar 2007). Thus, women and men are exposed to diverse environments, skills, and experiences, which helps to explain the gendered nature of ethnobiological knowledge (Pfeiffer & Butz 2005a).

Women's and men's social status differs and depends on different types of social and cultural capital (e.g., knowledge, skills, and networks). Food procurement and provision, as well as meal preparation and presentation, are means to achieve status and have important social significance and symbolism (Wiessner and Schiefenhövel 1996). Bird (2007), for example, explains gendered differences in fishing strategies among the Meriam of the Australian Torres Strait Islands in relation to social status; men seek larger fish, which are more difficult to catch, which demonstrates their skills. Regardless of the amount harvested, men's catches are more frequently shared within the community, which confers status on the fishermen who distribute their catch. Women, for whom higher social status is based on hard work, prefer more reliably available fish, which are better for provisioning their households

and also more accurately reflect the time invested in fishing. Different fishing strategies entail the use of different sets of knowledge and skills, so the ways in which different social groups achieve status also shapes their knowledge and skills.

Here we focus on social interactions and apply SNA to analyze whether people's choice of fishing partners is related to fisher's perceived fishing knowledge among the Tsimane' of Amazonian Bolivia. Beyond individual identities, we hypothesize that gender relations condition fishing routines, and that the social networks through which fishing knowledge is transmitted and acquired are influenced by the type and distribution of fishing knowledge that individuals have. We assume that people fishing together share related knowledge.

2. Fishing among the Tsimane'

There are some 12,000 Tsimane' people living in 125 villages located primarily along the Maniqui and Quiquibey rivers in the department of Beni in Bolivia (Reyes-garcía et al. 2014). We conducted research in the Tsimane' Indigenous Territory, which includes 55 Tsimane' villages and lies between the eastern foothills of the Andes and the flooded pampas of Moxos. Most vegetation is Amazonian lowland forest with a high semi-deciduous canopy (Guèze et al. 2013). San Borja is the primary town and economic center of the area, where the municipal government and the *Gran Consejo Tsimane'* (the Tsimane's political organization) are based. The villages situated closer to this town have easy access to state schools and markets by road, whereas the more remote villages have access to town only by river and do not always have access to schools.

The Tsimane' depend mostly on subsistence fishing, hunting, gathering, and swidden agriculture. Their primary sources of income are sales of palm thatch, rice, and plantain. While some Tsimane' men work as wage laborers for local loggers and ranchers, Tsimane' society continues to be highly self-sufficient.

Tsimane' social organization is largely kinship based, and most practice cross-cousin marriage (a man weds the daughter of his mother's brother or that of his father's sister and residence is matrilocal, i.e. living with or near the wife's parents) (Daillant 2003). In villages, households are scattered geographically according to clan groups, and social life is embedded in relations revolving around subsistence activities, particularly procuring and sharing food and drink, which strengthen cultural values of solidarity and reciprocity. Boys and girls learning of sex- specific subsistence tasks are based on observation and direct experience and acquired before marriage (Reyes-García et al. 2009). The products of women and men's labor enter different distribution spheres, which define the identity and relative status of each sex. The consumption and distribution of sweet manioc beer is a female domain, and is an important form of sociality; inter-household food distribution depends on men's capacity to provide fish and meat (Ellis 1996), and confer status on men. Ellis (1996) highlights the Tsimane' concern with, and interest in, the knowledge and capabilities of others, which are frequently discussed and picked apart in the minutest of detail.

Fishing is a principal source of subsistence and is a key component of the Tsimane's cosmological beliefs (Luz et al. 2014). For them, fish availability is regulated by their interactions with spirits (owners of fish). *I'dojore*' is a beneficent owner who provides the Tsimane' with fish, whereas *o'pito'* (rainbow) is a harmful owner who monopolizes fish without sharing them, causing fear and distrust (Huanca 2008).

Fishing is practiced for subsistence rather than for income generation, and occurs year round, with a peak in the dry season (August to November) when waters are calmer and fish capture is easier. The Tsimane' fish individually or in groups and employ various traditional (e.g. bow and arrow, plant poisons) and modern (e.g. hook and line, nets) techniques (Pérez-Limache 2001).

Only males fish with bow and arrow and craft these fishing implements. Bow and arrow fishing is practiced day and night, in rivers, streams, and ponds. Men usually do it alone or in groups of two to three while walking along the shore or from canoes as they travel downstream. Fish poisoning is another technique, usually performed in collective expeditions (*ñuttyi*) involving all members of a household or several households from the same village. Fish poisons are mostly used in the dry season when the current is slower and yields are higher. Icthyotoxic plants are used to paralyze fish, causing them to float, so they are easier to capture. Shallow areas of rivers or streams are temporarily blocked and poison is placed upstream so that the toxins diffuse downstream.

The division of tasks in fish poisoning is strongly gendered. Men and women gather various icthyotoxic plants. Women and children typically gather and prepare *chito'* (*Tephrosia vogelii* or *T. toxica*), found in homegardens and agricultural plots. Before going fishing, men collect a tree resin known as *conojfoto'* (*Hura crepitans)* and a vine, *vashi*' (*Serjania tenuifolia*), which are found in the forest or close to rivers and streams. Men and women block the water flow together, and men distribute the poison. As the fish begin to surface, men and young boys use bows and arrows to capture them, often from canoes. Women and young girls use knives, machetes, and their hands to catch fish from the riverbanks or while standing in shallow water. Elderly people and women with infants stay on shore to clean and cook the fish immediately after capture.

There are important gendered norms and beliefs that influence Tsimane' behavior around fish poisons. Women and men should refrain from sexual intercourse before engaging in a *ñuttyi*. Nor should pregnant women be present during the preparation of the poison, especially while diluting it, since their presence is believed to reduce the poison's effectiveness (Chicchón 1992).

Men, women, and children fish with hook and line all year round, either individually or in small groups along or in rivers and streams. The line is tied to one end of a piece of wood and the hook is tied to the other end. In the past, the Tsimane' crafted hooks and lines from plant materials, but today they are mostly purchased. The size of the hook depends on the size of the target fish. Men's hooks are larger than women's and children's, allowing them to capture larger fish. Bait includes small fish, larvae, or earthworms.

Men mostly fish with nets in streams, ponds, lagoons, or in rivers when the water level is low, and when fish migrate upstream to spawn. Nets are procured from merchants and are usually owned by men. At least two people are required to set up the nets, so it is common to see groups of men and young boys fishing together with nets.

3. Methods

Fieldwork was conducted between January 2012 and November 2013 in two villages on the Maniqui River. Before beginning, informed consent and permission to live in the villages were obtained both from villagers and the *Gran Consejo Tsimane'*. Two villages with differing access to urban areas were selected for study. The village closer to town (n=22 households) is in the middle of the Maniqui River, one day's canoe trip from San Borja. The village farther from town (n=37 households) is at the river's source, a three-day canoe trip from San Borja. All adults (16 years of age and older) were invited to participate in the research. Both women and men were encouraged to participate equally. In the closer village, men and women were represented nearly equally (n=89, women= 43, men=46) while there were fewer women (n=25) than men (n=33, total n=58) in the more isolated village. The participation rate was over 90% in both villages; therefore we consider that the sample captured all potential variability in fishing interactions.

Participant observation of fishing expeditions occurred throughout the fieldwork period and helped to contextualize the research and gain a broad overview of the social relations among villagers. We shared daily life with the Tsimane', which allowed us to gain interviewees' trust and explore social interactions. We helped set fishing nets, caught live bait, gathered plants used for poison, cleaned and prepared fish, and ate together. This allowed us to observe the distribution of tasks by technique. We took notes soon after the fishing events and used them to interpret our quantitative results. Additional data on age and schooling were collected in a census survey, while data on income comes from individual interviews collected once per quarter, and data on wealth (monetary equivalent of material possessions that the Tsimane' consider to be signs of modern wealth, i.e. fishing nets, chainsaws, radios, etc.) were collected twice, at the beginning and at the end of the study.

3.1 Assessing fisher's perceived knowledge through fishing ratings

Based on previous research (Davis and Wagner 2003; Kightley et al. 2013*),* we conducted a peer-rating exercise to develop a proxy for fisher's perceived knowledge and skills, or abilities (Reyes-García et al. *in press*). Informants were asked to rate other villagers' fishing abilities. To do so, we grouped names of adults in lists containing about 20 names. Six male and six female household heads from different clans in each village were asked to rate the fishing abilities of the people in one of the lists, interviewing each informant privately. We first asked, "Who are the best fishers in this village?" and assigned four points to the people who were mentioned. We then read the names on one of the lists and, for each, asked informants to assess whether the person was good (three points), average (two points), not

specialized in fishing (one point), or didn't fish (0 points). If one or more informants did not evaluate someone in the list, we asked another informant so that each person had a total of six scores. To assess a person's fishing performance or rating, we calculated the mean score given by the six informants who rated her/him.

3.2 Characterizing and analyzing fishing networks

Data on fishing networks were collected over a 12-month period, allowing us to capture seasonal variation in network composition attributable to the use of different techniques throughout the year. About once every fortnight, on a day chosen at random, each household in the village was visited (a total of 27 visits) and all informants were asked about their fishing expeditions in the two days before survey. Data collected included fishing location, technique used, and names of accompanying people (adults and children).

To explore fishing networks' structure, we first aggregated the longitudinal data to produce a network that included all fishing events in a village. We then explored the networks for the most common fishing techniques: bow and arrow, fish poison, hook and line, and net. Instead of using symmetric or undirected data as the result of the co-affiliation networks of fishing (i.e., assuming that informants' reports on people accompanying fishing expeditions were always reciprocal) we used the actual nominations (directed data). We did so because recall bias reflects, among other dimensions, perception of hierarchical positions and frequency of interaction (Brewer 2001), then, using actual nominations could help us to find hierarchies in the cultural transmission of fishing knowledge. Ethnographic data supports this approach. For example, we observed that, while fish poisoning is performed collectively because many people are needed to set up the dams, informants did not report all of the people participating, but cited just a few, mostly from the same household.

We also calculated five measures to describe networks structure: 1) *size*, or number of fishers (nodes) in the network; 2) *number of components,* or sub-networks, in which all individuals are directly or indirectly linked; 3) *density,* or proportion of existing connections in the network relative to the maximum possible number of connections (from 0 to 1); 4) *mean indegree*, or the average of incoming nominations that a person in the network received as fishing partner, and 5) *reciprocity,* a measure of the tendency for every pair of nodes (fishers) to have connections with each other (Wasserman and Faust 1994). In order to identify important fishers and their influence, we used the same data to generate two variables that capture a person's centrality in the network: 1) *indegree,* or number of times a person (Ego) is reported as a fishing partner; 2) *betweenness,* or the proportion of times that an Ego lies on the shortest path between each pair or alters (i.e. other fishers) with whom the Ego is directly or indirectly connected (Freeman 1978). This measure captures the importance of an Ego in her or his personal network.

To explore patterns in fishing connections, we tested the matrix of fishing ties (pairs of people fishing together) according to clan membership. First, we used emic kinship classifications to determine each person's clan membership. We then generated a matrix with all reported dyads. We tested the frequency of intra- and inter- clan dyads using a covariate

(same_clan) assigned the value 1 if people were from the same clan, or 0 if not. Other matrices were generated that captured whether people in the dyads: 1) were of the same sex (same_sex), and 2) shared the same life cycle stage (adults vs. children) (comp_adult). We tested dyadic fishing interactions with a Multiple Regression Quadratic Assignment Procedure (MRQAP) (Dekker et al. 2007). Social network data were analyzed with UCINET6-Netdraw for Windows, and network visualizations were designed with Gephi using the Force Atlas algorithm.

3.3 Testing the relation between fishers' perceived knowledge and their positions in the fishing network

To examine the associations between fisher's abilities (proxied by fishing ratings) and centrality in networks and sex, we ran a set of multivariate Ordinary Least Square (OLS) regressions. In a first model, we explored the association between fishers' ratings, centrality in fishing networks, and sex, controlling for socio-demographic variables (e.g. age, schooling). In a second model, we added fishing related variables (e.g. fishing frequency) and the person's level of integration into the market economy (e.g. income, wealth). We then added a term capturing the interaction between the centrality measures and sex. The interaction term allows us to examine whether the effect of the centrality measures on fishing ratings (outcome variable) differs by sex. Finally, we selected the statistically significant variables from these previous models as controls for the three regressions models presented here: Indegree_Model, including indegree and the interaction of indegree*sex and sex as explanatory variables: Betweenness_Model, including betweenness and its interaction with sex, and Net_Model, which includes the centrality measures and interactions that were statistically associated with fishing ratings. Clustered robust standard errors by household were used for all of the models, since the household is the primary unit where fishing competences and skills are shared. The option "cluster" relaxes the assumption that observations from people belonging to the same household are independent. Stata 13 for Mac was used for statistical analysis.

4. Results

4.1 Description of contemporary Tsimane' fishing

In the village closer to town, 16% of women reported participating in fishing expeditions in the two days prior to the survey, compared to nine percent in the farther from town village. In both villages, men reported fishing more often than women (33% in the closer vs. 62 % in the farther village). Men and women both fished mainly in the river, although women living closer to town regularly fished in streams (Table 10). Women's and men's frequency of use of different fishing techniques differed. Only men fished with bows and arrows (10% of the expeditions in the closer village and 21% in the farther village). Women widely practiced fish poisoning, especially in the closer village (48%). Men mainly used fishing nets in both villages (44% and 39% closer and farther from town). Both men and women frequently used hook and line in the two villages.

Table 10. Descriptive statistics of fishing by sex and village.

Variable	Definition		Women				Men			
			Closer to town		Farther from town		Closer to town		Farther from town	
			Obs	%	Obs	%	Obs	%	Obs	%
Fishing	Did the person go fishing in the past 48h?	No	654	83.7	345	90.1	406	66.6	179	37.3
		Yes	127	16.2	38	9.9	203	33.3	300	62.6
		Total	781	100	383	100	609	100	479	100
Fishing location	Fishing location	River	53	41.7	29	76.3	99	48.7	256	84.6
		Stream	58	45.6	7	18.4	51	25.1	26	8.6
		Pond	15	11.8	0	0	52	25.6	7	2.3
		Others	1	0.8	2	5.2	1	0.5	2	0.6
		Total	127	100	38	100	203	100	299	100
Fishing technique	Fishing technique	Bow and arrow	0	0	0	0	20	10	65	21.6
		Fish poison	60	48	14	36,8	36	18	21	7
		Hook	47	37.6	21	55.2	54	27	95	31.6
		Net	14	11.2	3	7.8	89	44.5	119	39.6
		Machete	4	3.2	0	0	1	0.5	0	0
		Total	125	100	38	100	200	100	300	100

4.2 Exploring the structure of fishing networks

Overall, the networks studied have low densities (Table 11, column 4) and are fragmented, i.e. have several sub-networks corresponding to different groups of fishers who are mainly organized by household. The number of fishers (or 'nodes') (total = 115) varies greatly in the closer village sub-networks (9 to 66). The differences in node composition in the farther village (total= of 69) are smaller (23 to 47) (Table 11). There was greater reciprocity, meaning that people named each other as fishing partners, and a higher mean indegree, meaning that people nominated more people in their fishing expeditions, in the farther village (Table 11).

Table 11. Structure of fishing networks by technique and village.

Village	Network name	Nodes (n)	Density	Components	Max. nodes in a connected component	Reciprocity	Mean Indegree	SD
Closer to town								
	All events	115	0.023	3	109	0.313	3.82	3.69
	Bow&arrow	9	0.069	4	3	0.000	0.55	0.49
	Fish poison	73	0.026	10	37	0.241	2.32	2.37
	Hook	60	0.016	15	11	0.132	1.40	1.26
	Net	66	0.033	6	45	0.464	2.53	2.50
Farther from town								
	All events	69	0.049	2	52	0.535	5.68	5.78
	Bow&arrow	23	0.047	7	5	0.333	1.60	1.68
	Fish poison	26	0.175	5	14	0.652	6.15	5.68
	Hook	47	0.030	10	19	0.416	1.76	1.57
	Net	39	0.053	3	28	0.519	2.87	2.75

The analyses of fishing ties (pairs of people fishing together) suggest that fishing interactions are shaped by kinship, age, and gender relations in both villages. Results of the MRQAP test for dyadic interactions show that the selection of fishing partners is associated with same clan (closer to town: coef= 0.519; p< 0.001; farther from town: coef= 0.395; p< 0.001), adults (closer to town: coef= 0.226; p< 0.00; farther from town: coef= 0.204; p< 0.001), and sex (closer to town: coef=0.16; p< 0.001; farther from town: coef=0. 218; p< 0.001). Meaning that, for their fishing expeditions, people tend to select partners that are of their clan, sex, and generally adults.

4.3 Fishers' rating and centrality in the fishing network

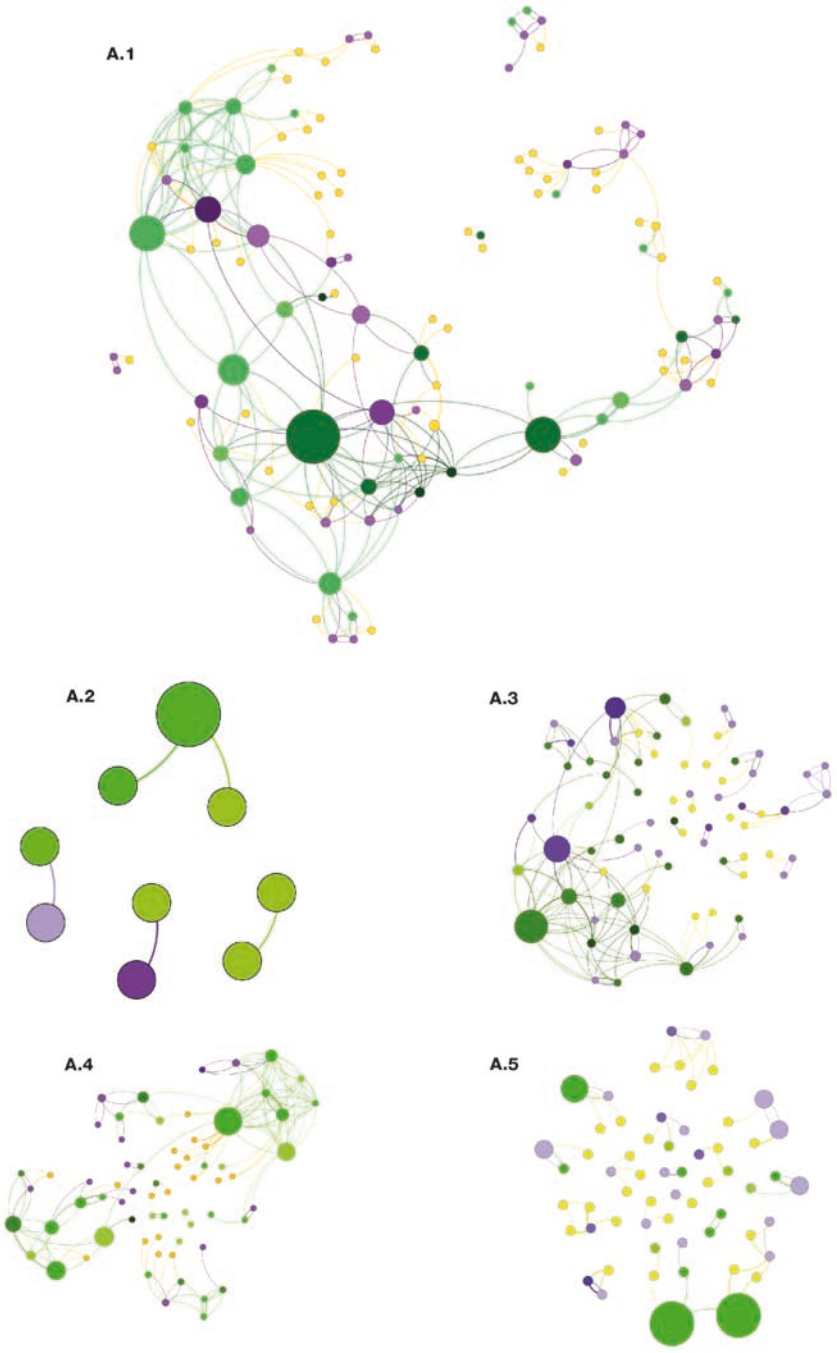
The average rating for women's fishing was considerably lower than men's average (1.19 vs. 2.28) (see Table 12). Average indegree was also lower for women, meaning that, on average, men were more often chosen as fishing partners than women. The average value of the variable betweenness was also considerably lower for women although, for men, betweenness displays greater variation, showing that men's bridging role varies widely. This skewed pattern suggests that some fishers have a much stronger centralizing role than others in the network (Table 12) see also Figure 10.

Table 12. Definition and summary statistics of the variables used in multivariate analysis by sex.

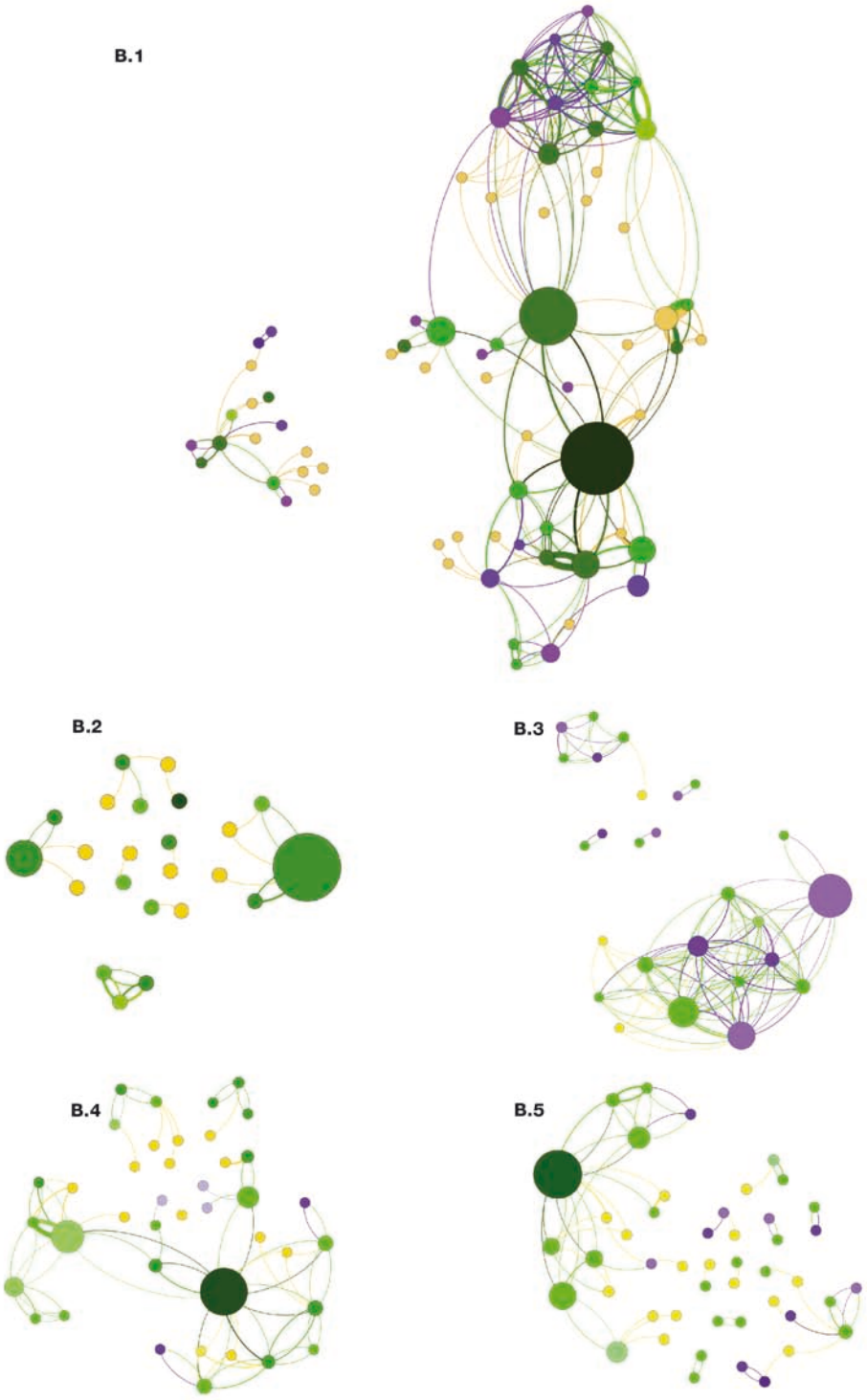
Variable	Definition	Women (N=50)					Men (n=59)				
		N	Mean	S.D.	Min.	Max.	N	Mean	S.D.	Min.	Max.
Outcome variable											
Fishers' ratings	Average of scores in rating survey (from 0 to 4)	50	1.19	0.63	0	3.16	59	2.28	0.69	1	4
Explanatory variables											
Indegree	Nominations in the fishing network	50	2.26	2.24	0	11	67	4.25	3.28	0	12
Betwenness	Grade of intermediation among people where each person is directly and indirectly connected	50	56.88	97.80	0	418.1	67	143.5	251.6	0	1392.5
		N		%			N		%		
Male	Dummy variable that captures the sex of the person, 1=man, 0=woman	50		45.87			59		54.13		
Control variables											
Age	Age of the person, in years	50	36.02	18.20	14	88	59	38.01	19.53	14	91
Age2	Squared term to control for non-linearity in the relation of age with fishing knowledge										
Wealth	Individual wealth in dollars purchasing power parity (ppp). In regressions enter as 1.000.	49	167.7	271.8	0	1058.8	59	1717.79	1750	0	10011.7
Frequency of fishing	Shared of times a person had gone fishing in the previous two days out of the total number of times she or he was interviewed.	48	0.17	0.14	0	0.8	59	0.48	0.23	0.07	0.93
Partners	Average number of adults joining in fishing expeditions.	48	0.34	0.34	0	1.58	59	0.54	0.43	0	1.88
		N		%			N		%		
Village	Dummy variable for village of residence										
	Closer to town	34		68			32		54.24		
	Farther to town	16		32			27		45.76		

Figure 10. Fishing networks by village. Village a) closer to town, b) farther from town. Node size shows betweenness centrality; colors shows women (purple), men (green), children (yellow). The color of the ties represents the color of the target node. Numbers show networks for different fishing techniques 1) all fishing events, 2) bow and arrow, 3) fish poisoning, 4) hook, and 5) nets.

a)



b)



We explored the link between a person's fishing rating and her or his centrality in the fishing network (see Table 12 for a definition and summary statistics for variables and controls used in regressions). Results from a set of regressions including socio-demographic identity, fishing, and market integration variables suggest that fishing frequency, age, wealth, and number of fishing partners are consistently associated with fishing ratings (not shown), so those variables were included in our models (Table 13).

A person's indegree is positively and significantly associated with fishing rating (coef = 0.116; p = 0.051) in Model [A] (Table 13). Similarly, in Model [B], where we use betweenness (intermediation among people with who each node is directly and indirectly connected) as the main explanatory variable, we found that being a man is associated with greater ratings. Moreover, there is a statistically significant association between the interaction term (the sex of a person and her or his position in the network) and fishing ratings. Specifically, people with more betweenness have greater ratings, and this relation is more striking for women than for men.

The two explanatory variables tested in previous models were included in our last Model ([C]). Again, we found a positive and statistically significant association between being male and fishing ratings, and between a person's fishing ratings and their indegree and betweenness. That is, people who received more nominations (have a high indegree) and who function more as brokers (linking others who would otherwise not be connected - high betweenness) are also perceived as better fishers. These results are consistent with Model [B], showing a statistically significant interaction between sex and intermediation in the network, which in turn are associated with their ratings.

Across all the models, the variable fishing frequency is consistently associated with fishing ratings, meaning that, the more frequently a person fishes, the more is perceived by other community members to be knowledgeable and skilled, suggesting that the perception of a person's fishing skills is related to the time they invest in fishing. Wealth also appears to be consistently associated with fishing ratings. The age variable was significantly associated with our abilities measure in either model, indicating that older people are not perceived *per se* to be more skilled fishers.

Table 13. Results of multiple OLS regression models

			Fishers' ratings
	[A]	[B]	[C]
	Indegree_Model	Betwenness_Model	Net_Model
Number of obs (n)	106	106	106
Male	0.537(0.206)**	0.628(0.178)***	0.573 (0.163)***
Indegree	0.116(0.058)*	^	0.078(0.039)*
Betweenness	^	0.002(0.000) **	0 .002(0.000)**
Interaction (male*centrality measure selected)	-0.054(0.056)	-0.001(0.000)**	|-0.002(0.000) **
Closer village	0.205(0 .161)	0.345(0.149)**	0.274(0.170)
Age	0.016 (0.013)	0.017(0.014)	0.018 (0.0149)
Age2	-0.000 (0.000)	-0.000(0.000)	-0.000(0.000)
Frequency of fishing	1.271(0.431)**	0.933(0.382)**	1.125(0.413)**
Company	-0.455 (0.284)	| -0.073(0.178)	-0.474(0.286)
Wealth	0.123(0.047)**	0.140(0.052) **	0.117(0.479)**
R^2	0.54	0.53	0.56

Note: For definition of variables see Table 12. Robust standard errors in parenthesis.
* ,**, and *** significant at the 10%, 5% and 1% level. ^variable intentionally omitted.

5. Discussion

We studied the interrelation between fisher's perceived knowledge and centrality in fishing networks among the Tsimane', hypothesizing that gender relations condition fishing routines and involvement in fishing, which in turn permit or constrain fishing knowledge and skills to be culturally transmitted. Four main findings derive from our work. Firstly, women and men have different fishing strategies involving different frequencies, techniques, ecological settings, and expedition partners. Secondly, there was a positive association between being male, fishing frequency, and a person's perceived fishing abilities. Thirdly, there was a positive association between fishers' structural position in fishing networks and their rating. Finally, the association between a fishers' position in the network and ratings is more striking for women than for men.

5.1 Gendered fishing strategies among the Tsimane'

Our results show that men and women adopt different fishing strategies. Men fish more frequently, especially in the farther village. They use different techniques and choose different ecological settings and partners for their expeditions. Field observations also suggest that women and men target different species; while women mostly focus on small catches in streams close to home to meet daily food requirements, men generally target larger species in more distant locations, producing yields that provision households for several days and that are also shared with other households. Such differences may affect not only men's and women's overall levels of knowledge and expertise but, more significantly, may result in different types of fishing knowledge or gendered knowledge (i.e., that held by women or by men but not by both) (Howard 2003; Pffeifer and Butz 2005). For example, Siar's (2003) study among small-scale fishing communities in the Philippines showed that the gender division of space and fishing resource use, where women mostly fish shell-fish in the intertidal zone and men fish in the coral reef, shapes women's and men's distinct knowledge about fishery resources.

The analysis of dyadic ties in both study villages suggests that kinship and gender relations mediate the selection of fishing partners (people tend to select partners of the same clan and sex), and thus are significant in the social organization of fishing. This tendency to relate with similar others in social networks has been defined as *homophily* where, to some extent, networks that are homogeneous with regard to socio-demographic and behavioral identities condition the information participants receive, the attitudes they form, and the interactions they experience (Smith-Lovin and McPherson 1993; McPherson et al. 2001).

Among the Tsimane', as in all other cultures, norms and beliefs regarding appropriate and expected gender behavior embed women and men in different social worlds and networks. For example, only Tsimane' men may craft and use bows and arrows, and women cannot be involved with fish poisons while pregnant. These norms and beliefs shape women's access, preferences, and skills in relation to different fishing techniques and their status as fishers, explaining the dissimilar perceived abilities of women and men with regard to fishing. Their socio-demographic identities, and specifically their sex, mediate the establishment of fishing routines and, in turn, fishing routines shape their fishing networks.

5.2 Fishers' ratings

The second important finding is that fishing ratings are unequal and vary according to socio-demographic identity and especially sex. Results from the multivariate analyses show that, in all models, fishers' ratings are consistently associated with fishing frequency. The Tsimane' apparently perceive expertise in relation to practice, i.e. those who more actively participate in fishing expeditions are considered to be more skilled (higher ratings). The other variable that is consistently associated with fishers' ratings is sex; men tended to have higher rating scores than women. This is not surprising, since men fish more frequently, fishing is culturally considered as a "male activity," and women are not generally perceived as *good fishers*, and high fishing status is ascribed to men.

5.3 Fishers' ratings and fishing networks

The third finding relates to the link between fishers' ratings and their centrality in fishing networks. Measures of network centrality (indegree and betweenness) are associated with higher ratings, underpinning previous findings on the importance of an individual's performance or status in relation their position in networks (Kawa et al. 2013). Our results also suggest a bias towards selecting males as fishing partners. This finding, however, should be interpreted with caution due to measurement errors. Since children were not included in the sample and women fish with children more often than men fish with children, women might have received proportionally fewer nominations compared with men, so their performance in fishing networks might be underestimated.

5.4 Fisher's ratings, centrality in networks, and gender relations

A final important finding is that the association between fishers' ratings and their roles in connecting individuals otherwise unconnected within the networks (betweenness) is more striking for women than for men. Although both being a male and greater betweenness are positively associated with higher ratings, the effect on fishing networks is stronger for women. This indicates that a person's sex mediates the interaction between the position of a person in the network and that person's rating. In our case study, there are not so many women seen as *good fishers* even within women. The effect of being a woman in a fishing network has an influence in the social organization of fishing and the transmission of fishing knowledge and skills, which can be explained in two ways. One the one hand, there is a gender difference in a brokerage position (Burt 1998). In the Tsimane' context, women are culturally regarded as fishing outsiders, and in general lack legitimacy as fishers. However, those women with higher betweenness may be in an advantaged position in the network, as they have more opportunities to access fishing knowledge, skills, and grounds, which may increase their competence, legitimacy, and perceived fishing skills. On the other hand, since there are fewer women who fish and who are considered *good fishers*, those that do fish more frequently can access more information, which reinforces their brokerage position. Women who can bridge relations between different individuals might acquire more knowledge and skills through these connections, which provides them with information that could be new and valuable. This result highlights how networks can both support and constrain the transmission of knowledge or access to resources (Salpeteur et al. 2015; Kawa et al. 2013).

Overall, our results suggest that cultural transmission of ethnobiological knowledge is biased, in the sense that people tend to imitate or learn from successful or prestigious individuals (Henrich and Gil-White 2001). Gender relations also seem to play an important role in cultural transmission, defining who has access to what knowledge and the cultural frame of references regarding who people chose to learn from (or as in our case study, with whom they fish). Gender relations and status judgments therefore flavor emic perceptions because they are associated with a society's belief systems. They are likely to be invoked each time researchers attempt to identify knowledgeable or skilled informants by asking locals' view. Furthermore, researchers should take care when studying intracultural knowledge variation since people have differentiated access to and use of resources and hold diverse

types of knowledge, rather than simply diverse *quantities* of knowledge, in which case gendered knowledge may be overlooked, leading to various scientific errors[5]. A power-knowledge framework, where knowledge is not simply reported by sex but rather specific gender relations are explored, is more appropriate for understanding diversity and variation within an ethnobiological knowledge domain (Kothari 2003).

6. Conclusion

A network approach proves useful for exploring ethnobiological knowledge transmission and distribution. It broadens our understanding of how the different social structures that derive from a particular cultural and economic context shape the opportunities and constraints that social relations impose on knowledge transmission, and on the use of natural resources. This study also highlights the importance of gender relations in the cultural transmission of fishing among the Tsimane'. Furthermore, as women and men adopt different fishing strategies, they may also hold gendered fishing knowledge.

7. References

Begossi, A., N.Hanazaki, and J.Y. Tamashiro. 2002. Medicinal plants in the Atlantic Forest (Brazil): knowledge, use, and conservation. *Human Ecology* 30(3):281-299

Bird, R.B. 2007. Fishing and the sexual division of labor among. *American Anthropologist* 109(3): 442–451.

Borgatti, S. P., A. Mehra, D. J Brass, and G. Labianca. 2009. Network analysis in the social sciences. *Science* 323: 892–895.

Boster, J. S. 1985. "Requiem for the Omniscient Informant": There's life in the Old Girl Yet. In: *Directions in cognitive anthropology,* ed. J. Dougherty, pp. 177–197. Urbana and Chicago: University of Illinois Press.

Boster, J. S., F. C. Lees, and F. Tierson. 1986. Exchange of varieties and information between Aguaruna manioc cultivators. *American Anthropologist* 88(2): 428–436.

Brewer, D. D. 2011. Biases in perceiving one's own social position and social ties as evolved psychological mechanisms. Available at SSRN: http://ssrn.com/abstract=1879624. DOI: http://dx.doi.org/10.2139/ssrn.1879624.

Brightman, R. 1996. The sexual division of foraging labor : biology, taboo, and gender politics. *Society for Comparative Study of Society and History* 38(4): 687–729.

Burt, R. S. 1992. Structural holes: the social structure of competition. Massachusetts: Harvard University Press.

Burt, R. S. 1998. The gender of social capital. *Rationality and Society* 10(1): 5–46.

Calvet-Mir, L., M. Calvet-Mir, J. L. Molina, and V. Reyes-García. 2012. Seed exchange as an agrobiodiversity conservation mechanism. A case study in Vall Fosca, Catalan Pyrenees, Iberian Peninsula. *Ecology and Society* 17(1): 29.

Cavalli-Sforza, L.L., and M.W, Feldman. 1981. Cultural transmission and evolution: A quantitative approach. Princeton N.J: Princeton University Press.

[5] See Howard, P. 'Gender bias in ethnobotany: proposals and evidence of a distorted science and promises of a brighter future.' Distinguished Economic Botanist Lecture, Kew Gardens, 2006. https://www.academia.edu/163864/Gender_Bias_in_Ethnobotany_Propositions_and_Evidence_of_a_Distorted_Science_and_Promises_of_a_Brighter_Future

Chicchón A. 1992. Chimane Resource Use and Market Involvement in the Beni Biosphere Reserve, Bolivia. PhD Thesis. University of Florida, Gainesville.

Crona, B., and Ö Bodin. 2006. What you know is who you know? Communication patterns among resource users as a prerequisite for co-management. *Ecology and Society* 11(2): 7.

Daillant, I. 2003. Sens dessus dessous: organisation sociale et spatiale des chimane d'Amazonie bolivienne. Nanterre: Société d'ethnologie.

Davis, A., and J. R. Wagner. 2003. Who Knows ? On the importance of identifying "experts" when researching local ecological knowledge. *Human Ecology* 31(3): 463-489.

Dekker D., D. Krackhardt, and T.A.B. Snijders. 2007. Sensitivity of MRQAP tests to collinearity and autocorrelation conditions. *Psychometrika* 72: 563-58.

Ellen, R. 2004. From ethno-science to science, or "what the indigenous knowledge debate tells us about how scientists define their project." *Journal of Cognition and Culture* 4 (3): 409–450.

Ellis, R. 1996. A taste for movement: an exploration of the social ethics of the Tsimanes of lowland Bolivia. PhD Thesis. St. Andrews University, Scotland.

Freeman, L. C. 1979. Centrality in social networks conceptual clarification. *Social Networks* 1:215–239.

Guèze, M., J. Paneque-Gálvez, A. C. Luz, J. Pino, M. Orta-Martínez, V. Reyes-García, and M. J. Macía. 2013. Determinants of tree species turnover in a southern Amazonian rain forest. *Journal of Vegetation Science* 24(2): 284–295.

Haselmair, R., H. Pirker, E. Kuhn, and C. R. Vogl. 2014. Personal networks: a tool for gaining insight into the transmission of knowledge about food and medicinal plants among Tyrolean (Austrian) migrants in Australia, Brazil and Peru. *Journal of Ethnobiology and Ethnomedicine* 10(1): 1.

Henrich, J., and F. Gil-White. 2001. The evolution of prestige. Freely conferred deference as a mechanism for enhancing the benefits of cultural transmission. *Evolution and Human Behavior* 22:165−196.

Henrich, J., and J. Broesch. 2011. On the nature of cultural transmission networks: evidence from Fijian villages for adaptive learning biases. *Philosophical Transactions of the Royal Society B: Biological Sciences* 366(1577)*:*1139-1148.

Hopkins, A. 2011. Use of network centrality measures to explain individual levels of herbal remedy cultural competence among the Yucatec Maya in Tabi, Mexico. *Field Methods* 23(3):307–328

Howard, P.L. 2003. Women and plants: gender relations in biodiversity management and conservation. London: Zed books.

Howard, P.L., and G. Nabanoga. 2007. Are there customary rights to plants? An inquiry among the Baganda (Uganda), with special attention to gender. *World Development* 35(9):1542–1563.

Huanca, T.2008. Tsimane' oral tradition, landscape and identity in tropical forest. La Paz: Imprenta Wangui.

Kawa, N. C., C. McCarty, and C. R. Clement. 2013. Manioc varietal diversity, social networks, and distribution constraints in rural Amazonia. *Current Anthropology* 54(6): 764–770.

Kelkar, M. 2007. Local knowledge and natural resource management: a gender perspective. *Indian Journal of Gender Studies* 14(2): 295–306.

Kightley, E., V. Reyes-García, K. Demps, R. Magtanong, V. Ramenzoni, G. Thampy, M. Gueze, and J.R. Stepp. 2013. An empirical comparison of knowledge and skill in the context of traditional ecological knowledge. *Journal of Ethnobiology and Ethnomedicine* 9 (71).

Kothari, B. 2003. The invisible Queen in the plant kingdom: gender perspectives in medical ethonobotany. In: *Women and plants: gender relations in biodiversity management and conservation,* ed. P. Howard, London: Zed books.

Luz, A.C., M., Guèze, J. Paneque-Gálvez, I. Díaz-Reviriego, and V. Reyes-García. 2014. Caza, pesca y recolección: descripción importancia y cambios. In: *Cambio global cambio local. La sociedad Tsimane' ante la globalización*, eds. V. Reyes-García, and T. Huanca. Barcelona: Icaria, Institut català d'antropologia.

McPherson, M., L. Smith-Lovin, and J. M. Cook. 2001. Birds of a feather : homophily in social networks. *Annual Review of Sociology* 27: 415–444.

Pérez-Limache, E. 2001. Uso de la Ictiofauna entre los Tsimane'. BS Thesis. Universidad Nacional Mayor de San Andrés, Bolivia.

Pfeiffer, J.M., and R.J. Butz. 2005. Assesing cultural and ecological variation in ethnobiological research: the importance of gender. *Journal of Ethnobiology* 25(2): 240-278.

Reyes-García V.,V. Vadez, E. Byron, L. Apaza, W. Leonard, E. Pérez, and D. Wilkie. 2005. Market economy and the loss of ethnobotanical knowledge: Estimates from Tsimane' Amerindians, Bolivia. *Current Anthropology* 46(4): 651-656.

Reyes-García, V., I. Díaz-Reviriego, R. Duda, A. Fernández-Llamazares, S. Gallois, M. Guèze, T. Nanitupulu, and A. Phyhälä. Accepted. Peer evaluation can reliably measure local ecological knowledge. *Field Methods*.

Reyes-García, V., J. Broesch, L. Calvet-Mir, N. Fuentes-Peláez, T. W. McDade, S. Parsa, and TAPS Bolivian Study Team. 2009. Cultural transmission of ethnobotanical knowledge and skills: an empirical analysis from an Amerindian society. *Evolution and Human Behavior* 30(4): 274-285.

Reyes-García, V., J. Paneque-Gálvez, P. Bottazzi, A. C. Luz, M. Guèze, M.J. Macía, M. Orta-Martínez, and P. Pacheco. 2014. Indigenous land reconfiguration and fragmented institutions : a historical political ecology of Tsimane' lands (Bolivian Amazon*). Journal of Rural Studies* 34: 282–291.

Richerson, P.J., and R. Boyd. 2005. Not by genes alone how culture transformed human evolution. Chicago:Chicago University Press.

Rocheleau. D., B. Thomas-Slayter, and E. Wangari. 1996. *Feminist Political Ecology: Global Issues and Local Experiences*. London and New York: Routledge.

Salpeteur M., H. Patel, A. Balbo, X. Rubio-Campillo, M. Madella, P. Ajithprasad, and V. Reyes-García. 2015. When knowledge follows blood. Kin groups and the distribution of traditional ecological knowledge in a community of semi-nomadic pastoralists, Gujarat (India). *Current Anthropology* 56(3).

Siar, S. 2003. Knowledge, gender, and resources in small-scale fishing: the case of Honda Bay, Palawan, Philippines. *Environmental Management* 31(5): 569-580.

Smith-Lovin, L., and J. M. McPherson. 1993. You are who you know: a network approach to gender. In: *Theory on gender, Feminism on Theory*, ed. P. England. New York: Gruyter.

Voeks, R. 2007. Are women reservoirs of traditional plant knowledge? Gender, ethnobotany and globalization in northeast Brazil. *Singapore Journal of Tropical Geography* 28(1): 7–20.

Wasserman, S., and K. Faust. 1994. Social networks analysis: methods and applications. Cambridge: Cambridge University Press

Wiessner, P.W., and W. Schievenhövel. 1996. Food and the status quest: an interdisciplinary perspective. Oxford: Berghahn Books.

Zarger, R.K. 2002. Children's Ethnoecological knowledge: situated learning and the cultural transmission of subsistence knowledge and skills among q'eqchi maya. PhD Thesis. University of Georgia, Georgia.

Chapter 6

Who get the big fish? Gendered fishing resource use among Amazonian foragers

Chapter 6

Who get the big fish? Gendered fishing resource use among Amazonian foragers[6]

Abstract

Gender relations define women's and men's domains of work and responsibilities and their resource use, but these responsibilities can potentially shift as other environmental and social changes affect societies. We employed a mixed methods approach to study subsistence fishing among the Tsimane' forager-horticulturalists of the Bolivian Amazonia from a gender perspective. Our findings show that fishery resources use, livelihood strategies, and ecological conditions in the studied villages are intertwined. Given the culturally defined division of labor and access to techniques and fishing grounds, Tsimane' women and men target different fish. Additionally, dependence on different livelihood strategies and engagement in new economic activities seem to affect women's and men's roles and responsibilities in fish provisioning. We conclude by highlighting the practical implications of our findings in relation to women's and men's fishing knowledge and expertise, for new fishing tourism projects, and for Tsimane' food security and sovereignty.

Keywords

Amazonia; ecotourism; gender division of labor; gendered resource use; livelihoods; Tsimane'.

[6] Díaz-Reviriego, I., Á. Fernández-Llamazares, and V. Reyes-García. *Who get the big fish*? Gendered fishing resource use among Amazonian foragers. Manuscript in preparation to be submitted to *Human Organization.*

1. Introduction

The ecological sustainability of Amazonian freshwater resources is threatened, with many fish resources considered to be overfished (Salo et al. 2013; Castello et al. 2013). Although fish are acknowledged as a principal dietary component of Amazonian forager societies', most discussions about Amazonian foragers are biased toward terrestrial food resources and hunting (Gragson 1992; Kuchikura 1996) (for exceptions see Chicchon 1992; Lu 1999; Domingues do Amaral 2004). This situation calls for a better understanding of indigenous foragers' fishing practices since, if Amazonian freshwater fish resource sustainability is compromised, so are indigenous subsistence and food security.

This study aims to contribute to the scientific understanding of indigenous people's subsistence fishing practices through a gender lens. The importance of gender relations has been demonstrated in every phase of the fish value chain in fisheries and aquaculture, from procurement to processing and marketing (Siar 2003; Choo et al. 2008; Walker and Robinson 2009; Makalle 2012; Fröcklin et al. 2014; Kleiber et al. 2015), as well as in inland or riverine non-market oriented subsistence fishing systems (Vázquez-Garcia and Montes-Estrada 2006; Arce-Ibarra and Charles 2008; Lopes et al. 2011). However, there is little research that focuses on gendered subsistence fishing practices among Amazonian forager societies, or that investigates how changes in livelihoods that are occurring among such societies might affect women's and men's fishing strategies. We thus adopt a gender perspective when examining fisheries resource use among the Tsimane, and seek to investigate and inter-relate: 1) gender relations and the division of labor, 2) access to and use of fishing technologies and resources, as well as 3) local fishing ecologies. We investigate two villages that present contrasting freshwater ecologies.

2. Complexity and the gendered natural resource access

Natural resource analysts have emphasized the importance of intra-community dynamics and the formal and informal or customary mechanisms that shape access to and control over resources for understanding how and why people manage resources in the ways that they do (Lu 2001; Agrawal 2003; Grigsby 2004; Aswani 2005; Schlager and Ostrom 2010). People's effective access to resources often cannot be explained exclusively by referring to normative or legal 'rights to resources' (Leach et al. 1999). Ribot and Peluso (2003) explicitly consider how people's social circumstances can constrain access to resources even when they ostensibly have normative or formal 'rights' to them. They broadly define access as 'the ability to derive benefits from things' (Ribot and Peluso 2003: 153), where the ability to benefit from resource use is mediated by specific political, economic, and cultural constraints. Such constraints define people's access to other resource use prerequisites, or precursors, such as their particular social identities and their access to other resources (e.g. land, livestock, and labor), technology and knowledge. According to these authors, access to technology and tools is often a prerequisite for accessing resources. This is well documented in the fisheries

literature, where it has been shown that access to different types of fishing gear facilitates or restricts the ability of given social groups to exploit specific types of fishing resources (Vázquez-Garcia and Montes-Estrada 2006; Makalle 2012).

Across the globe, natural resource access is mediated by gender relations (Rocheleau et al. 1996; Shaughnessy and Krogman 2011; Sunderland et al. 2014). In any society, there are gendered differences in technological skills and domains of expertise that are shaped by and shape masculinities and femininities (Bray 2007). Associated with this are heterogeneous assets and endowments that allow each or both sexes to access specific resources (Leach et al. 1999). Brightman (1996) argues that what appear to be gendered modes of labor among hunting and foraging societies are actually the effects of gendered access to precursor technologies. Likewise, Howard and Smith (2006) showed that, in the Ethiopian highlands, women's use of common pasturelands differs radically from men's not because women lack equal formal access to pastures, but because they do not own or graze oxen, which is considered to be a male privilege. In her study of small-scale fishing communities in the Philippines, Siar's (2003) demonstrates that the social constraints to effective resource entitlements are established early in life - the socialization of children into fishing and related social learning reinforces the gender division of space and the techniques and practices used, and therefore the opportunities to access fishing resources, which in this case are mediated by gender, age and knowledge.

Furthermore, the gendered division of labor intertwines the symbolic and the material aspects of human-environment relations. The concepts of masculinity and femininity and norms about appropriate behavior, activities, and responsibilities of each sex are embedded in religious and other social belief systems, strongly influencing women's and men's social position or status and the physical spaces and environments in which they may carry out their activities (Howard and Nabanoga 2007). Men's and women's gender roles often complement and reinforce each other (Rocheleau and Edmunds 1997; Howard 2006; Lope-Alzina 2007; Carr 2008; Lowassa et al. 2012) and are grounded in social contexts and livelihood strategies (Jackson 1993; Brightman 1996; Agarwal 2009), thus influencing the process by which each sex appropriates natural resources, for example, to produce food (Momsen 2007).

Gender divisions of labor can shift as other livelihood transformations occur, e.g. through increased commodification, changes in resource availability, and migration, which in turn modify gendered patterns in natural resource use (Vázquez-Garcia and Montes-Estrada 2006; Shaughnessy and Krogman 2011). For example, Walker and Robinson's (2009) study of fishing in a French Polynesian lagoon found that gendered fishing patterns are changing because women's favored nearshore invertebrate species are no longer available in the lagoon, so they have turned to other species and fishing methods that resemble more the methods that males use for fishing. Vázquez-Garcia and Montes-Estrada's (2006) study among Nahua fishing communities in Southern Veracruz, Mexico, also shows that long-term male migration has strengthened women's roles in subsistence fishing in order to maintain the household's food consumption and security in the absence of men. Overall, these studies suggest that the gender relations define women's and men's domains of work and responsibilities and their

resource use, but can potentially shift as other environmental and social changes affect societies.

3. The setting

The Tsimane' are a foraging-horticulturalist society of about 14.000 people living in the Department of Beni, Bolivian Amazonia (Undurraga et al. 2014). The Tsimane's traditional lifestyle has been described as highly mobile, with a semi-nomadic settlement pattern (Ellis 1996). It was not until the mid-twentieth century that missionaries succeeded in settling a fair number of Tsimane' in relatively permanent villages. The missionaries provided schooling and teacher training (mostly to young Tsimane' men) as well as basic biomedical services. The missionaries also supported the creation of the Tsimane's first officially-recognized representative body, the *Gran Consejo Tsimane'* (GCT), whose purpose at the outset was to defend Tsimane' land and resources given the encroachment of Andean colonist and loggers (Reyes-García, Paneque-Gálvez, Bottazzi, et al. 2014).

There are about 125 Tsimane' villages scattered across several territorial tenure regimes, i.e., indigenous territories, protected areas, logging concessions, and private lands (Reyes-García et al. 2014a). For this study, we researched two villages within the Tsimane' Indigenous Territory, a communal land lying between the eastern foothills of the Andes and the flooded pampas of Moxos. These villages lie along the banks of the Maniqui River in a lowland tropical forest containing semi-deciduous tree species. The area is covered mostly by old-growth *terra firme* forests although *bajío* forests also thrive in seasonally or permanently flooded areas (Guèze et al. 2013). Under current Bolivian legislation, people in the study villages have the right to use the land for traditional subsistence and to log for commercial purposes when adequate certification is provided (Reyes-García et al. 2014a). Natural resources are generally managed as common resources and their use is regulated through norms of customary access (Godoy et al. 2001; Fernández-Llamazares et al *in press*). Dispersed land occupancy, low intensity of natural resources use, and spatial overlap of resources use continue to be the norm in communities located far from roads and markets (Reyes-García et al. 2014a). The villages studied are relatively isolated, but are best characterized as on the verge of modernization (Ringhofer 2010), but are not yet differentiated by social or economic class. Isolation does not necessarily imply great geographical distance from urban areas, as a mere 32 kms and 122 kms (a one-to three-day journey by canoe) separate the villages from the closest market town (Luz 2012). Rather, isolation has more to do with general accessibility, as transport is only available by river.

In the two studied villages, social organization is mostly kinship based, where cross-cousin marriage and matrilocal residence are generally followed (Daillant 2003). In these villages, the cultural institution of food and manioc beer sharing is at the core of social life. Food is distributed among extended families or clan groups and primarily depends on men's capacity to provide fish and meat (Ellis 1996), which is a mark of high status. Women brew manioc beer, and its distribution also confer them status. Tsimane' livelihoods mostly depend on swidden agriculture, foraging, and hunting. Both women and men fish for subsistence, but

they employ different techniques and use different fishing resources. Only men use bows and arrows, whereas women and children use fish poisons, and mainly men fish with nets. Both women and men use hooks and lines, al though men use considerably larger hooks compared with women. For the Tsimane', success in fishing is one of the main reasons for happiness. The Tsimane' concept of "good food" revolves around wild products, including fish, so successful fishing permits them to enjoy their preferred food (Reyes-García 2012). Also, many rituals and taboos, such as sexual abstinence before an expedition and singing ritual songs to the fish "owners" asking them to release the fish, are considered to maximize the chances of a good catch (Chicchon 1992; Huanca 2006).

4. Methods

We used a mixed methods approach over the course of fieldwork, from January 2012-November 2013. We obtained consent from the *Gran Consejo Tsimane'* to visit the villages and the villager's agreement to reside in the villages. We also obtained the free prior and informed consent from all individuals participating in the study.

4.1 Sampling

Data were collected in two villages located along the Maniqui River (see Figure 2.a, chapter 2). The ecological and hydrologic characteristics of the two settings differ. One of the villages is in the middle Maniqui River, closer to town, whereas the other is located in the river's source, where waters are shallower and calmer. In upriver village, fish availability is higher because several of the Maniqui's fish species migrate upstream to the headwaters to spawn, a general pattern observed in various fish species in response to the annual hydrologic regime of large tropical rivers (Junk and Wantzen 2004; Cañas and Pine 2011). For example, the migrating black prochilodus (*Prochilodus nigricans*), locally known as *vonej*, is especially abundant in the upriver village. Other large-bodied catfishes such as *sonarej* (*Pseudoplatystoma fasciatum*), the gilded catfish (*Paulicea luetkeni*) or *cävädye'* and the golden dorado (*Salminus maxillosus*) or *cajsare'* are also plentiful in the Maniqui's headwaters. These three large-bodied species can reach up to one meter in length and play important ecological as well as economic roles in the study area by structuring aquatic foodwebs and providing highly regarded and culturally meaningful food resources for the Tsimane'. Due to these rich freshwater resources, the upriver village has been targeted by 'catch-and-release fishing' tourist projects, not without controversy (see Fernández-Llamazares et al. 2014). In contrast, in the mid-Maniqui village, fish resources are scarcer, perhaps in part because of deforestation (Paneque-Gálvez et al. 2013), which can lower water quality and increase sediments, altering the ecological conditions of nearby floodplains. It can also lead to overfishing, or a 'fishing down the foodweb' process, which means that the largest species from the top of the food web are depleted, thus shifting fishing pressures successively down the web toward smaller species, a phenomenon that has been observed in Amazonian rivers (Castello et al. 2013; Salo et al. 2013).

4.2 Data collection

We devoted the first six months of fieldwork to learning the Tsimane' language, building trust, and collecting socio-demographic data (i.e. age and sex) of study participants. Continued participant observation in Tsimane' daily life, taking part in fishing expeditions and engaging in informal conversations about the fish availability, reciprocity, and sharing of fish, among other topics, complemented the collection of contextual data.

We also formed four focus groups discussions to collect information on the annual seasonal activity calendar. Two focus groups were formed in each village, one with women and one with men. We had a final follow-up session with all of the focus group participants in which they reviewed a combined calendar created with the information gathered in the different focus groups. We use the seasonal calendar to explore the current pattern of principle activities (i.e. agriculture, hunting, foraging), and to explore the relative importance of fishing at different times of the year compared to other activities. We also conducted repeated individual surveys or 'scans' (Reyes-García et al. 2009) with a sample of 65 women and 73 men. Specifically, from July 2012 to November 2013, about once every fortnight, on a day chosen at random, we visited every household in the two villages and asked all adults (16 years of age and over) about their fishing trips the two days prior to the survey. This gave an average of about 27 observations per individual. Information collected in these surveys included people's involvement in fishing, agricultural work, hunting, and gathering, among others activities. If the informant reported to have fished during the previous two days, we asked about the fishing locations, techniques used, and fishing yields, including the vernacular name of the fish.

4.3 Data analysis

Using the data collected through the scans, we calculated the percentage of days that an individual reported engaging in any of the following main activities: fishing, hunting, gathering (including the extraction of edible and non-edible forest products, firewood, and palm thatch), trade (usually selling agricultural or forest products), wage labor (in the case of men, mostly logging, and in the case of women, mainly working as cook in the logging camps), agricultural work (clearing fields, planting, weeding, harvesting, etc.), and travelling (including to the market town or to visit family in neighboring villages). We present confident interval graphs describing the time allocated by women and men in the two villages. To gain an overall impression of the importance of fishing activities for different social groups, we also described mean percentage time spend in fishing by sex, village, and age categories (<25 years, ≥25≤50, >50).

To explore resource use and the differences and/or similarities between the species that women and men caught, we first identified the species caught by sex using the fishing yield data reported in the scans (Appendix 3). Of all of the species reported, we selected the five most frequently reported by sex and village, which resulted in 13 different species. To understand the structure of the fish community most frequently captured by the Tsimane', we followed Goulding (1980) and Pérez-Limache (2001) and used body size estimations to

classify the 13 fish species most frequently reported into three categories: small species (<15cm), medium species (15-50 cm), and large species (>50cm). We used a Pearson Chi^2 test to analyze species' distribution frequency according to 1) fishing ground and 2) fishing technique. We provide information disaggregated by sex and village for the grounds and techniques for each of the 13 most frequently caught species. Statistical analyses were performed using Stata 13 for Mac.

5. Findings

5.1 Dynamics of the gender division of labor among contemporary Tsimane'

Focus groups results indicate that, overall, Tsimane' livelihoods are predominantly organized around agricultural tasks and game and fish availability, although men in the mid-river village spend a substantial proportion of their time on income generating activities.

The Tsimane' practice slash-and-burn agriculture in two types of agricultural fields: agricultural plots, or *chacos,* and homegardens. Mostly men clear and prepare the plots in the cold season (*Jätisdye',* April to May, when cold winds from the South lower the temperature considerably). Generally, women and men work together burning and planting these fields in September-October (*Tsuñedye'*); they also work together in weeding and in harvesting in February-March (*Añedye'*) (Figure 11, B). Women also typically cultivate a variety of fruits, medicinals, and fiber plants around agricultural plots and in homegardens. Overall, across the two villages, women spend about 25 % of their time in agricultural work (Figure 12, a). Men spend about 20 % of their time in agricultural work in the mid-river village, and 14 % in the upriver village (Figure 12, b).

According to the Tsimane', the best time for hunting is right after the end of the rainy season (May-June), when game is fatter and their preferred species can be found (Figure 11, C). Hunting is typically a male activity since, traditionally, only men used bows and arrows and, today, only men use shotguns. However, some women reported hunting equipped with machetes and dogs (Figure 11, C). Men spend between six and seven percent of their time hunting in both villages, whereas women only spent one percent (Figure 12, a).

Gathering of non-edible forest products such as firewood and thatch palm takes place all year round. Wild fruit gathering occurs mostly in the rainy season, from December to March *(Añedye'*), sometimes during hunting or fishing trips (Figure 11, D). The time spent in gathering was similar for women and men in the two villages: about four percent in the mid-river village, compared with 11 % in the upriver village, probably as a consequence of the latter's greater dependence on harvesting *cajtafa'* (*Geonoma deversa*), a thatch palm used for roofing and to generate income (Figure 11, F). Thatch palm harvesting occurs year round, with a peak in the dry season (*Tsuñedye'*, August to November), and at the onset of the rainy season (Figure 11, F). Harvesting is usually performed in collective expeditions involving all members of a household and, in many cases, several households from the same clan or extended family.

Other income generating activities includes sales of agricultural products and wage labor in logging. Logging occurs year round but is more frequent in the rainy season (Figure 11, E), when the river is higher and it is easier to transport logs out of the forest, so men spend more days away from the villages, which is more common in the mid-river village (11 % of their time, Figure 12, b). In the upriver village, men spend about three percent of their time engaged in wage labor. Women in both villages rarely engage in wage labor (Figure 12, a).

Compared with men in the upriver village, men in the mid-river village spend a greater percent of their time travelling (15 % *vs.* three percent). Trading consumes only one percent of men's time in both villages. Women spend little time travelling, trading, or working as wage laborers (Figure 12, a).

Figure 11. Tsimane' seasonal calendar of main activities throughout the year.

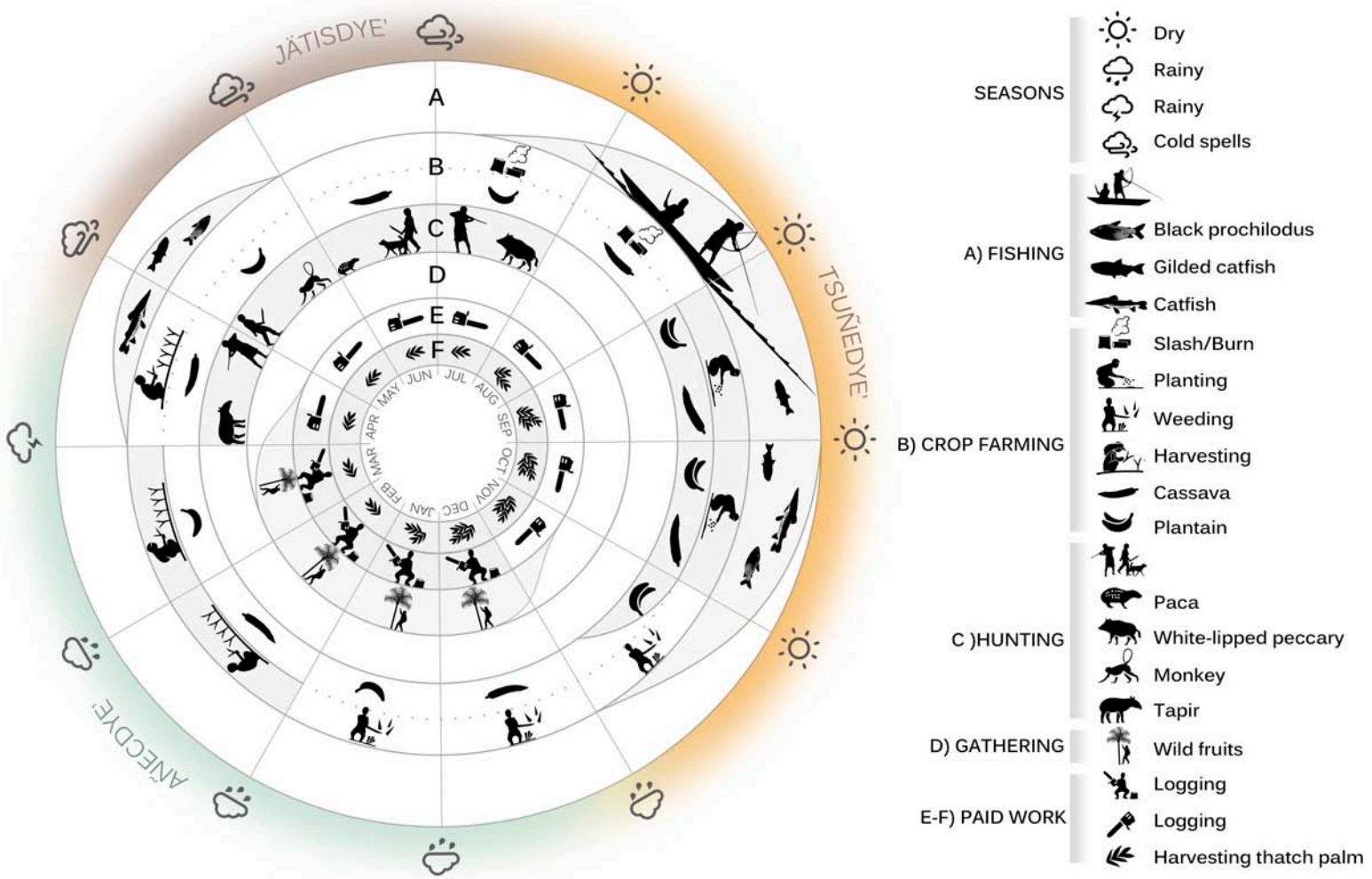
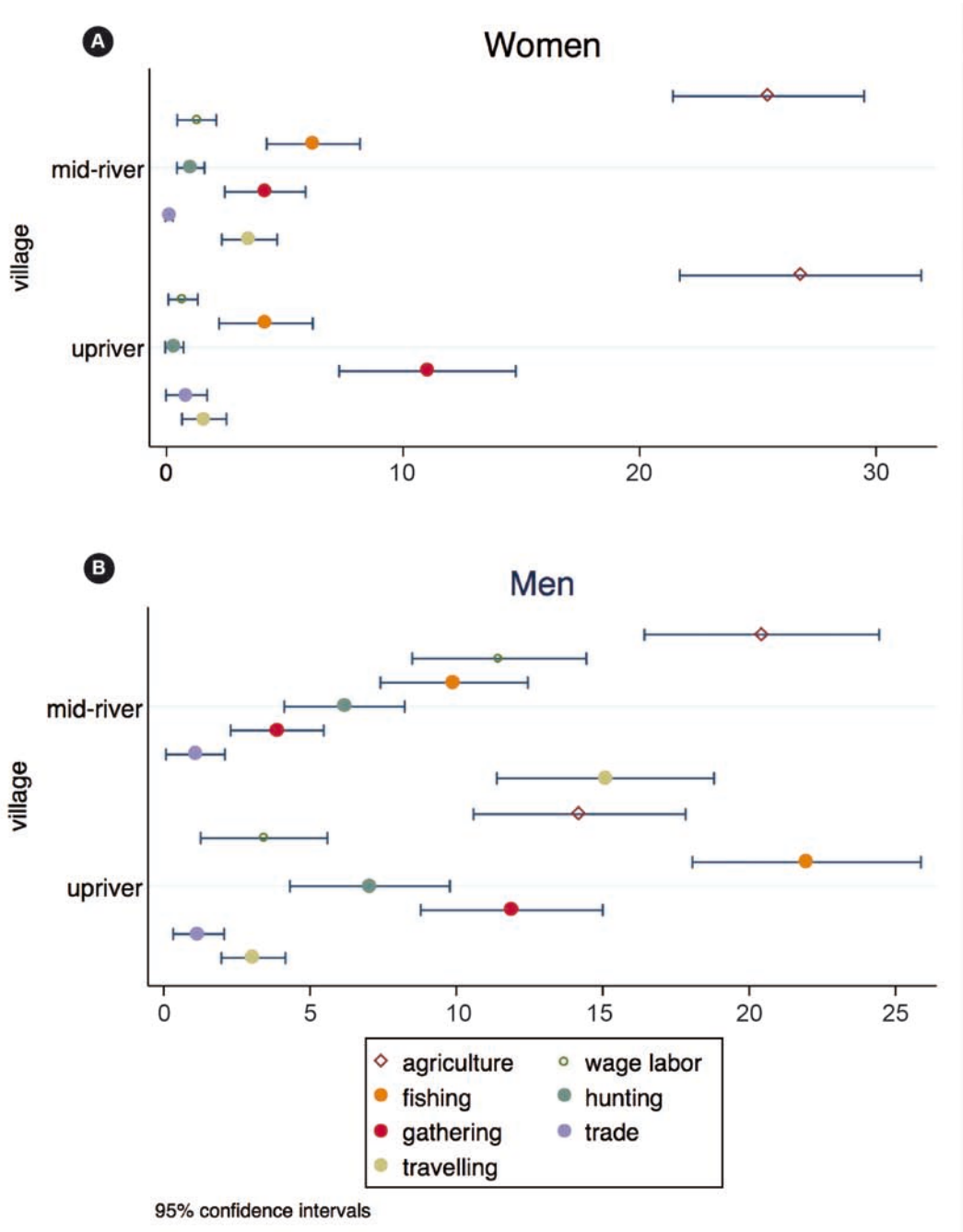


Figure 12. Subsistence activities confidence intervals for women and men



5.2 Fishing among the Tsimane' by village, sex, and age categories

Fishing occurs year round, although there are two major fishing seasons. First, fishing is relatively more important during the cold season, which coincides with the upstream migration of *vonej*' and *sonare*. The second important fishing period occurs in the dry season when river waters are calmer and fish capture is easier (Figure 11, a).

Women in the mid-river village spend six percent of their time fishing compared with those in the upriver village, who spend four percent. In contrast, men in the mid-river village spent nine percent fishing compared with 21 % for men in the upriver village. Comparing

fishing involvement by sex and age groups, women in all age groups in the mid-river village spent more time fishing than women in the upriver village, except for women over age 50, who spent about six percent in both villages.

In contrast, for men, we found that men in the mid-river village in all age groups spent between nine and ten percent fishing, whereas younger men in the upriver village spent 25 %, a percentage considerably higher than men in other age groups in the same village, who spent between 18 and 19 % (Table 14).

Table 14. Involvement in fishing activities by village, age category, and sex (in %).

Village	Age category (in years)	Women	Men
Mid-river	<25	6	10
	≥25≤50	7	10
	> 50	6	9
Upriver	<25	2	26
	≥25≤50	5	19
	> 50	6	18

Overall, fishing appears to be the Tsimane's principal foraging activity, with some differences by sex, age, and village. Fishing is the main foraging activity for women of all ages in the mid-river village whereas, in the upper river village, fishing is most important for older women, as younger women spend more time gathering than fishing. Men in the mid-river village spend more time in agriculture and wage labor than in fishing, but fishing is their main foraging activity. Fishing seems to be the primary activity for men in the upriver village, especially for younger men.

5.3 Species, techniques, and grounds

Over the course of a year, women reported to have fished 25 and 21 different species in the mid-river and upriver villages, respectively, whereas men reported to have fished 40 and 29 different species, respectively.

Here we focus on the 13 fish species that appeared as the five most frequently reported species by sex and village. Among these, there were more similarities in the species reported between men from the mid-river village and women from the upriver village, which have three of the five most frequently reported species in common (*vonej, tobiri and sherejsherej*) (see Table 15).

Table 15. Fish species more frequently catch by women and men in studied villages.

	Village	Vernacular Name	Scientific name	% of the species reported
Women	middle river	*cum'*	*Markiana nigrinpinnis*	20
		cotyij	unidentified	13
		vonej	*Prochilodus cf. nigricans*	10
		pu'na	*Hoplerytrinus unitaeniatus*	8
		bojmo	*Curimata* sp.	7
	upriver	*jutiru*	*Pimelodus sp.*	25
		vonej	*Prochilodus cf. nigricans*	13
		sherejsherej	*Hoplias malavaricus*	9
		shicurity	*Hemisorubim platyrhynchos*	7
		tobiri	*Schizodom fasciatum*	7
Men	middle river	*vonej*	*Prochilodus cf. nigricans*	16
		tobiri	*Schizodom fasciatum*	9
		sherejsherej	*Hoplias malavaricus*	7
		bojmo	*Curimata* sp.	7
		vat'se	*Pterygoplichthys multiradiatus*	6
	upriver	*vonej*	*Prochilodus cf. nigricans*	42
		sonarej	*Pseudoplatystoma fasciatum*	11
		cajsarej	*Salminus maxillosus*	10
		cävädye'	*Paulicea luetkeni*	6
		jutiru	*Pimelodus sp.*	6

The techniques employed and the grounds where women and men fish as well as the targeted species were different in the two villages (Table 16). Overall, it seems that, compared to women, men target a larger number of species and use a wider set of techniques and fishing grounds. Men in both villages targeted - or managed to catch - large fish species (*sonarej, cajsare'*, *cävädye'*), which were typically caught in the river with large hooks and lines (Table 16). Women and men in both villages targeted medium-sized species (*vonej, shicurity, sherejsherej*), whereas mainly women in the mid-river village fished smaller species (*cum'*). Men fished medium species mainly in the river using nets and hooks, whereas women caught them using poison and hooks in the river and streams. Especially in the mid-river village, women caught smaller species (*cum', bojmo, cotyij*) in streams using poison, which are also used for larger species. Our results also show that the use of bows and arrows, which were traditionally widely used, has sharply declined, and is being replaced by nets and hooks.

Table 16. Results of the Pearson Chi^2 test for most frequently catch fish species by sex and village. Frequencies are shown for the combinations of species/technique/ground with more observations. Statistical significance shows the relation between the fish species, the fishing ground and the technique used. Fishing grounds are R: river, S: streams, P: ponds and fishing techniques are N: net, H: hook and line, P: poisoning.

			Women				Men			
Species size	**Vernacular name**	**Scientific name**[β]	**middle river**		**upriver**		**middle river**		**upriver**	
Large > 50cm	*sonarej*	*Pseudoplatystoma fasciatum*			RP	1/2	RH	4/6	RH	17/38
	cajsare'	*Salminus maxillosus*					RH	2/6	RN/RH	14/45-13/45
	cävädye'	*Paulicea luetkeni*			RH	1/1	RH	3/4	RH	12/24
Medium >15<50cm	*vonej*	*Prochilodus cf. nigricans*	RP**	7/16	RP	5/7	RN	15/49	RN**	69/167
	shicurity	*Hemisorubim platyrhynchos*	RH	2/4	RH	2/4	RH	5/11	RH	4/7
	sherejsherej	*Hoplias malabaricus*	SH	3/8	RH	2/5	PN	7/23	RH	2/4**
	tobiri	*Schizodom fasciatum*	RP**	5/9	RH	2/4	RN	11/28	RN	2/7
	vat'se	*Pterygoplichthys multiradiatus*					PN	12/18		
	pu'na	*Hoplerytrinus unitaeniatus*	SP**	6/13			SN	6/16		
	jutiru	*Pimelodus sp.*			RH	7/14			RH	8/23
Small <15cm	*cum'*	*Markiana nigrinpinnis*	SP	27/33			SP	11/15	RN	2/4
	bojmo	*Curimata* sp.	SP**	7/12			PN**	10/21		
	cotyij	*Pimelodella sp.*	RH**	15/22	RH/RP	2/4	RH**	9/14		

[β] sources: Chiccón 1992 and Pérez-Limache 2001

6. Discussion

In order to explore how informal gendered norms regarding fishing activities influence the species that women and men fish, in this article, we have examined the interrelations between the division of labor and women's and men's use of fishing technologies and resources in two Tsimane' villages that have differing local hydrologic ecologies. The main findings of this work are that 1) involvement in fishing activities differs by village, sex, and age categories, where younger men in the upriver village devote the most time to fishing, 2) in both villages men target larger species than women, typically catching them in the river with large hooks and lines, 3) there is some overlap between the most frequently reported fish species caught by women in the upriver and men in the mid-river villages, and 4) overall, women and men in

the mid-river village fish a wider diversity of species compared with women and men in the upriver village. We devote the rest of this section to analysing these results as a whole.

6.1 Gendered fishing resource extraction

Socio-cultural norms such as those related to the gender division of labor and responsibilities around food procurement shape fishery resource use among the Tsimane'. Compared with women and irrespective of local ecology, men's involvement in fishing is prominent. This can be explained by their role as principal fish providers, both for own household consumption and inter-household distribution within extended kin networks (Ellis 1996). Tsimane' social relations are nurtured by the sharing of food, including fish, which mostly depends on men's ability to provide fish, which confers them with status that satisfies their sociopolitical goals and reputations as skilled fishermen (Ellis 1996; Díaz-Revieriego et al. forthcoming; see also Bird 2007). Fishing of larger species is 'gendered' - typically only men target these more prestigious and culturally meaningful species, which readily provide quality protein for provisioning households and sharing extensively with relatives.

Our results also show that, among the 13 species most frequently caught, there were more similarities between those that men in the mid-river village caught, and those caught by women in the upriver village. This may indicate that medium-size species are not *per se* 'gendered' - rather, which sex captures which species depends on the resources available in each location; from the species available in each location, men always target the larger ones. This may indicate that men and women are not 'competing' for the same fish resources, or interfering in each other's socially expected roles and responsibilities.

Likewise, access to and use of fishing techniques that are required in order to catch the larger species is socio-culturally framed. Traditionally, only men crafted and used bows and arrows. Today, bows and arrows are seen as inferior to nets and large hooks and lines, which men prefer. However, it seems that women's access to nets and larger hooks is still constrained, since women are rarely seen fishing with these implements, which may be in part exacerbated by their limited access to cash income (Godoy et al. 2007).

Women's access to fishing grounds also seems to be limited. For example, in the mid-river village, some of the most frequently fished species were caught in ponds, which are farther from the village compared with streams, which are closer to or within the village and more accessible for women. Women reported in focus groups discussions that they typically fish in streams close to their households, which are the same shallow streams they use daily to wash clothing and fetch water. Also, being closer to their households allows them more time for caretaking and food and agricultural processing responsibilities. This gendered use of space, or fishing grounds, may explain the gendered extraction of species (Siar 2003; Lope-Alzina 2007; Makalle 2012). Women target small fish species (such as *cum'*) that are found in the shallower areas of the streams and that can be caught with fish poison and small hooks.

6.2 The effect of local ecologies and livelihoods in shaping fishery resource use

In terms of the diversity in fisher's catches, we found a wider diversity of species caught in the mid-river village compared with those in the upriver village. This result can be explained by the intersection between fish availability and food preferences. The three large-bodied catfishes, the Tsimane's favorite fish, are plentiful in the upriver village, so it appears that where these species' availability is higher, fishers these species and then mostly the larger ones. In contrast, where preferred and larger fish species are scarcer, fishers target a wider variety of species, or 'fish down the foodweb' (Salo et al. 2013). The finding that men in both villages reported a wider diversity of fish species compared with men seems to be related to their responsibilities in terms of gendered roles as main fish providers and therefore, their access and use of more techniques and grounds.

Recent research among the Tsimane' has shown that change in livelihoods and attachment to traditional customs and beliefs have been occurring both among individuals and in larger social units, such as the village level (Reyes-García et al. 2014b). At the time of our study, we observed differing involvement in income generating activities in the two villages. For example, in the mid-river village, men are significantly and increasingly involved in wage labor in logging and therefore spend a considerable amount of time, sometimes weeks, outside of the village. Some women in this village complained that their men were not fulfilling their roles as meat and fish providers. Women's involvement in fishing is also slightly higher in this village compared to women in the upriver village, where thatch palm harvesting is the main source of income, which is performed collectively and involves all household members, so that men are not absent for long periods of time (Fernández-Llamazares et al. *in press*). We argue that the change in livelihood strategies due to integration in the market economy might influence the fluidity of gender roles and labor, increasing women's labor and involvement in fishing. As well, inequalities in food distribution within Tsimane' households are emerging as men become increasingly involved in external market-related activities; men eat fresh fish and meat more consistently when they are away from home, whereas women have more limited access to these food sources (see Godoy et al. 2007; Zycherman 2013). Thus, Tsimane' women in the mid-river village may be forced to more actively engage in fishing when food supplies are shrinking, partly because men fish less when they engage in income-generating activities outside the village, and also since the best time for logging (rainy season) coincides with a traditional period of food scarcity (Byron 2003). Women - and children - target smaller species that can be caught with the tools that they can access (poison and small hooks) which, at times of male absence from the household, provide the only source of protein in the daily diet (Zycherman 2013). Tsimane' women have to confront social norms about access to grounds, techniques, and the time they can spend away from their households, which restricts their success as fishers and also their households' food security. Nevertheless, we would like to point out that, even though the generalization that men work as wage laborers and women remain in the villages applies to many households, this obscures a great deal of variation that exists among households and individuals.

6.3 Practical implications

We would like to highlight some potential implications of our findings regarding gendered fishery resource extraction among the Tsimane'. First, the differences in women's and men's fishing strategies in both villages may have implications for their ecological expertise and knowledge of fishery resources. Research has shown that differences in women's and men's production spaces partly explain differences in the species that are managed or exploited ('gendered species') as well as gendered knowledge and use of agrobiodiversity (Zimmerer 1991; Lope-Alzina 2007; Carr 2008), tree diversity (Fortmann 1996; Howard and Nabanoga 2007) and coastal resources (Makalle 2012). As Pfeiffer and Butz (2005) argue, ecological expertise is in part a function of the frequency of contact with a resource. The more frequently different people encounter a given resource (in this case a given fish species), the more detailed and potentially accurate the knowledge they hold. Consequently, since Tsimane' women and men target and extract different fish species, their knowledge and expertise should be taken into account when seeking to improve management and conservation of fishery resources. Also, the advantages of integrating local people's nuanced and valuable knowledge and insights into the scientific analysis of, for example, fishing diversity, food web structures, and spawning times have been also reported (Silvano and Valbo-Jørgensen 2008; Rosa et al. 2014; Ramires et al. 2015). Also, the beneficial impacts of women's participation in forest governance and conservation have been empirically demonstrated (Agarwal 2001, 2009). Thus, these integrated scientific approaches may greatly benefit from considering local people's potential gendered fishing knowledge and expertise.

Secondly, potential environmental conflicts (Martínez-Alier 2004) over the use of fishery resources may arise in the area. Just recently, 'ecotourism' associated with catch-and-release sport fishing has been promoted and partially implemented in the Tsimane' Territory, with scant participation of the affected villages in the decision making process (Fernández-Llamazares et al. 2014). These kinds of projects are seen as a potential pathway for 'sustainable development' in remote villages that are rich in fish resources. Catch-and-release fishing tourism is also promoted as a tool for the conservation and management of recreational fisheries (Cooke and Schramm 2007), since the desired species will continue to be available for breeding, predation, and provision of food for other species, as well as available for others to catch again. However, when catch-and-release fishing projects are designed within indigenous territories, local people may agree as well as contest these initiatives; some people see them as a threat to the ecosystems and to the species that they depend upon for subsistence (Fernández-Llamazares et al. 2014). Fishing projects within indigenous territories must evaluate the possible implications for local subsistence and livelihoods through a gender lens. These initiatives may significantly affect villages and intra-household dynamics, gendered customary norms regarding fishing, livelihood strategies, and access to and use of fishery resources, thus, food security and sovereignty (see also Hanazaki et al. 2013). Assuring that free prior informed consent is provided by the villages affected and ensuring the participation of women and men in the decision making process may help to reduce the potential negative impacts of fisheries tourism on local peoples.

7. Conclusions

This study of subsistence fishing among contemporary Tsimane' shows that gendered fishery resource use, livelihood strategies, and ecological conditions in the studied villages are intertwined. Tsimane' women and men target different fish species influenced by the local ecology, the gendered division labor, and the access to fishing techniques and fishing grounds. We also show how the different livelihood strategies and new economic activities could also potentially change women's and men's responsibilities and roles in food provisioning. We have noted that the implementation of fishing tourism projects should carefully evaluate the potential impacts that they may create for local people in terms of rights and access to fishing resources, food security, and sovereignty. The equal participation of women and men in the decision-making processes could reduce these potential negative impacts. Recognizing and including local's gendered fishing knowledge and management practices may also enhance environmental policies that aim at improving fishery resource management and conservation.

8. References

Agarwal, B. 2001. Participatory exclusions, community forestry, and gender: an analysis for South Asia and a conceptual framework. *World Development* 29 (10): 1623–48.

Agarwal, B. 2009. Gender and forest conservation: the impact of women's participation in community forest governance. *Ecological Economics* 68: 2785-2799.

Agrawal, A. 2003. Sustainable governance of common-pool resources: context, methods, and politics. *Annual Review of Anthropology* 32 (1): 243–62.

Arce-Ibarra, M., and A. T. Charles. 2008. Inland fisheries of the Mayan zone in Quintana Roo, Mexico: using a combined approach to fishery assessment for data-sparse fisheries. *Fisheries Research* 91 (2-3): 151–59.

Aswani, S. 2005. Customary sea tenure in Oceania as a case of rights-based fishery management: does it work? *Reviews in Fish Biology and Fisheries* 15 (3): 285–307.

Bird, R. 2007. Fishing and the sexual division of labor among the Meriam. *American Anthropologist* 109 (3): 442–51.

Bray, F. 2007. Gender and technology. *Annual Review of Anthropology* 36 (1): 37–53.

Brightman, R. 1996. The sexual division of foraging labor : biology, taboo, and gender politics. *Society for Comparative Study of Society and History* 38 (4): 687–729.

Cañas, C.M, and W.E Pine. 2011. Documentation of the temporal and spatial patterns of Pimelodidae catfish spawning and Llarvae dispersion in the Madre de Dios River (Peru): insights for conservation in the Andean-Amazon Hheadwaters. *River Research and Applications* 27: 602–11.

Carr, E. R. 2008. Men's rrops and women'scCrops: the importance of gender to the inderstanding of agricultural and development outcomes in Ghana's central region. *World Development* 36 (5): 900–915.

Castello, L., D. G. Mcgrath, L. L. Hess, M. T. Coe, P. Lefebvre, P. Petry, M. N. Macedo, V. F. Renó, and C. C. Arantes. 2013. The vulnerability of Amazon freshwater ecosystems. *Conservation Letters* 6 (4): 217–29.

Chicchon, A. 1992. Chimane Resource Use and Market Involvement in the Beni Biosphere Reserve, Bolivia. PhD Thesis, University of Florida.

Choo, P. S., B. S Nowak, K. Kusakabe, and M. J Williams. 2008. Guest editorial: Gender and fisheries. *Development* 51 (2): 176–79.

Cooke, S J, and H L Schramm. 2007. Catch-and-release science and its application to conservation and management of recreational fisheries. *Fisheries Management and Ecology* 14 (2): 73–79.

Daillant, I. 2003. *Sens Dessus Dessous : Organisation Sociale et Spatiale Des Chimane d'Amazonie Bolivienne,*

Société D'ethnologie, Recherches Américaines 6, Nanterre.

Davis, A., and John R. Wagner. 2003. Who knows ? On the Importance of Identifying 'experts' when researching local ecological knowledge. *Human Ecology* 31 (3).

Domingues do Amaral, B. 2004. Fishing territoriality and diversity between the ethnic populations Ashaninka and Kaxinawá, Breu River, Brazil/Peru. *Acta Amazonica* 34 (1): 75–88.

Ellis, R. 1996. A Taste for Movement: an Exploration of the Social Ethics of the Tsimanes of Lowland Bolivia. PhD Thesis, Sant Andrews University.

Fröcklin, S., M. Torre-Castro, E. Håkansson, A. Carlsson, M. Magnusson, and N. S. Jiddawi. 2014. Towards improved management of tropical invertebrate fisheries: including time series and gender. *PLoS ONE* 9 (3):

Godoy, R., K. Kirby, and D. Wilkie. 2001. Tenure security, private time preference, and use of natural resources among Lowland Bolivian Amerindians. *Ecological Economics* 38 (1): 105–18.

Godoy, R., V. Reyes-García, V. Vadez, W. R. Leonard, and E. Byron. 2007. How well do foragers protect food consumption? Panel evidence from a native Amazonian society in Bolivia. *Human Ecology* 35 (6): 723–32.

Gragson, T. L. 1992. Fishing the waters of Amazonia: native subsistence economies in a tropical rain forest. *American Anthropologist* 94 (2): 428–40.

Grigsby, W. J. 2004. The gendered nature ofsSubsistence and its effect on customary land tenure. *Society and Natural Resources* 17: 207–22.

Guèze, M., J. Paneque-Gálvez, A.C. Luz, J. Pino, M. Orta-Martínez, V. Reyes-García, and M.J. Macía. 2013. Determinants of tree species turnover in a Southern Amazonian rain forest. *Journal of Vegetation Science* 24 (2): 284–95.

Goulding ,M. 1980. *The Fishes and the Forest: Explorations in Amazonian Natural History*. University of California Press.

Hanazaki, N., F. Berkes, C. S. Seixas, and N. Peroni. 2013. Livelihood diversity, food Security and resilience among the Caiçara of coastal Brazil. *Human Ecology* 41 (1): 153–64.

Howard, P. L., and G. Nabanoga. 2007. Are there customary rights to plants? An Inquiry among the Baganda (Uganda), with special attention to gender. *World Development* 35 (9): 1542–63.

Howard, P.L, and E. Smith. 2006. Leaving two thirds out of development: female headed householdls and common property resources in the highlands of Tigray, Ethiopia. *Livelihood Support Program Working Paper, FAO.*

Jackson, Cecile. 1993. Doing What Comes Naturally? Women and Environment in Development. *World Development* 21 (12): 1947–63.

Junk WJ, and K.M Wantzen. 2004. The flood pulse concept: new aspects, approaches, and applications - an update. In: Welcomme R.L, and T. Petr (eds) *Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries* Volume I 117–149, FAO-RAP Publication:Bangkok.

Kleiber, D., L.M. Harris, and A. C. J Vincent. 2015. Gender and small-scale fisheries: a case for counting women and beyond. *Fish and Fisheries* 16(4):547-562.

Kuchikura, Y. 1996. Fishing in the tropical rain forest : utilization of aquatic resources among the Semaq Beri hunter-gatherers of Peninsular Malaysia. *Senri Ethnological Studies* 42: 147–74.

Leach, M., R. Mearns, and I. Scoones. 1999. Environmental entitlements: dynamics and institutions in community-based natural resource management. *World Development* 27 (2): 225–47.

Lope-Alzina, D. Gabriela. 2007. Gendered production spaces and crop varietal selection: case study in Yucatán, Mexico. *Singapore Journal of Tropical Geography* 28 (1): 21–38.

Lopes, P.F.M., N.Hanazaki, R. A.M. Silvano, M. Clauzet, M. Ramires, and A. Begossi. 2011. Foraging behaviour of Brazilian riverine and coastal fishers: how much is explained by the optimal foraging theory? *Conservation and Society* 9 (3): 236.

Lowassa, A., D. Tadie, and A. Fischer. 2012. On the role of women in bushmeat hunting – insights from Tanzania and Ethiopia. *Journal of Rural Studies* 28 (4).

Lu, F. E. 2001. The Common property regime of the Huaorani Indians of Ecuador : implications and challenges to conservation. *Human Ecology* 29 (4).

Lu, F. E. 1999. Changes in Subsistence Patterns and Resource Use of the Huaroni Indians in the Ecuadorian

Amazon. PhD Thesis, University of North Carolina at Chapel Hill.

Luz, Ana Catarina. 2012. The Role of Acculturation in Indigenous Peoples Hunting Patterns and Wildlife Availabililty. The Case of the Tsimane' in the Bolivian Amazon. PhD Thesis. Institut de Ciencia i Tecnologia Ambientals, Universitat Autònoma de Barcelona.

Makalle, A.M.P. 2012. Gender relations in environmental entitlements: case of coastal natural resources in Tanzania. *Environment and Natural Resources Research* 2 (4).

Momsen, J. H. 2007. Gender and agrobiodiversity: introduction to the special issue. *Singapore Journal of Tropical Geography* 28 (1): 1–6.

Paneque-Gálvez, J., Jean-François M., M. Guèze, A. C. Luz, M. J. Macía, M. Orta-Martínez, J. Pino, and V. Reyes-García. 2013. Land tenure and forest cover change. The case of Southwestern Beni, Bolivian Amazon 1986–2009. *Applied Geography* 43.

Pfeiffer, J. M, and R. J. Butz. 2005. Assesing cultural and ecological variation in ethnobiological research: the importance of gender. *Journal of Ethnobiology* 25 (2): 240–78.

Ramires, M., M. Clauzet, W. Barrella, M.M. Rotundo, R.A. Silvano, and A. Begossi. 2015. Fishers' knowledge about fish trophic interactions in the Southeastern Brazilian coast. *Journal of Ethnobiology and Ethnomedicine* 11 (1): 19.

Reyes-García, V. 2012. Happiness in the amazon. Folk explanations of happiness in a hunter-horticulturalist society in the Bolivian Amazon. In: *Happiness across Cultures. Views of Happiness and Quality of Life in Non-Western Cultures*, 34:1–31.

Reyes-García, V., J. Paneque-Gálvez, P. Bottazzi, and A.C Luz. 2014. Indigenous land reconfiguration and fragmented institutions : a historical political ecology of Tsimane' lands (Bolivian Amazon). *Journal of Rural Studies* 34: 282–91.

Reyes-Garcia, V., R. A. Godoy, V. Vadez, I. Ruiz-Mallen, T. Huanca, W. R. Leonard, T. W. McDade, and S. Tanner. 2009. The pay-offs to sociability. *Human Nature-An Interdisciplinary Biosocial Perspective* 20 (4):431-446

Reyes-García, V., J. Paneque-Gálvez, A.C. Luz, M. Gueze, M.J Macía, M. Orta-martínez, and J. Pino. 2014. Cultural change and traditional ecological knowledge: an empirical analysis from the Tsimane' in the Bolivian Amazon. *Human Organization* 73 (2).

Ribot, J. C, and N. L. Peluso. 2003. A Theory of access. *Rural Sociology* 68 (2): 153–81.

Ringhofer, L. 2010. *Fishing, Foraging and Farming in the Bolivian Amazon. On a Local Society in Transition.* Dordrecht: Springer Netherlands.

Rocheleau, D., and D. Edmunds. 1997.Women, men and trees: Gender, power and property in forest and agrarian landscapes. *World Development* 25 (8): 1351-71

Rosa, R., A.R. Carvalho, and R. Angelini. 2014. Integrating fishermen knowledge and scientific analysis to assess changes in fish diversity and food web structure. *Ocean and Coastal Management* 102.

Salo, M., A. Sirén, and R. Kalliola. 2013. Fishing in and fishing out the Amazon." In: *Diagnosing Wild Species Harvest*, 93–110.

Schlager, E., and E. Ostrom. 2010. Property-rights regimes and natural resources : a conceptual analysis. *Land Economics* 68 (3): 249–62.

Shaughnessy, S.O., and N.T. Krogman. 2011. Gender as contradiction : from dichotomies to diversity in natural resource extraction. *Journal of Rural Studies* 27 (2).

Siar, Susana V. 2003. "Knowledge, Gender, and Resources in Small-Scale Fishing: The Case of Honda Bay, Palawan, Philippines." *Environmental Management* 31 (5): 569–80.

Silvano, R.M, and J. Valbo-Jørgensen. 2008. Beyond fishermen's tales: contributions of fishers' local ecological knowledge to fish ecology and fisheries management. *Environment, Development and Sustainability* 10 (5): 657–75.

Sunderland, T., R. Achdiawan, A. Angelsen, R. Babigumira, A. Ickowitz, F. Paumgarten, V. Reyes-García, and G. Shively. 2014. Challenging Perceptions about Men, Women, and forest product use: a global comparative study. *World Development* 64(S1):S56-S66.

Vázquez-Garcia, V., and M. Montes-Estrada. 2006. Gender, subsistence fishing and economic change. A comparative study in Southern Veracruz, Mexico. *International Journal of Sociology of Foof and Agriculture* 14: 1–22.

Walker, B.L.E., and M. Robinson. 2009. Economic development, marine protected areas and gendered access to fishing resources in a Polynesian Lagoon. *Gender, Place and Culture* 16 (4): 467–84.

Zycherman, A. 2013. The Changing Value of Food: Localizing Modernity among the Tsimané Indians of Lowland Bolivia. PhD Thesis. Columbia University.

Chapter 7

Conclusions

Chapter 7
Conclusions

In the previous chapters, I have analyzed different issues regarding the practices, knowledge, and social relations, particularly gender relations, of Tsimane' women and men with regard to fishing, medicinal plants and homegardening. Through these chapters I have covered each of the specific objectives of this thesis. In particular, the *specific objective 1*, to assess diversity and redundancy of knowledge in Tsimane' ethnomedicinal system through a gender lens, has been addressed in Chapter 3. In this chapter, drawing on the ecological concepts of functional diversity and ecological redundancy, I proposed a conceptual framework to assess knowledge diversity and redundancy within ethnomedicinal knowledge systems. I also discussed the relevance of addressing gendered knowledge to understand local knowledge systems' adaptive capacity to a changing environment. The *specific objective 2*, to explore the role of social networks in explaining 1) medicinal plant richness in homegardens and 2) medicinal plant knowledge distribution among gardeners, has been addressed in Chapter 4. Specifically, I analyzed exchange networks of medicinal plant material and knowledge. Results from this chapter highlight that homegarden richness is strongly intertwined with the Tsimane' social organization so that the access to and exchange of planting material influence the biodiversity that an individual maintain in her/his homegarden. The *specific objective 3*, to describe potential pathways for the transmission of fishing knowledge in relation to fishers' knowledge as perceived by others in this process, has been explored in Chapter 5. Results from this chapter suggest that the cultural transmission of knowledge follows a prestige bias, according to which people tend to imitate or learn from successful or prestigious individuals. Furthermore, results also show that gender relations seem to play an important role in defining who has access to what knowledge, thus highlighting the importance of understanding gendered biases of knowledge transmission. Finally, the specific *objective 4*, to ascertain the interrelations among 1) gendered division of labor, 2) technology use, and 3) local ecologies, in freshwater resource use, specifically on fish species extraction, has been investigated in Chapter 6. In this chapter, I explored the complexity of intracommunity dynamics and gendered access to fishing resources focusing on the access to technology and fishing grounds as a prerequisite to have access to the extraction of fish species. Findings of this chapter show that women and men target different species, however, in both villages men target larger species than women, typically catching them in the river with large hooks and lines ('gendered species'). Results from this chapter also suggest that shifting livelihood strategies and new economic activities could change women's and men's responsibilities and roles in food provisioning.

Hereafter, I use the empirical evidences and the experience acquired in the learning process of this thesis to address the general aim of this dissertation of advancing the scientific understanding about the set of social relationships, and particularly gender relations, that

define women's and men's practices and knowledge of the environment. In this sense, results from this dissertation indicate that Tsimane' local environmental knowledge and practices are mediated by social relations. Specifically, gendered relations result in women and men having differential access to, use of, and knowledge about medicinal plants and fishing resources. Both women and men have knowledge of fishing and medicinal plants, however, their different positions in social networks – and also the different network composition - seems to influence, and in turn be influenced, by their level of knowledge and performance in these same networks. As a consequence of this loop of gendered social relations there is gendered knowledge diversity.

The present chapter is devoted to integrate the findings across the various chapters, to understand their implications and to draw attention to its contributions. In the first section, I reflect on the theoretical frameworks in which I draw for developing this research. The second section comprises the methodological contributions to the field of ethnoecology. The third section discusses the practical implications of the research findings, the fourth section underlines some limitations and caveats of the methodology employed, and finally, the fifth section provides recommendations for future research.

1. Reflection on the theoretical framework

This dissertation adopted an ethnoecological perspective, enriched by integrating insights from theoretical and empirical frameworks on cultural evolution theory, social networks analysis, and gender relations in biodiversity and natural resources management. Across the different empirical chapters in this thesis, I have focused both on the content of knowledge but also on the context of its production, as the content of knowledge is likely shaped by the context and the material practices of women and men within the environment.

At the theoretical level, this study contributes to the current literature on local environmental knowledge by emphasizing the importance of understanding and addressing gender relations in the quest to explaining intracultural variation in local environmental knowledge systems. The more relevant contribution of my approach is the innovative manner of assessing people's gendered practices and knowledge. Differently than most previous work in intracultural local environmental knowledge variation, I go beyond individual socio-demographic characteristics and focus on explaining individuals' practices and knowledge in the light of the social structure in which they are embedded. Therefore, from the perspective adopted here, gendered knowledge and practices are the product of 1) women's and men's social relationships and 2) their positions in the social networks (i.e. in fishing and medicinal plant networks which are the specific examples examined here).

In the light of the findings presented in this thesis, I argue that, by looking at gender as an individual trait, it is reduce to biological sex, when as a social construct gender is essentially interpersonal and both fluid and context-specific. The gender dimension acquires meaning when approached as a relational variable. For example, results from this work evidence the significance of *homophily,* or the tendency to relate to similar others (i.e., people from the

same age, sex, or social group) in social networks. Networks that are homogeneous with regard to socio-demographic and behavioral identities condition the information people receive, the attitudes they form, and the interactions they experience (Smith-Lovin and McPherson 1993; McPherson et al. 2001). Both in fishing and in homegarden exchange networks (chapters 4 and 5), gender and kinship relations mediate the selection of fishing partners, and the selection of gardeners with whom to exchange medicinal plant material and knowledge. Thus, Tsimane' people tend to be involved in same-sex and same-clan fishing and planting material exchange networks. This situation determines individuals' position networks, which can provide both possibilities and constraints for accessing resources and knowledge through other people in the network (Calvet-Mir et al. 2012; Kawa et al. 2013). In other words, among the Tsimane', norms and beliefs regarding appropriate and expected gender behavior embed women and men in different networks, and consequently in different social worlds. Pertinence to one social network or another can constraint or allow their access to knowledge and resources through a gendered-bias cultural transmission that ultimately define women's and men's practices and knowledge.

Another theoretical contribution of this dissertation is the conceptual framework provided in Chapter 3. Drawing on Alburquerque and Oliveira's (2007) utilitarian redundancy model in medical systems, I have proposed a conceptual framework focusing on the potential for medicinal plant knowledge to sustain the functionality and adapt to the dynamics of the ethnomedicinal system undergoing social and ecological change. Specifically, the purpose of the conceptual framework is to assess diversity and redundancy within local knowledge systems by taking into account the importance of acknowledging lay gendered knowledge. Gendered knowledge about medicinal plants may provide more treating options within an ethnomedicinal knowledge system from the same pool of medicinal plants available. There is ongoing debate about the contributions of local environmental knowledge to adaptive capacity and resilience of knowledge systems and communities (Gómez-Baggethun et al. 2012; Ruelle and Kassam 2011; Ferreira Junior et al. 2013; Santoro et al. 2015). When referring to the role of intracultural diversity of knowledge, some argue that - from a probabilistic perspective - a normal distribution of knowledge in an ethnomedicinal system may reduce its vulnerability to disturbances (Ferreira Junior et al. 2013; Santoro et al. 2015). On the other hand, it has also been claimed that knowledge diversity may contribute to adaptability in the long-term (Ruelle and Kassam 2011). Results from chapter 3 support the idea that lay gendered knowledge contribute to the adaptive capacity of the Tsimane' ethnomedicinal system. Intracultural knowledge diversity, and precisely women's higher knowledge about medicinal plant uses, may provide more treating options from the same pool of medicinal plants available. The conceptual and analytical approach that I proposed can be a useful for researchers who seek to evaluate the adaptive capacity and resilience of knowledge systems, in particular, of ethnomedicinal knowledge systems, by taking into account the previously overlooked gendered nature of local environmental knowledge systems (Pffeifer and Butz 2005; Howard 2003).

In addition of these two main theoretical contributions, results from this dissertation also give support to previous research. Scholars have shown that an individual's performance or

prestige influence their position in networks (Kawa et al. 2013). Empirical results in chapter 5 underpin this previous finding, showing that people who were considered as more skilled fishers were more central in fishing networks, so that people tend to choose them as fishing partners. This finding supports the idea that people tend to learn or imitate others they consider successful or prestigious (see Henrich and Gil-White 2001; Henrich and Broesch 2011).

Researchers from a kaleidoscope of disciplines have recognized that biological diversity and the cultural diversity of worldviews, beliefs, languages, livelihoods, and institutions overlap (Maffi 2005; Pretty et al. 2008). For example, researchers have shown that agrobiodiversity and culture are intertwined (see Howard 2006; Reyes-García et al. 2010; Leclerc and D'Eeckenbrugge 2012; Labeyrie et al. 2013). Findings of this dissertation provide further evidences, showing that the richness of medicinal plants in homergarndens is associated to the exchange of knowledge and plant material among the Tsimane'; exchanges that are not random, but embedded within networks based on kinship and gender relations (chapter 4).

This study also provides an empirical case study which extends and reinforces the theoretical inquiries on the importance of gender relations in defining access, use and knowledge of natural resources (Rocheleau et al. 1996; Shaughnessy and Krogman 2011; Sunderland et al. 2014) and agrobiodiversity conservation (Howard 2003; Momsen 2007). In the context of the Tsimane' villages studied where there are no ethnic, class, religious, or other social divisions, I found that the intersection of gender with age, but also the interrelation of other social aspects – such as kinship - and the biophysical environment in which the two villages are placed, nuanced the gendered use and management of medicinal plants and fishing resources (chapters 3-6). Findings from chapters 3 and 4 show that medicinal plant knowledge and the maintenance of medicinal plants in homegardens is gendered. Both women and men have knowledge of medicinal plants and maintain medicinal plants in homegardens, however, women as principal caregivers and health custodians at a household level have a prominent role in this domain. Regarding fishing practices (chapter 5 and 6), I also showed that both women and men fish, but the interplay among them and with the environment depended on their age, but also on their material and social endowments and the local ecology, which ultimately define the species they fished.

2. Methodological contributions

The major methodological contribution of this thesis relates to the use of social nework analysis for exploring gendered environmental knowledge and practices within the field of ethnoecology. By relying on social networks analysis (chapters 4 and 5), this dissertation offers a fresh interdisciplinary take on the study of both knowledge transmission and gendered practices and knowledge. Network analysis is a research tool that has provided many insights for exploring how gendered patterns of social interactions produce and reproduce gendered practices and knowledge in different domains. This research suggests that social network analysis is an appropriate and useful tool for tracing the uneven flow of homegarden

medicinal planting material and knowledge among the Tsimane' (chapter 4), as well as for exploring fishing cultural knowledge transmission through fishing networks (chapter 5). A network approach has proved to be suitable for investigating the people-biodiversity interlink as it broadens our understanding of how the different social structures that derive from a particular cultural context shape the opportunities and constraints that social relations impose on environmental knowledge transmission and on the use of natural resources.

A second important methodological contribution of my work is the assessment of medicinal knowledge and use separately. Researchers interested in medicinal plant knowledge and use have indicated the need to disentangle these two aspects in ethnobotanical research (Reyes-García et al. 2005, Wayland and Walker 2014). Since medicinal knowledge and practice or use do not always go hand in hand, medicinal knowledge may not be and accurate proxy for use, and vice versa (Wayland and Walker 2014). In this dissertation, to explore knowledge and use of medicinal plants two different and separated methodologies have been employed (chapter 3). On the one hand, I use free-listings and a knowledge survey to assess the knowledge that people hold. On the other hand, I assessed the use of medicinal plants through a health survey that was administered up to six times in the course of a year (chapter 3) and through homegarden inventories (chapter 4). Approaching knowledge and use of medicinal plants separately helped me to better capture the nuances and differences between knowledge and practice regarding health concerns, as a medicinal knowledge system extends beyond treating aliments, and also includes preventive medicine and the treatment of different health states or minor afflictions that are not always classified as ailments. For example, in chapter 3, the knowledge survey captured many medicinal plants for treating reproductive concerns, but these concerns were not reported in the health survey (except for post-partum problems), probably because most of those concerns are not perceived as ailments as they are related to a specific stage in the life cycle (e.g., fertility, pregnancy, childbirth). Likewise, in the homegarden inventories in chapter 4, plants to treat minor daily accidents (e.g., cuts, wasp sting, stingray bite) were very commonly found, though, these were not reported in the free-listing.

This study also contributes to the increasing body of gender-sensitive research that acknowledges women's practices and knowledge and its interplay with men's. Results from this work stress the methodological bias in ethnobiological and ethnoecological research if gender is not integrated as a relational variable and if people-biodiversity relations, specifically gender relations around the knowledge, use, and management of resources are overlooked. Incorporating women as participants into the projects is essential, but it is also fundamental paying attention to the often complementary roles of women and men in crafting and enforcing rules of governing the extraction and the provision of natural resources, which influence their motives and means to exploit or conserve resources, and therefore have key implications for sustainability (Meinzen-Dick et al. 2014).

3. Practical implications of the research findings

Findings from this study have several practical implications. Researchers have emphasized that the interdisciplinary study of local environmental knowledge and human-environment relations is valuable to inform development interventions and biocultural approaches to conservation (Bicker et al. 2006; Wolverton et al. 2014; Gavin et al. 2015). In this line of thought, this work provides a detailed and contextualized approach to Tsimane' local environmental knowledge; grounded on systematic fieldwork and on the application of both qualitative and quantitative methodologies. Results from this work deliver exhaustive information on Tsimane' local knowledge distribution and use, which is key to understand Tsimane' biodiversity and natural resources management practices and, therefore, Tsimane' impact upon their territory.

Results from this work can be particularly relevant to inform policy-makers, NGOs, and agencies at the local and national levels in Bolivia. Tsimane' dynamic culture, practices, and knowledge must be considered when developing and implementing cooperation projects and other interventions (e.g. healthcare systems and natural resource conservation management programs). For example, the findings related with the Tsimane' ethnomedicinal knowledge system, health care practices, and the use and cultural meaning of different fish species can be used to develop interventions that are socially and culturally acceptable and that acknowledge, promote and reinforce Tsimane' local environmental knowledge and practices in the current policy debates concerning conservation and development. They could also be useful to identify and address the increasing social differentiation between Tsimane' women and men previous to any interventions, so that interventions can serve to reduce gender inequalities and not to create new or exacerbate existing ones.

In chapters 3 and 4, I have addressed Tsimane' medicinal plant knowledge distribution, their use of biomedicine and the presence of medicinal plants in homegardens. Understanding Tsimane' healing practices as well as their access, use, and management of medicinal plants is urgently needed in the current sociopolitical changes taking place in Bolivia. For example, since 2003, the "Universal Mother and Child Insurance Scheme" (*Seguro Universal Materno Infantil*, SUMI) has focused on improving equality in the access to obstetric healthcare and reducing maternal and infant mortality. This package of free services, intended to improve equality in the access to obstetric care, theoretically recognizes the intercultural diversity in sexual and reproductive health among indigenous and peasant peoples in Bolivia. Furthermore, the intercultural health component of this program considers the adaptation of services to include the use of traditional medicine and healing practices in state healthcare programs. These intercultural health initiatives are promoted from governmental instances also with the aim of improving the collaboration between local communities, traditional healers, and biomedical staff, to offer a more culturally sensitive and integrative public health services for indigenous and peasant people. At the practical level, however, these initiatives face important epistemological challenges because of the differential value assigned to knowledge that comes from groups within different socioeconomic and cultural positions in a intercultural approach to health (Wayland 2003; Calvet-Mir et al. 2008; Torri and Hollenberg

2013). Moreover, intercultural approaches to healthcare can also have significant impact on women's authority at a local level since their responsibilities as household and community caregivers and healers could be undermined if they are not actively involved in these initiatives or if their knowledge and expertise is neglected in such strategies (Wayland 2001). Thus, if not carefully tailored, these initiatives, could compromise people's ability to choose culturally relevant health care options and their health sovereignty.

In this context, the knowledge, practices, and beliefs of Tsimane' women with regard to reproductive health should be taken into account at a local level. As traditional medicinal specialists with midwifing expertise, Tsimane' women active participation in the design and delivery of intercultural health services should be encouraged. Recognizing women's knowledge and expertise can help to promote equity and social justice from a biocultural perspective. Findings from this research can help recognize Tsimane' women's knowledge and contributions to subsistence, which can provide insights for a better design of participative intercultural health initiatives. Furthermore, understanding which factors pattern medicinal plant diversity in homegardens, can also help policy-makers, health providers, and local communities to better understand how to promote and preserve medicinal plants *in situ,* so that they can continue to provide locally accessible, culturally appropriate, and economically affordable health care options for people with scarce access to biomedical healthcare systems.

In chapters 5 and 6, I have also delineated some broad practical implications of the research findings regarding transmission and distribution of fishing knowledge and the use of fishery resources by the Tsimane' people. In particular, I highlighted that people have differentiated access to and use of resources and hold diverse *types* of knowledge, rather than simply diverse *quantities* of knowledge, in which case gendered patterns of knowledge distribution should be acknowledged. Therefore, integrated biocultural approaches that consider both scientific and local knowledge should recognize gendered knowledge and expertise of local people beyond stereotypes and assure that knowledge diversity is represented in any intervention by promoting the participation of both women and men in the planning and implementation of programs affecting them. Likewise, women's ane men's knowledge and expertise should be taken into account for improving the management and conservation of their territory.

Finally, the increasing interest and partially implemented 'ecotourism' project associated to catch-and-release sport fish in the Tsimane' territory may benefit from a better design of the decision making process and a evaluation of the potential benefits and challenges that this kind of strategies may bring to the inhabitants of the villages affected, and to Tsimane' Territory as a whole (Fernández-Llamazares et al. 2014). These initiatives may significantly affect villages and intra-household dynamics, gendered customary norms regarding fishing and livelihood strategies, as well as Tsimane' access and use of fishery resources, thus, their food security and sovereignty (see also Hanazaki et al. 2013). Assuring that free prior informed consent is provided by the villages affected and also the participation of women and men in the decision making process may help to reduce the potential negative impacts of 'ecotourism' on local peoples.

4. Limitations

Findings of this dissertation are limited in several ways. First, in this study I have collected data on social networks (chapters 4 and 5) to explore social relations, which are intrinsically dynamic, fluid, and constantly changing. In the same way, local environmental knowledge and the way it is transmitted is also dynamic (Gómez-Baggethun and Reyes-García 2013). Hence, I have captured a snapshot of relations. I am aware that these relations are likely to change over time, even within short time slots, which basically means that my results are limited in their temporal dimension. Besides that, in order to assure manageability and feasibility of the social network data, I used the village level as a bounded universe for data collection. I did not include networks with Tsimane' that live in other villages nor relations or exchanges with non-Tsimane' visiting the villages (e.g. merchants, loggers, anthropologists, tourists). Although I acknowledge that this limits the findings to a very narrow local context, in practice, for most Tsimane' in the villages analyzed, social relations at other local and regional scales are very sporadic. Thus a sociocentric network approach at a village level, despite limited, was appropriated to measure Tsimane' pattern of relations.

A second limitation of this work is that I have assumed that people fishing together share information and knowledge about fishing. Thus, I presumed social network data might reflect potential pathways for acquiring and transmitting environmental knowledge about fishing (chapter 5). This assumption highlights that despite I made an effort to including both quantitative and qualitative methods, qualitative methods were mostly used for contextualizing the research, for example through participant observation in fishing expeditions, these information did not give concrete meaning to some of the quantitative methods employed (i.e. social networks). In other words, social network data would have been richer if I would have use specific open questions about the tasks performed with each of the people accompanying the informant, or should I have asked about their interpretation of fishing networks graphs.

Third, a common thread in all four empirical chapters was the categorization 'women' and 'men' as homogenous groups. I have only used age to explore diversity within women and men at a local level. Through my fieldwork experience I observed heterogeneity within Tsimane' women and men beyond age. I am convinced that exploring other sources of diversity within women and men in relation to livelihood strategies within households and villages could have provided a more nuanced understanding of femininities, masculinities, and gendered practices and knowledge among the Tsimane'. I would suggest future ethnobiological research to pay attention to heterogeneities beyond 'bounded' categories of women and men.

Fourth, as a first attempt to examine the adaptive capacity and potential resilience of ethnomedicinal knowledge systems, the approach and data collected in chapter 3 only considered the use of individual plants while, in practice, the Tsimane' employ mixed remedies. Thus, medicinal knowledge redundancy may have been underestimated. Additionally, beyond medicinal plant knowledge redundancy and its effect on knowledge

system functionality, this research would have benefitted from an evaluation of the distribution and availability of medicinal plant species in the study area.

A final limitation of my findings relates to the temporal ecological variability. Homegarden inventories were collected just one time during the dry season and it was only inventoried the presence of different plants. Therefore, I could not monitor the diversity in homegardens in the course of a year and diversity measures could not be calculated, limiting the assessment of plants in homegardens to species richness (see Vogl et al. 2004).

5. Recommendations for further research

More studies are required to improve the scientific comprehension on the processes of cultural knowledge transmission, distribution, and the formal and informal mechanism that shape the access, use, knowledge and management of biodiversity and natural resources by local populations. Also, those studies are needed for supporting and promoting sustainable livelihoods *with* and *for* local people (Escobar 1995, 1999). The limitations aforementioned indicate that further investigation is needed and illustrate prospective study areas.

This research shows the potential of using social networks analysis methods for exploring knowledge transmission and distribution, which is also attested by an increasing body of research applying those methods within this area of inquiry (Hopkins 2009; Calvet-Mir et al. 2012; Reyes-García et al. 2013). However, a strict quantitative social network analysis approach in knowledge transmission and distribution studies limits the breadth and depth of the explanatory power of the method, as we may be loosing important elements of this process by just looking at the network structure from an 'outsider's' view. A mixed method approach can help to overcome this limitation. Mixed methods social network research that combines the mapping and measuring of social relations using quantitative data (e.g. number of relationships between members of a network) with qualitative data (e.g. the actors interpretations, perceptions and explanations from their actions *vis-à-vis* other members of a network) can add value to the explanations and inferences researchers make when using social networks analysis to explain social phenomena (Hollstein 2014). Mixed methods social networks research can foster with content and meaning the networks processes observe and documented by researchers from the 'insider's view'. Mixed methods in network research can also serve to study both the content of knowledge and the context of its production, transmission, and transformations. As local knowledge systems are not in isolation and are constantly evolving, more studies are needed to understand processes of transformation in local practices and knowledge (Ellen et al. 2005; Gomez-Baggethun and Reyes-García 2013). Mixed methods approach can be an appropriate research tool to explore knowledge transformations and other sources of knowledge beyond other people (e.g. media, books, etc.) (see Haselmair et al. 2014). Moreover, as networks are complex and dynamic, the analysis of longitudinal data can provide better insights on the dynamic patterns of social relationships (Steglich et al. 2010).

I also call for additional research adopting a relational perspective on gender and environmental issues that pay attention to the dynamics of gender differentiated activities including the knowledge, use, and control over biodiversity and natural resource within ethnoecology and ethnobiology. Ethnobiological studies also need to enrich the 'women' and 'men' categories and look at the *intersectionality* of gender (Banerjee and Mayerfeld 2007). A gender lens can help to shed light to understand women's and men's strategies for adapting to rapid environmental and socioeconomic changes. Insights from feminist political ecology and poststructuralist feminist research can provide clues on how to 'unpack' the binary categories of 'women' and 'men' by looking at the nuances of local gender diversity, as gender and gender roles intersect with other issues as age, social status, kinship relations, residential location, class, ethnicity (Leach 2006, 2007; Carr 2008) and how these intersections differentiate a multi-layered forms of environmental practices and knowledge. Thus, going beyond static and stereotypical conceptions of women's and men's subsistence roles, ethnobiologists should acknowledge the dynamic nature of gender roles, especially in the face of environmental, socioeconomic and political changes as well as the shifting social relations in each particular context. For example, even in a context like the Tsimane' villages, where there are no ethnic, class, or religious divisions, exploring other sources of social diversity such as income or livelihood strategies within households and villages can be a fruitful arena for examining how knowledge and practices are being shape by the increasing exposure to the market economy. Understanding different modes of livelihoods within villages and identifying the social groups associated with these various livelihoods, for example, who is engage in market oriented activities, subsistence, and diversified activities within households and between individuals (Carr 2008) or differentiated access to biomedicine, can provide a much richer comprehension of intracultural practices and knowledge distribution and diversity.

It has been claimed that ethnobiology can be profoundly relevant to offer possible solutions to social and environmental injustice issues on multiple scales (Maffi 2004). For that aim, and to foster the interdisciplinary nature of ethnobiological or ethnoecological studies it would be necessary to use disciplinary tools and theories that become pertinent as new issues and perspectives arise within the discipline (Newing 2010; Wolverton et al. 2014). I propose ethnobiologist to engage with a social network perspective and to nurture the gender lens in ethnobiological studies with insights from feminist political ecology to approach the diversity of gendered practices and knowledge within communities. To embrace complexity theory and moving from linear or simple vertical hierarchies (chains of explanations) to complex assemblages, webs of relation and "rooted networks" (Rocheleau 2008: 724) that can provide more nuanced understandings of the diversity of knowledge and practices in dynamic local contexts.

6. References

Alburquerque, U.P., and R.F. Oliveira. 2007. Is the use-impact on native caatinga species in Brazil reduce by the high species richness of medicinal plants? *Journal of Ethnopharmacology* 113:156-170.

Banerjee, D., and M. M. Bell. 2007. Ecogender: locating gender in environmental social science. *Society and Natural Resources* 20 (1): 3–19.

Bicker, A., P. Sillitoe, and J. Pottier. 2004. *Development and Local Knowledge* Routledge Harwood Anthropology.

Calvet-Mir, L., M. Calvet-Mir, J.L. Molina, and V. Reyes-García. 2012. Seed exchange as an agrobiodiversity conservation mechanism: a case study in Vall Fosca, Catalan Pyrenees, Iberian Peninsula. *Ecology and Society* 17(1):29.

Calvet-Mir, L., V. Reyes-García, and S. Tanner. 2008. Is there a divide between local medicinal knowledge and Western medicine? a case study among native Amazonians in Bolivia. *Journal of Ethnobiology and Ethnomedicine* 4:18.

Carr, E. R. 2008. Men's crops and women's crops: the importance of gender to the understanding of agricultural and development outcomes in Ghana's Central Region. *World Development* 36 (5): 900–915.

Ellen, R., P. Parkes, and A. Bicker, eds. 2005. *Indigenous Environmental Knowledge and Its Transformations: Critical Anthropological Perspectives*. The Neatherlands: Harwood.

Ellis, R. 1996. A Taste for Movement: An Exploration of the Social Ethics of the Tsimanes of Lowland Bolivia. PhD Thesis. St. Andrews University, Scotland.

Escobar, A., 1995. *Encounting Development: The Construction and Deconstruction of the Third World*. Princeton University Press, Princeton.

Escobar, A., 1999. After nature: steps to an antiessentialist political ecology. *Current Antropology* 40 (1):1–30.

Fernández-Llamazares, Á., I. Díaz-Reviriego, and I.V. Sánchez. 2014. Las voces del cambio: percepciones de una sociedad ante el proceso de cambio. In: V. Reyes-García and T. Huanca (eds) *Cambio global, cambio local. La sociedad Tsimane' ante la globalización*, Barcelona: Icaria.

Ferreira Júnior, W.S., F.R. Santoro, A.L. Borba, A.H. Ladio, and U.P. Albuquerque. 2013. The role of individuals in the resilience of local medical systems based on the use of medicinal plants – a hypothesis. *Ethnobiology and Conservation* 2(1):1-10.

Gavin, M. C., J. McCarter, A. Aroha, B. Fikret, J.R. Stepp, and D. Peterson. 2015. Defining biocultural approaches to conservation. *Trends in Ecology and Evolution* 30(3): 140-145.

Godoy, R., V. Reyes-García, V. Vadez, W.R. Leonard, and E. Byron. 2007. How well do foragers protect food consumption? Panel evidence from a native Amazonian society in Bolivia. *Human Ecology* 35(6):723-732.

Gómez-Baggethun, E., and V. Reyes-García. 2013. Reinterpreting change in traditional ecological knowledge. *Human Ecology Interdisciplinary Journal* 41(4):1-9.

Gómez-Baggethun, E., V. Reyes-García, P. Olsson, and C. Montes. 2012. Traditional ecological knowledge and community resilience to environmental extremes: A case study in Doñana, SW Spain. *Global Environmental Change* 22(3): 640-650.

Haselmair, R., H. Pirker, E. Kuhn, and C. R. Vogl. 2014. Personal networks: a tool for gaining insight into the transmission of knowledge about food and medicinal plants among Tyrolean (Austrian) migrants in Australia, Brazil and Peru. *Journal of Ethnobiology and Ethnomedicine* 10(1): 1.

Henrich, J., and F. Gil-White. 2001. The evolution of prestige. Freely conferred deference as a mechanism for enhancing the benefits of cultural transmission. *Evolution and Human Behavior* 22:165−196.

Henrich, J., and J. Broesch. 2011. On the nature of cultural transmission networks: evidence from Fijian villages for adaptive learning biases. Philosophical Transactions of the Royal Society B: Biological Sciences 366(1577):1139-1148.

Hollstein, B. 2014. Mixed methods social network research: an introduction. In: Dominguez, S. and B. Hollstein (eds) *Mixed Methods Social Network Research: Desing and Applications*. Cambridge University Press.

Hopkins, A. 2009. Medicinal Plant Remedy Knowledge and Social Networks in Tabi, Yucatán, Mexico. PhD Thesis, University of Florida.

Howard, P.L. 2006. Gender and social dynamics in swidden and homegardens in Latin America. In: Kumar B.M. and Nair P.K.R. (eds), *Tropical Homegardens: A Time-tested Example of Sustainable Agroforestry*. Springer Science, Dordrecht, The Netherlands.
Howard, P.L. 2006. Gender and social dynamics in swidden and homegardens in Latin America. In: Kumar B.M. and Nair P.K.R. (eds), *Tropical Homegardens: A Time-tested Example of Sustainable Agroforestry*. Springer Science, Dordrecht, The Netherlands.
Jules, P., B. Adams, F. Berkes, S. Ferreira de Athayde, N. Dudley, E. Hunn, L. Maffi, K. Milton, D. Rapport, P. Robbins, C. Samson, E. Sterling, S. Stolton, K. Takeuchi, A. Tsing, E. Vintinner, and S. Pilgrim. 2008. How do biodiversity and culture intersect? Plenary paper for Conference "Sustaining Cultural and Biological Diversity In a Rapidly Changing World: Lessons for Global Policy". American Museum of Natural History's Center for Biodiversity and Conservation, IUCN-The World Conservation Union/Theme on Culture and Conservation, and Terralingua. 17pp.

Kawa, N. C., C. McCarty, and C. R. Clement. 2013. Manioc varietal diversity, social networks, and distribution constraints in rural Amazonia. *Current Anthropology* 54(6): 764–770.

Labeyrie, V., R. Bernard, and C. Leclerc. 2014. How social organization shapes crop diversity: an ecological anthropology approach among Tharaka farmers of Mount Kenya. *Agriculture and Human Values* 31(1):97–107

Leach, M. 2006. Gender and the environment: traps and opportunities. *Development in Practice* 2(1):12-22.

Leach, M. 2007. Earth mother myths and other ecofeminist fables: how a strategic notion rose and fell. *Development and Change* 38(1): 67-85.

Leclerc, C., and G. Coppens d'Eeckenbrugge. 2012. Social organization of crop genetic diversity. The G x E x S interaction model. *Diversity* 4(1): 1–32.

Maffi, L. 2004. *Maintaining and Restoring Biocultural Diversity: The Evolution of a Role for Ethnobiology. In Ethnobotany and Conservation of Biocultural Diversity*, edited by T. J. S. Carlson, and L. Maffi, pp. 9–36. New York Botanical Garden, Bronx, NY. Marviera,

Maffi, L. 2005. Linguistic, cultural, and biological diversity. *Annual Review of Anthropology* 34: 599–617.

McPherson, M., L. Smith-Lovin, and J. M. Cook. 2001. Birds of a feather : homophily in social networks. *Annual Review of Sociology* 27: 415–444.

Momsen, J. H. 2007. Gender and Agrobiodiversity: Introduction to the special issue. *Singapore Journal of Tropical Geography* 28 (1): 1–6.

Nazarea, V. 1999. Introduction. A view from a point: ethnoecology as situated knowledge. In: Nazarea, V. (ed) *Ethnoecology: Situated Knowledges/Located Lives.* University of Arizona Press, Tucson.

Newing, H. 2010. Bridging the Gap: Interdisciplinarity, Biocultural Diversity, and Conser- vation. vation. In Nature and Culture: Rebuilding Lost Connections, edited by S. Pilgrim, and J. Pretty, pp. 23–40. Earthscan, New York, NY.

Pfeiffer, J.M., and R.J. Butz. 2005. Assesing cultural and ecological variation in ethnobiological research: the importance of gender. *Journal of Ethnobiology* 25(2): 240-278.

Reyes-García V., M. Gueze, A. C. Luz, M. Macia, M. Orta-Martínez, J. Paneque-Gálvez, J. Pino, and X. Rubio-Campillo. 2013. Evidence of traditional knowledge loss among a contemporary indigenous society. *Evolution and Human Behaviour* 34: 249-257.

Reyes-García, V., J. L. Molina, L. Calvet-Mir, L. Aceituno-Mata, J. J. Lastra, R. Ontillera, M. Parada, M. Pardo-de-Santayana, M. Rigat, J. Vallès, and T. Garnatje. 2013. "Tertius gaudens": germplasm exchange networks and agroecological knowledge among home gardeners in the Iberian Peninsula. *Journal of Ethnobiology and Ethnomedicine* 9(1): 53-62.

Reyes-García, V., S. Vila, L. Aceituno-Mata, L. Calvet-Mir, T. Garnatje, A. Jesch, J.J. Lastra, M. Parada, M. Rigat, J. Vallès, and M. Pardo-de-Santayana. 2010. Gendered homegardens: a study in three mountain areas of the Iberian Peninsula. *Economic Botany* 64(3):235-247.

Reyes-García, V., V. Vadez, E. Byron, L. Apaza, W.R. Leonard, E. Perez, and D. Wilkie. 2005. Market economy and the loss of folk knowledge of plant uses: estimates from the Tsimane' of the Bolivian Amazon. *Current Anthropology* 46(4):651–656.

Rocheleau, D. 2008. Political ecology in the key of policy: from chains of explanation to webs of relations. *Geoforum* 39(2): 716-727.

Rocheleau, D., Roth, R., 2007. Rooted networks, relational webs and powers of connection: rethinking human and political ecologies [Editorial]. Geoforum 38 (3), 433–437.

Ruelle, M.L., and K.A. Kassam. 2011. Diversity of Plant Knowledge as an Adaptive Asset: A Case Study with Standing Rock Elders. *Economic Botany* 65(3):295-307.

Salpeteur M., H. Patel, A. Balbo, X. Rubio-Campillo, M. Madella, P. Ajithprasad, and V. Reyes-García. 2015. When knowledge follows blood kin groups and the distribution of traditional ecological knowledge in a community of semi-nomadic pastoralists, Gujarat (India). *Current Anthropology* 56(3): 471-483.

Santoro F.R, W.S. Ferreira Júnior, TAdS. Araújo, A.H. Ladio, and U.P. Albuquerque. 2015. Does Plant Species Richness Guarantee the Resilience of Local Medical Systems? A Perspective from Utilitarian Redundancy. *PLoS ONE* 10(3).

Shaughnessy, S.O., and N.T. Krogman. 2011. Gender as Contradiction : from dichotomies to diversity in natural resource xxtraction. *Journal of Rural Studies* 27 (2): 134–43

Smith-Lovin, L., and J. M. McPherson. 1993. You are who you know: a network approach to gender. In: *Theory on gender, Feminism on Theory*, ed. P. England. New York: Gruyter.

Steglich, C., T. a. B. Snijders, and M. Pearson. 2010. Dynamic networks and behavior: separating selection from influence. *Sociological Methodology* 40(1): 329–393.

Sunderland, T., R.Achdiawan, A. Angelsen, R. Babigumira, A. Ickowitz, F. Paumgarten, V. Reyes-García, and G.Shively. 2014. Challenging perceptions about men, women, and forest product use: a global comparative study. *World Development* 64(S1): S56-S66.

Torri, M.C., and D. Hollenberg. 2013. Indigenous traditional medicine and intercultural healthcare in bolivia: a case study from the potosi region. *Journal of Community Health Nursing* 30(4):216-229.

Vogl, C.R., B.Vogl-Lukasser, and R. K. Puri. Tools and Methods for Data Collection in Ethnobotanical Studies of Homegardens. *Field Methods* 16(3): 285-306.

Wayland, C. 2001. Gendering local knowledge: Medicinal plant use and primary health care in the Amazon. *Medical Anthropology Quarterly* 15 (2): 171–188.

Wayland, C. 2003. Contextualizing the politics of knowledge: physicians' attitudes toward medicinal plants. *Medical Anthropology Quaterly* 17(4): 483-500.

Wayland, C. and S. Walker. 2014. Length of residence, age and patterns of medicinal plant knowledge and use among women in the urban Amazon. *Journal of Ethnobiology and Ethnomedicine* 10:25.

Wolverton, S., J. N. Nolan, and W. Ahmed. 2014. Ethnobiology, political Ecology, and conservation. *Journal of Ethnobiology* 34(2): 125-152.

Zycherman, A. 2013. The Changing Value of Food: Localizing Modernity among the Tsimané Indians of Lowland Bolivia. PhD Thesis. Columbia University.

Appendices

Appendices

Appendix 1

1.1 Chapter 3. Correspondence of medicinal plant vernacular names with scientific names

Vernacular name	Scientific name	Taxonomic family
apainiqui	*Pera benensis* (Rusby)	Euphorbiaceae
arara	*Urera laciniata* (Goudot) Wedd *urticaria*	Urticaceae
ashashaj	*Citrus limon* (L.) Burn	Rutaceae
Ava' ava'	*Prockia crucis* L.	salicaceae
banana	*Musa x acuminata*	Musaceae
bätin	*Syagrus sancona* Karsten	Palmae
bejqui	*Hymenaea courbaril* L.	Leguminosae-Cae
buisi	*Entada sp.*	Leguminosae-Mim
caji'si	*Martinella ovovata* (H.B.K) Bureau & Schumann	Bignoniaceae
cam	*Otoba parvifolia* (Markgraf) A. Gentry	Myristicaceae
canau		
cashcaria	*Cinchona* cf. *Officinalis* L.	Rubiaceae
cata		
ca' babas	*Olyra latifolia*	Gramineae
chij	*Triplaris americana* L.	Polygonaceae
chito	*Tephrosia vogelii J. D.* Leguminosae-Pap	Leguminosae-Pap
chorecho'	*Aniba canelilla* (H.B.K.) Mez	Lauraceae
chujbubuty	Peperomia rotundifolia (L.) Kunth	Piperaceae
chura'	*Swietenia macrophylla* (King)	Meliaceae
conojfoto	*Hura crepitans* L.	Euphorbiaceae
copaiva	*Copaifera reticulata* Ducke	Fabaceae
cos	*Nicotina tabacum*	Solanaceae

Vernacular name	Scientific name	Taxonomic family
coti’	*Psidium guajava L.*	Myrtaceae
cravu		
curi	*Lantana cf. Aristat*	Verbenaceae
curu		
dyesatdyes	*Baccharis trinervis* (Lam) Pers.	Compositae
ere’	*Petiveria alliacea* L.	Piperaceae
ibiñe		
ijmeme	*Myrcia fallax*	Myrtaceae-Leg
irepij	*Ocimum micranthum* Willd.	Labiatae
itsi	*Picramnia* aff. *Sellowii* Planchan subsp *sprucanea* (Engl.) Pirari	Simaroubaceae
jamo’tarara	*Margarita nobilis* L.F	Euphorbiaceae
macha	*Amburana caerensis*	Fabaceae
manai	*Attalea phalerata C.* Martius ex Sprengel	Palmae
marva	*Sida rhombifolia L*	Malvaceae
maschaty		
mature	*Acmella oleracea*	Compositae
merique	*Ananas comosus*	Bromeliaceae
mojmosh		
morifi	*Dichorisandra sp.*	Commelinaceae
nashdyes		
orotas		
oteti		Amarilliadaceae
oveto	*Uncaria guianensis (Aubl.)*	Rubiaceae
oyoj’ oyoj	*Urvillea sp.*	Sapindaceae
parta	*Persea americana* C. Miller	Laureaceae
potona	*Kalanchoe pinnata* (Lamark) Persoon	Crasulaceae
punuvacdyes		
que’tsetsej	*Davilla nitida* (Vahl) Kubitzki	Dilleniaceae
rovocdyes		
saute	*Zingiber officinale*	Zingiberaceae
sebiria	*Cymbopogon citratus*	Gramineae
shepi	*Gallesia integrifolia* (Sprengel) Harms	Phytolaccaceae
shepi’is	*Mansoa alliacea* (Lamark) A. Gentry	Bignoniaceae

Vernacular name	Scientific name	Taxonomic family
shiveñi		
siyamo	*Cedrela odorata* L.	Meliaceae
sicoco	*Chenopodium ambrosioides*	Chenopodiaceae
tamtac	*Galipea longiflora* K. Krause	Rutaceae
tiribui		
titij	*Ficus insipida* Willd	Moraceae
tson' sonty	*Ampelocera edentula* Kuhml	Ulmaceae
tubuij	Gouania adenophora	Rhamnaceae
tyi'	*Genipa americana* L.	Rubiaceae
tyi'mujmure	Piper pelatum Ruiz&Pay	Piperaceae
ufajre	*Brugmansia arborea* (L.)	Solanaceae
undye		
u'puyu	Piper laevigatum Kunth	Piperaceae
vambason	*Aspidosperma rigidum*	Apocinaceae
vashi	*Serjania caracasana*	Sapindaceae
vayori	*Sparattanthelium glabrum*	Hernandiaceae
vijsi	Not identified	
viyucure	Not identified	
vujnare	Not identified	
yäcäni	Not identified	
yän	Not identified	
yantes	Not identified	
yavitus	Not identified	

1.2 References consulted for linking vernacular names with scientific names:

Huanca, T. 1999.Tsimane' Indigenous Knowledge. Swidden Fallow Management andConservation. PhD Thesis, University of Florida

Reyes-García, V. 2001. Indigenous people, ethnobotanical knowledge, and market economy. A case study of the Tsimane' Amerindians in lowland Bolivia. PhD Thesis, University of Florida

Guéze, M. 2011. Evaluation of tree diversity and utilization: the role of acculturation. A case studyin the Bolivian Amazaon. PhD Thesis, Institut de Ciéncia i Tecnologia Ambientals, Universitat Autònoma de Barcelona.

Ticona, J.P. 2010. Los chimane: conocimiento y uso de plantas medicinales en la comunidad de Tacuaral del Matos, Provicia Ballivian, Departamento del Beni. Bachelor Thesis, Universidad Mayor de San Andrés.

1.3 Appendix 1. Plant parts, preparation means and application means.

Plant parts
bark
leaf
stem
root
tuber
oil
water
sprout
savia
seed
fruit

Preparation means
boiled
mashed
smoke
sirope
direct use
burnt/heat in the fire
grind
mixed with other plants

Application means
rubbed
spread
bath
ritual (abstinence/ moon time)
poultice
chew
inhale

Appendix 2

2.1 Chapter 4. List of species inventoried in homegardens in two Tsimane' villages. Uses code as Medicinal: M, Food: F, Artisanal: A, Other: O.

Vernacular name	Scientific Name	Taxonomic Family	Source	Use	Code
ajosh	*Allium sativum*	Amaryllidaceae		M,F	122002
apaijniquij	*Pera benensis* (Rusby)	Euphorbiaceae	1	M, O	122068
arara'	*Urera laciniata* (Goudot) Wedd *urticaria*	Urticaceae	1, 3, 4	M	122003
ashashaj	*Citrus limon* (L.) Burn	Rutaceae	1, 4	M,F	122004
asuntena	Not identified			M, F	122001
ava-ava	*Prockia crucis* L.	Salicaceae	3	A	122097
bäcäj-bäcäj	Not identified			F	122005
bajna	*Gossypium barbadeense* L.	Malvaceae	1, 4	A, O	122006
banana	*Musa x acuminata*	Musaceae	1	M	122007
bejqui	*Hymenaea courbaril* L.	Leguminosae-Cae	1, 3, 4	M, F	122008
binca	*Passiflora triloba* R.&P. ex DC	Passifloraceae	1	F	122009
bira-bira	Not identified			M	122010
buisi	*Entada sp.*	Leguminosae-Mim	1	M	122011
buvui'	Not identified			M, A	122070
					122012
cafe	*Coffea sp.*	Rubiaceae		F	
caij	*Ipomoea batatas*	Convolvulaceae	4	F	122071
cajna	*Bactris riparia*	Palmae	1	F	122098
cashtira	*Musa xacuminata*	Musaceae		F	122085
cebolla	*Allium cepa*	Amaryllidaceae		F	122013
chipapa	Not identified			F	122014

Vernacular name	Scientific Name	Taxonomic Family	Source	Use	Code
chirimolla	*Anona cherimola*	Anonacea		F	122015
chito'	*Tephrosia vogelii* J. D.	Leguminosae-Pap	1, 3, 4	O	122016
chocorati	*Theobroma cacao* L.	Sterculiaceae	1	F	122017
chorecho'	*Aniba canelilla* (H.B.K.) Mez	Lauraceae	1, 3	M, F	122072
chujbubyty	*Peperomia rotundifolia* (L.) Kunth	Piperaceae	1	M	122018
chura'	*Swietenia macrophylla* (King)	Meliaceae	1	A, O	122073
coco	*Cocos nucifera*	Palmae	1	F	122019
cocob	Not identified			F, A	122099
cojco	*Pachyrhizus tuberosus* Spreng	Leguminosae-Pap	1	F	122020
conei	Not identified			M, A, O	122100
corishi	*Cajanus cajan*	Fabaceae		F, A	122025
cos'	*Nicotina tabacum*	Solanaceae	1, 4	M, O	122021
coti'	*Psidium guajava* L.	Myrtaceae	1, 3, 4	M, F	122022
cuimashi	Not identified			A	122101
cu'na	*Inga crestediona* Benth ex Seeman	Leguminosae-Mim	1, 3	F	122023
curi	*Lantana* cf. *Aristat*	Verbenaceae	1, 4	M ,F	122024
curij	*Lantana* cf. *Aristat*	Verbenaceae	1	F	122102
dabaj	*Arachis hypogaea*	Papilionaceae-Leg	4	F	122026
dyestsadyes	*Baccharis trinervis* (Lam) Pers.	Compositae	1	M	122103
ere'	*Petiveria alliacea* L.	Phytolaccaceae	1, 4	M	122027
erepa'/erepaj	*Crescentia cujete*	Bignoniaceae	1, 4	M, A,	122028

Vernacular name	Scientific Name	Taxonomic Family	Source	Use	Code
				O	
faj/fa'	*Bixa orellana* L.	Bixaceae	1	F, A, O	122029
frutilla	*Fragaria sp.*	Rosaceae		F	122107
guineo	*Musa xacuminata*	Musaceae	1	F	122085
ibijqui	*Rheedia gardneriana* Miers ex. Planch &Triana	Clusiaceae	1, 2, 3, 4	F	122031
i'fare	*Brugmansia arborea*	Solanaceae	4	M	122030
ijmemej	*Myrcia fallax*	Myrtaceae-Leg	4	M	122032
ij'sita	*Pseudolmedia laevis* (Ruiz & Pavon) J.F. Macbr.	Moraceae	1	F	122074
irepij	*Ocimum micranthum* Willd.	Labiatae	1, 4	M	122033
irepij	*Ocimum micranthum* Willd.	Labiatae	1	M	122075
ja'me	Not identified			M, A, O	122076
lima	*Citrus sp.*	Rutaceae		F	122034
limonara	*Citrus limetta*	Rutaceae	1	F	122035
macdarina	*Citrus reticulata*	Rutaceae	1, 4	F	122038
manai'	*Attalea phalerata* C. Martius ex Sprengel	Palmae	1, 2, 4	F, O	122036
manco	*Mangifera indica*	Anacardiaceae	1	F	122037
manzana	Not identified			F	122039
maraca	*Citrus sinensis*	Rutaceae	1, 4	F	122040
marva	*Sida rhombifolia* L	Malvaceae	1	M	122041
mature'	*Acmella oleracea*	Compositae	4	M	122077
merique	*Ananas comosus*	Bromeliaceae	4	F	122042

Vernacular name	Scientific Name	Taxonomic Family	Source	Use	Code
mora	*Maclura tinctoria*	Moraceae	4	F	122078
morifi	*Dichorisandra sp.*	Commelinaceae	3, 4	M	122043
nonoj	*Nectandra caucana*	Lauraceae	1	A, O	122095
ña'me	*Inga* cf. *ruiziana* Don.	Leguminosae-Mim	1, 3	F, O	122094
ñapis	Not identified			M	122096
ocoró	*Rheedia acuminata* (Ruiz & Pavon) Planch. & Triana	Clusiaceae	1	F, A	122045
onomaj	*Passiflora sp.*	Passifloraceae	3	A	122079
oteti	Not identified	Amarillidaeceae	1	M	122046
o'yi	*Manihot esculenta*	Euphorbiaceae	4	F	122044
pacay	*Inga sp.*	Leguminosae-Mim	1	F	122109
parta	*Persea americana* C. Miller	Lauraceae	1	M, F, A	122047
pe're	*Musa x balbisiana*	Musaceae	1	F	122048
pofi	*Carica papaya* L.	Caricaceae	1	F	122049
potona	*Kalanchoe pinnata* (Lamark) Persoon	Crassulaceae	1	M	122050
queru-queru	*Ormosia nobilis*	Fabaceae	1	A	122108
ribo'	Not identified	Fabaceae		F, A	122093
rosario	*Coix lachryma-jobi*	Gramineae	4	A	122051
sapaio	Not identified			F	122104
saute	*Zingiber officinale*	Zingiberaceae	1, 4	M ,F	122052
sebiria	*Cymbopogon citratus*	Gramineae	1	M, F, O	122053
shabai	Not identified			F	122080
shandia	*Citrullus lanatus*	Cucurbitaceae	1	F	122054
shepi	*Gallesia integrifolia* (Sprengel) Harms	Phytolaccaceae	1, 4	M, O	122111
shepi'is	*Mansoa*	Bignoniaceae	1	M,	122081

Vernacular name	Scientific Name	Taxonomic Family	Source	Use	Code
	alliacea (Lamark) A. Gentry			F, A	
shishivutuij	Not identified			M	122091
shuru'	*Gynerium sagittatum* (Aublet) P Beauv.	Gramineae	1, 3, 4	F, A	122056
sicoco'	*Chenopodium ambrosioides*	Chenopodiaceae	4	M	122110
siyamo	*Cedrela odorata* L.	Meliaceae	1, 3	M, A, O	122082
ta'	*Capsicum sp.*	Solanaceae	1, 4	F, O	122055
tamtac	*Pilocarpus sp.*	Rutaceae	3	M, F	122057
ta'ra	*Zea mays*	Poaceae		F	122056
toronja	*Citrus paradisi* Macf.	Rutaceae	1, 4	F	122058
totop	*Passiflora sp.*	Passifloraceae	3	F	122059
tsocon	*Rheedia acuminata* (Ruiz & Pavon) Planch. & Triana	Clusiaceae	1, 2	F	122060
tsocon	*Rheedia cf. brasiliensis* (Mart.) Planch. & Triana	Clusiaceae	3		122060
tyi'/pa'ñe	*Genipa americana* L.	Rubiaceae	1, 2	M	122061
tyutyura'	*Mauritia flexuosa*	Palmae	1, 3	F, O	122090
u'puyu	*Piper laevigatum* Kunth	Piperaceae	1, 3	M	122089
vadaca	*Passiflora sp.*	Passifloraceae	1, 3	F	122083
väij	*Bactris gasipaes* (H.B.K.)	Palmae	1, 4	F, A, O	122062
varosa	*Xanthosoma sp.*	Araceae	1	F	122084
vina'j	*Stylogyne cauliflora* (Mart & Miq.) Mez	Myrsinaceae	1, 3	F	122064
vira' vira'	*Cymbopogon citratus*	Gramineae	1		122053

Vernacular name	Scientific Name	Taxonomic Family	Source	Use	Code
virij	Not identified			F	122088
viroj	*Saccarum officinarum*	Poaceae		F	122065
virui'	*Inga sp.*	Leguminosae-Mim	1, 3	O	122066
vishirij	*Inga punctata* Willd.	Leguminosae-Mim	1	F	122087
viyucure	Not identified			M	122067
vo'codyes	*Jatropha curcas* L.	Euphorbiaceae	1, 3	M	122086
vujnare	Not identified			M, O	122106
winsi winsi	*Cardiospermum halicacabum*	Sapindaceae	1	A	122063
yajyare	*Eleuthernine citriodora* Rav.	Iridaceae	1	M	122105

2.2 References consulted for linking vernacular names to scientific names

Reyes-García, V. 2001. Indigenous people, ethnobotanical knowledge, and market economy. A case study of the Tsimane' Amerindians in lowland Bolivia. PhD Thesis, University of Florida.

Huanca, T. 1999. Tsimane' Indigenous Knowledge. Swidden Fallow Management andConservation. PhD Thesis, University of Florida.

Guéze, M. 2011. Evaluation of tree diversity and utilization: the role of acculturation. A case study in the Bolivian Amazaon. PhD Thesis, Institut de Ciéncia i Tecnologia Ambientals, Universitat Autònoma de Barcelona.

Ticona, J.P. 2010. Los chimane: conocimiento y uso de plantas medicinales en la comunidad de Tacuaral del Matos, Provicia Ballivian, Departamento del Beni. Bachelor Thesis, Universidad Mayor de San Andrés.

Appendix 3

3.1 List of fish species reported in the scans by women and men by frequency of report.

Vernacular name	Scientific name	Taxonomic family	Frequency of report	
			Women	Men
Vonej	*Prochilodus cf. nigricans*	Prochilodontidae	24	215
Cajsare'	*Salminus maxillosus*	Characidae	0	51
Sonarej	*Pseudoplatystomafasciatum*	Pimelodidae	2	44
Tobiri	*Schizodomfasciatum*	Anostomidae	15	35
Cavadye'	*Paulicea luetkeni*	Pimelodidae	1	28
Sherejsherej	*Hoplias malabaricus*	Erythrinidae	13	26
Paquisdye	*Surubim lima*	Pimelodidae	7	25
Jutiru	*Pimelodus sp.*	Pimelodidae	17	24
Bojmo	*Curimata* sp.	Curimatidae	14	21
Cum'	*Markiana nigrinpinnis*	Characidae	34	19
Shiare'	*Cynopotamus* cf. *amazonus*	Characidae	11	19
Shicurity	*Hemisorubim platyrhynchos*	Pimelodidae	8	19
Vat'se	*Pterygoplichthys multiradiatus*	Loricariidae	2	17
Jo'sa	*Brycon* sp.	Bryconidae	1	16
Pu'na	*Hoplerytrinus unitaeniatus*	Erythrinidae	13	15
Cotyij	*Pimelodella sp.*	Heptapteridae	22	14
Vutity	*Pseudodoras Níger*	Doradidae	2	13
Boyatdye'	*Leporinus trifaciatus*	Anostomidae	1	13
Sisij	*Hoplosternum thoracatum*	Callichthyidae	3	11
Bonoja	*Potamorhina altamazonica*	Curimatidae	3	9
Tomsis	*Leporinus* cf. *friderici*	Anostomidae	1	7
Ishij	*Pimelodella* sp.	Heptapteridae	6	6
Co'ro	*Hypostomus* sp.	Loricariidae	4	6
Queñedye	*Megalonema* sp.	Pimelodidae	3	5
Cupinaty	*Mylossoma duriventre*	Serrasalmidae	0	5
Pincushi	*Callophysus macropterus*	Pimelodidae	1	4

Tavava	*Pterodoras granulosus*	Doradidae	1	4
Suityi'	*Sternopygus macrurus*	Sternopygidae	1	4
Irimo'	*Serrasalmus spilopleura*	Serrasalmidae	0	4
Itsiquindye	*Pseudoplatystoma tigrinum*	Pimelodidae	0	3
Chäe	*Colossoma macropomum*	Serrasalmidae	0	3
Pacupeva	Not identified		0	3
Isino	*Potamotrygon* cf. *histryx*	Potamotrygonidae	1	2
Nabatdye	*Raphiodon vulpinus*	Cynodontidae	1	2
Yatorana	Not identified		1	2
Shivajneraty	*Leiarius marmoratus*	Pimelodidae	0	2
Meruj	*Batrachops* sp.	Cichlidae	2	1
Tsitsi'	*Callichthys callichthys*		1	1
Tserpapa	*Astronotus Ocellatus*	Cichlidae	0	1
Enono'	*Gymnotus sp.*	Gimnotidae	0	1
Romova	*Acestrorynchus* sp.	Callichthyidae	0	1
Siyaj siyaj	*Triportheus* cf. *angulatus*	Anostomidae	1	0
Awowo	*Apteronotus albifrons*	Apteroniditidae	1	0
Rabaj' rabaj'	*Tetragonopterus argenteus*	Characidae	1	0
Shirica	Not identified		1	0
Pashe	*Cichlasoma boliviense*	Cichlidae	1	0

3.2 References consulted for linking vernacular names to scientific names

Chicchón A. 1992. Chimane Resource Use and Market Involvement in the Beni Biosphere Reserve, Bolivia. PhD Thesis. University of Florida, Gainesville.

Pérez-Limache, E. 2001. Uso de la Ictiofauna entre los Tsimane'. BS Thesis. Universidad Nacional Mayor de San Andrés, Bolivia.

Annex

Annex

Besides the four empirical chapters presented in this dissertation, during my PhD I have co-authored the following scientific and research-based policy publications.

1. Peer-review articles

Fernández-Llamazares, Á., M.E. Méndez-López, **I. Díaz-Reviriego**, M.F. McBride, A. Pyhälä, A. Rosell-Melé, and V. Reyes-García. 2015. Links between media communication and local perceptions of climate change in an indigenous society. *Climatic Change* 131(2): 307-320.

Abstract

Indigenous societies hold a great deal of ethnoclimatological knowledge that could potentially be of key importance for both climate change science and local adaptation; yet, we lack studies examining how such knowledge might be shaped by media communication. This study systematically investigates the interplay between local observations of climate change and the reception of media information amongst the Tsimane', an indigenous society of Bolivian Amazonia where the scientific discourse of anthropogenic climate change has barely reached. Specifically, we conducted a Randomized Evaluation with a sample of 424 household heads in 12 villages to test to what degree local accounts of climate change are influenced by externally influenced awareness. We randomly assigned villages to a treatment and control group, conducted workshops on climate change with villages in the treatment group, and evaluated the effects of information dissemination on individual climate change perceptions. Results of this work suggest that providing climate change information through participatory workshops does not noticeably influence individual perceptions of climate change. Such findings stress the challenges involved in translating between local and scientific framings of climate change, and gives cause for concern about how to integrate indigenous peoples and local knowledge with global climate change policy debates.

Fernández-Llamazares, Á., **I. Díaz-Reviriego**, A.C, Luz, M. Cabeza, A. Pyhälä, and V. Reyes-García. 2015. Rapid ecosystem change challenges the adaptive capacity of Local Environmental Knowledge. *Global Environmental Change* 31: 272-284.

Abstract

The use of Local Environmental Knowledge has been considered as an important strategy for adaptive management in the face of Global Environmental Change. However, the unprecedented rates at which global change occurs may pose a challenge to the adaptive capacity of local knowledge systems. In this paper, we use the concept of the shifting baseline

syndrome to examine the limits in the adaptive capacity of the local knowledge of an indigenous society facing rapid ecosystem change. We conducted semi-structured interviews regarding perceptions of change in wildlife populations and in intergenerational transmission of knowledge amongst the Tsimane', a group of hunter-gatherers of Bolivian Amazonia (n = 300 adults in 13 villages). We found that the natural baseline against which the Tsimane' measure ecosystem changes might be shifting with every generation as a result of (a) age-related differences in the perception of change and (b) a decrease in the intergenerational sharing of environmental knowledge. Such findings suggest that local knowledge systems might not change at a rate quick enough to adapt to conditions of rapid ecosystem change, hence potentially compromising the adaptive success of the entire social-ecological system. With the current pace of Global Environmental Change, widening the gap between the temporal rates of on-going ecosystem change and the timescale needed for local knowledge systems to adjust to change, efforts to tackle the shifting baseline syndrome are urgent and critical for those who aim to use Local Environmental Knowledge as a tool for adaptive management.

Fernández-Llamazares, Á., **I. Díaz-Reviriego**, M.E. Méndez-López, I.V. Sánchez, A. Pyhälä, and V. Reyes-García. 2014. Cambio climático y pueblos indígenas: Estudio de caso entre los Tsimane', Amazonía boliviana. *REDESMA Online Journal* 7: 110-119.

Abstract

Indigenous peoples are great observers of environmental changes. Therefore, they could also be potential allies to help map climate change at local and regional scales. Despite this, studies aimed at documenting traditional ethnoclimatic knowledge of indigenous peoples are still scarce, particularly in regions such as Amazonia. The present article aims to contribute to filling this gap by analyzing the climate change perceptions of the Tsimane', an indigenous society of hunter- gatherers and horticulturalists in Bolivian Amazonia. The results of this research show that the Tsimane' are perceiving different effects of climate change, especially a decrease in rainfall and a general increase in temperature, as well as changes in phenology and climate seasonality. Moreover, the Tsimane' are responding actively to this climatic variability: their ethnoclimatic knowledge and traditional subsistence practices constitute the assets of their adaptation strategies to face climate change. Understanding the perceptions, interpretations and responses of climate change by indigenous peoples represents an essential first step for incorporating them into the design and implementation of effective adaptation strategies at the local level.

Reyes-García, V., **I. Díaz-Reviriego**, R. Duda, Á. Fernández-Llamazares, S. Gallois, M. Guèze, T. Napitupulu, and A. Pyhälä. *In press*. Peer evaluation reliably measures local ecological knowledge. *Field Methods*.

Abstract

We assess the consistency of measures of individual local ecological knowledge obtained through peer evaluation against three standard measures: identification tasks, structured questionnaires, and self-reported skills questionnaires. We collected ethnographic information among the Baka (Congo), the Punan (Borneo), and the Tsimane' (Amazon) to design site-specific but comparable tasks to measure medicinal plant and hunting knowledge. Scores derived from peer-ratings correlate with scores of identification tasks and self-reported skills questionnaires. The higher the number of people rating a subject, the larger the association. Associations were larger for the full sample than for subsamples with high and low rating scores. Peer evaluation can provide a more affordable method in terms of difficulty, time and budget to study intracultural variation of knowledge, provided that researchers 1) do not aim to describe local knowledge, 2) select culturally-recognized domains of knowledge, and 3) use a large and diverse (age, sex, kinship) group of evaluators.

Reyes-García, V., M. Guèze**, I. Díaz-Reviriego**, R. Duda, Á. Fernández-Llamazares, S. Gallois, T. Napitupulu, M. Orta-Martínez, and A. Pyhälä. *In press.* The adaptive nature of culture. A cross-cultural analysis of the returns of local environmental knowledge in three indigenous societies. *Current Anthropology*.

Abstract

Researchers have argued that the behavioral adaptations that explain the success of our species are partially cultural, i.e., cumulative and socially transmitted. Thus, understanding the adaptive nature of culture is crucial to understand human evolution. We use a cross-cultural framework and empirical data purposely collected to test whether culturally transmitted and individually appropriated knowledge provides individual returns in terms of hunting yields and health and, by extension, to nutritional status, a proxy for individual adaptive success. Data were collected in three subsistence-oriented societies: the Tsimane' (Amazon), the Baka (Congo Basin), and the Punan (Borneo). Results suggest that variations in individual levels of local environmental knowledge relate to individual hunting returns and to self-reported health, but not to nutritional status. We argue that this paradox can be explained through the prevalence of sharing: individuals achieving higher returns to their knowledge transfer them to the rest of the population, which explains the lack of association between knowledge and nutritional status. The finding is in consonance with previous research highlighting the importance of cultural traits favoring group success, but pushes it forward by elucidating the mechanisms through which individual and group level adaptive forces interact.

Reyes-García, V., A. Pyhälä, **I. Díaz-Reviriego**, R. Duda, Á. Fernández-Llamazares, S.Gallois, M. Guèze, and T. Napitupulu. *In press*. The impacts of schooling and local knowledge on working memory: A study among three contemporary hunter-gatherer societies. *PLoS ONE*.

Abstract

Researchers have analysed whether school and local knowledge complement or substitute each other, but have paid less attention to whether those two learning models use different cognitive strategies. In this study, we use data collected among three contemporary hunter-gatherer societies with relatively low levels of exposure to schooling yet with high levels of local ecological knowledge to test the association between *i)* schooling and *ii)* local ecological knowledge and verbal working memory. Participants include 94 people (24 Baka, 25 Punan, and 45 Tsimane') from whom we collected information on 1) schooling and school related skills (i.e., literacy and numeracy), 2) local knowledge and skills related to hunting and medicinal plants, and 3) working memory. To assess working memory, we applied a multi-trial free recall using words relevant to each cultural setting. People with and without schooling have similar levels of accurate and inaccurate recall, although they differ in their strategies to organize recall: people with schooling have higher results for serial clustering, suggesting better learning with repetition, whereas people without schooling have higher results for semantic clustering, suggesting they organize recall around semantically meaningful categories. Individual levels of local ecological knowledge are not related to accurate recall or organization recall, arguably due to overall high levels of local ecological knowledge. While schooling seems to favour some organization strategies this might come at the expense of some other organization strategies.

Fernández-Llamazares,Á., **I. Díaz-Reviriego**, M. Guèze, M. Cabeza, A. Pyhälä, and V. Reyes-García. *In press.* Local perceptions as a guide for the sustainable management of natural resources: empirical evidence from a small-scale society in Bolivian Amazonia. *Ecology and Society*.

Abstract

Limited, this work explores the role of local perceptions as drivers of harvesting and management behavior in a small-scale society in Bolivian Amazonia. We conducted structured interviews to capture local perceptions of availability and change in the stock of thatch palm (*Geonoma deversa*) amongst the Tsimane', an indigenous society of foragers-horticulturalists (n=296 adults in 13 villages). We analyzed whether perceptions of availability match estimates of abundance obtained from ecological data and whether differences in perception help to explain harvesting behavior and local management of thatch palm. Perceptions of availability of *G. deversa* are highly contingent upon the social, economic and cultural conditions within which the Tsimane' have experienced changes in the availability of the resource, thus giving a better reflection of the historical, rather than of the ecological, dimensions of the changes undergone. While local perceptions might fall short in precision when scrutinized from an ecological standpoint, their importance in informing sustainable management should not be underestimated. Our findings show that most of the

harvesting and management actions that the Tsimane' undertake are, at least partially, shaped by their local perceptions. This paper contributes to the broader literature on natural resource management by providing empirical evidence of the critical role of local perceptions in promoting collective responses for the sustainable management of natural resources.

Fernández-Llamazares, Á., R. Garcia, **I. Díaz-Reviriego**, M. Cabeza, A. Pyhälä, and V. Reyes-García V. *Under review*. An empirically-tested overlap between indigenous and scientific knowledge of a changing climate. *Regional Environmental Change*.

Abstract

Current climate models in Bolivian Amazonia rely on data from a few sparse weather stations, interpolated on coarse-resolution grids. At the same time, the region hosts numerous indigenous groups with rich knowledge systems that are hitherto untapped in the quest to understand local climate change. Drawing on an empirical dataset of climate change observations by an Amazonian native society, we assess the potential use of indigenous knowledge for complementing climate models. We find indigenous observations to be robustly associated with local station data for climatic changes over the last five decades. By contrast, there are discrepancies between global climate models and both indigenous observations and local station data. Indigenous knowledge can be instrumental to enhance our understanding of local climate in data- deficient regions. Indigenous observations offer a tool to ground-truth modelled descriptions of climatic changes, thereby making adaptation strategies more robust at local scales. We contend that the use of indigenous knowledge could help to assist the downscaling process and address the prevailing uncertainties in local assessments of climate change. However, if such aspirations are to be reflected in practice, there is an urgent need to formulate strategic plans to document indigenous knowledge before it vanishes.

Salpeteur, M., L. Calvet-Mir, **I. Díaz-Reviriego**, and V. Reyes-García. Networking the environment: social network analysis in environmental knowledge and management. Introduction to special feature. *Ecology and Society.* Manuscript in preparation.

2. Book chapters

Fernández-Llamazares, Á, **I. Díaz-Reviriego**, and I.V. Sánchez. 2014. Las Voces del Cambio: percepciones de una sociedad ante el proceso de cambio. In: Reyes-García, V and T. Huanca (eds) *Cambio global, cambio local. La sociedad tsimane' ante la globalización* (pp. 355-380). Icaria Editorial, Barcelona, Spain.

Luz, A.C., M. Guèze, J. Paneque-Gálvez, **I. Díaz-Reviriego**, and V. Reyes-García. 2014. Caza, pesca y recolección: descripción, importancia y cambios. In: Reyes-García, V and T. Huanca (eds) *Cambio global, cambio local. La sociedad tsimane' ante la globalización* (pp. 121-147). Icaria Editorial, Barcelona, Spain.

Fernández-Llamazares, Á., **I. Díaz-Reviriego**, and V. Reyes-García. *In press.* Defaunation through the eyes of Tsimane'. In: A. Pyhälä and V. Reyes-García (eds) *Hunter-gatherers in a changing world.* Springer.

3. Policy briefs

Reyes-García, V., **I. Díaz-Reviriego**, R. Duda, A. Fernández-Llamazares, S. Gallois, M. Guèze, L. Napitupulu, P. Pérez, A. Pyhälä, and V. Reyes-García. 2015. Lessons from the field: what can the knowledge society learn from the study of local environmental knowledge? *LEK-Project Policy brief 1*. Available at: http://icta.uab.cat/etnoecologia/lek.

Guèze, M., **I. Díaz-Reviriego**, R. Duda, A. Fernández-Llamazares, S. Galloois, L. Napitupulu, P. Pérez, A. Pyhälä, and V. Reyes-García. 2015. A biocultural approach to conservation: what can conservationists learn from forest use by contemporary indigenous peoples? *LEK-Project Policy brief 2*. Available at: http://icta.uab.cat/etnoecologia/lek.

Reyes-García, V., A. Pyhälä, M. Guéze, A. Angelsen, **I. Díaz-Reviriego**, Á. Fernández-Llamazares, S. Gallois, L. Napitupulu. 2015. Local perceptions of wellbeing. Insights from the Global South. *LEK-Project Policy brief 3*. Available at: http://icta.uab.cat/etnoecologia/lek.

4. Outreach efforts

By the end of the fieldwork, I participated in the dissemination and giving back to the communities of the research results in order to reciprocate their patience, kindness, and their cooperation during the 18 months that the research lasted. Two main activities were undertook by the field team.

4.1 Radio podcasts

In agreement with the *Gran Consejo Tsimane'* and the villages, we recorded a set of radio podcasts in Tsimane' language to be broadcast by the local radio station Horeb. The main goals of the podscasts were 1) to provide information that may help to support the wellbeing and health of Tsimane' people, and 2) to rise awareness of the value of Tsimane' culture and environmental knowledge that may help to foster their self-steem. 11 podscats were recorded revolving around different topics such as the use of medicinal plant, the pollution associated to batteries, the sustainable practices in fishing, foraging and agriculture, the fight to end male violence against women, and the importance of hygiene and diet for a good health, to cite a few. The podcasts begin and end with traditional Tsimane' songs. We have received a very positive feedback for this iniciative both from the people in the communities and the political representatives.

4.2 Tsimane' calendar

We produce a bilingual Tsimane' calendar for the year 2014. The goal of the calendar was to contribute to the revalorization of the Tsimane' culture and the strengthening of their cultural identity. The calendar included the yearly cultural prominent events, seasons, lunar cycles, Tsimane' and customs along with some of the pictures taken during the fielwork. The calendars were distributed in the villages that participated in the study and also in the city of San Borja.

Further activities carried out on site to benefit the Tsimane' people can be find at:

http://icta.uab.cat/Etnoecologia/lek/