JUSTICE SOCIALE ET INTEGRITE ENVIRONNEMENTALE DANS LES CONFLITS LIES A LA BIODIVERSITE : RECHERCHE DE TERRAIN D'ENTENTE DANS LA CONSERVATION DU JAGUAR (*PANTHERA ONCA*)

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SOCIAL JUSTICE AND ENVIRONMENTAL INTEGRITY IN BIODIVERSITY CONFLICTS: SEARCHING FOR COMMON GROUND AND SUSTAINABILITY IN THE CONSERVATION OF JAGUAR (*PANTHERA ONCA*)

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SOMMAIRE

Les *conflits liés à la biodiversité* se produisent lorsque les objectifs ou les priorités des individus par rapport à la biodiversité diffèrent. Ils sont présentés ici comme un symptôme de notre échec face au développement durable, le développement durable étant défini dans cette étude comme un processus visant l'intégrité environnementale et la justice sociale. Des recherches antérieures ont abordé les *conflits liés à la biodiversité* principalement sous l'angle de l'intégrité environnementale, visant à réduire les conflits par la réduction des *impacts liés à la biodiversité* (i.e. interactions négatives entre les humains et la biodiversité). Cependant, la mise en œuvre de stratégies visant à réduire les *impacts* a rarement conduit à une gestion des *conflits* à long terme. Cela suggère que la gestion des *conflits* pourrait être principalement affectée par la justice sociale et le conflit sous-jacent entre humains.

À travers une approche interdisciplinaire, j'explore comment la notion de justice sociale et la recherche de terrains d'entente peuvent aider à développer de nouvelles solutions pour gérer les *conflits liés à la biodiversité* et à atteindre une meilleure intégrité environnementale. En particulier, j'essaie de comprendre : (1) Quelle est la relation entre les *impacts* et les *conflits liés à la biodiversité* ? (2) Comment la justice sociale est-elle reliée aux *conflits* et comment sa prise en compte offre de nouvelles approches ou solutions pour renforcer l'intégrité environnementale ? (3) Les approches basées sur le dialogue et la collaboration peuvent-elles contribuer à la gestion des *conflits liés à biodiversité* ? Ma recherche est basée sur une étude empirique explorant la gestion de l'environnement à Calakmul, au Mexique. La région de Calakmul accueille la plus grande forêt tropicale et la plus grande population de jaguar (*Panthera onca*) au Mexique, mais supporte également des activités agricoles, ce qui entraîne un conflit en lien avec la gestion du jaguar. La gestion du jaguar est un fil conducteur constant au travers des chapitres de ma thèse ; cependant, je me concentre également sur les avantages d'explorer de multiples problématiques pour comprendre le contexte dans lequel la gestion environnementale a lieu.

Dans le chapitre 2, j'évalue l'ampleur de l'*impact* des grands félins dans la région de Calakmul et les facteurs qui influencent l'occurrence des attaques de bétail et leur distribution

spatiale. Je développe une approche bidimensionnelle pour considérer séparément les caractéristiques du paysage et la pression humaine. J'utilise également un modèle géostatistique, qui tient compte de l'autocorrélation spatiale dans les données, ainsi qu'une approche multi-échelle pour sélectionner l'échelle spatiale pertinente pour chaque variable. Je prends aussi en compte des données historiques sur l'habitat disponible pour le jaguar. Les résultats montrent que les moutons sont particulièrement menacés, où qu'ils soient dans le paysage et sans importer leur gestion. Les caractéristiques fonctionnelles du paysage (ici liées au processus de fragmentation) sont les variables qui expliquent ensuite le mieux l'occurrence d'attaque, alors que l'effet de la pression humaine est moins important. Cette recherche suggère que le risque d'attaque est largement répandu dans la région de Calakmul. De plus, une utilisation accrue de l'écologie du paysage pour l'estimation du risque spatial de prédation pourrait potentiellement améliorer l'utilité d'un tel outil pour la conservation.

Dans le chapitre 3, je propose une nouvelle approche qui soutient le démarrage des processus collaboratifs en se concentrant sur les terrains d'entente. Je souhaitais comprendre les préoccupations des acteurs locaux concernant la gestion de l'environnement dans la région d'étude, et mettre en contexte la gestion du jaguar parmi les autres problématiques. Je propose donc un moyen d'identifier et de quantifier les terrains d'entente pour les différentes préoccupations soulevées par des représentants locaux. Je montre que les positions des acteurs sont diverses et qu'il n'est pas possible de les regrouper en fonction de leurs occupations professionnelles. Ensuite, je suggère qu'en situant les problématiques soulevées par les acteurs selon leur niveau de terrain d'entente et d'importance, il est possible de cibler des problématiques qui soutiennent positivement les premières étapes d'une collaboration. En ciblant d'abord des préoccupations importantes et présentant un fort potentiel de terrain d'entente, il est possible d'installer des relations entre acteurs basées sur la confiance et la réciprocité. L'exploration de plusieurs issues peut également favoriser une négociation entre acteurs pour trouver des solutions qui répondent simultanément à plusieurs problématiques. Ce travail sur les terrains d'entente évite ainsi les préjugés sur les positions des différents acteurs. Il adopte également une vision plus large du contexte dans lequel la gestion environnementale a lieu, afin de mieux traiter les problèmes de conservation.

Enfin, j'explore la construction du sentiment de justice à travers plusieurs *conflits liés à la biodiversité* à Calakmul, pour ensuite considérer les facteurs affectant ce sentiment dans le cadre de la gestion du jaguar. Les préoccupations en lien avec la justice sont souvent considérées comme un déclencheur de *conflits*, et sont aussi fortement reliées au contexte dans lequel elles apparaissent. L'approche qualitative du chapitre 4 me permet d'obtenir une compréhension contextualisée du sentiment de justice à Calakmul. D'autre part, elle permet de proposer un nouveau cadre théorique qui rassemble quatre dimensions de la justice (reconnaissance, écologique, distributive et procédurale). Deux dimensions de la justice sont présentées comme conditionnelles : la « justice-comme-reconnaissance » admet qu'il existe différentes conceptions de la justice entre les individus, tandis que la justice écologique se préoccupe d'obtenir un juste traitement du monde naturel. Ces deux dimensions conditionnelles délimitent la possibilité d'atteindre la justice dite pratique, correspondant aux deux autres dimensions, procédurale et distributive ; celles-ci interagissent pour définir des procédures et distributions considérées comme justes. L'étude quantitative du chapitre 5 met l'accent sur la gestion du jaguar. Elle permet d'examiner les facteurs influençant la priorisation des critères utilisés par les personnes pour expliquer leur sentiment de justice. Basés sur un outil statistique innovant, les résultats montrent l'influence limitée de l'expérience personnelle d'attaque de bétail sur la perception de justice. Ils soulignent plutôt l'importance des relations, telles que la cohérence intragroupe, ou la perception des entités responsables. Je propose de ne pas négliger le sentiment de justice dans la gestion des *conflits liés à la biodiversité* et de mettre en place des processus inclusifs, afin de réconcilier des perspectives de justice parfois contradictoires et parvenir à une meilleure gestion de l'environnement.

Ma recherche intègre à la fois sciences sociales et naturelles pour fournir, à chaque chapitre, des recommandations spécifiques pouvant améliorer la gestion de l'environnement, et plus précisément la gestion du jaguar dans la région de Calakmul. Elle permet de confirmer que le lien entre *impacts* et *conflits liés la biodiversité* n'est ni simple, ni causal : une réduction des *impacts* n'est pas nécessairement suffisante pour réduire les *conflits*. Je propose donc que la justice sociale est une réponse aux préoccupations liées aux deux : *les impacts* à travers la justice distributive et écologique et *les conflits* à travers l'ensemble des dimensions puisque notre approche plurielle révèle la variabilité des points de vue entre les acteurs. Ma thèse souligne

l'importance pour la conservation de l'environnement de s'engager dans des approches collaboratives basées sur les terrains d'entente et de mettre l'accent sur le dialogue et la reconnaissance. Je crois que pour ce faire, la biologie de la conservation doit élargir ses frontières. Tout en reconnaissant son objectif d'atteindre une plus grande protection de la biodiversité, elle doit promouvoir la compréhension interdisciplinaire et s'engager avec les acteurs de terrain pour la conservation. Les chercheurs ont un rôle important à jouer en s'engageant à développer davantage de relations avec les autres, tels que les chercheurs d'autres disciplines, les praticiens et les acteurs locaux. En reconnaissant le potentiel du processus de recherche de changer à la fois le chercheur et l'individu sujet de la recherche, les chercheurs peuvent aider à établir des ponts entre des points de vue divergents, créer des relations de confiance, et soutenir le développement de points communs. Je crois que cela peut être une première étape importante pour gérer les *conflits* et atteindre une gestion durable du jaguar.

Mots clés : Conflit lié à la biodiversité, impact lié à la biodiversité, intégrité environnementale, justice social, risque spatial de prédation, terrain d'entente, approche collaborative, sentiment de justice

SUMMARY

Biodiversity conflicts occur when people's objectives or priorities over biodiversity differ. They are presented here as a symptom of our failures to reach sustainable development targets, sustainable development being defined in this study as a process aiming at environmental integrity and social justice. Previous research approached *biodiversity conflicts* primarily under the environmental integrity component of sustainable development, aiming to reduce conflicts through the reduction of *biodiversity impacts* (i.e., the negative interactions between humans and biodiversity). However, the implementation of strategies aiming to reduce *biodiversity impacts* has rarely led to long-term conflict management, suggesting that conflict management could be principally affected by social justice and the underlying human conflict.

Through an interdisciplinary approach, I explore how the notion of social justice and the pursuit of common ground may help develop new solutions to manage *biodiversity conflict* and achieve better environmental integrity. More specifically, I try to understand: (1) What is the relationship between *biodiversity impact* and *biodiversity conflict*? (2) How is social justice related to *biodiversity conflict*, and how might its consideration offer new approaches or solutions to strengthen environmental integrity? (3) Can dialogic and collaborative approaches contribute to managing *biodiversity conflicts*? My research is based on an empirical study exploring environmental management in Calakmul, Mexico. Calakmul region, while hosting the largest tropical forest and population of jaguar (*Panthera onca*) in Mexico, is also a place for agricultural activity, resulting in a conflict about jaguar management. While jaguar management is a common thread among the chapters of my thesis, I also focus on the benefits of exploring multiple issues to understand the context in which environmental management takes place.

In chapter 2, I assess the extent of large cats' impact in the region and the factors that influence the occurrence of livestock attacks and their spatial distribution. I develop a two-dimensional approach to consider landscape characteristics and human pressure separately. I also use a geostatistical model, accounting for spatial autocorrelation in the data, as well as a multi-scale approach to select the relevant spatial scale for each variable and consider historical data on landscape attributes. Results show that sheep are particularly at risk, regardless of their

spatial distribution in the region or other factors. Attack occurrence is best explained by the functional characteristics of the landscape (here, linked to fragmentation process), whereas the effect of human pressure is of lower importance. This research suggests that attack risk is widely spread across the Calakmul region, and that strengthening the use of landscape ecology for spatial predation risk estimation might improve the potential of such tool for conservation.

In chapter 3, I propose a novel approach to start collaboration that focuses on common ground. I was interested in understanding local actors' concerns regarding environmental management in the region, and to contextualize jaguar management among other issues. I propose a way to identify and quantify common ground among multiple issues raised by local representatives. I show that actor positions are diverse and that there is a lack of consistent grouping by occupational activity. Then, I suggest that by locating issues according to the level of common ground and importance among actors, it is possible to target issues to support the first stages of collaboration. Starting with issues of high importance and high common ground can enable actors to build norms of reciprocity and trust. Exploring multiple issues can also support negotiation among actors to find solutions of mutual benefit across issues. This work on common ground avoids preset assumptions about actors and embraces a larger view of the context in which environmental management takes place to address conservation issues.

Finally, I explore the framing of construction of justice across multiple *biodiversity conflicts*, and the factors affecting feelings of justice surrounding jaguar management in Calakmul. Fairness concerns are often considered to be triggers for *biodiversity conflicts* and also to be highly context-dependent. The qualitative investigation of Chapter 4 allows me to derive a context-specific understanding of fairness in Calakmul, while providing a new framework that brings together four dimensions of justice (recognition, ecological, distributive and procedural). I consider two justice dimensions as conditional: justice-as-recognition, which acknowledges that there are different conceptions of justice among individuals, and ecological justice, which is about the fair treatment of the natural world. Both underpin practical justice, procedural and distributive, which interact to define fair procedures and distribution. The quantitative study of Chapter 5 focuses on jaguar management and allows to examine the factors influencing the prioritization of the criteria used by people to explain their feelings of justice. Based on a pioneering statistical tool, the results show the limited influence that personal

experience of livestock attacks has on fairness perception, and rather emphasize the importance of relationships, such as intragroup coherency, or the perception of the responsible entities. I propose that fairness should not be neglected when trying to manage *biodiversity conflicts* and that inclusive processes are needed in order to reconcile conflicting justice perspectives and achieve more successful environmental management.

My research integrates both social and natural sciences perspectives to provide, for each chapter, specific recommendations that can improve environmental management, and more specifically, jaguar management in the region of Calakmul. I confirmed that the link between *biodiversity impact* and *biodiversity conflict* is not simple and causal: a reduction of impacts might not be sufficient to reduce conflict. I propose that social justice allows addressing concerns related to both: *biodiversity impact* through the lens of distributive and ecological justices, and conflict across all justice dimensions as our plural approach reveals the variability of points of views among actors. My thesis emphasizes the importance for conservation to engage in collaborative approaches that are supported by common ground and based on dialogue and recognition. I believe that to do so, conservation biology will have to expand its boundaries. While recognizing its primary aim of ensuring biodiversity protection, conservation biology shall advance interdisciplinary understanding and engage with conservation practices. Researchers will have an important role to play by committing to develop more relationships with others: researchers from other disciplines, practitioners, and local actors. By acknowledging the potential of the research process to change both researchers and the subjects of the research, researchers can help build bridges between divergent points of view, create trusting relationships, and support the development of commonalities. I believe this can be an important first step to manage conflicts and reach sustainability in jaguar management, and biodiversity conservation more broadly.

Keywords: biodiversity conflict, biodiversity impact, environmental integrity, social justice, spatial-risk of depredation, common ground, collaborative approach, fairness.

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IUCN	International Union for Conservation of Nature	Page 2
NGO	Non Governmental Organisation	Page 6
WCED	World Commission on Environment and Development	Page 6
SPRM	Spatial Predation Risk Models	Page 22
INEGI	Instituto Nacional de Estadística y Geografía	Page 25
VHF	Very High Frequency	Page 28
MSPA	Morphological Spatial Pattern Analysis	Page 30
INLA	Integrated Nested Laplace Approximation	Page 33
MCMC	Markov chain Monte Carlo	Page 33
VIF	Variance Inflation Factors	Page 33
wAIC	Watanabe–Akaike information criterion	Page 34
CMDRS	Consejo Municipal para el Desarrollo Rural Sustentable	Page 57
US	United States	Page 59
NMDS	Nonmetric MultiDimensional Scaling	Page 65
BTLLasso	Bradley-Terry-Luce lasso	Page 109
LASSO	Least Absolute Shrinkage and Selection Operator	Page 112
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales	Page 115
CNOG	Confederación Nacional de Organizaciones Ganaderas	Page 116
CBD	Convention on Biological Diversity	Page 144
UN	United Nation	Page 144
FAG	Fondo de Aseguramiento Ganadero	Page 211

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CHAPTER 1

GENERAL INTRODUCTION

In a world with increasing competition over habitats and natural resources, conservation biology has to answer to the growing challenges of finding solutions for humans and nature to coexist. While natural science has had some successes in significantly influencing conservation practice (Robinson, 2006), conservation is as much about the requirement of ecosystems to survive as about the people who decide to protect or exploit that same ecosystem. Conservation practice is inherently a social phenomenon and a product of human behavior (Mascia et al., 2003). People play a crucial role and will often express having different objectives toward environmental management that might result in conflict among multiple actors (Redpath et al., 2013). This is particularly true for the conservation of jaguars (*Panthera onca*). Some actors wish to protect it for the top-predator value it brings to an ecosystem, others do it for its symbolic representation of the wild, while for others it represents a threat to their economic activities (Inskip and Zimmermann, 2009). Such issues raise both the question of environmental integrity and social justice, and consequently of how to reach sustainability for jaguar conservation. Social justice in this work is approached through an empirical approach that recognizes the subjective aspect of justice, while environmental integrity is associated with having a healthy environment and the aim to reach higher biodiversity conservation. This thesis presents my research results on this issue. It takes an innovative approach to biodiversity conflict, placing it in the context of sustainable development to find alternative solutions to improve the conservation of jaguars in the Calakmul region, Mexico. In this introductory chapter, I first clarify what the practical nature of the problem is and the conceptual framework and the research paradigm I adopted. Finally, I explore what can be the role of academia toward conservation and explain the general inquiry and structure of my research. I propose an interdisciplinary approach using viewpoints from the many players and different disciplines embedded in

conservation which allow to innovate and open a new perspective on the issue of biodiversity conflict.

Nature of the problem

Biodiversity conflicts are likely to increase in frequency and intensity concomitantly with the growth of human populations and their resource use (Redpath et al., 2015). My understanding of a biodiversity conflict is that it emerges when interested parties compete over some aspects of biodiversity, and pursue their interests at each other's expense (Marshall et al., 2007; White et al., 2009; Young et al., 2010). Biodiversity impact stands for the direct negative interactions between humans and other species (Redpath et al., 2013) such as depredation upon livestock and game, safety threat for people through attacks and disease transmission, or retaliatory killing or poisoning of the involve animal or clearing of their habitats (Bagchi and Mishra, 2006; Nyhus et al., 2005; Zarco-González et al., 2013). While some biological studies focus on the impacts to try to achieve conservation (Bagchi and Mishra, 2006; Mishra, 1997; Zarco-González et al., 2013), I here emphasize the importance of understanding the multiple drivers of biodiversity conflict. I am particularly interested in one type of biodiversity conflict that occurs when different key interest groups disagree over the management objectives and priorities for a species of ecological interest – in my case, the jaguar.

Large carnivore populations face severe declines worldwide due to destruction and fragmentation of their habitats, reduction of their preys, and hunting pressure (Treves and Karanth, 2003). Consequently, approximately 17 % of those species are now considered as threatened by IUCN (IUCN, 2011). The jaguar is no different, classified as Near Threatened on the IUCN Red List (IUCN, 2011). While ranging originally from Mexico to Argentina, it currently only occupies 46 % of its original geographic range (Sanderson et al., 2002). As a top predator and a flagship species, the jaguar is a species of high interest for conservation and environmental protection. For others, it represents a threat to their way of life because of depredation of livestock (Polisar et al., 2003; Zarco-González et al., 2013). This may result in

retaliation where the affected humans kill or poison the jaguars, representing an additional threat to the species' survival. The impact could be quite severe for jaguar populations (Inskip and Zimmermann, 2009).

Previous research on impacts, commonly referred to "human-wildlife conflict", has primarily focused on ecological contexts (e.g. animal population, habitats, diet), and often aimed at reducing the damage caused by a specific species on humans through technical fixes (Young et al., 2010). In the case of carnivores, the focus was put on damage reduction through the use of livestock guarding dogs, herders, enclosures to protect livestock, or management of the calving period, among others (e.g., Treves and Karanth, 2003). However, this research has lead to two important misconception. First, those studies emerged from the assumptions: "(A) that the level of wildlife damage is directly related to the level of conflict engendered; (B) that the level of conflict elicits a proportionate response; (C) that altering the response to conflict will have proportionate conservation effects" (Dickman, 2010, p. 459). However, if the biodiversity impact was its main component, the conflict should have been reduced after having reduced the damages. Yet, the implementation of strategies aiming at reducing biodiversity impacts has rarely led to long-term conflict resolution (Dickman, 2010; Madden and McQuinn, 2014). To a certain point, attacks on livestock, for example, would not represent a biodiversity conflict if actors would agree on how to manage the species blamed for the attack (e.g. by killing or protecting it). Furthermore, biodiversity conflict can be very intense even when having few biodiversity impacts (Young et al., 2006). In this perspective, people then become the central actors in a conflict, and thus, for managing it, it requires a higher understanding of its socio-economic and political context (Young et al., 2010).

Secondly, the use of the word 'conflict' to describe impacts suggests that wildlife is a conscious antagonist, making a conscious decision to specifically damage human properties and purposefully seeking to undermine human goals (Peterson et al., 2013; Redpath et al., 2013). Yet, such level a of consciousness in wildlife has not been documented and is unlikely. There is also a deeper consequence of using the term "conflict" to describe what is merely biodiversity impact: people tend in this case to express their anger against the animal and turn their attention

away from the actual conflict with people who hold different management objectives (Peterson et al., 2010). While biodiversity impact management can be achieved through the creation of tools or legislation to reduce wildlife damage, biodiversity conflict requires a different management approach, involving the reconciliation of different points of view, and can be therefore more challenging to manage (Redpath et al., 2013). By distinguishing biodiversity impact and biodiversity conflict, we recognize that "conflict" involves a dispute between actors, whereby conservation might be more about working with people. Conservationist and their advocating position will then have to be reintegrated as part of the multiple point of views involved (Pooley et al., 2017; Young et al., 2010).

One example of a biodiversity conflict is the burden of living and co-existing with a species that can have a negative impact on livelihoods while protected by legislation, and sometimes perceived as an emblem of environmental protection (Bagchi and Mishra, 2006; Cihar and Stankova, 2006; Marker et al., 2003; Rastogi et al., 2012). Facing global environmental threats, international institutions have multiplied measures aiming at protecting the environment and increased their objectives in terms of areas under protection (Borrini et al., 2004; Negi and Nautiya1, 2003; Paavola, 2004; West et al., 2006). Despite the complexity of establishing environmental conservation plans in respect to every key interest groups, governments and conservation groups have been working towards enforcing conservation measures irrespective of local interests and rights (Borrini et al., 2004; Negi and Nautiya, 2003; Paavola, 2004). Through a top-down approach, they have imposed on local communities the responsibility of environmental protection, creating a debate regarding environmental fairness (Yearley, 2005). While I recognize that fairness and justice are sometimes considered to represent different concepts (Rawls, 1958), in my research, justice and fairness will be used interchangeably and will refer to the perception and the subjectivity of justice appraisal made by individuals. Other notions express the same idea, such as fairness judgment, justice judgment, and feelings of justice.

I propose, then, that biodiversity conflicts be seen as a symptom of our failure to reach sustainable development. While jaguar conservation and environmental integrity, for example,

might be the principal interest of some actors and the focus of most research looking at biodiversity conflicts, feelings of injustice might also arise from such conflicts and represent an obstacle to social justice. My interest does not lie in an objective representation of justice, with a distinction of what is right or wrong, but in the perception and subjectivity of justice appraisal by individuals in regards of environmental management. My research will investigate how social justice can give us a new understanding of biodiversity conflict and provide recommendations to increase environmental integrity through jaguar conservation. The case study is set in the region surrounding the Calakmul Biosphere reserve in South-East Mexico. This area, while showing a strong potential for jaguar conservation, is also a center of agricultural activity with a wide diversity of actors[1] and approaches to environmental management, which might lead different groups to engage in a conflict over their differing objectives. Ultimately, I want to know if the consideration of an alternative approach, one that emphasizes dialogues and individual appreciations, could lead to a more effective management of biodiversity conflicts in a way that reduces biodiversity impacts, resulting in more positive outcomes for wildlife conservation.

Development of conceptual framework

In this section, I come back in more detail on the reflections that lead me to explore how biodiversity conflict can be related to sustainable development, recognizing the importance of social justice and the need to explore feelings of justice.

[1] In this research, *actors* will be used as a general term referring to individuals involved in the situation investigated. While some other studies might use this term as a synonym of stakeholder or key interest group, I decided to use the term actors as I think it better represents the human dimension of people involved in the conflict, and better suggests their involvement in social dynamics. In particular, the term *actor* is particularly appropriate in describing people as an active and interactive part of the conflict, through their participation in discussion, remediation, and decision-making regarding environmental conservation.

Sustainable development: beyond biodiversity conservation

Sustainable development has been defined and integrated into language in the last thirty years, and its definition has been the subject of numerous debates (Redclift, 2005). While the concept emerged after the demographic explosion and the energy crisis during the 1970's, the term gained momentum only after the Brundtland Report in 1987 (Brunel, 2004). Sustainable development was then defined as "development that meets the need of the present without compromising the ability of future generations to meet their own needs" (Bruntland, 1987). Since then, sustainable development has become a major reference used by public policies, NGOs, and the scientific community. Sustainable development was then being perceived as a way to achieve biodiversity conservation and reduce social inequalities (Stevance, 2015; WCED; White 2013), although its interpretation and mode of implementation remain contested.

Whilst some debates within conservation domains have focused on perceived tensions between conservation and economic development, I argue that considering sustainable development as the process that try to integrate environmental integrity and social justice is a more useful (Ferraro et al., 2011; White, 2013). Sustainability can be seen as "a process offering multiple pathways towards alternative futures; a plurality of perspectives that offers a new model of knowledge generation, mobilization, and implementation" (White, 2013, p. 179). By taking distance from the debate surrounding the definition and articulation of sustainable development, and describing sustainable development as a process that can be reached in different ways, I endorse in my research the importance of acknowledging that people can hold different worldviews, and that these will impact how they will try to achieve sustainable development.

With this vision of sustainable development, one important aspect becomes the interaction between environmental integrity and social justice. A general statement would be that environmental integrity is concerned with maintaining the environment in a healthy state while social justice is concerned with human well-being. I will not try to provide a precise definition of the two concepts as I think that the most important is the balance pursued between them and

that different perception of those notions might lead to different equilibria (Dobson, 1998). As Dobson (1998, p. 5) mentions in his book:

> "*no one would accept as legitimate a society which was environmentally sustainable but wholly unjust, just as no one would accept as legitimate a society which was wholly just, yet destined for ecological collapse within twenty years or so. As far as legitimacy is concerned, then, both objectives will continually vie for attention, and if policymakers and the rest of us are to make sound judgements when faced with choices between them, or when attempting to pursue courses of action which will maximize them both, they, and we, need some guidance on the legitimizing options available*".

Without going further into the debate on the general balance between those two notions in the context of sustainable development, I would like to stress how the relationship between those two notions is directly related to biodiversity conflicts and jaguar management. In fact, while environmental integrity might mean a complete protection of the jaguar, social justice might look at how the impacts of the jaguar are distributed and might result in authorization of jaguar killings. Compromise will have to be made where social justice and environmental integrity are both considered and integrated into decision-making (McShane et al., 2011). While environmental integrity is always considered in environmental management and is one of the main objectives of conservation biology, this is not the case for social justice. In regard to this gap in the literature, this research will look at biodiversity conflicts under the perspective of social justice and will provide more "guidance on the legitimizing options available" (Dobson, 1998, p. 5) to environmental managers and biologists.

Social justice and the consideration of feelings of justice

Previous attempts to reconcile both social justice and environmental integrity have been done within the framework of environmental and ecological justice (Parris et al., 2014; Shoreman-Ouimet and Kopnina, 2015). To date, environmental justice has been a term mostly used in research referring to cases of environmental harm such as chemical pollution or noise produced by humans that might harm other humans (e.g. Bullard and Wright, 1993; Bunyan and

Mohai, 1992). It mostly addressed justice among humans on environmental issues and risks, but did not expand on the issue of justice to nature. On the other hand, the notion of ecological justice was explored and defined "not so much by a particular philosophical perspective (e.g. equality of rights, individual or group level) as by the inclusion of remote entities, such as the environment or future generations, in one's consideration of a just resolution to a conflict" (Clayton, 2000, p. 467). Ecological justice allows including non-human entities in the scope of justice and recognizes the position of numerous environmental protection movements that also use the notion of injustice to claim for more conservation. My research answers the recent call of Martin et al. (2015) to use the frame of environmental justice in a broader range of issues, which leads to the examinations of the global nature of environmental injustices, and involves the human relationship with the non-human world (Agyeman et al., 2016; Clayton and Opotow, 2003).

However, how can social justice and previous work on environmental justice be related to biodiversity conflicts? Biodiversity impacts such as jaguar attack on livestock, often do not affect everyone and vary in the intensity it will affect one person in comparison to others. Such differences on how it affects people raises questions about justice; i.e., how to distribute the burden of living near such species (e.g. through compensation) and which decision-making process should underpin species' management (e.g. participatatory decision making). Furthermore, the populations affected by biodiversity conflicts share similarities with those affected by environmental hazards: they are socio-economic minorities, having a lower access to political, legal, and scientific resources than their opponents, and stigmatized citizens to whom other social groups do not feel accountable (Čapek, 1993). In biodiversity conflict, affected populations are often rural individuals carrying activities that are already suffering from external global pressure, making them economically more vulnerable (e.g., sheep farmers in Europe, Young et al., 2005; poor rural populations living nearby protected areas in Africa, Paavola, 2004; Treves, 2009; West et al., 2006). Stigmatization of the interest groups holding opposite views and antagonism are common in biodiversity conflict (Endter-Wada et al., 1998; Hickey, 2009). Affected populations often claim to be under-represented and lacking in power (Patterson et al., 2003; Stoll-Kleemann, 2001). They reclaim a meaningful participation to

decision making, and compensation for costs (Nyhus et al., 2005; Reed, 2008; Treves, 2009). There is a need then to critically analyse the notions of environmental justice, ecological justice, and social justice to interrogate both the philosophical underpinnings of sustainable development and find a pragmatic route to manage biodiversity conflict.

It is important to clarify how I will approach the notion of justice in my research: I am interested in subjective justice. Primary theorization regarding justice has been looking for a unique norm that would explain each individual reaction. Theories of justice have been vigorously debated, particularly since the publication of John Rawls' "A Theory of Justice" (1971). Rawls argues that people can achieve a common perspective on justice if they can reach a common understanding of the notion of justice that is based on a just distribution of goods and benefits. This vision has been criticized because it omits other factors, such as social, cultural, and institutional conditions involved in the causes of such distribution (Kellerhals et al., 1988). Furthermore, contribution and remuneration are defined subjectively: they depend on the perceptions of those involved in the exchange. The injustice lies in "the eye of the actor" and not in the objective characteristics of the situation. Feelings of justice[2] are not universal and timeless, but instead represent actors' positions on particular issues, at certain times, and in certain contexts (Martin et al., 2014; Schlosberg, 2007; Sikor et al., 2014). What is exposed here is the variety of ways to see and appreciate the notion of justice. This reflection is leading research away from the common debate around justice theory towards an empirical approach acknowledging the social construction of the "feeling of justice," also called "fairness judgment."

There has been increasing research focus and policy output supporting the incorporation of justice concerns into many environmental issues, including climate change (Agyeman et al.,

[2] *Feeling of justice* is the literal translation of the French terms "sentiment de justice" used by Kellerhals in his different books (Kellerhals, 2003; Kellerhals et al., 1997, 1988) and in some rare occasions in English (Bouden and Betton, 1999). However, it seems that English literature more often uses the terms fairness, justice judgment, justice appraisal, or norm of justice. Again, they all refer to perception and the subjectivity of justice appraisal made by an individual.

2016), protected area management (Dawson et al., 2018), payments for ecosystem services (Martin et al., 2014) and large carnivore conservation (Bredin et al., 2018; Jacobsen and Linnell, 2016). Researchers have begun to find that perceived justice is a good predictor of environmental attitudes, often better than self-interest (Clayton, 2000; Reese and Jacob, 2015) and that injustice very often guides the appraisals, feelings, and behavior of the parties involved (Kals and Russell, 2001). For example, perceived fairness in procedure leads to higher acceptance of the outcome, satisfaction, and support to decision-makers and higher trust in authorities (Davenport et al., 2007; Lauber, 1999; Oldekop et al., 2016). To approach biodiversity conflict without considering feelings of (in)justice could impede getting to the root of the problem and taking the risk of not asking the right question. Giving attention to people's concerns about fairness and justice can help us understand the causes of biodiversity conflict and clarify the arguments underlying perceptions of justice.

Interdisciplinarity and the research paradigm

To incorporate justice concerns with the goal to support environmental integrity, I adopt an interdisciplinary approach. Interdisciplinarity has been proposed as a solution since it "avoids partial framing of the problem and research questions, contextualizes environmental and technological constraints and opportunity, and enhances the potential for stakeholder's interactions" (White, 2013, p. 173). While there is no full consensus on a definition of interdisciplinarity, this term covers the production of research which crosses disciplinary boundaries and includes two key components: multiple disciplines are used to borrow, share, and transfer knowledge, and this combination allows a more comprehensive understanding of the subject covered (Hicks et al., 2010). However, diverse disciplines often approach conservation differently, using discipline-specific approaches to define and study a similar problem (Campbell, 2005). This can become a strong obstacle to interdisciplinary projects, and in order to prevent difficulties one must clarify the research paradigm in which the research occurs (Boulton et al., 2005).

In my research, I adopt a relativist approach, acknowledging that reality (i.e. perceptions of justice in biodiversity conflicts) is relative and unique to each individual who experiences it at a given time and place (Crotty, 1998). Experience, social norms, and cultural background will play a role in how people give meaning to a given situation. The present aim is not to separate the issue into discrete components and procure a "one size fit all" approach (Sunderland et al., 2009), but to embrace a holistic view of the issue. According to this approach, my research represents a "scientific point of view" which is consciously constructed based on the activity of the subject doing the research and its position regarding reality (Hubert, 2007). There is no claim for a better scientific point of view, but instead, a multitude of points of view that are relevant with regard to who is supporting and expressing them (Hubert, 2007).

Conservation biology was described as a mission-driven discipline rather than merely an objective, hypothetico-deductive science, since it is dedicated to the normative goal of averting biodiversity loss (Meine et al., 2006; Soulé, 1985). Most scientists working in conservation might like to think they contribute neutral ecological information, without explicitly recognising that the goal of most studies is "the maximization of biodiversity" (White, 2013, p. 243). Scientific knowledge for conservation is not neutral since it is defined by conservation values (Robinson, 2006). It should be then integrated as one aspect of a negotiation that includes different forms of knowledge and points of view (Giller et al., 2008). My research therefore stands along the lines of constructiovism and acknowledges that research and researchers may themselves be affected by the research process. In my research, I move away from the positivist approach, relying only on pre-defined hypotheses. Instead, I take a constructivist approach where I explore the subjectivity of people's perceptions of biodiversity conflict in order to generate a contextual understanding of a given conservation topic.

Overall, this research is not committed to one philosophical position and associated characteristics. This research could therefore be qualified as pragmatic (see Hookway, 2010) as I will use an array of methods to produce practical outcomes toward the management of the biodiversity conflict surrounding jaguar management. Different positions can serve different purposes for conservation. Realism can help by ensuring reproducibility and consistency across

results obtained, while approaches more embedded in relativism will provide contextual knowledge and can reveal how individual experiences can be shared for greater insight in how conservation is perceived (Moon and Blackman, 2014). In sum, the important message to retain from this explanation of my interdisciplinary approach is the recognition that science is plural rather than unitary (Brand and Karvonen, 2007).

Roles and forms of academia in conservation

Scholarship to address real world issues

The main objective of my research, while being concerned by the notion of social justice, is to increase the conservation status of the jaguar. It is then embedded in the meta-discipline of Conservation Biology, whose purpose is to conserve biodiversity on earth (Ehrenfeld, 2000). The first assumption of the discipline was that insufficient scientific knowledge was one of the main obstacles preventing people from supporting conservation (Robinson, 2006). While this meta-discipline emerged specifically to adopt broad interdisciplinary approaches to real-world problem-solving, many of the early conservation biologists were field biologists (Evely et al., 2008). Research in conservation biology thus focused mainly on accumulating ecological knowledge in order to inform conservation practice. Biology has provided theory, analysis, and tools relevant to identify rare and threatened species and ecosystems or the impact of humans on the sustaining of ecosystem function (Mascia et al., 2003). While it is essential to understand those elements to conserve species and ecosystems, biodiversity losses still occur and conservation biology has failed to meet the expectations preceding its emergence (Bennett et al., 2016; Mascia et al., 2003). The compartmentalization of disciplines has been shown to be an impediment to effective conservation (Mascia et al., 2003; Reyers et al., 2010; Robinson, 2006), and conservation practitioners have called for a move toward conservation practices integrating wider social concerns (Forbes, 2011). The challenge today then lies in the research into different approaches that will integrate social and natural science perspectives (Giller et al.,

2008; Sayer and Campbell, 2004) in order to increase the capacity of conservation science to be more effective (Sunderland et al., 2009).

It has then become widely recognized that social research is important to deliver strong, effective, and acceptable conservation actions (Bennett et al., 2016, 2017; Endter-Wada et al., 1998; Mascia et al., 2003; Sandbrook et al., 2013). Social research can share the objective of contributing to biodiversity conservation and provide a better understanding of human belief, attitudes, and behavior, as well as insight into why, how, and when biodiversity loss occurs (Sandbrook et al., 2013). In my research, I will draw from different disciplines of social research, including some reflection on justice that stems from the arts and humanities. It is important to understand the principles and assumptions that are embedded in the different disciplines in order to strengthen the integrity and validity of research designs and interpretation of research outcomes (Moon and Blackman, 2014). Here, I will briefly describe the principal roles social psychology and social sociology can play in conservation, as both are rooted in different ontology and epistemology. Social psychology often focuses on individuals and explores their thoughts and behaviors, and how they can be modified by actions (Myers, 1987). It uses a wide range of methods but often aims at measuring psychological variables such as values, attitudes, and norms in controlled experimentation through quantitative approaches. It has been proposed that social psychology could be an important tool to improve human care for nature and motivate people to adopt pro-environment behaviors (Clayton and Myers, 2015). Sociology, on the other hand, focuses on the social context and aims at understanding how society and human interactions can influence people's lives and how it can shape society (Giddens et al., 2016). It emphasizes exploration of the context of social life, relationships, interactions, and culture. It uses both quantitative and qualitative methods and often combines both methodologies. In conservation, it can be used to explore concepts such as power, class, or social capital (Bennett et al., 2016). My research builds from these disciplines and uses both quantitative and qualitative approaches in order to reach a better understanding of biodiversity conflicts. In particular, I use social research to explore in greater detail the notion of social justice and the relationships among actors involved in jaguar management in order to manage the conflict more effectively.

Finally, I build my approach in light of recent work done regarding sustainability science, which questions the role of academia regarding real world issues and seeks to "understand the fundamental character of interactions between nature and society" (Kates et al., 2001). Sustainability science, has its origins in the concept of sustainable development (Komiyama and Takeuchi, 2006), and was presented as an interdisciplinary science that needs to adopt a holistic approach to solve complex, interrelated, and multidimensional problems (Komiyama and Takeuchi, 2006). However, sustainability science need not to only focus on developing technical solutions and models to predict future scenarios but can also address questions related to the processes needed for those to be accepted by the population (Brand and Karvonen, 2007). Sustainability science often implies then that scientific exploration and practical applications happen simultaneously, becoming entangled with each other (Kates et al., 2001). This includes endeavors to combine different forms of knowledge and learning in order to take action in the face of much uncertainty and limited information. The strength of sustainability science lies in approaching issues that have often been treated in isolation or in competition pluralistically, and trying to accommodate a multiplicity of interests through open discussions and negotiations (Jerneck et al., 2011). Framing biodiversity conflict in the scope of sustainability science allows one to explicitly address the necessity to find a middle ground between the different points of view and disciplines embedded in conservation biology.

From theory to practice

One other important dimension to conservation biology and sustainability science is that they are sciences that should contribute to decision-making. A large number of articles have called for a greater integration of science in the practice of conservation in the field (Knight et al., 2008; Pullin et al., 2004; Sunderland et al., 2009; Sutherland et al., 2004). There is a lack of recognition of the socio-cultural context leading to a "disconnection between scientific understanding of conflicts and knowledge exchange, and applicability of use to practitioners" (Young et al., 2010, p. 3974), creating a further dichotomy between science and practice. Furthermore, critics of the "top-down approach" of expert-driven decision-making have demanded greater participation of actors to ensure that relevant contextual knowledge, values,

and perspectives are incorporated in policy and technological design (Aarts and van Woerkum, 2002; Giller et al., 2008; Hagmann et al., 2003; Leeuwis and others, 2000). Some researchers have then pushed forward the recognition of different types of expertise (Brand and Karvonen, 2007; Carolan, 2006) and to create bridges with non-experts, and between disciplines and forms of expertise (Brand and Karvonen, 2007). While my research aims at obtaining higher environmental integrity for jaguars through an approach acknowledging social justice, I find it crucial to engage with local actors and to develop other forms of expertise during my training. This project at large therefore includes some action-research elements and parallel work to communicate about the project and to increase the participation of local actors in the decision-making process of jaguar management.

General inquiry and thesis

The general objective of this thesis is to explore biodiversity conflict within the frame of sustainable development, and assess how the notion of social justice and the pursuit of common ground could help the development of new solutions to manage biodiversity conflict and reach higher environmental integrity. Especially, I am interested in the conservation of jaguars and will build on different discipline to investigate biodiversity impacts, biodiversity conflicts, social justice and interaction (Figure 1.1).

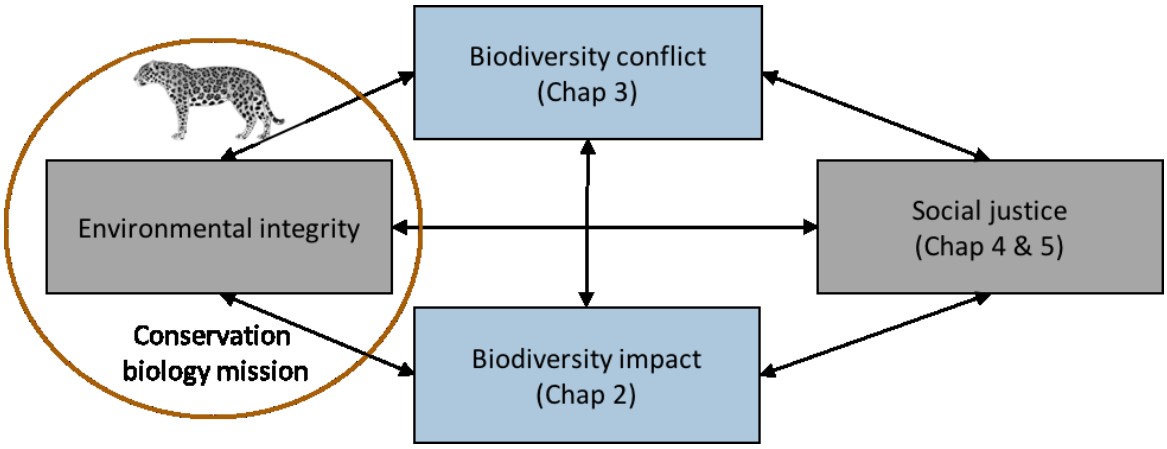

Figure 1.1 Framing of the thesis approach and associated chapters

Specifically, I address the following questions:

- What is the relationship between biodiversity impact and biodiversity conflict?
- How is the concept of social justice related to biodiversity conflict and how might its consideration offer new approaches or solutions to strengthen environmental integrity?
- Can dialogic and collaborative approaches contribute to managing biodiversity conflicts?

To approach this general inquiry, this thesis is divided into four chapters (figure 1.1). While these chapters are assimilated to a particular concept, my constructive approach leads to each chapter being used to inform the following one. The first chapter assesses the occurrence and extent of biodiversity impact, in that case I investigate the spatial risk of livestock depredation by large cats in the Calakmul region. More particularly, it tries to understand the effect of natural habitat and human activity on the occurrence of large attacks at different spatial and temporal scales. The second chapter aims to understand in more detail who are the different actors and their interplay in the Calakmul region, as well as their concerns regarding the environment (i.e., does it include jaguar management). While previous studies have focused on antagonism between different actors, I explore the concept of common ground among actors on

multiple issues and examine how it can help foster collaboration among actors, resulting in new solutions for conflict resolution. Finally, the last two chapters will explore the feeling of justice in environmental management. The third chapter of this thesis will assess the local perception of justice in environmental management, and how people construct their feeling of justice and the criteria they justify it by. This chapter will not only focus on jaguar management but also include other resources (forest, water) to grasp the full extent of people's construction of justice and potential variation. The final chapter, built upon the third, will focus specifically on jaguar management. It will attempt to elucidate the potential factors that influence feelings of justice toward jaguar management. All the chapters will explore recommendations that will hopefully aid in achieving environmental integrity and improve jaguar conservation in the region. While the thesis is divided into chapters with specific objectives, it is in the conclusion that I will come around to the whole framing and to the question of the general inquiry.

Environmental integrity, in the framing (figure 1.1), appears attached to jaguar conservation to remind the reader that the achievement of a stronger conservation of the species is one of the main objectives of this project. However, to do so, I don't follow the common path usually followed in biology, but instead try to explore the potential of integrating both natural and social science in managing biodiversity conflict. My research proposes a comprehensive approach, based on strong theory while being grounded in what emerges from my empirical study. I apply pioneering quantitative methodologies and collected deep qualitative data to include a diversity of disciplines and a diversity of point of views from different actors, in order to shed a new light on potential actions to manage biodiversity conflict. Biodiversity conflict, as framed in my research, questions not only our ability to coexist with wildlife but also our ability to communicate with each other and agree on fair solutions that can support conservation. This is an urgent question to ask if we want to succeed in preserving biodiversity on Earth.

Study site description

Ecological landscape

Calakmul is a region of the state of Campeche, located in Southern Mexico, at the northern border of Guatemala (Figure 1.1.). The region is characterized by a sub-humid climate of a warm tropical type with marked rainy and dry seasons. The mean annual temperature is 26°C and the mean annual precipitation is 1223 mm with high inter-annual variation (Mardero et al., 2015). These conditions support a seasonal tropical forest differentiated by stature, deciduousness, and the relative abundance of species (Vester et al., 2007). In recognition of the biological importance of this area, a Biosphere reserve was created through a presidential decree in 1989. The reserve covers 723 185 ha, the largest tract of tropical forest in Mexico, and forms part of a larger system of protected areas in Mexico, Guatemala, and Belize covering 25 000 km². Calakmul reserve hosts species considered as threatened such as white-lipped peccary (*Tayassu pecari*), Central American tapir (*Tapirus bairdii*), spider monkey (*Atteles geoffroyi*), howler monkey (*Alouatta pigra*), king vulture (*Sarcoramphus papa*), jaguar and puma (*Puma concolor*) (Ceballos et al., 2002; Haenn et al., 2014; Reyna-Hurtado et al., 2009).

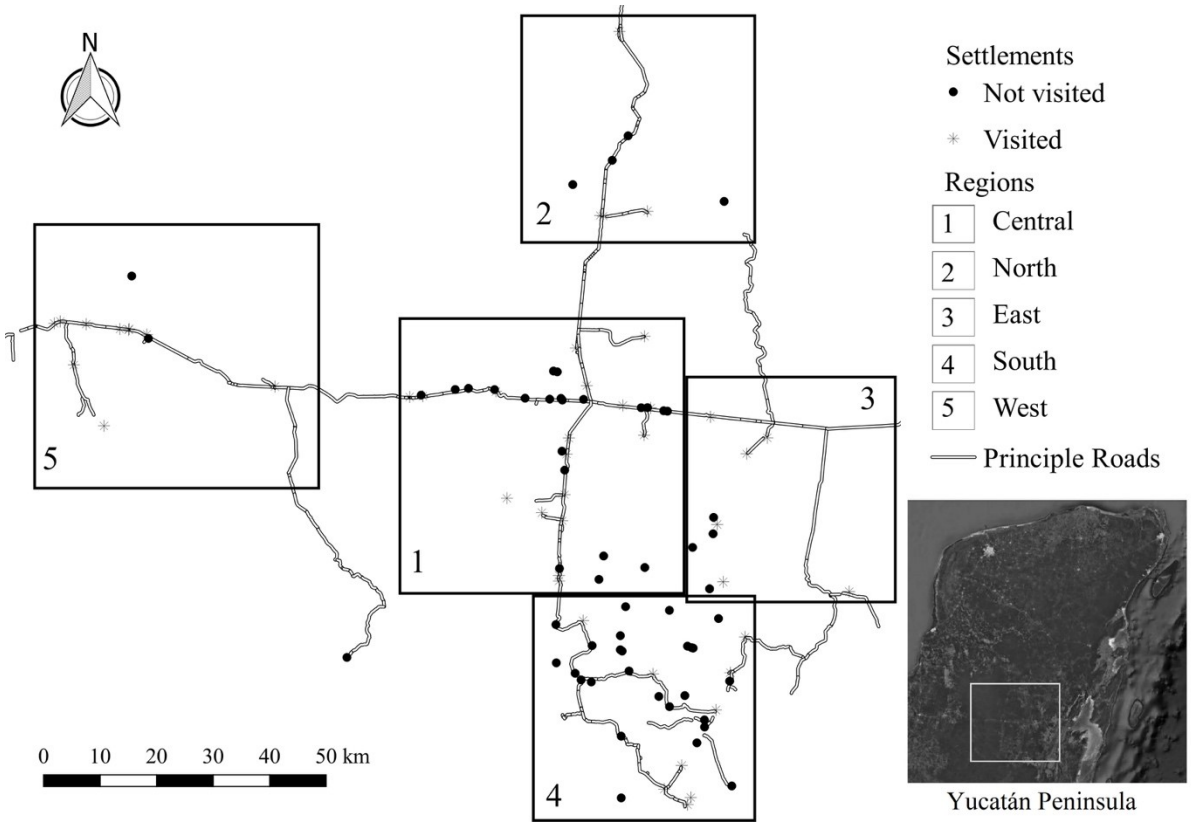

Figure 1.2. Study area. Settlements represented within the study area are the one visited for the quantitative interviews. Black dots represent settlements that were not visited for interviews; white dots represent settlements that were visited. Regions are numbered as follows: 1, Central; 2, East; 3, South; 4, West; and 5, North.

The jaguar, species of interest

The Yucatán, and especially the Calakmul area, is believed to host one of "the largest continuous high suitability habitats" for jaguar (Rodríguez-Soto et al., 2011). The jaguar, listed as Near Threatened in the IUCN red list, depends on large tracts of forests, which has led to the loss of more than half of its original range in the last 100 years (Sanderson et al., 2002). In Mexico, it has been extirpated from 60% of its range (Chávez and Ceballos, 2006). A population

of approximately 900 individuals is estimated to live in the southeastern part of the Yucatan peninsula, representing the largest known population of jaguars in Mexico. They are sympatric to pumas but seems to select different prey, consuming more species such as the collared peccary (*Tayassu tajacu*), paca (*Cuniculus paca*) and armadillo (*Dasypus novemcinctus*) (Ceballos et al., 2002). Both species prey on large species such as white-tailed deer (*Odocoileus virginianus*), red brocket deer (*Mazama temama*) and collared peccary (*Pecari tajacu*). They also sometimes prey on livestock and are responsible for the majority of livestock predation in the Calakmul region (Fondo de aseguramiento ganadero, unpubl. data).

Socio-economic conditions

The Calakmul area has been inhabited since ancient times when the classic Maya civilization occupied there with high population density from 250 to 800 AD. Between the 1800s and early 1900s, the area was exploited by large lumber concessions and gum-tappers for the extraction of chicle latex. Chicle extraction attracted many people leading to seasonal work camps being established (Ericson, 2006). Since the 1960s, Mexican national policies have been supporting the development of agriculture in southern Mexico by allocating land through the granting of *ejidos*. An *ejido* is a land tenure system combining both individual and communal land rights and in which decisions affecting *ejido* life are taken collectively among the *ejidatarios*, the land-tenure right holders (Warman and Warman, 2001). People living in an *ejido* who do not beneficiate from land-rights uses are called *pobladores* and live often in poorer conditions than *ejidatarios* (Navarro-Olmedo et al., 2016). Prior to the Reform in 1992, ejidal land was non-transferable and inalienable other than through inheritance. The Reform, however, allowed the land to be leased, mortgaged, transferred, and sold if approved by two-thirds of the *ejidatarios*. The availability of land in the south, the abundant forests, and the tranquility of a low-density population attracted numerous landless settlers from all of Mexico. In 1995, there was 114 settlements in the area. The population grew from 6 000 to 25 000 between 1980 and 1995 (Ericson, 2006). After the creation of the Reserve in 1989 and the Calakmul municipality in 1997, a new wave of settlers arrived in the area, mostly white-collar workers employed by the government or working in the tourism industry and its related services (Ericson, 2006). For

example, approximately 2 000 researchers have been working there since the creation of the reserve (Haenn et al., 2014).

Today, Calakmul municipality is home to 28,424 people (INEGI, 2015). On the "Index of Marginalization" of Mexico's National Population Council which compares municipalities on housing quality, education and household income, Calakmul is rank as "high" marginalization. It was before considered a zone of "very high marginalization" but its status was changed in 2005 in part due to state investments in housing and education (Navarro-Olmedo et al., 2016). However, most of Calakmul farmers still lack formal education and depend on scant economic resources. Calakmul is home to an ethnic mix of peninsular Mayans, Mayan people mostly from Chiapas (e.g. Ch'ol and Tzeltal), and mestizos or non-indigenous people predominantly from the Mexican states of Veracruz and Tabasco (Gurri, 2003). The majority of the population practices subsistence *milpa* farming (producing traditional foodstuffs such as maize, beans, and squash), livestock husbandry, and forest-dependent activities for both timber and non-timber products (Monzón-Alvarado et al., 2014). A total of 11 330 heads of cattle was reported in the most recent census made available from the Calakmul municipality (Censo Agropecuario, 2007). Agricultural activities are subsidized by the state, and most of the population relies on these subsidies for their livelihoods (Ericson, 2006; Haenn et al., 2014). Furthermore, as a Reserve part of the Man and Biosphere program, the Calakmul reserve should help meeting the livelihood needs of local communities. Therefore, rural development initiatives have proliferated in the region in the last two decades, focusing on livelihood diversification and (non-timber) forest extraction, such as honey production and handicraft. Finally, recent years have seen an increase in rural households depending on salaried labour, most of which through migration to the nearby tourist corridor of Cancun – Playa del Carmen and the USA (Haenn, 2011).

Challenges for environmental management

Calakmul's recent history of immigration from other parts of Mexico has created a mosaic of customs, languages, religions and agricultural practices (Murphy, 2004) which

constitutes a challenge for its inhabitants to work peacefully together (Ericson, 2006). The Reserve's delineation and establishment were mostly undertaken without local consultation, leading to conflicts between those who depend on the land for production and those who sought to conserve it, reinforcing state presence in the region (Haenn, 2005). For example, deforestation is prohibited on government land (most of the Reserve core zone) and 17 *ejidos'* forest extensions. Forest resources are important for many economic activities, such as timber extraction but also allspice, beekeeping, and ecotourism, which represent alternative incomes for communities (Turner et al., 2004). Commercial hunting is also prohibited and only subsistence hunting is allowed. However, there is some confusion on what is considered subsistence hunting (J.Z.M., personal communication) and previous research have shown negative consequences of subsistence hunting on some species (Ceballos et al., 2002; Reyna-Hurtado and Tanner, 2007). Furthermore, national conservation policies and global funds related to conservation agendas, which promote non-resource or alternative forms of production (e.g. ecotourism, organic farming, agroforestory programs), are often in contradiction with other national programs that facilitate access to farming and agricultural inputs (Haenn, 2005). Coupled with a complicated land tenure system, conservation efforts are then often deflected by a power struggle between producers and the government (Haenn, 2005).

In addition, environmental conditions also make it a difficult place to prosper. Lack of water during the dry season sand recent droughts have resulted in water limitations and inequalities in water access, which created tension in the region. Interactions with wild species lead sometimes to serious economic losses for the locals: herbivores such as wild peccary or tapir, but also bird such as parrots, often feed on crops; while carnivores such as puma and jaguar are sometimes considered a threat to livelihood because of livestock depredation (Zarco-González et al., 2013). This can result in hunting and poisoning of wild animals, representing a threat to their survival (e.g., Inskip and Zimmermann, 2009). Nevertheless, government programmes have sponsored sheep production; hence there has been a recent increase in families owning small flocks of sheep as a complementary income (Schmook and Radel, 2008). Due to a lack of experience or money, only a few livestock owners can implement husbandry practices that prevent large cat's depredation. Standards of husbandry practices are really poor, with many

animals ranging freely, while other producers use barbed wire not tall enough to impede big cats from jumping in (personal observation).

With *ejidos* legally entitled to 22.6% of the Reserve, reserve officials work with local communities, and others governmental agencies and nongovernmental organizations regarding land management decisions, with mixed success (Klepeis and Vance 2003, Abizaid and Coomes 2004). The Reserve plays a key role in the region with different programs in place, such as the annual "Temporary Employment Program" with which *ejidatarios* are paid to clear firebreaks, or other programs providing sporadic help such as electric fences for ranchers to protect their livestock. Other actors have also played an important role for wildlife conservation in the region, such as PRONATURA PY that started working in the region even before the reserve was implemented. One of their programs, for example, has been providing camera traps to ranchers to identify the predator in case of an attack. This can provide significant help for the rancher to receive compensation. In fact, ranchers can claim compensation in case of depredation through the *Fondo de Aseguramiento Ganadero* (FAG), a national compensation scheme that covers livestock losses to predators such as the jaguar, puma, and feral dogs (*Canis familiaris*), among others. The FAG is accessible to any livestock breeder who can provide evidence of ownership, without any insurance cost to the claimant and is funded both by large livestock breeding companies and by smaller scale breeders. Different initiatives have also taken place in the region in order to achieve more collaboration toward environmental management. The Council of Rural and Sustainable Development in Calakmul (CMDRS) was created in 2005 as a state effort to facilitate cross-sector approaches to sustainability. They regroup representatives from the government sector, the NGO sector and representatives of local productive groups and local communities. They meet every month to discuss issues sometimes related to environmental management. The Reserve, PRONATURA and other local NGOs, the FAG, and the CMDRS are the main entities working in the region and are of interest in this research in order to understand better biodiversity conflicts.

Ethic statement

This research (projects 2015-1290 and 2014-94-LSH) has been subjected to a full evaluation and approval by the research ethic committee of University of Sherbrooke to ensure that it was conducted in full compliance of research ethics norms, and more specifically the codes and practices established at University of Sherbrooke.

CHAPTER 2

THE EFFECT OF NATURAL HABITAT AND HUMAN ACTIVITIES ON LARGE CATS' PREDATION RISK IN A TROPICAL LANDSCAPE: INCLUDING SPATIAL AND TEMPORAL SCALES IN A TWO-DIMENSIONAL APPROACH

Description of the article and contribution

This first chapter allowed us, first, to assess the impact of large cats in the Calakmul region, i.e. attacks on livestock. A two-dimensional approach, one that approaches landscape characteristics and human pressure separately, was developed as they might require different actions at different organizational levels. We used state-of-the-art procedures of landscape ecology, integrating spatial and temporal scales, spatial autocorrelation in the data, 'true' presence and absence data, and taking into consideration the expanding numbers of ecological studies on jaguars. Our results demonstrated that the species of livestock raised was the main determinant of large cats' attacks in the region, with sheep being particularly at risk. Livestock attacks were then best explained by the functional landscape characteristics, including the fragmentation process that is often ignored in other studies trying to assess the spatial risk of depredation. Human pressures were of low importance; most importantly, our data showed that management practices are endemically poor in the region, in particular concerning attack prevention. While our results should be considered with caution due to large credible intervals, they show that the region of Calakmul offers conditions facilitating attacks by large cats in the whole region.

The initial idea for this chapter was proposed by Sophie Calmé, while I defined its final form. I helped Harry Marshall develop the questionnaire and the sampling strategy with the support of Sophie Calmé. I realized the data collection with the help of Harry Mashall, Nayla Barrera Mora, Morgan Nigon and Sophie Calmé. I chose the variables to include in the models

after discussion with Sophie Calmé and François Rousseu. Zhiwen Zhu and John Rogan classified the 2000 and 2015 maps and derived most variables from it. The statistical analyses were done in collaboration with François Rousseau. I wrote most of the text, while Zhiwen Zhu provided the section on data extraction and François Rousseau helped me for the section on data analysis. Sophie Calmé, François Rousseau, Zhiwen Zhu and John Rogan commented on previous versions of the article, and helped with phrasing to improve the manuscript. This article will be submitted shortly to the journal "Ecological application" although some modifications could be made to the current chapter before submission.

The effect of natural habitat and human activities on large cat's predation risk in a tropical landscape: including spatial and temporal scales in a two-dimensional approach

Lou Lecuyer, François Rousseu, Zhiwen Zhu, John Rogan, Sophie Calmé

Abstract

Livestock predation by large cats represents a threat both to livestock production and to large cat conservation when retaliation occurs. Therefore, understanding the factors that influence the occurrence of depredations and their spatial distribution has become an important task for conservation managers. However, the importance of spatial and temporal scales has often been overlooked. In this study, we investigated the risk of depredation on livestock by large cats through developing a two-dimensional approach to consider landscape characteristics and human pressure separately and selecting the appropriate temporal and spatial scales to analyze depredation occurrence. We collected geospatial data on attack and non-attack sites (2011-2015) in the region of Calakmul, which hosts the largest population of jaguars in Mexico, and obtained additional information relative to livestock management through 165 interviews with ranchers. We derived ecological and anthropogenic variables from two land-use maps (2000 and 2015) at

four scales relevant for large cats (0,5 km, 2,5 km, 5 km and 10 km-radius). We built two sets of models, one on the effect of landscape characteristics (structural and functional), and the other on the effects of human pressure (human population, land use, and livestock production). Following a hierarchical information-theoretic approach, we first selected the appropriate temporal and spatial scales and then contrasted our two sets of models all while controlling for spatial autocorrelation. Five variables best explained the occurrence of depredations at a specific spatial scale, while past forest area appeared more important than current forest area showing a time-lag effect. The species of livestock raised was by far the main determinant of depredations in the region, with sheep being particularly at risk compared to cattle. Functional characteristics related to landscape fragmentation were also important in explaining the risks of depredations, while human pressure appeared less important. This study, based on a robust approach using sophisticated procedures in landscape ecology, shows the importance of incorporating multiple spatial and temporal scales. It also highlights the benefit of using a two-dimensional approach to support conservation management measures at the appropriate organizational level. For instance, livestock management might be better addressed at a community level, whereas landscape fragmentation will be better tackled at a regional or state level.

Keywords: spatial predation risk, spatial autocorrelation, time-lag effect, jaguar, puma, Calakmul

Introduction

Interactions between humans and wild animals are likely to keep increasing around the world due to land use change and climate change (Nyhus et al., 2005; Raik et al., 2005). Interactions that have a negative impact on humans or wild species are referred to as biodiversity impacts (Redpath et al., 2013; Young et al., 2010). Biodiversity impacts can span from crop-raiding and destruction of stored foods, predation upon livestock and game, to threats to humans through attacks and disease transmission (Madden, 2004; Nyhus et al., 2005). In response, humans have retaliated by killing the species in cause, which may cause a serious threat to these

species'survival (Treves and Naughton-Treves, 2005; Woodroffe and Ginsberg, 1998). Furthermore, once a negative impact of wild species has occurred, negative attitudes and actions towards them may persist for a long time (Marker et al., 2003), so it is arguably far more effective to prevent impact from occurring (Abade et al., 2014).

In order to prevent impacts, numerous research projects have tried to identify the drivers of predation risk and predict locations of future depredationss. Predation risk is known to be spatially unevenly distributed (Jackson et al., 1996): habitat and landscape characteristics, as well as anthropogenic factors can influence the odds of impact and determine the existence of predation hotspots (Fernández and Paruelo, 2009; Zarco-González et al., 2013). Miller (2015) showed that the risk of large carnivore attacks is commonly related to four main factors: species biology, natural landscape structure, human pressure, and management. Spatial predation risk modeling correlates landscape attributes with the occurrences of biodiversity impacts (Abade et al., 2014; Miller, 2015). This allows to focus prevention efforts and mitigation measures towards high-risk areas so as to optimize resource use (Zanin et al., 2015). Given the challenge of accommodating the conservation of predators in multiple-use landscapes, these predictive models can help manage some of these factors before impacts occur (Behdarvand et al., 2014; Wilson et al., 2006).

Despite recent efforts to develop improved spatial predation risk models (SPRM) (Miller, 2015), there remain many challenges linked to landscape studies, in particular the spatial and temporal scales to be considered for understanding biodiversity impact (Turner et al., 2001). Multi-scale approaches have been proposed for studying habitat selection (Pedrana et al., 2014; Savignac et al., 2000) because species respond to habitat at different spatial scales (Holland et al., 2004). For instance, carnivores might respond to a large spatial scale for reproduction and to a small scale for hunting. However, some SPRM do not consider any scale extent (e.g., Rosas-Rosas et al., 2008) or arbitrarily choose one (e.g., Behdarvand et al., 2014; Wilson et al., 2015). Also, authors often consider scales smaller than the range of movements of the species of interest (e.g., Davie et al., 2014) or apply a single radius to the full set of variables instead of selecting the appropriate scale for each variable (Kaartinen et al., 2009).

Furthermore, time-lag effect (i.e. consideration of temporal scale) can also be an important factor to consider where habitat loss occurs rapidly as the effect of fragmentation and habitat loss on species distribution may be delayed (De Angelo et al., 2013; Ewers et al., 2013). In addition, some SPRM studies used long-term attack data but extract landscape variables for a single year (Miller et al., 2016a; Zarco-González et al., 2013), ignoring changes in the landscape. Only a few studies accounted for landscape changes and the process of fragmentation over time (Acharya et al., 2017; Carvalho et al., 2015).

SPRM also tend to suffer from potential bias related to the very nature of the data on depredations (Miller, 2015). SPRM are often based on attack-only data and data collection can be biased by the accessibility of the sites of attack, by the willingness to inform responsible authorities, or by differences in report probability across livestock species and across geographical areas (García-Rangel and Pettorelli, 2013). Some approaches also require the use of pseudo-absence data, which can directly influence the resulting map and interpretation (Wisz and Guisan, 2009). Choosing meaningful pseudo-absences, determining how many points should be generated and checking for their reliability can prove challenging (Barbet-Massin et al., 2012) and few authors explain how they generated these pseudo-absences (e.g., Treves et al., 2011). Additionally, there are difficulties associated with using spatial data: some sites might be close to each other leading to non-independence between observations and spatial autocorrelation (Dormann et al., 2007). Unfortunately, it is not always clear how spatial autocorrelation is dealt with, if it is at all (eg. Abade et al., 2014; Soto-Shoender and Giuliano, 2011).

Even when SPRM aim to inform conservation action, Miller (2015) found that there remains a gap between the development of SPRM and the implementation of appropriate resulting actions. We believe that a hindrance stems from the very form of risk maps, which are often based on all significant variables, preventing the identification of key variables from which potential actions could be derived. However, SPRM could take advantage of habitat models developed for endangered carnivores that consider separately each key demographic feature, e.g. reproduction and mortality (De Angelo et al., 2013; Naves et al., 2003). These authors

argued that the management actions related to each set of models would differ substantially in their nature, as reproduction in these species is more likely related to natural factors, whereas mortality is more related to human factors. We consider that the evaluation of depredation risk also requires a two-dimensional approach as there are two distinctive elements required for impact to occur: suitable habitat for the wild species to exist nearby, and livestock availability and accessibility which might vary according to husbandry and human presence. The former relates more to the natural landscape dimension, whereas the latter relates to the human dimension. Acting upon the natural landscape dimension might require higher protection of natural habitat or restoration (De Angelo et al., 2013), while acting upon the second dimension would require education or technical improvement for livestock protection. Risk maps associated with each of these dimensions may help managers target specific actions in order to reduce the risk of biodiversity impact.

In the present study, we focus on livestock predation by jaguars (*Panthera onca*) and pumas (*Puma concolor*) in a region of interest for conservation, the greater Calakmul in Southern Mexico. A number of recent studies have provided an understanding of these species' use of habitat and movements, allowing us to determine relevant variables to consider and to build sound biologically-based hypotheses. Our objectives were 1) To explore the usefulness of a two-dimensional approach for SPRM to support specific actions related to the effect of "natural" and "human" landscapes on large cat predation 2) To integrate spatial and temporal scales in the estimation of the risk of large cat depredations on livestock in Calakmul; 3) To include spatial correlation in risk prediction. We modeled the risk of depredations using true absence data and a multi-scale approach that selects the relevant scale for each explanatory variable, considering historical data on landscape attributes and the fragmentation process ongoing in the region. Furthermore, we accounted for spatial autocorrelation in the data through a geostatistical model. We propose strengthening the use of landscape ecology for conservation, by providing a guideline for land-use management targeting management actions that reduce large cat impact and support conflict management in the region of Calakmul.

Methods

Study area

Calakmul is a municipality of the state of Campeche, located in Southern Mexico, at the northern border of Guatemala. The region is characterized by a sub humid climate of a warm tropical type with marked rainy and dry seasons. The mean annual temperature is 26°C and the mean annual precipitation is 1223 mm with high inter-annual variation (Mardero et al., 2015). These conditions support a seasonal tropical forest differentiated by stature, deciduousness, and the relative abundance of species (Vester et al., 2007). In recognition of the biological importance of this area, a Biosphere reserve was created through a presidential decree in 1989. The reserve covers 723 185 ha, the largest tract of tropical forest in Mexico, and enters into a larger system of protected areas in Mexico, Guatemala, and Belize covering 25 000 km². One hundred and fourteen communities and private ranches surround the reserve with an approximate population of 30,000 people (INEGI, 2015), who are mostly engaged in nature-based economic activities such as subsistence agriculture, livestock production, chili cultivation (*Capsicum* spp.), timber logging, charcoal production, allspice (*Pimienta dioica*) harvesting, beekeeping, tourism, and handicrafts (Turner et al., 2004).

The Yucatán, and especially the Calakmul area, is believed to host one of "the largest continuous high suitability habitats" for jaguar (Rodríguez-Soto et al., 2011). The jaguar, listed as Near Threatened in the IUCN red list, depends on large tracts of undisturbed forests, which has led to the loss of more than half of its original range in the last 100 years (Sanderson et al., 2002). In Mexico, it has been extirpated from 60% of its range (Chávez and Ceballos, 2006). A population of approximately 900 individuals is estimated to live in the southeastern part of the Yucatan peninsula, representing the largest known population of jaguars in Mexico. Yucatán was also defined as a high predation risk area in the spatial model developed by Zarco-Gonzalez et al. (2013). The Yucatán peninsula has been presented as highly fragmented and threatened by severe anthropogenic activities (Faller et al., 2007) with a large number of cattle, 60% of which graze freely (Zarco-González et al., 2013). However, conditions surrounding the Calakmul

reserve are different from the rest of the Yucatán peninsula: human pressure is restricted to small communities that practice small-scale agriculture and livestock breeding. Even if jaguars in the Selva Maya tend to be restricted to natural protected areas such as Calakmul (de la Torre et al., 2016), they require large territories and will venture out of protected areas where predation can occur and retaliation can take place and threaten the species (Amador-Alcalá et al., 2013). Jaguars and pumas are responsible for the majority of predation of livestock in the Calakmul region (*Fondo de aseguramiento ganadero*, unpubl. data). How to manage biodiversity impact in the surrounding area of this reserve is thus of high importance for the conservation of jaguars.

Depredation data

Between March and June 2015, we conducted 165 interviews with ranchers using a snowball sampling technique (Faugier and Sargeant, 1997), across the whole region surrounding the Calakmul biosphere reserve during a larger study aiming at evaluating local perception of the compensation scheme in the region. The interviews gathered data including livestock activities (e.g., number of animals, pasture area) and management (e.g., frequency of visits to tend to the animals, fence type), as well as the occurrence of livestock loss. Out of the 165 participants, 101 accompanied us to locate with a GPS either the approximate centroid of the pasture in the case they had not suffered attacks or at the attack location they remembered if they had suffered predation by large cats. We are aware that those points might not be the exact position of attack as jaguar and puma can drag their prey and this was recognized in the smallest scale selected below. We also recognize that caution should be exerted in analyzing reported information. However, the majority of our participants were interviewed up to three times by a person related to the project in the last 6 years, which allowed us to check for consistency in the information related to livestock predation. Two cases that presented incoherencies were discarded. Furthermore, we informed ranchers that interviews would be kept confidential, we asked no question that could put them at risk and we made clear that we were independent of any agency from which they could receive compensation. Finally, we considered depredationss that occurred during the last 5 years, i.e., since 2010, to improve the quality of the data, and

because landscape change between 2010 and 2015 was negligible: the percentage of global change of the different land cover were equal or less than 1% (unpublished data).

Jaguar as a surrogate for large cats

Due to uncertainty regarding the species involved in a given attack, we grouped together attacks that interviewees attributed to either jaguars or pumas. Our assessment is therefore of the risk of attack by large cats in the region. However, we focus our analysis on landscape variables affecting jaguars which can be justified in part by the fact that jaguar and puma are sympatric across the entire jaguar range. Studies in Calakmul and similar landscapes have shown that: 1) The two species do not differ in their use of mature forest as their major habitat type (Chávez, 2010; de la Torre et al., 2017; Foster et al., 2010; Harmsen et al., 2009), even if pumas in Calakmul use evergreen forest and seasonally flooded forest more frequently than jaguars (Chávez, 2010); 2) Co-existence is made possible by temporal segregation and because they target slightly different prey (Chávez, 2010; de la Torre et al., 2017; Foster et al., 2010; Harmsen et al., 2009). Furthermore, depredation events that have been subject to reports and confirmation of the predator in Campeche over four years by the compensation fund show that the most livestock predation is done by jaguar relative to puma (respectively 75% and 25%; unpubl. data).

Hypotheses and variables associated

To allow for a more management-relevant assessment, we developed two sets of hypotheses to investigate the risk of depredations from the perspective of two key factors, the landscape characteristics and human pressure on the landscape. We set out two general hypotheses: 1) Depredation occurrence depends on surrounding natural habitat that can be a suitable landscape for jaguars depending on both structural and functional characteristics of the habitat; 2) Depredation occurrence depends on anthropic effects on the landscape, human population density, and livestock management. We are aware that human pressure also drives

the structural and functional characteristics of the habitat as the process of forest loss and fragmentation are often caused by human activities such as agriculture and cattle ranching. However, the distinction here is made between long-term human impact (included in the landscape characteristics hypothesis) and short-term effect related to direct human activity and presence. Furthermore, the human pressure in this study doesn't include direct killings of jaguars by humans. To capture how big cats perceive the different landscape elements, we analyzed scale-dependent variables at four different radii (0.5, 2,5, 5, and 10 km) relevant to large cats (see Table 1). We then formulated sub-hypotheses regarding which aspects of the landscape characteristics and human pressure should best explain depredation occurrences (see Table 2 for hypotheses and their justifications). The process of formulating hierarchically structured sub- and general hypotheses can support recommendations addressing the influence of specific drivers.

Table 2.1 Scale definition according to jaguar ecology

Scale	Justification	References
0.5 km	The presence of forest at a distance of 250 m influences jaguar movement and habitat use. Considering measurement errors in the location of kill sites, we decided to use a scale of 500 m.	(Azevedo and Murray, 2007; de la Torre et al., 2017)
2.5 km	A circular area with a radius of 2.5 km represents the mean home range of female jaguars in the study region and Mexico, as measured using Very High Frequency (VHF) telemetry.	(Aranda, 1998; Ceballos et al., 2002; Chávez, 2010; Rodríguez-Soto et al., 2011)
5 km	A circular area with a radius of 5 km represents the mean home range of male jaguars in the study region and Mexico, as measured using VHF telemetry.	(Aranda, 1998; Ceballos et al., 2002; Chávez, 2010; Rodríguez-Soto et al., 2011)
10 km	A circular area with a radius of 10 km represents the mean annual activity area of jaguars of both sexes equipped with GPS collars in the study region and other parts of tropical Mexico.	(Chávez, 2010; de la Torre et al., 2017)

To describe landscape characteristics and human pressure stated in the different hypotheses, we used a total of 20 variables (Appendix 1). Data related to livestock management were derived from the interviews while the rest were extracted from a land cover and use map of the region. Data related to livestock management were derived from the interviews while the rest were extracted from 30 m spatial resolution land cover maps of the region in 2000, 2010 and 2015 (figure 1). The land cover maps in 2000 and 2010 were produced from Landsat Thematic Mapper (TM) imageries using a step-wise maximum likelihood/In-Process Classification Assessment (IPCA) procedure, which allows for an iterative procedure of signature development and refinement, and thus improved distinction of land-cover classes (Schmook et al., 2011). The land cover map in 2010 was updated to generate the land cover map in 2015 using the Global Forest Change 2000-2014 dataset (Hansen et al., 2013). The forest losses during 2000-2014 were reclassified as Agriculture or Pasture in the 2015 land cover map. The mature forest included classes of Selva Baja, Selva Mediana, Selva Alta/Mediana, Mediana Subcaducifolia and Baja Subcaducifolia in the land cover maps. The short statured forest included classes of Bajos and Selva baja inundable. The secondary forest included classes of Arboreous Secondary and Shrubby Secondary.

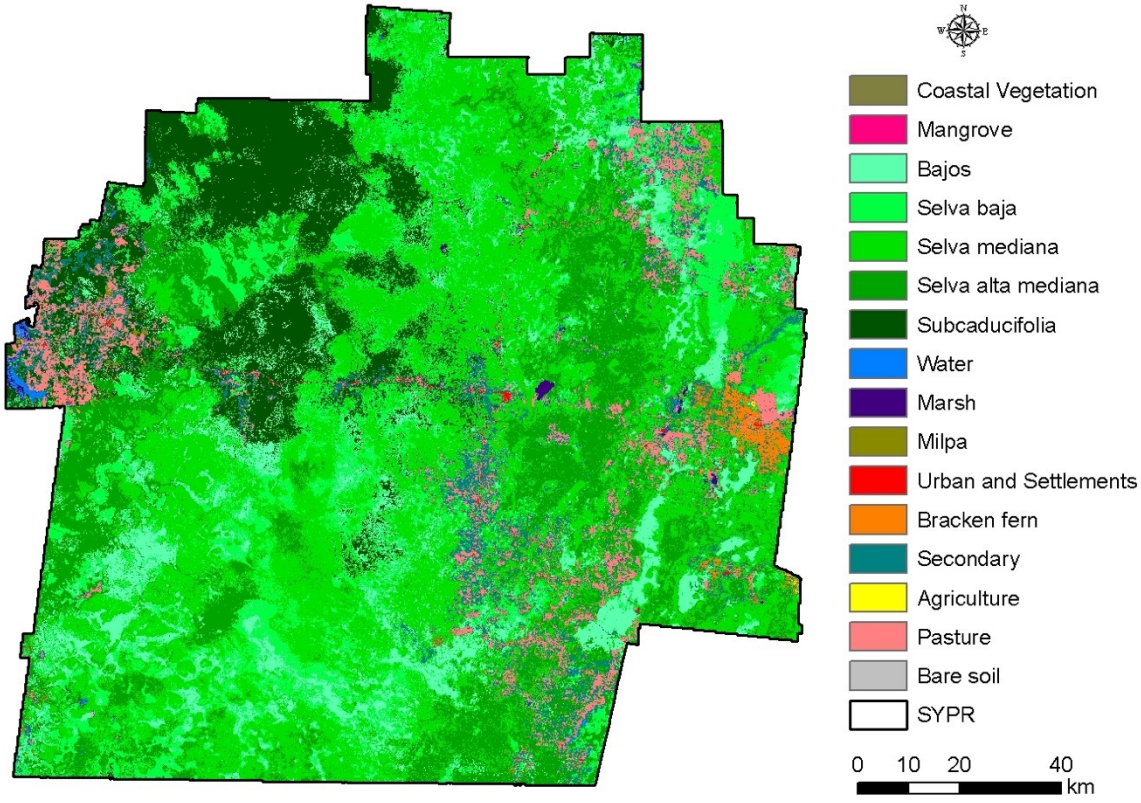

Figure 2.1 Land cover map of Southern Yucatán Peninsular Region (SYPR).

To characterize the fragmentation process in the region, we used Morphological Spatial Pattern Analysis (MSPA) (Soille and Vogt, 2009), which allowed us to consider functional and structural connectivity between forest patches. Only three of the seven MSPA classes were used (Perforation, Bridge and Branch) as the other classes would have duplicated other variables. To assess the temporal effect, we only used data related to forest area (mature, inundated and secondary forests) as we were interested in the potential effect of habitat availability in 2000 on the presence of large cats in 2015 and if it could influence the occurrence of depredations. While we recognized that past landscape configuration could also influence the movements of large cats, fragmentation in the area was so low that we assumed it had a limited effect on their movements. As a consequence, we did not include MSPA data from 2000. We are aware that further variables could have been useful, such as prey density, higher level hydrographic

networks or unpaved road network. However, those data were not available in the region and were impossible to collect during the timeframe of this study.

Table 2.2 Main hypothesis and sub-hypotheses related to large carnivore attack on livestock and their justification

General hypothesis and justification	Sub-hypothesis	Reference
Landscape characteristics hypothesis (LC)		
Structural characteristics (SC): jaguar attack is directly conditioned by the presence of natural habitat nearby	(SC1) The present area of upland mature forest (%matFor_r), inundated short-stature forest (%indFor_r) and secondary forest (%secFor_r), as well as past area of upland mature forest (%matFor_2000_r), inundated short-stature forest (%indFor_2000_r) and secondary forest (%secFor_2000_r) favors the presence of jaguar, but also of prey and thus influences the occurrence of attacks (SC2) The creation of non-forest habitat within forest (Perforation_r) can affect the quality of jaguar and prey habitat, hence influencing the occurrence of attacks (SC3) Water (WatPA) in the pasture area attracts jaguars and hence favors attack on livestock (SC4) The combined effects of the structural characteristics of the natural habitat are important to explain occurrence of attacks	Chávez, 2010; Colche et al., 2011; Conde et a 2010; Foster et al., 201 Michalski et al., 2006; Zanin et al., 2015; Zar González et al., 2013
Functional characteristics (FC): Landscape fragmentation can also influence jaguar movement and jaguar presence and in consequences, potentially influence the occurrence of attacks	(FC1) The abundance of patches of minimum size (i.e., patches that can be temporally occupied by jaguar; 2 km^2) (Dens-MinP) influences jaguar movement and if sufficient, can allow jaguar to come closer and increase the number of attacks. (FC2) The distance to the nearest habitat patch (Dist-HabP) (i.e., a patch of mature forest large enough to sustain a viable population, in the area 1500 km^2) influences the presence of jaguar and if closed, might increase the number of attacks. (FC3) The fragmentation process (corridors, Bridge_r, and "false corridor", Branch_r) can influence the movement of jaguar and if too fragmented, the landscape may impede jaguar movement and reduce the number of attacks (FC4) The combined effects of the structural characteristics of the natural habitat are important to explain occurrence of attacks	Behdarvand et al., 201 Chávez, 2010; Dar et a 2009; de la Torre et al. 2016; Olsoy et al., 201 Ramirez-Reyes et al., 2016; Thorn et al., 201 Watkins et al., 2015; Zanin et al., 2015
Landscape characteristics (LC): Jaguar attack is determined by the structural and functional characteristics of the natural habitats	LC = SC + FC	

Human pressure hypothesis (HP)		
Human population and activity (HPA): human activity influences jaguar distribution and the occurrence of attacks, while human settlements and road have a negative effect on jaguar presence and the occurrence of attacks	(HPA 1) The area of land dedicated to agriculture (%Agr) reduces the presence and movement of jaguars and the occurrence of attacks, (HPA2) Jaguar attacks will be favored by small areas of pasture (%Past) but will decrease in an area dominated by pasture as male jaguars venture more easily into low-intensity cattle ranches, while female avoids them (HPA3) Jaguars avoid human presence (Hum_Pres) and are limited in their movement by roads (Dist_Road), which will influence the occurrence of attacks (HPA4) The combined effects of human population and activities are important to explain occurrence of attacks	Behdarvand et al., 201 Carvalho et al., 2015; Colchero et al., 2011; Cullen Junior et al., 20 De Angelo et al., 2013 de la Torre et al., 2016 Rabinowitz and Zeller, 2010; Soh et al., 2014; Zarco-González et al., 2013
Livestock production (LP): Attack of jaguar depend on the type of cattle and the management practice used by ranchers	(LP1) Type of livestock production (Liv_Sp) can influence the occurrence of attacks as jaguars mainly attacks sheep or calves. Previous studies have also shown that cattle density (Dens-Liv) can influence the occurrence of attacks. (LP2) Livestock management (Liv-Mgmt) might help to prevent attack if appropriate practices are implemented (good fencing, night surveillance, human presence). (LP3) The combined effect of type of livestock production and livestock management practices are important to explain the occurrence of attacks.	Carvalho et al., 2015; Ceballos et al., 2002; Conde et al., 2010; Jackson et al., 1996; Rodríguez-Soto et al., 2011; Soto-Shoender a Giuliano, 2011; Zanin al., 2015; Zarco-González et al., 2013
Human pressure (H): Jaguar attack might be influenced by the combination effect of human population and activity and livestock management.	HP = HPA + LP	

Model formulation

We tested our hypotheses using a generalized linear geostatistical model (glgm) (Diggle et. al., 1998; Diggle and Ribeiro, 2007) with a binary response variable (attack or no-attack). Preliminary analyses revealed the presence of residual spatial autocorrelation when using generalized linear models. Hence, we opted for a glgm model to account for the dependence between observations. We used the package geostatsp (Brown, 2015) which implements a matern2d model through the R-INLA package (Rue et. al., 2013). The integrated nested Laplace approximation (INLA) provides an alternative to MCMC for estimating latent Gaussian models in a Bayesian context (Rue et. al., 2009). We used the default INLA non-informative priors for the regression coefficients and slightly more informative priors for the spatial covariance. In geostatsp, priors for the range parameter and for the standard deviation are specified using lower and upper bounds of 95% intervals and are internally converted to Gamma priors for the range scale parameter and precision, respectively (Brown, 2015).

The prior on the range parameter controlling the extent of the spatial dependence was set to 2 and 50 km. These values roughly correspond to the minimal and maximal jaguar home ranges (between 50 km^2 and 1000 km^2, Chávez, 2010). The prior for the standard deviation was set to 0.4 and 4. These two set of values represent a large range of possibilities when it comes to the variability in the probability of attack across the study region and the distance at which residual spatial autocorrelation is present. The same priors were used for all models. The roughness parameter of the matern covariance function was set to 1. A buffer of 10 km was used around the study region to decrease the edge effect when generating predictions.

Prior to each model formulation, multicollinearity among variables was assessed using variance inflation factors (VIF). VIF are values that quantify how variance of parameters are inflated by collinearity in the predictors. They also reflect to what extent a given predictor is explained by all other predictors in the model (Zuur et al. 2010). One strategy for addressing this problem is to sequentially drop the covariate with the highest VIF, recalculate the VIFs and

repeat this process until all VIFs are smaller than a pre-selected threshold (here <3) (Zuur et al., 2010). This led us to drop the variable related to the area of secondary forest.

Model selection

We wanted to compare the support received by our a priori hypotheses on the factors that influence the occurrence of large-cat attacks on cattle farm in the region surrounding the Calakmul Biosphere reserve. Our models were organized hierarchically and selected following an information theoretic approach, using Watanabe–Akaike information criterion (WAIC) (Watanabe, 2010; Gelman et al. 2014). Compared to alternatives such as DIC, WAIC has the advantage of using the entire posterior distribution instead of relying on the posterior means of parameters (Vehtari et al. 2016).

Prior knowledge and initial analyses showed that livestock species (Liv_Sp) was a strong predictor of the occurrence of attacks, with sheep being almost always attacked compared to other species of livestock (Table 3). We thus included this variable in all our models.

Table 2.3 Initial analyses showing model comparison between the null model and the model including livestock species.

Model	wAIC	Δ_{wAIC}	w_r (%)
Liv_Sp	105.56	0.0	1
Null Model	126.46	20.9	0

First, we preselected a priori every spatial and temporal scale-related variable (12 out of the 20 variables) within each sub-hypothesis model: percentages of mature forest, inundated forest, secondary forest, percentage of agriculture, percentage of pasture, proportion of perforation, branch and bridge, the density of minimum patch size and the population index for spatial scale, and the percentage of mature forest, inundated forest and secondary forest for the temporal scale. The spatial scale-dependent model with the lowest WAIC for each of those

variables was then selected to be included in the subsequent models testing sub-hypotheses. Furthermore, we selected for one temporal scale dependent model (SC1) by comparing the support received by a model including forest area in 2015 with a model including forest area in 2000.

The second step of our hierarchical selection was to select the four sub-hypothesis models (Table 2). The model with the lowest WAIC was selected and kept for the following model selection step (general hypothesis). The models selected for each of the two sets of general hypotheses (e.g., SC and FC) and their combination (e.g., SC + FC) were compared and the best model was selected using the same criterion to represent the general hypothesis (i.e N and H). Finally, we compared the two selected models of landscape characteristics and human pressure and their combination to select one final model of the factors influencing large cat attack in the region.

During the hierarchical selection, some alternative hypothesis also received some support according to the WAIC values. While we selected only the models that received the strongest support to be included in the following step, models with WAIC values inferior to two were considered for interpretation of the results.

Results

Attack data and explanatory variables - Among the 101 interviews conducted for which we had an attack/non attack GPS point, 59 reported the occurrence of at least one attack between 2010 and 2015. Twenty-three interviewees bred sheep only, 56 bred cows only and 22 had both. Livestock density (number of livestock/size of the pasture area) ranged from 0.13 to 13.50 individuals per km^2 (mean=1.75; SD=2.44). Livestock management indices ranged from 1 to 17, with 59% scoring ≤4, and 31% scoring ≥16.

Livestock species and risk of attack - The main determinant of attack risk in the region was by far and large the species of livestock that ranchers owned: sheep are at a much higher risk of attack than cows (see Table 3; Figure 2).

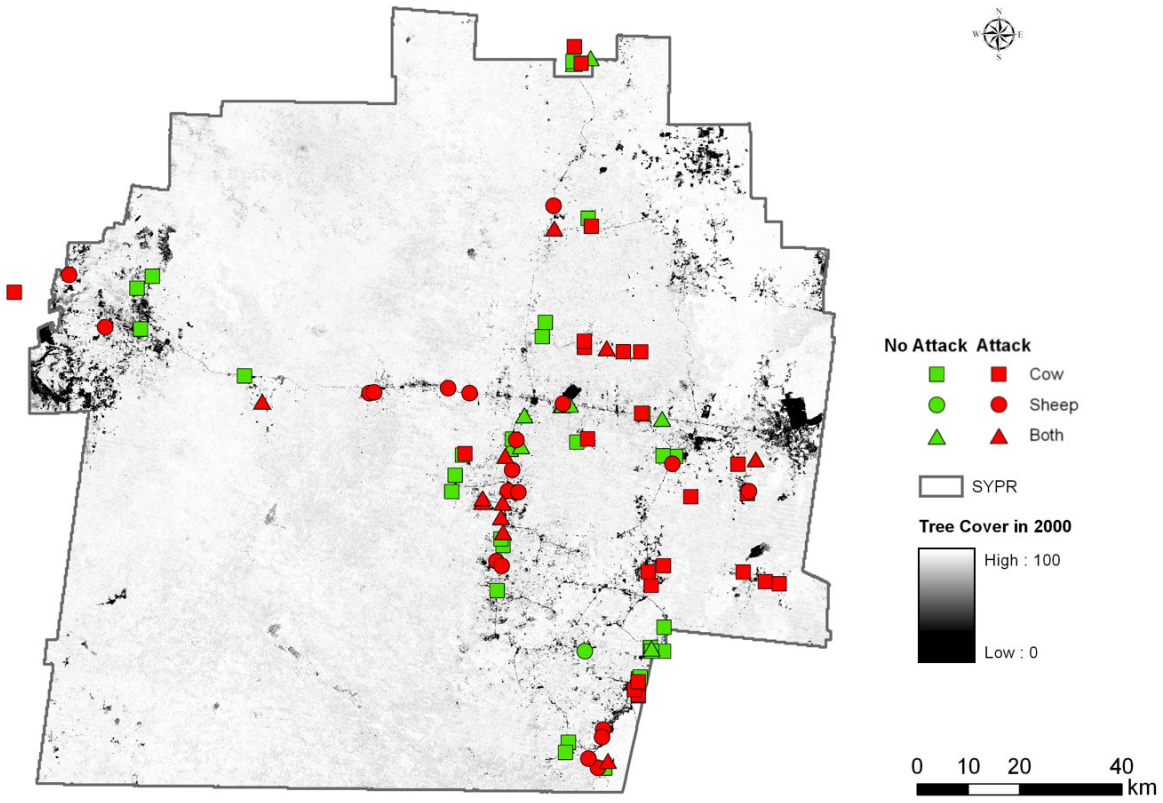

Figure 2.2. Map of the attack point and non-attack point of large cats according to the livestock species breed in Calakmul.

Spatial scale and temporal scale - On the 10 scale-dependent variables, Perforation_r, Dens_MinP_r, P_Agr_r, P_Past_r received similar support from the data for all scales with ΔwAIC mostly under 2. P_matFor and P_indFor received similar support at the scale of 10 km, 5 km, 2.5 km but a lower support at the scale of 0.5 km. Specific scales strongly supported our data for Bridge_0.5, Branch_0.5, Human_ind_8, P_matFor_2.5_2000 and P_indFor_2.5_2000.

Percent of forest cover in 2000 best explained attack occurrence compared to forest cover in 2015. Over that time span, changes in the percentage of mature forest area around our data points ranged from -26.0% to 55.5% (mean change=3.1%; SD=19.4%), and changes in the percentage of inundated short stature forest ranged from -45.3% to 16.9% (mean change=-7.4%; SD=10.7%).

Hierarchical model selection outcomes- For the sub-hypothesis structural characteristics (SC) included in the landscape characteristics hypothesis (LC), the model selected was the model related to the forest area in the landscape in 2000 (Table 5). For the second sub-hypotheses functional characteristics (FC) included in the landscape characteristics hypothesis (LC), higher support was found for the combined models. In the next step that compared and combined the model representing the sub hypothesis to select model related to landscape characteristics (N), the model selected was the one related to the functional characteristic hypothesis (SC).

Table 2.5 Result of model selection

General hypotheses	Sub-hypotheses	Variables in the final model	wAIC	Δ_{wAIC}	w_r (%)
Null Hypothesis		**Liv_Sp**	**105.56**		
Structural Characteristics (SC)	**SC1) Area of forest**	**P_matFor_5_2000 + P_indFor_5_2000**	**91.07**	**0.00**	**0.99**
	SC2) Forest alteration	Perforation_10	102.75	11.68	0.00
	SC3) Presence or absence of water	Wat PA	102.55	11.48	0.00
	SC4) Combination	P_matFor_5_2000 + P_indFor_5_2000+WatPA+Perforation_10	149.01	57.94	0.00
Functional Characteristics (FC)	FC1) The presence of minimum patch size	Den__MinPS_5	102.67	22.18	0.00
	FC2) The distance to habitat patch	Dist_HabP	100.42	19.94	0.00
	FC3) Fragmentation	Bridge_0.5+Branch_0.5	86.64	6.16	0.04
	FC4) Combinations	**Den__MinPS_5+Dist_HabP+Bridge_0.5+Branch_0.5**	**80.48**	**0.00**	**0.96**
Landscape characteristics (LC)	SC1		91.07	10.59	0.00
	FC4		**80.48**	**0.00**	**0.99**
	SC1+FC4	P_matFor_5_2000 + P_indFor_2000+ WatPA+Perforation_10+ Den__MinPS_5+Dist_HabP+Bridge_0.5+Branch_0.5	155.89	75.41	0.00

Human population and activity (HPA)	HPA1) Agriculture	P_Agr_5	100.40	6.04	0.05
	HPA2) Pasture	P_Past_5	103.54	9.19	0.01
	HPA3) Presure	Human_ind_8+Dist_Road	102.25	7.89	0.02
	HPA4) Combinations	**P_Agr_5+P_Past_5+ Human_ind_8+Dist_Road**	**94.36**	**0.00**	**0.92**
Livestock production (LP)	LP1) Livestock density	Dens_Liv	101.39	3.23	0.16
	LP2) Livestock management	Liv_Mgmt	105.10	6.94	0.02
	LP3) Combinations	**Dens_Liv+Liv_Mgmt**	**98.16**	**0.00**	**0.80**
Human pressure (HP)	HP4		94.36	6.83	0.03
	LP3		98.16	10.63	10.63
	HP4 + LP3	**P_Agr_5+P_Past_5+ Human_ind_8+Dist_Road+Dens_Liv+Liv_Mgmt**	**93.45**	**0.00**	**0.00**
Final Model	**FC4**	**Den__MinPS5+Dist_HabP+Bridge_0.5+Branch_0 .5**	**80.48**	**0.00**	**0.97**
	HP	P_Agr_5+P_Past_5+ Human_ind_8+Dist_Road+Dens_Liv+Liv_Mgmt	87.53	7.05	0.03
	FC4+HP	Den__MinPS_5+Dist_HabP+Bridge_0.5+Branch_0. 5+ P_Agr_5+P_Past_5+ Human_ind_8+Dist_Road+Dens_Liv+Liv_Mgmt	358.83	278.35	0.00

For both of the sub-hypotheses included in the human pressure hypothesis (H), higher support was found for the combined model of human population and activity (HPA) and livestock production (LP) (Table 5). For the general model of human pressure, the combined effect of the two precedent sub-hypotheses received the highest support from our data, included all the previous variables in the general model.

For the final model, it clearly appeared that the model including landscape characteristics was best supported by our data. This model, which only included functional characteristics, performed largely better than the human pressure model or the combined model. However, our estimates generally show very large credible intervals, which prevents us from interpreting the effect of our explanatory variables with sufficient certainty.

Discussion

Our research aimed at determining the relative importance of two potential drivers of large cat predation on livestock in the greater Calakmul, landscape characteristics and human pressure. Using a geostatistical approach including presence and true absence data, we showed the importance of considering multiple spatial scales that include scales large enough to accurately capture large cats' response to human presence and scales small enough to capture large cats' behavior. Moreover, our results highlight the importance of considering temporal scales as forest cover in 2000 also allowed us to better explain attack occurrence. Furthermore, our functional characteristics hypothesis, which received the best support from the data in explaining attack occurrence, showed the importance of including fragmentation process in SPRM. Finally, our hierarchically structured model selection process allowed us to use the results of both landscape characteristics and human pressure models to develop recommendation at the appropriate institutional scale. Our study demonstrates that using the best practices in landscape ecology can be useful to robustly inform conservation action.

Largest risk factor: breeding sheep

Livestock species was the major determinant of the risk of attacks in the region, independent of spatial location. This was an interesting finding in view of the fact that most studies look indistinctively at the type of livestock or only focus on high-value species such as cattle (e.g., Miller, 2015; Rosas-Rosas et al., 2008). Our results stress the importance of looking at all individual livestock species in such studies, to avoid hiding unique predation risk gradients for some species.

Sheep producers suffered an extremely high risk of predation, as all except one had suffered at least one attack in the last five years. Sheep are smaller and therefore easier prey than cattle (Amador-Alcalá et al., 2013). In such a region, still dominated by mature forest and where perturbations are relatively small (Turner, 2004), large cats can move freely over the landscape, targeting easy prey such as sheep. Sheep vulnerability could be exacerbated by poor husbandry practices, such as free-grazing or fragile enclosures that have been proven to increase the risk of predation (Zarco-Gonzales et al., 2013). While attacks on sheep may not have as much of an economic impact as attacks on cattle, the significant number of sheep lost to predation can lead people to retaliate or develop negative attitudes against carnivores (Rosas-Rosas et al., 2008; Soto-Shoender and Giuliano, 2011). The number of small sheep-breeding ranches is increasing in the region (Radel et al., 2017), as it requires only a modest investment and it is supported by government subsidies. It may lead to further impact on large cats in the region and eventually become a threat to their conservation.

Limited importance of human pressure

In the Calakmul region, the limited influence of human pressure on livestock predation risk by large cats may be explained by a relatively low human abundance, the predominance of small-scale ranching and subsistence agriculture, and a low hunting pressure (Reyna-Hurtado and Tanner, 2007). However, we believe that the effects of human pressure still encompass important information that should inform future research and practical actions in the region.

First, it highlights the importance of looking at large-scales to accurately understand the effect of human population on predation risk. Furthermore, roads have been shown to strongly limit female jaguar movement (Colchero et al., 2011). Besides affecting jaguar habitat use (de la Torre et al., 2016; Foster et al., 2010; Rodríguez-Soto et al., 2011), increasing human population and activity could also influence attack occurrence in the region. Secondly, while husbandry explains risk of predation in other regions (Carvalho et al., 2015; Michalski et al., 2006), it had a limited effect in Calakmul because practices were generally poor with regards to protection against predation. In tropical regions, people may not have the appropriate knowledge or may perceive implementing mitigation technique as an expensive investment (Peña-Mondragón et al., 2017).

The importance of the fragmentation process

Our research shows that a strong driver of attacks occurrence was related to "natural" landscapes but more importantly to the functional characteristics of the landscape surrounding pastures. This may modify the way predation risk is approached in tropical landscapes, as usually researchers only look at the area of suitable habitat near livestock, assuming that it is one of the variables most related to predation risk (Azevedo and Murray, 2007; Fernández and Paruelo, 2009; Miller, 2015; Soh et al., 2014; Soto-Shoender and Giuliano, 2011). However, our results indicated that habitat connectivity (*Bridge* and *Branch*) at a small scale (0.5 km), the distance to habitat patch, and the abundance of patches large enough to be temporarily occupied by jaguar, better explained attacks on livestock than the area of habitat. Habitat connectivity (De Angelo et al., 2013; Zemanova et al., 2017) and patches of minimum size (Ramirez-Reyes et al., 2016) facilitate jaguar movement and persistence in fragmented landscapes. Furthermore, connectors between forest patches and "false corridor" close to pasture area can allow jaguars, a stalk-and-ambush predator (Zarco-González et al., 2013), to attack. Looking at the area of habitat only might increase the risk of overlooking how some configurations of the landscape may provide easy and safe access to livestock for predators. Calakmul region is a rather well preserved forest landscape (Vester et al. 2007), where connectivity among forest patches and "false" corridors lead to a high predation risk in most of the landscape. Livestock become an

easy additional potential prey in such a landscape. Similarly to Acharya and colleagues (2017), we encourage future SPRM to include fragmentation to better understand the extent of its effect.

Limitations of the study

While we proposed an approach to predation risk that is powerful because it accounts for spatial autocorrelation, and includes spatial and temporal scales in a hierarchical two-dimensional model selection approach, we recognize some limitations. First, other important landscape variables such as wild prey density may influence predation risk (Amador-Alcalá et al., 2013; Burgas et al., 2014) and could help us understand better how puma and jaguar use the landscape. For instance, large cats might actually choose more fragmented parts of a landscape to hunt ubiquitous prey that use small-scale agricultural plots (Amador-Alcalá et al., 2013). Furthermore, water networks (Atwood and Breck, 2012; Behdarvand et al., 2014; Rosas-Rosas et al., 2008; Thorn et al., 2012) may also influence predation risks; we had information regarding yearlong water access for livestock, but it does not represent an accurate estimation of water access by large cats in the region. Second, not being able to discriminate between jaguar and puma predation risks prevented us from studying the specific temporal and spatial patterns of risk factors associated to each species (Miller et al., 2016a). While both species are known to use disturbed habitats, puma has a larger tolerance towards humans and venture more often into modified landscapes (De Angelo et al., 2011; Lantschner et al., 2012). Third, our relatively small dataset resulted in high uncertainty in our parameter estimates preventing us from providing clear practical recommendations and building useful predictive maps. Attack sites were also considered independently of the number of attacks occurred and of animals lost (less reliability exists around those data as ranchers do not consistently report losses, and because they often move the herd after an attack). This limits our analysis by failing to consider the frequency of attacks and by only representing the realized predation risk (where direct mortality occurs in comparison to injured or frightened animals) (Miller, 2015).

Implication for future research and conservation planning

This research, while highlighting challenges associated with predicting predation risk, proposed different tools and approaches to consider for future research. Our research exploited recent knowledge on large cats' habitat use and movement, as well as sophisticated statistical analyses to tackle the challenges associated with spatial estimation of predation risk in a well preserved tropical landscape. Using a geostatistical approach allowed us to control for pseudoreplication, demonstrating that it is possible to not discard spatially dependent data. It also permits running multi-scale analyses that incorporate spatial scales large enough to appropriately encompass predators' movements without incurring into problems of overlapping buffers. However, our research also highlights additional challenges for SPRM. In fact, our results shows a widespread risk of predation with large credible intervals, limiting its use to understand trends in the risk distribution. Our research shows as well that caution should be taken with predation risk maps: in Calakmul, for example, explanatory variables are highly dynamic in time (e.g., livestock practice, and to a certain extent, fragmentation) and zones of high risk might vary quickly over time. This highlights the importance of considering temporal scales in the evaluation of risk.

Furthermore, while husbandry practice did not explain predation risk in this study , it does not mean that it cannot be effective to protect livestock. Further studies should try to understand if the risk of predation on sheep is related mainly to 1) poor husbandry, and if so, how to improve it; 2) sheep characteristics (e.g. size, docility, and anti-predator behavior) (Amador-Alcalá et al., 2013; Miller et al., 2016a) or; 3) large cats becoming accustomed and inclined to kill livestock opportunistically (Azevedo and Murray 2007; Rosas-Rosas et al. 2008). Additional studies tracking the movements of large cats could actually give interesting information on how often large cats visit pasture areas and if predation on livestock in the region is performed by the same individual repeatedly, indicating the potential to manage problem animals (Polisar et al., 2003).

By addressing predation risk under hypotheses related to either landscape characteristics or human pressure and using a hierarchical selection of variables, we facilitate decision making in conservation management at the appropriate organizational level (household, reserve or

regional entities). For example, while policy should encourage restoring connectivity in the landscape to ensure large cats conservation, it might increase predation risk. Complementary actions should then be implemented to address the impact on ranchers and the potential resulting conflict among actors. Those actions should be more related to the human component and target livestock management practice at a community or ranch level. This further implies the development of economic incentives, such as veterinary care or provision of certificates for good livestock practices (Peña-Mondragón et al., 2017), to increase ranchers' capacity and willingness to adopt good practices to co-exist with large carnivores.

Finally, conflicts related to large cat management are not only related to the real risk of depredation (impact) but also other sociological data, such as attitudes, perceptions and beliefs related to large cats. For example, more research should be spatially investigating the tolerance (Atwood and Breck, 2012) or perception of risk (Miller et al., 2016b) of those animals as they might be important determinants of people willingness to retaliate. Conservation measures to address social aspects would differ from the technical solutions usually proposed, and would include approaches to prevent tensions and social conflicts among actors involved in large cats' management (Redpath et al., 2015). By incorporating social data, risk maps will improve their potential to support large cat conservation.

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CHAPTER 3

BUILDING ON COMMON GROUND TO ADRESS BIODIVERSITY CONFLICTS AND FOSTER COLLABORATION IN ENVIRONMENTAL MANAGEMENT

Description of the article and contribution

This chapter focuses on the notion of biodiversity conflict and common ground. As explained in the introduction, I built this thesis using a constructive approach, sensitive to the fact that the purpose of research should make sense to local actors and the context in which it takes place. I first wanted to verify if jaguar management was considered an issue by local actors, and understand how it was embedded in the regional context of environmental management. Through a mixed method of qualitative interviews and quantitative analysis. I proposed a critical analysis, identification, and quantification of the notion of common ground. Firstly, I showed that people from the same occupational communities do not share more common ground than with others, as sometimes assumed under collaborative process (engaging with persons representing the government, NGOs, and productive sector, for example). Secondly, I suggested the use of a new framework that incorporates importance and the degree of common ground among actors around multiple issues, to decide which issues to address during the initial stages of collaborative conservation. The pursuit of common ground allows us to understand the wider context of environmental management, highlighting potential solutions across different issues. It also pinpoints relevant issues to address in order to support a successful first collaboration while allowing actors to build relationships and trust, which can support future cooperation. Finally, while this chapter addresses environmental management issues at large, it allowed us to confirm that the management of jaguars in the region was an issue that was attached to strong feelings of injustice.

For this article, I developed the qualitative approach and the sampling strategy with the support of Sophie Calmé, Rehema White and Birgit Schmook. I collected the data with an assistant, Juan Carlos Joo Chang. I performed the quantitative analyses with the help of Cedric Frenette Dussault for coding on R. I wrote the main text of the manuscript. Sophie Calmé, Rehema White and Birgit Schmook commented on previous versions of the article, helping me with English editing, the structure of the manuscript and the clarification of concepts. This article will be considered after substantial revision by *Journal of Environmental Management*.

Building on common ground to address biodiversity conflicts and foster collaboration in environmental management

Lou Lecuyer, Rehema M. White, Birgit Schmook, Sophie Calmé

Abstract

Conservation biology faces critical challenges that require collaborative approaches, including novel strategies to support interactions among actors in biodiversity conflicts. The goals of this study were to investigate the concept of common ground across multiple issues and to explore its practical application for the support of environmental management. We conceptually defined common ground as the areas of relevance underlying the suite of issues expressed by people regarding environmental management in a particular context. We then empirically tested this in the Calakmul region of Mexico, where the complex socio-historical context and high biodiversity have created environmental management challenges that are now being addressed by a local, multi-stakeholder management board. We conducted 26 open interviews with members of the board and a further round of quantitative prioritisation of issues raised . Using a coding process designed to reveal common ground, we categorized the issues at four levels ranging from coarse to fine (*themes*, *topics*, *sub-topics* and *perspectives*). We then analysed two

levels, *topics* (n=14 issues) and *sub-topics* (n=51 issues). To do so, we built common ground matrices to identify and analyse common ground among actors and across issues. First, cluster and non-metrical data analyses revealed the diversity of actor positions and the lack of consistent grouping among actors by occupational activity. This demonstrated that focusing on actors' differences might be misleading, and that actors' views were not closely aligned with their roles. Second, we located issues according to their levels of common ground and importance among actors. We showed that by not focusing on single issue conflicts, the identification of common ground across multiple issues can pinpoint synergies. We then proposed a framework for collaboration that prioritizes issues of high importance with greater common ground (e.g. sustainable resource use activities), to support the development of trust and norms of reciprocity among actors, strengthening the potential for future cooperation. By adopting this approach, environmental managers could support the initial stages of collaborative conservation strategies, engaging with other actors to seek common ground, avoid the creation of polarised groups and help effectively manage biodiversity conflicts.

Keywords: Biodiversity conflict, actor identity, collaborative approaches, Calakmul, Mexico.

Introduction

It is now accepted that ecological knowledge-gathering alone is insufficient to achieve biodiversity conservation (Ehrenfeld, 2000). Conservation practitioners have called for alignment of conservation with larger social concerns (Bennett et al., 2017; Forbes, 2011) and greater input by multiple actors to influence the pursuit of sustainable and equitable development (Giller et al., 2008). This trend is in line with arguments in favour of collaborative approaches in environmental management to build trust and accommodate multiple perspectives to more succesfully manage biodiversity conflicts (Gutiérrez et al., 2016; Redpath et al., 2013, 2015, 2017). Biodiversity conflicts are defined as conflicts between groups of actors with differing interests, where at least one group acts against the interests of another (Marshall et al., 2007).

Collaborative conservation strategies have received attention within studies on collaborative governance, adaptive co-management and knowledge co-production, among others (Berkes, 2009; Bouwen and Taillieu, 2004; Cash et al., 2006; Plummer, 2009). Collaboration is situated at the higher end of involvement on the participation spectrum (Davies and White, 2012) and culminates in a collective entity acting together and sharing the consequences of their actions (Bouwen and Taillieu, 2004). Collaborative approaches typically include: 1) phases comprising limited interaction between actors, joint working then action implementation (Plummer, 2009); 2) an iterative process, including monitoring for each phase and adaptation to new conditions (Fabricius and Currie, 2015; Plummer, 2009); and 3) an emphasis on the social process and context specificity surrounding the approaches (Armitage et al., 2009; Plummer and Hashimoto, 2011). Some studies have investigated the exogenous variables (e.g. ecosystems change or economic drivers) and endogenous variables (e.g. organization attributes, individual traits) that influence the emergence and outcome of these collaborative approaches (see review by Plummer, 2009). Other studies have explored the wider social processes of collaboration and have proposed different typologies of collaboration (Diaz-Kope and Miller-Stevens, 2015). Previous works have distinguished collaborative approaches according to their organizational arrangement (i.e. the level of coordination between entities, Mandell and Steelman, 2003); the goal of the collaborative approach (i.e. from informal collaboration to action implementation; Agranoff, 2006; Margerum, 2008); membership composition (e.g. government/agency based or citizen based; Moore and Koontz, 2003); and the type of governance (i.e. interagency, cross-sector or grassroots governance; Diaz-Kope and Miller-Stevens, 2015).

In this study, we explored a novel approach to support the collaborative activities of the *Consejo Municipal para el Desarrollo Rural Sustentable* (CMDRS, Council of Rural and Sustainable Development in Calakmul), a multi-stakeholder management board in the Calakmul area of Mexico. The complex socio-historical context and high biodiversity have led to a diversity of actors and approaches to environmental management and have created a number of active or potential biodiversity conflicts (Lecuyer et al., 2018). Not all collaborative approaches

stem from conflicts, but biodiversity conflicts can be seen as an opportunity, creating an imperative for people to work together to manage their problems (Fabricius and Currie, 2015), and collaborative approaches have been used in conflict resolution (Butler et al., 2015). The CMDRS was created in 2005 as a state effort to facilitate cross-sector approaches to sustainability. However, since its creation, the CMDRS has struggled to develop a coherent agenda and maintain interest, participation and action (MLL., SC., BS., participant observation). Through this research, we explored with them ways to facilitate the co-management of natural resources in the region.

Initial steps of active collaboration are described as crucial moments when actors need to realize their interdependency in managing shared resources (Bouwen and Taillieu, 2004). In this study, we focus on what has been called the initiation phase of the decision process, where problems have to be identified and placed on the public agenda (Clark et al., 2001). Creating actor interaction, often targeted according to actor roles (e.g. NGO, policy maker), and identifying matters of mutual interest (i.e. common ground) are among the first challenges of collaborative strategies (Fabricius and Currie, 2015). Many studies related to government/agency-based collaboration have undertaken analyses of which actors to engage (see Reed, 2008). However, the notion of common ground, while suggested by some authors (e.g. Bouwen and Taillieu, 2004; Fabricius and Currie, 2015; Manzo and Perkins, 2006) has not been well defined and has been left open to interpretation. Often, researchers investigate the differences at an institutional, rather than individual, level (see Davies et al., 2013) and tend to assume that a lack of common ground arises from "occupational communities" (Schein, 1996), i.e., groups in which shared assumptions are typically generated by educational background and working activities. Doing so increases the risk of developing dichotomous categorizations of perspectives, which can be an obstacle to finding common ground (Flores and Clark, 2001). Additionally, focusing on a single biodiversity conflict limits the potential to discover common ground among actors.

The overarching aim of this study is thus to investigate the concept of common ground among actors and across multiple issues to seek how it can practically inform processes that

support environmental management. We specifically ask the following research questions: 1) How can common ground be defined in the context of environmental management? 2) How can common ground be identified among actors and how does it relate to group identity? 3) How can common ground be identified across multiple issues? 4) How can the exploration of common ground support collaborative approaches in environmental management in practice? We address the first question in the literature review section below, and the following questions in the case study on the CMDRS of Calakmul that follows. What we propose is a new mind-set to engage people in collaborative approaches for conservation; the establishment of ground work preceding the selection of particular tools to use for decision-making or management.

The notion of Common Ground

The notion of common ground in the field of environmental management is recognized to be important, but it has not been defined or operationalized and it has been used in diverse ways as a synonym for common interest, common knowledge and common understanding (Bouwen and Taillieu, 2004; Brunner, 2002; Manzo and Perkins, 2006; Patterson et al., 2003; but see Flores and Clark, 2001; Bath, 2000). Meaning(s) of common ground, approaches to identify common ground, and mechanisms to support its development are thus important, but neglected elements in facilitating collaboration for environmental management. In this section, we investigate how common ground has been used and defined in other fields, and then propose a definition which enables us to explore this notion in practice.

In the context of collaboration, the definition of 'common' would be "belonging to or shared by two or more people" or by "members of one or more nations or communities" (Collins English Dictionary online, 2014). 'Ground', in this context, describes "a position or viewpoint, as in an argument or controversy" (Collins English Dictionary online, 2014). When linked together, 'common ground' has been defined as "shared beliefs or interests, a foundation for mutual understanding" (Ammer, 2003). Common ground thus goes beyond simple shared interest and is not a synonym for mutual understanding but rather a factor that will facilitate it. Furthermore, the regular definition of common ground omits the geographical dimension of

'ground'. Space and place are important in the search for common ground in environmental management (Manzo and Perkins, 2006). This dimension has been investigated under the concept of place attachment, which refers to an emotional, cognitive, and functional bond with a place (Jorgensen and Stedman, 2001). Places, and ground, are then more than physical settings but also bear witness to dynamic contexts of social interaction (Stokowski, 2002). We propose in this research to define common ground as the areas of relevance underlying the suite of issues expressed by people regarding environmental management in a particular context.

Common ground should not be confused with common interest, because the latter is value-laden and the decision of who holds a legitimate interest is subjective (Reed, 2008). In adopting a definition of 'common ground' in the context of this study, we argue that using vocabulary focusing on interest does not foster collaboration, as it emphasizes that a particular interest is at stake and has to be defended against other interests. Similarly, we reject the term 'stakeholder', often defined as people having an interest or 'stake' in a subject, for the term 'actor'. 'Actor' is particularly appropriate in describing people as an active and interactive part of a conflict, with agency for collaboration and potential to act differently in response to diverse issues and conditions.

The concept of common ground also differs from that of social capital. Social capital has been associated with collaborative processes (Pretty, 2003), since a participation process leads participants to view themselves in relation to others (Flores and Clark, 2001). Whilst it is a contested concept, social capital often refers to the social bonds, norms, and resulting benefits that can be mobilized to facilitate action (Adler and Kwon, 2002). Social capital refers then to relationships between individuals (Barnes-Mauthe et al., 2015) whereas common ground is associated with the issues concerned. We acknowledge some cross influence as social capital might help develop common ground around issues, and successful collaboration can help develop social capital (Margerum, 2008).

Finding common ground may not guarantee conflict resolution, and does not prevent differences between actors. Other concepts are important in collaborative processes, such as

trust (Young et al., 2016) or adequate leadership (Emerson et al., 2012). Alternative frameworks to initiate collaboration have been proposed (e.g. actor agreement over issues: Marshall et al., 2007; comparison of actors' identities, demands and expectations: Flores and Clark, 2001). Nevertheless, together with other researchers (Fabricius and Currie, 2015; Patterson et al., 2003) we believe that exploring common ground will enhance understanding of environmental issues, allow for less dichotomized forms of communication and create more productive long-term dialogues. In the following sections, we now explore the concept of common ground within an empirical case study.

Methods

Study area

Calakmul, in the southeastern state of Campeche, Mexico, is a conflicted area with a complex socio-cultural history and rich biodiversity (Haenn, 2005; Turner et al., 2004). In the 1960s, Mexican national policy promoted agricultural development in this densely forested region by granting *ejidos* (communal lands). In response to agricultural pressures and international commitments, the Calakmul Biosphere Reserve was created in 1989 encompassing 723,185 ha, making it the largest tropical forest protected in Mexico. The Reserve's delineation and establishment were mostly undertaken without local consultation, leading to conflicts between those who depend on the land for production and those who sought to conserve it, reinforcing state presence in the region (Haenn, 2005). The municipality of Calakmul was then established in 1997, centered on the Calakmul Biosphere Reserve, which covers half of the municipal territory.

Calakmul is home to 28,424 inhabitants (INEGI, 2015), who are mostly engaged in nature-based economic activities such as subsistence agriculture (maize), livestock production, chili cultivation (*Capsicum spp.*), timber logging, charcoal production, allspice (*Pimienta dioica*) harvesting, beekeeping, tourism, and handicrafts (Turner et al., 2004). However, recent

years have seen an increase in rural households depending on state subsidies, salaried labour, and labour migration to the nearby tourist corridor of Cancun – Playa del Carmen and the USA (Haenn, 2011). Calakmul's recent history of immigration from other parts of Mexico has created a mosaic of customs, languages, religions and agricultural practices, which constitutes a challenge for its inhabitants to work peacefully together (Ericson, 2006).

Additional challenges for environmental management in the region are linked to its natural conditions and unpredictable, ambivalent governmental policies. Calakmul is a tropical karstic landscape with thin and stony soils, where rainfall is seasonal and periodic droughts are common (Márdero et al., 2012). Consequently, there are few surface-water bodies (García Gil et al., 2002) and water is a rare resource, especially during the dry season, making it a difficult farming environment. Furthemore, national conservation policies and global institution funds related to a conservation agenda, which promote non-resource or alternative forms of production (e.g. ecotourism, organic farming, agroforestory programs) are often in contradiction with other national programs that facilitate access to farming and agricultural inputs (Haenn, 2005). Coupled with a complicated land tenure system, conservation efforts are then often deflected by a power struggle between producers and the government (Haenn, 2005). This conflicted context makes it a particularly interesting location and context to study common ground.

Data collection

To explore people's matters of concern regarding environmental management in Calakmul, and to enable investigation of potential common ground, we used a mixed method approach combining qualitative and quantitative data collection (see Creswell and Clark, 2007). Qualitative approaches gather detailed and specific information about people's values, perceptions, and experience, and enable us to understand the wider context in which complex events occur (Miles and Huberman, 1994). In June 2014, we carried out 35 open-ended individual interviews ranging from 50 to 90 minutes each. Our open-ended interviews began by asking: "which issues regarding the environment concern you in your community/organization?" This allowed the initiation of an open conversation in which the role

of the interviewer was to maintain a discussion of environmental management issues and to obtain clarification or additional information on some issues raised by participants, as described by Turner (2010). Only issues raised spontaneously by the interviewees were addressed.

We first interviewed 26 participants from the CMDRS, using purposive sampling (Oliver and Jupp, 2006) to select representatives with a diverse array of knowledge and values. The CMDRS included, at that time, 42 members, of whom 30 regularly attended meetings (pers. obs.). It is composed of elected representatives (elected for a three year term at the municipal level and also at the community level), federal officers, NGO representatives, academics and representatives of local producer groups. Theoretical saturation (Miles and Huberman, 1994) was reached rapidly, in that no additional environmental issues were mentioned by our participants after approximately ten interviews. However, our objective was not merely to identify issues, but also to develop a deeper understanding of commonalities on perspectives and topics. We thus continued interviews with a larger number of actors to seek and analyze 'common ground'. Furthermore, we wanted to ensure that these representatives raised all environmental issues that mattered to local communities, hence we conducted nine additional interviews with local actors who were not associated with the CMDRS. These interviews did not highlight any additional issues. Because we wanted to support collaborative approaches through the multi-stakeholder management board, we present here only the analysis of the 26 interviews of CMDRS representatives.

We presented preliminary results to the CMDRS and their feedback was that for environmental management, they wanted to know not only about common ground but also about the importance of the issues raised. We thus undertook a second, quantitative phase of data collection. To reveal the importance that people attached to the issues they raised, we re-interviewed 22 of the 26 actors (four actors could not be reached again). We presented them with a questionnaire asking to rate each issue raised during their open-ended interview and identified by our coding process, from 1 (higher importance) to 3 (lower importance).

Data analysis

Coding and categorization

For our initial analysis, we applied a general inductive approach in which codes were developed from the transcript of the open-ended interviews and the following categories emerged only from the data (Thomas, 2006). This approach was selected because the objective of the analysis was to present data and contribute new understanding, in our case potential common ground among actors, rather than test theory (see Creswell and Clark, 2007). An initial descriptive coding captured all issues raised by participants. We then developed from the initial descriptive coding a hierarchical category system (Thomas, 2006) to allow us to reveal common ground. We started with a detailed level of categorization called *perspective* that grouped our initial descriptive coding into 158 items (see Supp. material 1). This level of categorization is not presented here because these items were too detailed to capture common ground. These detailed items were grouped under a coarser category called *sub-topic*, which was again grouped under a category called *topic* and finally into *theme* (Figure 1, see Supp. material 1).

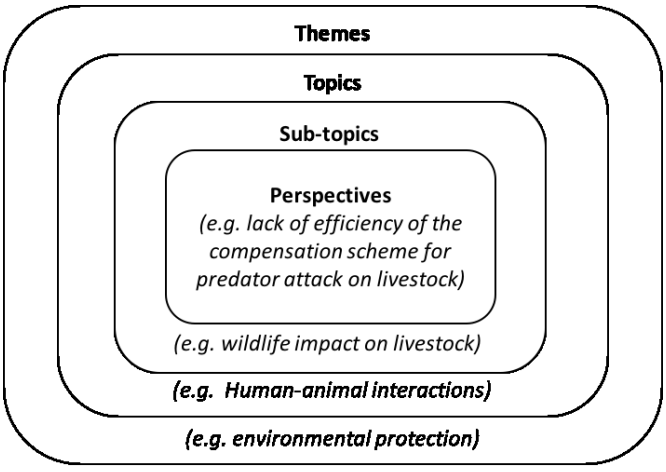

Figure 3.1 Detailed coding identified people's particular *perspectives* about the issues they raised; *perspectives* are grouped under a second, broader category, representing the *sub-topics* peoples raised; *sub-topics* were then grouped in *topics*; a final coarser category represented the *themes* underlying *topics*.

Framing of the categories was undertaken in line with our definition of common ground, focusing not on the direction of interest or perspective, but rather highlighting areas of relevance underlying the issues participant adressed. For example, *lack of mitigation measures* and *retaliation against jaguars* are two perspectives that could be considered as opposing views, but that were grouped under the issue of *animal impact* at the sub-topic level. Also, productive activities were framed and grouped together to emphasize the common issues raised, instead of insisting on differences. These *topics* were natural resource-dependent activities (i.e. agriculture, livestock production and timber harvesting), alternative activities (i.e. handcrafting and tourism) and perceived sustainable activities (i.e. management of secondary forest and beekeeping). Interview coding was undertaken by the first author, with discussion and clarification of codes among all authors to strengthen the rigor of coding and allocation of hierarchical categories. The coding system was verified with participants collectively during a presentation to the CMDRS and individually during the following quantitative interview. In the latter process, participants were invited to offer perceived missing information (e.g. two participants raised additional issues during the second round of interviews that were then integrated in the common ground matrices). Longstanding engagement with participants over the years also made us confident that our categories were meaningful and broadly representative of different positions.

Common ground matrices across categorization levels

Our hierarchical category system was then subject to a form of quantitative content analysis. Quantitative content analysis allows us to offer additional visual interpretation and theoretical and practical insights (Creswell and Clark, 2007). Firstly, for each level of category, a common ground matrix was created in which actors as individuals were listed in columns, and issues of this particular category were listed in rows (see Bath, 2000). The matrix was populated with '1' if an actor spoke about this particular topic or sub-topic and '0' if they did not. Common ground was then computed at each level of categorization as the sum of actors, who addressed a particular issue in line with our definition. The values in the common ground matrices were used for the subsequent analyses.

Logically, the categorization process will influence this analysis, with common ground anticipated to increase from fine to coarse category levels, because coarser categories comprised a number of issues raised by different individuals and listed in finer category levels (see values summary of the common ground matrix in Appendix 1). We thus decided to explore across different levels of categorization in order to draw more rigorous theoretical insights and practical implications from our research. We ran the analysis at two levels of category where common ground existed but still showed variability (see appendix 1): *topics*, represented by 14 issues, and *sub-topics*, represented by 51 issues (see list in Figure 3). Our other category levels were too broad (*themes*) or too detailed and directed (*perspectives*) and were not used to quantify common ground but instead informed our qualitative and quantitative analyses (see appendix 1). We also retained the voice of participants through offering representative quotes in relation to higher categories.

Common ground and group identities

We wanted to know if common ground between actors at the two levels showed a grouping pattern related to predetermined groups of actors. To explore the manifestation of common ground among groups, each participant was assigned to a group to verify if group identity was a valid predictor of issues raised and potential for common ground. Groups were elected governmental representatives (EG; 6 participants), non-elected governmental representatives (GI; 6 participants), non-governmental organization representatives (NG; 6 participants) and production group representatives (PG; 8 participants). We then ran a hierarchical cluster analysis for each of the common ground matrix levels of topics and sub-topics and performed a nonstatistical validation analysis (see Supp. material 2, Murtagh and Legendre, 2014). Cluster analysis has been used as a heuristic method to recognize objects that are sufficiently similar to be placed in groups (Murtagh and Legendre, 2014). The results did not confirm the preset grouping pattern nor illuminate any other clear pattern of grouping. We therefore chose to visually represent the relationships between individual actors according to common ground at the topic and sub-topic levels, and performed a complementary nonmetric multidimensional scaling analysis (NMDS). The NMDS analysis allows us to represent the

actors on a two-dimensional graph while preserving the ordering relationships. We used the metaMDS function of the vegan package in R, using Jacquard distance in our matrices (actor × *topics* and actor × *sub-topics*).

Common ground and issue importance

We visually explored the relationship between the levels of common ground and importance of each issue in order to highlight areas for potential initiation of collaboration. Common ground values were standardized to their Z-score values in order to be able to compare the two levels of categorization. The indicator of importance was determined by calculating the mean importance score (1, 2 or 3) that participants individually associated with each issue.

Results

Common ground among actors and group identity

The first part of our results illustrates individual actors' positions according to their common ground. The hierarchical cluster analysis (see Supp. Material 2) and the NMDS, did not reveal any pattern of actor grouping, neither at the *topic* (Figure 2, left) nor at the *sub-topic* levels (Figure 2, right). In other words, the actors we interviewed seemed to have diverse and individual views when talking about environmental issues in Calakmul, and we did not find groups in line with our *a priori* allocation of actors to membership of particular groups. Each level of categorization, while presenting similarities in the ordering relationship, also show some differences: while at the *topic* level two actors may show high similarities, the same two actors may be highly dissimilar at the *sub-topic* level (e.g. PG6 and EG2; Figure. 2). This confirms that the level of categorization can influence common ground identification among the actors.

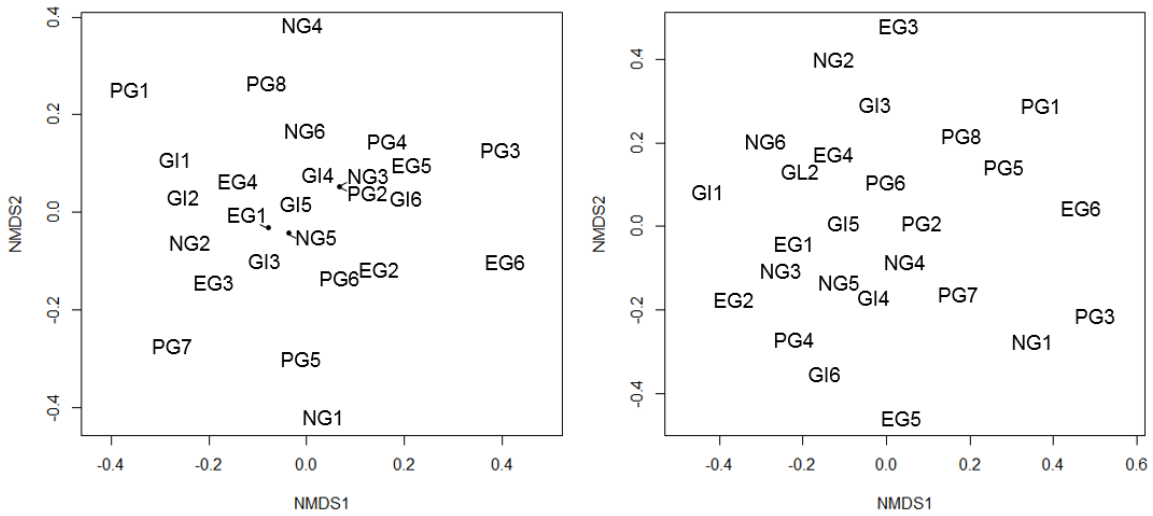

Figure 3.2 Relative position of the actors according to *topic* (left) and *subtopic* (right) using a non-metric multidimensional scaling analysis. Codes for actors are found in section 2.3.3.

Whilst the previous analysis did not show any grouping patterns, looking in detail at participants' answers for every single topic and sub-topic provided additional information regarding potential role categorizations (unpubl. results). In fact, the role of actors did cause some polarization of views when analyzing sub-topics one by one. For example, actors within our defined groups had different training priorities. The sub-topic of training capacity (#1.1) under the topic of natural resource-dependent activities (see Suppl. Mat. 1) was only raised by elected or representative members of governmental institutions, whereas this sub-topic (#2.3) under the topic of alternative activities was raised principally by members of production groups. Our results thus show that, far from being static, actors' positions and common ground with other actors vary among issues, with group membership partially determining the responses of individuals within some of the finer categories. Hence, focusing only on one sub-topic or topic could risk polarization of perspectives, whilst viewing multiple issues reveals less polarization and a greater potential for finding common ground.

Common ground across issues and levels of importance

In this second part of our results, we investigated common ground and perceived importance across issues rather than across actors (Figure 3). At the *topic* level (Figure 3, top), six topics demonstrated a high degree of common ground between actors, and high importance. Two of those topics, biodiversity loss (#5) and human-animal interactions (#7), are directly connected with the biophysical environment. These two topics represent a variety of perceptions of the severity of environmental threats and potential management actions: while one actor noted that "*people still cut down trees, still burn indiscriminately, keep hunting randomly and still damage the environment*" (GI2), another informant described a "*rate of deforestation that doesn't put ecosystems at risk*" (GI6) and another emphasized that it was important "*overall, to maintain connectivity between the reserves*" (NG6). Two other topics, actor relationships (#14) and governmental capacity (#13), reflected a common desire for more participation, more power-sharing, and more efficiency in governmental processes. For example, one elected government representative said "*…there are programs […] that apply to the entire country or the whole state, when they should contain distinctive features for Calakmul, and this, at the end, has a negative effect on our capacity to care for the environment*" (EG1). The last two important topics with a high degree of common ground included alternative activities (#2) and perceived sustainable activities (#3), illustrating a shift from exploitation towards conservation. Some issues exhibited less common ground but were still considered important. For instance, water access (#9) is important because access varies across communities. Finally, because issues were all raised by participants themselves in the open interviews, only a few of them were ranked as having low importance.

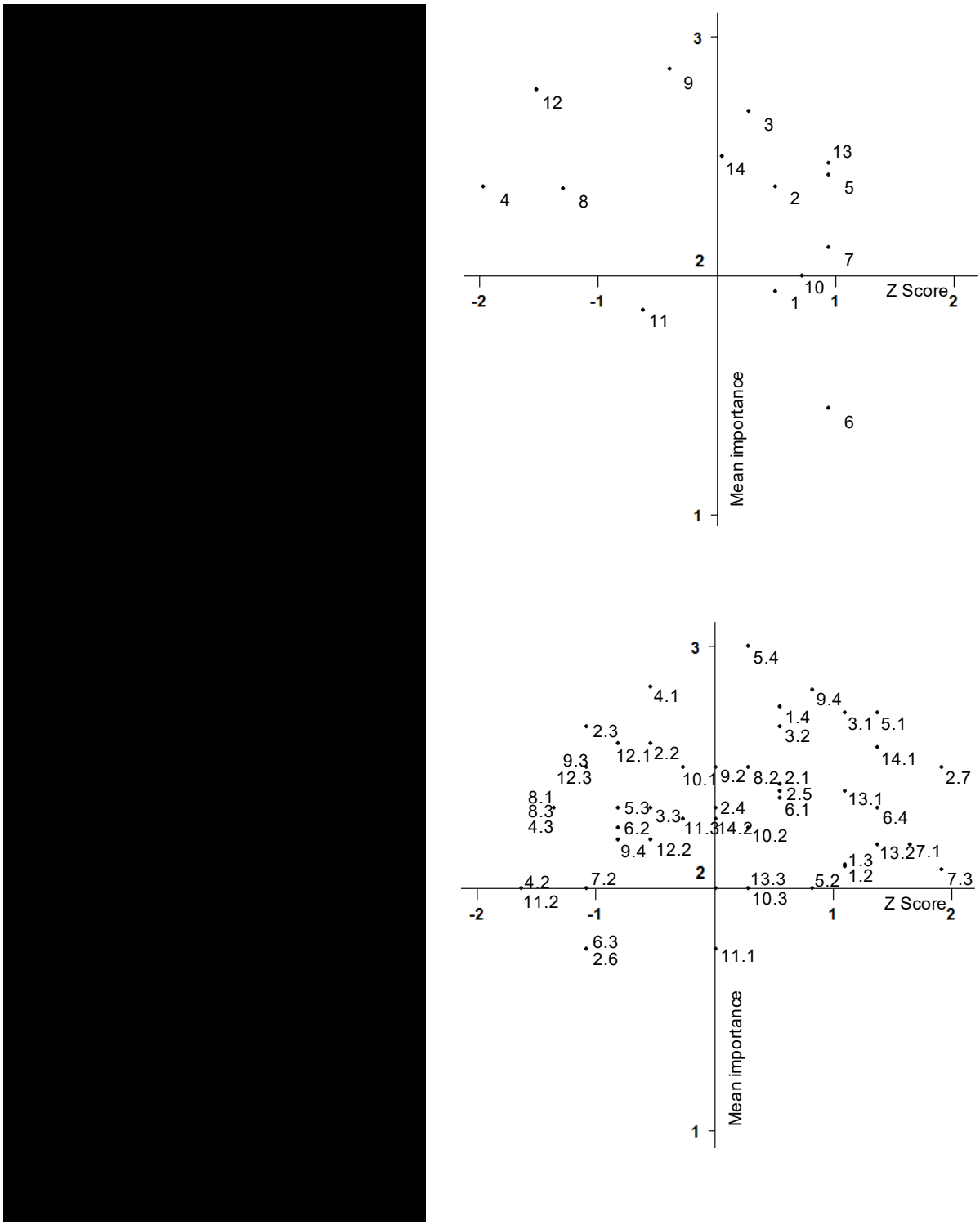

Figure 3.3 **Position of issues according to common ground (represented by Z-score) on the x-axis, and their importance on the y-axis: the upper figure represents the 14 issues at the *topic* level; the lower figure represents the 51 issues at the *subtopic* level. *Topics* and *subtopics* are listed and numbered on the left side.**

The *sub-topic* level (Figure 3, bottom) allowed for a deeper exploration of actors' positions toward issues and their importance. The positions of the sub-topics related to one particular topic were not situated in exactly the same part of the graph as seen at the *topic* level and they were not grouped together. This allowed us to investigate which sub-topics seemed to prevail in actors' perceptions of a particular topic. For example, the topic concerning alternative activities (#2) (high degree of common ground and high importance) was broken down into seven sub-topics (see Figure 3). Out of these seven sub-topics, only three remained in the section with high common ground and high importance: development opportunities (#2.1), commercialization (#2.5), and environmental integrity (#2.7). Thus, under the alternative activities topic, actors seemed to share particularly high commonalities toward the development and promotion of activities such as ecotourism. Issues regarding training capacity (#2.3), infrastructure requirements (#2.4), or financial solvency (#2.2), were still important but yielded less common ground.

This analysis also identified sub-topics with high common ground and high importance that were not revealed at the coarser *topic* level (Figure 3, bottom). For example, two issues related to extractive activities fostered more perceived importance at the *sub-topic* level: pollution and unsustainable extraction (#1.3), and the need for technical improvement (#1.4). Those two issues were closely related and highlighted potential impacts of agriculture or livestock production on the environment and the necessity to improve current practices, as expressed by a representative of a production group, "*…because if we increase [agricultural] productivity, well, I won't be chopping trees anymore*" (PG4).

It is also possible to get a better understanding of contentious sub-topics under topics that show little common ground (Figure 3, bottom). Sub-topics with little common ground are the price of water (#9.3) and water management (#9.4). This reflects the discrepancy between communities that have year-long water access and communities that may experience water scarcity during the long dry season and only have limited access through water trucks. One production group member reported (NG3): "*not everyone has a pipeline or wells and sometimes people have to buy water from far away and it's expensive*".

Finally, one strength of examining the sub-topics is the opportunity to pinpoint synergies across various issues (Figure 3, bottom). For example, an existing

initiative in the region is tackling more than one of the sub-topics regarding animal impacts (#7.1) on livestock breeding, and monitoring (#5.5): a local NGO and the reserve provide camera-traps to cattle ranchers to enable them to capture evidence of large carnivore attacks for compensation claims within the risk zone. Another synergy that addresses multiple issues would be for conservation programs to support water access, be it for human consumption or for sustainable activities (#9.3, #9.4). This would reduce pressure on natural seasonal water bodies (#5.4) that are essential for the survival of a number of wildlife species.

Discussion

This study presented a detailed analysis of the notion of common ground and explored how it could in practice support collaborative approaches to address biodiversity conflicts and ultimately lead to adaptive environmental co-management initiatives. We believe that exploring the concept of common ground permits us to envision and implement new strategies to understand and support forms of conservation practice that use a positive and future-looking approach, incorporating increased societal negotiation and acknowledging wider context.

We first question the common practice of grouping actors by their role (e.g. policy-makers, NGO members) and agree with the few authors who have shown that shared perspectives can be patchy within and across groups (Schein, 1996; Van Wyk et al., 2008). Within our study, and in line with single-issue studies, we did find some polarization of actors when focusing on single, specific issues. However, we also demonstrated through our open, grounded methodology that when we viewed multiple issues together at the topic and sub-topic levels, our data did not reveal consistent group patterning, indicating that assumptions of group characteristics and views can be misleading. The existence of strong sub-groups can present a challenge to develop joint action and can reinforce the risk of ‘‘us-and-them’’ attitudes among actors (Bodin and Crona, 2009, Flores and Clark, 2001). False categorizations can polarize actors and highlight their differences and how they compete, which does not promote biodiversity conflict management (Skogen and Krange, 2003). Although we had only small numbers of participants in each of our pre-determined groups,

participants were involved with the multi-stakeholder management board CMDRS and as such held key informant rather than random participant status. Furthermore, grouping of actors could also be undertaken differently (e.g. according to the objectives of their organizations) which might result in a different number of groups. However, our choice of grouping was selected to explore the way people are categorized according to their occupational activities (Schein, 1996), as in other studies of collaborative approaches. While people's interpretations of their environment are becoming increasingly individualized (Flores and Clark, 2001, Patterson et al., 2003), we propose the recognition of both individual and group priorities and the necessity of multi-issue investigation. Looking at multiple issues together may avoid the artificial creation of strong sub-groups on single issues and uncover potential common ground, therefore enabling us to build more collaborative processes.

The second part of this research operationalized the identification of common ground among multiple issues and investigated how it can support early stages of collaborative strategies. To turn a set of conflicted actors into constructively interacting actors, social relations have to be generated among them (Bodin and Crona, 2009). Fostering the development of actors' relationships and collaboration has proven to support natural resource governance (Hahn et al., 2006) and the management of biodiversity conflicts (Redpath et al., 2017). However, collaborative experiences can produce mixed outcomes and depend on context and timing (Berkes, 2009; Heinmiller, 2009). So, how can the exploration of common ground support collaborative approaches in environmental management in practice? In the case of the CMDRS, defining and prioritizing the issues on which to focus has proven to be challenging, limiting the engagement of the different actors in this collaborative approach. We then mapped multiple environmental issues according to their level of common ground and, in response to the need expressed by the CMDRS, according to their importance. Whilst additional factors influence the early success of collaboration (see Plummer et al., 2009 for a comprehensive list), we propose to intitiate active collaboration with an issue of high common ground to support the first collaborative steps. Furthermore, building on common ground will be important for future collaborative initiatives as positive initial collaborative experiences have been shown to support the

development of trust or shared knowledge, further enhancing actors' capacity for collective action (Berkes, 2009; Davies and White, 2012; Hahn et al., 2006).

To support collaboration, we suggest an adaptation of the framework proposed by Marshall et al. (2007) to address biodiversity conflicts. Whilst those researchers proposed to locate issues according to the level of importance and position of actors, we refine their approach by accounting for the degree of common ground among actors, rather than emphasizing a dichotomous position on issues (i.e. agree/disagree). We suggest then that collaboration could be developed by first addressing issues with high degrees of common ground and importance (quadrant 1 in Figure 4). Secondly, issues with high common ground but low importance (quadrant 2) could be tackled; whilst of perceived low importance, addressing them may help to further develop collaboration. Issues in quadrant 3 have lower common ground but higher importance, which will be potentially more contentious and hence better avoided until collaborative processes are well established and mature (e.g. Berkes, 2009). Issues in quadrant 4 of less importance and little common ground should not be prioritized. The application of the framework at different categorization levels could also be useful for identification of issues more considerate of local perspectives and priorities (as advised by Van Wyk et al. 2008). Whilst coarser levels may give prior direction to regional or large research programs, more detailed levels include local perspectives and opportunities for smaller scale collaborative projects.

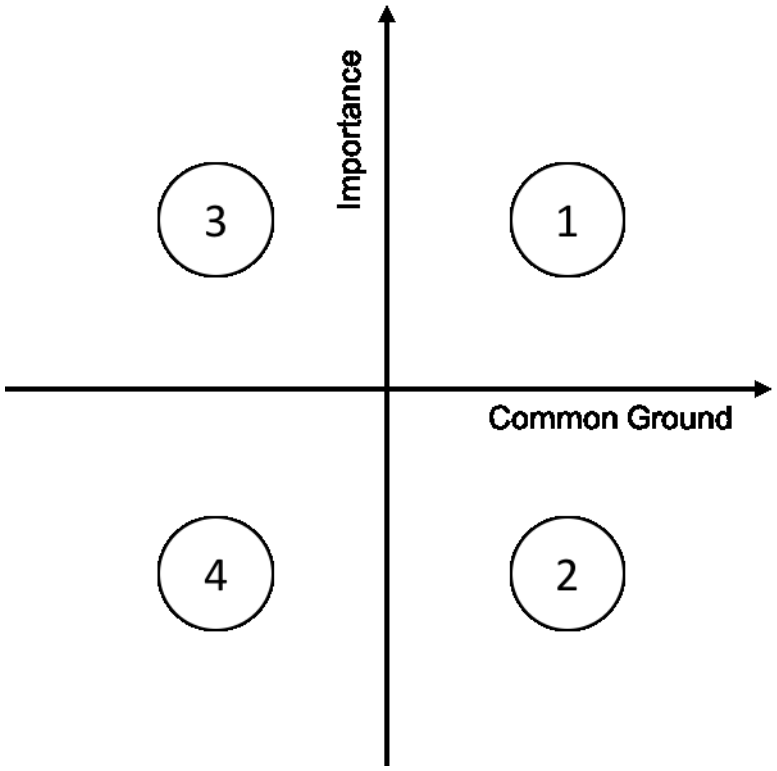

Figure 3.4 Proposed order of collaborative action on different issues according to the level of common ground between actors and the perceived importance of the issues.

How can this approach be used in other case studies and be useful to environmental managers? We are aware that our work focuses on one particular type of collaboration, which can be described as a government/agency-based collaboration, in which only a small number of participants are enrolled with specific representative roles and expected contributions. The present research proposes an elaborate codification process that may seem overwhelming at first sight. However, the multi-level coding analysis was used principally to understand the type of codification necessary to uncover common ground. What level of precision regarding people´s perspectives would be of practical use, and for whom? We believe that managers should focus on the level of precision necessary for their project. For instance, management in a specific biodiversity conflict could start with more focused questions, if managers want to explore detail (e.g. wolf management; Bath, 2000). Managers or researchers could also pre-prepare a list of issues to limit the extent of data collection. In the case of citizen or community based collaboration, a wider range of individuals may need

to be interviewed to determine the issues at stake and the levels of common ground. However, the common ground approach described here does not advocate full consensus among all participants, which might have negative consequences (see Peterson et al., 2005). We propose instead that broadening the context by considering variability in response between individuals and a wider range of issues of interest to them will support the identification of potential processes to manage biodiversity conflicts.

We acknowledge that collaborative strategies cannot be implemented overnight (Fabricius and Currie, 2015) and necessitate time for social capital to develop (Armitage et al., 2009). Such approaches contradict the demand for more drastic measures to address the urgency of biodiversity losses (Oldekop et al., 2010). Furthermore, collaborative approaches can fail when existing conflicts between parties already exist and are not acknowledged (Armitage et al., 2009). However, even if emergency interventions were undertaken by some actors to protect conservation interests at the expense of other actors' interests, this framework could help identify issues to assist in re-establishing motivation for collaboration. In Calakmul, it enabled us to contextualize issues and inform future decision-making processes by identifying potential synergies and trade-offs. Uncovering common ground among actors can thus facilitate the development of constructive and collaborative strategies that address larger social tensions and help effectively manage biodiversity conflicts in the long term. Future studies could also explore if common ground actually increased over time.

What opportunities does pursuing common ground offer to address biodiversity conflicts in Calakmul? Issues expressed by actors included an interest in strengthening collaboration among them and in government programs that take into consideration people's needs, are more transparent and allow for wider participation. Our results were presented to the CMDRS as an opportunity for them to review each other's concerns in Calakmul and focus initially on issues of high common ground and high importance (e.g. perceived sustainable extractive activities and alternative activities). Issues such as access to water and climate change, whilst considered important, were presented as requiring longer-term collaborative experience, given the lower degree of common ground. Furthermore, solutions of mutual benefit could also be developed: social issues regarding technical improvement in extractive activities were revealed as being of high importance and high common ground, as

were the issues of monitoring and animal impact. We then discussed, for example, that the existing camera-trap monitoring program to document predators' attack on livestock be reinforced by providing veterinary care for livestock breeders in return for predator protection. By engaging actors in a collaborative decision-making process on issues of common concern, the CMDRS could position itself as a bridging organization (see Berkes, 2009) to link heterogeneous actors, promote information and knowledge exchange, and foster trust and collaboration (Bodin and Crona, 2009; Pretty and Ward, 2001).

While the principle of common ground could help to set up an agenda to develop collaboration, it does not guarantee an efficient and fair decision-making process. Decision aid tools such as participatory multi-criteria decision analysis (Davies et al., 2013), structured decision making (Gregory et al., 2013) and others (see Lynam et al., 2007) can then be explored as appropriate during the following stages of collaboration, in order to identify best conservation actions. For example, in the case of the CMDRS, our research allowed participants to recognize their shared concerns and values around environmental management issues and establish some priorities. However, the tools to address these issues require further discussion, and action will still take time and effort. Nonetheless, the search for common ground represents a mind-set change in the way we approach biodiversity conflict. Without ignoring contentious issues, it offers an innovative approach that engages actors in context-relevant reflection about environmental management, and catalyzes the establishment of positive relationships between individuals.

Conclusion

Our research addresses a knowledge gap regarding the definition, interpretation and identification of common ground in relation to environmental management. We propose a new framework with the potential to support and speed collaborative processes through provision of a sound base and mutually constructive starting point. It invites a change in attitude regarding 'common ground', and recognition of the need to address multiple issues and issues at appropriate levels of detail in order to identify and act on commonalities in people's perspectives for long term collaboration. Perhaps this process will seem threatening

or frustrating for environmental managers with a mandate to tackle particular interests or a desire to propose technical solutions to a single conservationist-defined issue. However, we believe, like Giller et al. (2008), that a more interactive process allows each actor to reflect on their position and build confidence and enthusiasm for their participation in collaboration. We suggest that environmental managers can also acknowledge their positionality and the roles they play in collaborative strategies, as actors engaged in a process of mutual learning. This will require that we blur the boundaries and preset assumptions between researchers and other actors, and search for common ground in order to reduce, and not exacerbate, biodiversity conflicts.

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CHAPTER 4

THE CONSTRUCTION OF FEELINGS OF JUSTICE IN ENVIRONMENTAL MANAGEMENT: AN EMPIRICAL STUDY OF MULTIPLE BIODIVERSITY CONFLICTS IN CALAKMUL, MEXICO

Description of the article and contribution

In the following chapter, I address feelings of justice in biodiversity conflicts and provide means of understanding what local actors meant when telling me "This is unfair." While I explore the literature on the different debates surrounding the notion of fairness, this chapter uses a bottom-up qualitative approach to understand how people define and construct their feeling of justice in the study region, the criteria they use and how they vary. I identified 16 criteria that participants used to construct their perception of justice. Those criteria are articulated around four dimensions of justice: recognition, ecological, distributive, and procedural. It is the first time those four dimensions are grouped together and presented under a common framework that articulates their relationships through conditional and practical justices. Recognition and ecological justices stand as conditional justice, since they underpin the practical forms of justice, distributive and procedural. Finally, our use of various examples of natural resources allowed us to identify different sources of variation that influence which criteria people call for in describing their feelings of justice: the resources in question, the social scale of focus and participant activities and roles, and whom they perceived to be responsible for resource management. This article provides guidance to practitioners and researchers in understanding the place of feelings of justice in biodiversity conflicts, and proposes to support the development of interventions that reinforce values and attachment to nature and recognize the different ways of seeing the world.

For this article, I developed the idea with the support of Violaine Lemay. The qualitative approach and the sampling strategy were developed in collaboration with Sophie Calmé, Rehema White and Birgit Schmook. I collected the data with an assistant, Rodrigo

Salguero, during focus groups. I performed all the qualitative analyses with some important insightful comments on the region from Sophie Calmé and Birgit Schmook. I wrote the main text of the manuscript. Sophie Calmé, Rehema White, Birgit Schmook and Violaine Lemay commented on previous versions of the article helping me with English editing and with structuring the manuscript. This article was accepted for publication in the "Journal of Environmental management" in its present form on February 14, 2018.

The construction of feelings of justice in environmental management: an empirical study of multiple biodiversity conflicts in Calakmul, Mexico

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Abstract

A failure to address social concerns in biodiversity conservation can lead to feelings of injustice among some actors, and hence jeopardise conservation goals. The complex socio-cultural and political context of the Calakmul Biosphere Reserve, Mexico, has historically led to multiple biodiversity conflicts. Our goal, in this case study, was to explore perceptions of justice held by local actors in relation to biodiversity conflicts. We then aimed to determine the following: 1) people's definitions of their feelings of justice; 2) the criteria used in this assessment; 3) variability in the criteria influencing them; and 4) implications for environmental management in the region and beyond. We worked with five focus groups, exploring three examples of biodiversity conflict around forest, water and jaguar management with a total of 41 ranchers, farmers and representatives of local producers. Our results demonstrated that people constructed their feelings of justice around four dimensions of justice: recognition (acknowledging individuals' rights, values, cultures and knowledge systems); ecological (fair and respectful treatment of the natural environment), procedural (fairness in processes of environmental management), distributive (fairness in the distribution of costs and benefits). We identified a list of criteria the participants used in their

appraisal of justice and sources of variation such as the social scale of focus and participant role, and whom they perceived to be responsible for resource management. We propose a new framework that conceptualizes justice-as-recognition and ecological justice as forms of conditional justices, and procedural and distributive justices as forms of practical justice. Conditional justice allows us to define who is a legitimate source of justice norms and if nature should be integrated in the scope of justice; hence, conditional justice underpins other dimensions of justice. On the other hand, procedural and distributive address the daily practices of fair processes and distribution. We propose that the perception of justice is a neglected but important aspect to include in integrative approaches to managing biodiversity conflicts. Addressing demands of justice in environmental management will require us to consider more than the distribution of costs and benefits among actors. We also need to respect the plurality of fairness perspectives and to recognise the benefits of dialogical approaches to achieve more successful environmental management.

Keywords: fairness; procedural justice; distributive justice; ecological justice; recognition justice

Introduction

Top-down biodiversity conservation plans have often enforced conservation measures irrespective of locals' interests and rights (Negi and Nautiya, 2003; Paavola, 2004). The imposition on local communities of the responsibilities of environmental protection and the resulting conflicts have opened up debates regarding environmental fairness (Yearley, 2005). A potential paradox emerges: while environmental protection is required to contribute significantly to global well-being, it often depends on local communities' support; yet these communities can experience disproportionately high costs and thus perceive unfairness (McShane et al., 2011). Decision-making in biodiversity conservation therefore needs to not only ensure ecological integrity, but also to integrate social justice among other dimensions of sustainable development.

The question of social justice in biodiversity conservation is vital, as biodiversity conflicts often stem from feelings of injustice, with involved parties sometimes strongly defending the rights of individuals, communities, future generations and the environment (Clayton, 2000; Clayton et al., 2016). In this research, biodiversity conflict is defined as occurring when the interests of two or more parties in some aspect of biodiversity compete, and when at least one of the parties is perceived to assert its interests at the expense of another (Marshall et al., 2007). It is proposed that in such conflict, perceived justice may even be a better predictor of environmental attitudes than self-interest (Clayton, 2000; Reese and Jacob, 2015), and very often guides the assessments, feelings, and behaviours of the parties involved (Kals and Russell, 2001). For example, perceived fairness in a procedure leads to higher acceptance of the outcome, satisfaction with the result, support of decision-makers, and trust in authorities (Lind and Tyler, 1988; Syme and Nancarrow, 2012). We support the proposal of Ohl and colleagues (2008) that the feeling of justice (i.e. fairness) in biodiversity conservation is a prerequisite for effective biodiversity conflict management. Considering people's concerns regarding fairness and justice, rather than just individual interests, can help us to understand the causes of biodiversity conflict and address injustice (Clayton, 2000; Müller, 2011).

A complex socio-cultural and political context around the Calakmul Biosphere Reserve in Mexico has led to multiple biodiversity conflicts in the region. We used three of these identified conflicts as examples to explore feelings of justice in environmental management: forest, water and wildlife management. For this study, we conducted focus groups with local actors to investigate their perception of justice regarding these conflicts, the criteria on which they build their perception, and the variation among those criteria. We proposed that local actors would have diverse ways of seeing 'justice', and that justice appraisals would be tentative and likely to vary across communities, issues, and contexts, as suggested by others (Kals and Russell, 2001; Kellerhals et al., 1997; Paavola, 2004). Specifically, we asked the following research questions: 1) How do people feel and define their notions of justice regarding environmental management? 2) Which criteria do they use to assess the fairness of environmental management in the region? 3) What are the sources of variation in these criteria? 4) What are the implications for environmental management

in the region and beyond?[3] We first explore the debates surrounding environmental justice and ecological justice as they may apply within environmental management. Secondly, we test the variability in local actors' justice appraisals. Finally, we explore how the theory of and the practical quest for subjective justice help us to understand and address biodiversity conflicts and contribute to our pursuits of sustainable development and environmental management.

Feelings of justice in environmental management

In this section, we critically analyze the debates within the literature around environmental justice and fairness, particularly considering our instrumental focus on achieving enhanced biodiversity conservation. We take some distance from the dominant debate around justice theory (Rawls, 1971) and adopt an empirical approach acknowledging the social construction of 'feelings of justice', which is also referred to as 'fairness judgment'. The way justice is perceived is by nature subjective: the injustice lies in "the eye of the actor", and what is considered just by one might be seen as unjust by another (Gross, 2011; Lauber, 1999). Feelings can differ widely depending on individual views of justice, values, needs and attachment to nature, with no single understanding of what is morally right (Martin et al., 2013; Müller, 2011). Furthermore, individuals might use different criteria of justice depending on the situation. For example, in Western societies, the right to vote is based on equality, while job attribution is based on merit (Deutsch, 2011). Our approach recognizes that justice claims are plural and contextual, and that to improve biodiversity conflict management, we will have to identify sources of variation in the perception of justice and which dimensions of justice prevail against others.

Previous attempts to reconcile social justice and environmental integrity have been attempted under the environmental justice framework (Schlosberg, 2013; Shoreman-Ouimet and Kopnina, 2015; Walker, 2012). 'Environmental justice' is a concept once employed in cases of environmental harm (e.g. chemical pollution) imposed by humans on other humans (Čapek, 1993). Its use has since broadened to other issues such as climate change (Agyeman

[3] While this paper focuses on the instrumental benefit of achieving or improving feelings of fairness, we recognize that the pursuit of fairness is itself a desirable goal and has wider moral imperatives.

et al., 2016) and wildlife management (Dawson et al., 2018; Jacobsen and Linnell, 2016; Lauber, 1999), ranging from local to global focus (Walker, 2009), and developed conceptual depth such as giving moral consideration for nonhuman nature (Schlosberg, 2013). Recent works in environmental justice have also attempted to look beyond the concern of fair resources distribution, to other concerns such as decision-making, identity and power-relations (Lauber, 1999; Martin et al., 2013, 2014; Schlosberg, 2007; Walker, 2012). These different debates have thus explored the notion of justice in diverse ways.

Early research towards the construction of environmental justice appraisal focused mainly on the distribution of environmental benefits and negative impacts through *distributive* and *procedural justices* (Cohen, 1985; Deutsch, 1975). *Distributive justice* explores the fair and equitable distribution of resources at individual and societal levels (Deutsch, 1985). For example, Loomis and Ditton (1993) highlighted the importance of understanding the perception of *distributive justice* in the allocation of fishery quotas when resources are scarce. Their study demonstrated that there is little guidance on how 'fair' can be qualified and quantified, and how the concept can be applied or evaluated in management decisions. There was then an emphasis on exploring the dimension of *procedural justice*: the decision process leading to the distribution of costs and benefits (Lind and Tyler, 1988). An example is the Natura 2000 zone in Europe, for which there was insufficient public consultation in the decision-making process leading to its establishment, resulting in mistrust and a reduced list of designated protected sites in France (Paavola, 2004). While often approached separately, distributive and procedural justices interact, as acknowledged early on by Lind and Tyler (1988). Fair perceptions of the decision-making process increase potential perceptions of a fair distributive outcome, while a fair outcome might make actors evaluate the procedure more positively (Van den Bos et al., 1997). Similarly, perceived unfavorable outcomes might make actors more likely to find fault with a decision-making process (Bies, 1987).

The construction of justice, however, is not only about how decisions are taken and costs and benefits shared; it is also about who should be considered during these processes. This is where the dimension of *ecological justice* is relevant, as it recognizes the right to live of other species (Clayton, 2000; Parris et al., 2014). *Ecological justice* is defined in the field

of social psychology "not so much by a particular philosophical perspective (e.g. equality of rights, individual or group level) as by the inclusion of remote entities, such as the environment or future generations, in one's consideration of a just resolution to a conflict" (Clayton, 2000, p. 467). Ecological justice thus allows inclusion of non-human entities in the scope of consideration of justice and has been used to support environmental protection goals. For instance, Opotow (1994) showed that people who included the bombardier beetle (*Brachinus* sp.) in their scope of justice were more willing to preserve it. Ecological justice was also discussed more recently by authors who wish to expand the consideration of environmental justice to human relationships with non-humans (Schlosberg, 2013). Schlosberg (2007) suggested shifting the discussion of environmental justice from using environmental conditions as an example of social injustice, to addressing how justice could also incorporate the treatment of the environment itself.

Other debates regarding environmental justice have focused on the notions of identity, right to self-determination and actors' relationships. At the individual level, researchers have sometimes distinguished particular aspects of procedural fairness, around interactions among actors, which they refer to as *interactional justice* (Bies et al., 2001; Syme and Nancarrow, 2012). *Interactional justice* considers components of the communication process between the source and the recipient of justice, such as politeness and honesty (Bies et al., 2001). The debate has widened to cover the importance of cultural diversity, misrecognition, and misrepresentation under the concept of *justice-as-recognition* (Schlosberg, 2007; Walker, 2012). In the field of environmental management, *justice-as-recognition* was defined as the need to respect differences in value and knowledge systems and the struggle to avoid cultural domination (Martin et al. 2016). Studies referring to *justice-as-recognition* often emphasized indigenous rights (Martin et al., 2013, 2014, Schlosberg and Carruthers, 2010); however, *justice-as-recognition* was also used more broadly to include the recognition of the right to dignity, denunciating all forms of denigration and stigmatisation that devalue some people in comparison to others (Fraser, 2001). *Justice-as-recognition* can therefore exist beyond the question of indigenous right and address claims to preserve identity, community, and traditional ways of life (e.g., Olive, 2016). Finally, it is important to mention that some authors (e.g., Jacobsen and Linnell, 2016; Martin et al., 2016; Schlosberg, 2007) have included in the scope of justice-as-recognition,

acknowledgement of the right of biodiversity (often represented as particular species or ecosystems) to exist, which relates to ecological justice.

This reflection on the plurality of justice dimensions and the debates surrounding them helps us enrich our conceptualization of justice and support its application to different situations (Sikor et al., 2014). We have reviewed here how different debates have arisen regarding procedural and distributive justices, ecological justice, justice-as-recognition and interactional justice. These discourses on justice propose different but sometimes complementary explanations of the dimensions of justice while suggesting different relationships between these dimensions. Our research, while considering existing definitions and dimensions of justice, will empirically pursue perceptions of fairness, offering an opportunity to challenge the debate surrounding the theorisation of environmental justice by examining how it is articulated on the ground. We aim to contribute conceptually to the framing of constructions of justice and also to offer practical recommendations for how different claims for justice could be incorporated in the management of biodiversity conflict.

Methods

Study area

Calakmul (Figure 4.1) is home to 28,424 people (INEGI, 2015), two-thirds of whom work in semi-subsistence agriculture. Calakmul's settlements, mostly *ejidos*[4] (communal land tenure settlements), mainly date from the 1970s and 1980s, when timber extraction, road construction, and state-sponsored land distribution created villages. In the 1980s and 1990s, Calakmul population had turnover often precipitated by violent conflicts over resources (Ericson et al., 1999). Today Calakmul is home to an ethnic mix of peninsular Mayans, indigenous people mostly from Chiapas (e.g. Ch'ol and Tzeltal), and mestizos or

[4] An *ejido* is constituted with community members called *ejidatarios* who for the most part individually farm designated parcels while collectively maintaining communal holdings. *Ejidatarios* do not actually own the land but are allowed to use their allotted parcels indefinitely as long as they do not fail to use the land for more than two years.

non-indigenous people predominantly from the Mexican states of Veracruz and Tabasco (Gurri, 2003).

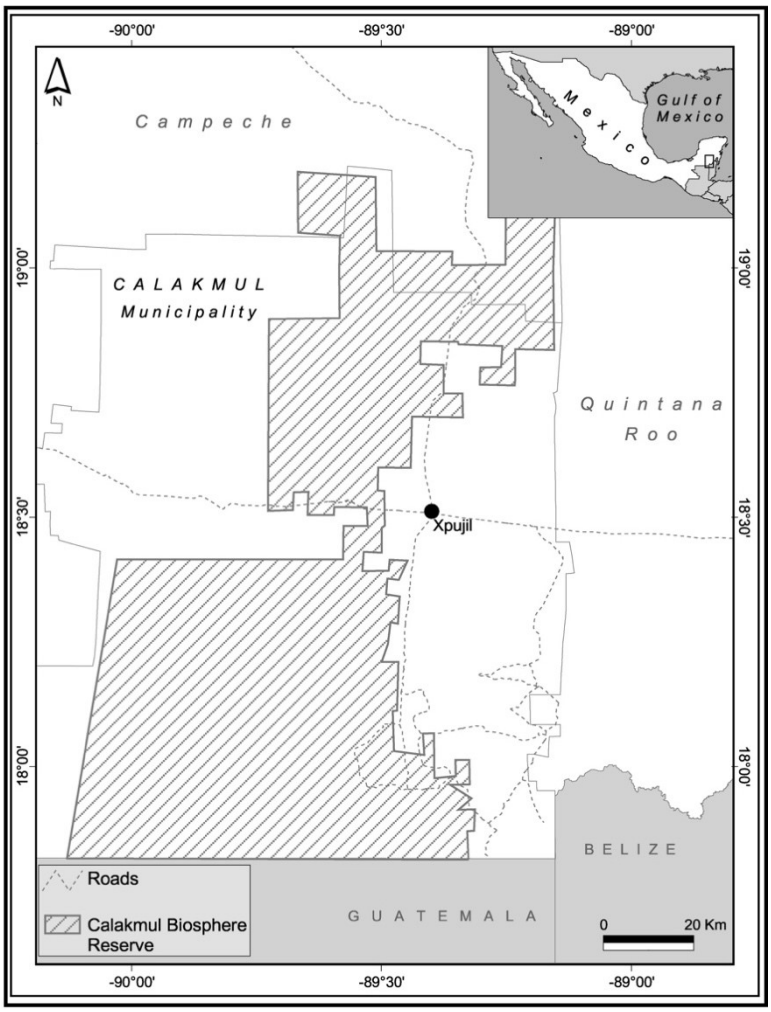

Figure 4.1 Study area. Calakmul sits on the meseta, the central karst uplands that form the Yucatan Peninsula's spine. Insert figure on the upper right corner shows the position of the study area in Mexico.

The region's forests are broadly classified as seasonally dry tropical forests (Peréz-Salicrup, 2004). A large area (723,185 ha) was declared a biosphere reserve in 1989, the Calakmul Biosphere Reserve. Deforestation rates in the areas adjacent to the reserve nowadays are low compared to the last century, and the principal cause of deforestation is small-scale cattle ranching. Though several communities still retain large expanses of forest, today only a few are granted the right of timber extraction. Forest resources are important

for other economic activities, such as allspice, beekeeping, and ecotourism, which represent alternative incomes for communities (Turner et al., 2004). Conflicts around forest management and conservation have arisen in response to the divergent interests of actors over land and resources.

Because of the karstic nature of the region and a seasonal pattern of rainfall (Magaña et al., 1999), there are few permanent streams and water bodies. Precipitation patterns have become more spatially and temporally inconsistent during the last decades, mainly after the mid-1980s (Márdero et al., 2012). These biophysical characteristics present a challenging context for agricultural production, and in drought or hurricane years' harvests are often completely lost. Water is then the most limiting factor in the area, especially in the dry season, when people rely primarily on *aguadas* (waterholes) (Márdero et al., 2012). There are also large discrepancies between communities regarding water access. Over the years several governmental and non-governmental programs have been implemented to provide rainwater storage facilities to families, and some communities have benefitted from yearlong access through a pipeline situated near the highway or through deep wells. Water limitations and inequalities in water access have created tension in the region.

Calakmul hosts the largest population of jaguars (*Panthera onca*) in Mexico and is part of a Jaguar Conservation Unit (Sanderson et al., 2002). The region has also witnessed a notable increase in cattle husbandry over the last two decades. As opposed to crop production, cattle ranching is less vulnerable to drought and hurricane events and cattle act as a form of household savings. State subsidies and remittances also fostered pasture establishment and cattle ranching (Schmook and Radel, 2008). Depredation of cattle by jaguars and retaliation by farmers against jaguars have created conflicts surrounding jaguar management.

Data collection

While many other studies looking at subjective justice used predetermined definitions of justice and criteria, we wanted to understand how feelings of justice are constructed and defined, and against which criteria they are assessed in a particular context.

We thus used a grounded approach to explore the context and perspectives of participants. We drew on long term engagement with local communities by two of the authors (SC and BS) and two years of immersion in local communities to observe and talk about environmental issues by another (MLL). To explore the construction of feelings of justice in depth, we selected two communities adjacent to the Calakmul Biosphere Reserve based on their level of collaboration with the reserve (see supp. material C1 for community selection). We assumed that the strength of the relationships with local conservation authorities in the region affected their feelings of fairness toward environmental management. Drawing on ethnographic methods, the first author spent two weeks in each community to explore daily routines, livelihood activities and relationships with governmental institutions, and organize focus groups (see supp. material C1 for justification of focus groups). A reflexive field diary captured data from these sojourns, helping to direct the discussions during the focus groups as well as to support the thematic data analysis.

We organized two focus groups in each community: one with 'farmers' (focusing mainly on crop production; henceforth named groups F1 and F2) and one with 'ranchers' (focusing mainly on livestock production; henceforth named R1 and R2). Farmers and ranchers often perceive the use of natural resources differently; ranchers also have a different socioeconomic status, often being wealthier and having better representation at the local, regional and national levels (Gurri, 2006). We also focused on actors who had land rights in their community (*ejidatarios*), which can improve their sense of cohesion and facilitate information exchange in the group (Vaughn et al., 1996). Focus groups each lasted one to two hours and had between six and eleven local participants, including at least two women. We also asked ranchers for species and numbers of livestock owned and if they had experienced livestock depredation. We organized an additional focus group with sectoral representatives who sit at the Council of Rural and Sustainable Development in Calakmul (CMDRS), a regional multi-stakeholder management board, to see if further aspects would be identified during a multiple-actor focus group discussion (group MA). A total of five focus groups is generally considered adequate to reach data or theoretical saturation (Krueger, 2014; Morgan, 1997).

We used three examples of natural resource management as a starting point for discussion: forest, water, and jaguar management. These examples represent local actors' concerns and potential biodiversity conflicts in the region (Lecuyer et al., in review), and their characteristics offer diverse opportunities to understand people's construction of justice appraisal. The participants were invited to consider all resource uses and management options, including who should be involved in their management, and finally to reflect on their experiences and perceptions of the fairness of the management of these resources. The facilitator provided guidance, using open questions and image stimuli to develop the conversation, requesting detail on key issues and facilitating contributions by all participants (as suggested by Onwuegbuzie et al., 2009). At the end, the facilitator presented a summary of the issues identified by the participants for confirmation or clarification (Manning, 1997).

Data analysis

Our analysis was embedded in the philosophy of social phenomenology (Schutz, 1967) as we recognize the importance of both social relationships and social and temporal aspects of experience. In fact, we were interested in being able to interpret the subjective meaning of participants' feelings of justice toward environmental management. To analyse our data, we thus used a combination of deductive and inductive thematic analyses (see Fereday and Muir-Cochrane, 2006). Deductive analysis was employed in acknowledgement of previous research exploring the concept of fairness, which created a partially pre-determined structure to the investigation (Crabtree and Miller, 1992). However, we also pursued inductive exploration of the concept to enable new information or modification of previous knowledge to emerge (Boyatzis, 1998). Thematic analysis allowed us to collate and compare conversations around themes and examine variation between individuals and between groups (Guest et al., 2011). Specifically, we adapted the framework analysis described by Ritchie and Spencer (2002), with suggestions made by Rabiee (2004) for the focus group analysis, and included an additional stage of discourse analysis to interpret group interactions (supp. material C1).

The first stage (familiarization) included listening thoroughly to the audios and transcribing partially whilst making an early identification of the dimensions of justice

(distributive, procedural, ecological, or others). The second stage (inductive and deductive coding of criteria of justice) consisted of developing a coding manual, indexing our text to *a priori* categories, identifying emergent new issues and refining the categories according to participant responses. In the third stage (contextualization and pattern of justice construction), we explored the interconnectedness of criteria, and uncovered the patterns and contexts in which they arose. The fourth stage (parallel coding of relational and directional aspects of feelings of injustice) represented an additional data indexing phase. We did not want to limit our investigation to the identification of criteria but rather to observe their variability and then create parallel coding in order to analyse with whom participants identified and who they perceived to be responsible in their construction of justice (see example in supp. material C2). The fifth stage (comparison of feelings of justice) was a charting phase in which we used comparative analysis to identify the differences in feelings of justice among individuals, groups, activities and communities. A final stage of analysis (analysis of group interactions) was undertaken to see if group interactions could add to the framework analysis and inform us about the level of group consensus or disagreement. Although presented as a linear, step-by-step procedure, the research analysis was an iterative and reflexive process. Finally, care was taken to not take quotes out of context and to show where participants had different views; here we only offer short quotes, given word limitations.

Results

The dimensions of justice and associated criteria

The interest demonstrated by participants during focus group discussions confirmed the importance of perceptions of justice toward environmental management for local actors and validated the importance of four of the dimensions of justice presented above (section 1.1). Biodiversity conflicts were not only provoked by the (unfair) distribution of costs and benefits of environmental management (e.g. the cost of jaguar impact on livestock production), but were also reinforced by negative feelings toward the decision-making process, and failure to recognize their identity and knowledge or the importance of the

natural environment. Our coding approach allowed us to identify, for the three cases presented, 16 criteria on which these feelings were based. Eight of these criteria had been defined *a priori*, two were modified from prior definitions in the literature and six emerged from the data (Appendix C1). These criteria can be used to operationalize the concept of fairness in Calakmul. However, it is important to be aware that criteria definition and priorities are likely to vary with context.

For distributive justice, the criteria used were related to merit, equality, and need. The principle of equality was ever present in the discourse of our participants at the individual and community levels, as every *ejidatario* originally received the same land area when *ejido* communities were created. This led participants to claim for the right to receive the same amount of support for environmental management. However, after group discussions, the participants agreed that other criteria related to distributive justice: "*Justice doesn't mean that there is equality, but that one's needs are met, or not (R1)*". Most of our participants were poor and they also used the criterion of need to justify violating existing rules of environmental protection: "*I need to cultivate to live. It is not that felling a tree is just but I need to survive. There is a contradiction, they want us to care [for the environment], but they don't want to help us. (...) Out of necessity, we do things we shouldn't (R1)*". They called for a higher consideration of their needs against environmental protection. Finally, under the equity criterion, participants agreed that the greater the engagement of an individual toward environmental protection, the higher the individual benefit should be: "*The person with most [conserved forest] is the one who should receive more [benefits] from conservation (F1)*". However, some claimed the equity principle should rather apply to the amount of work engaged in their activity.

Procedural environmental justice proved as relevant as distributive environmental justice to participants. Several participants claimed that money was not the only issue, and discussed how decisions were made about environmental management, and how they felt left out: "*We aren't stupid. It [the government] decides rules and we cannot say anything (L.P.1)*". They discussed how they could be involved and treated in the environmental management processes (see criteria in Appendix C1).

Participants also showed real concern about the importance of the natural world, underlying the recognition of ecological justice: "*Although it can attack my flock, the jaguar has the right to live (L.P.2)"*. Some participants expressed their feeling of responsibility toward non-human entities and towards future generations. In particular, the right to live in nature for jaguars and other wildlife was a point raised during every focus group.

Furthermore, local actors expressed concerns related to access to land rights and rules of use in *ejidos*. Demands for land use rights and for consideration as responsible and able land managers strongly underpinned our focus group discussions on justice. One participant expressed his frustration over land use rules: "*The government thinks it owns us (...) Here it's just land use right. (...) We can't progress without the permission of the government (R1)*". Limited property rights were one of the main concerns regarding environmental management, and villagers strongly demanded that their rights to act freely on their land be recognised. Finally, local actors demanded that no single interest and form of knowledge should dominate in environmental management. An unbiased approach was thus one of the criteria used to justify their feelings of justice.

Variability in the criteria definitions and uses across the dimensions of justice

Our use of example scenarios illustrated how actors do not use the same criteria in each case, because of variation in how they perceive natural resources. For example, the criterion of need dominated the discussion about water management, which actors perceive to be a basic need to which everyone is entitled. However, their perception of need varied regarding jaguar management: while some participants associated need with those having only a few animals, others associated it with the level of jaguar impact, regardless of livestock herd size. Also, for those who believe it is possible to manage jaguars, they perceived merit as more important and argued that financial compensation and support related to jaguar attacks should be given in relation to individual management efforts to protect herds. Finally, forest was often perceived as an economic resource that should be shared equally between land-right owners, leaving non-*ejidatarios* with no right to access it.

Furthermore, criteria associated with procedural justice carried different meanings for each individual. Opportunity for representation might be articulated differently, as shown by concerns of this rancher: *"I am not prepared to take decisions for a village, so it is important to listen to the government's proposals, bring the communities in and decide together. Because we are not prepared to take that kind of decisions (R1)"*. Some might only want to participate in the determination of the priorities, while others want full representation in the decision-making process.

Variability of the criteria according to social scale of focus and participant activities and roles

Perception of justice also varied according to whether participant discourse was at the individual or community level. At an individual level, equality was considered one way to distribute benefit of forest resources. For example, each *ejidatario* of the community should receive the same area of forest and support to use it. However, at a community level, the criterion of merit or effort was proposed for the payment of environmental services and forest conservation. For example, a community should deserve more support and payment if it protects a larger forest area. One of the community members commented that "*In Polo Norte [another community] they have 200 ha [of forest reserve] (...) and the ejidatarios receive money for it, and [here] we have 1000 [ha] but we don't receive anything (R2)*".

The activities and roles of participants had some influence on their perception of justice. First, distinctions and comparisons were made, such as by this member of the multi-actor focus group: "*There is no program to protect [campesinos], besides the case of ranchers. The rancher always has an advantage, unfortunately. He is the one harming the most [the environment], but the one who receives the most; the farmer no (MA)*". Further comments made by farmers regarding consistency in decision-making sometimes originated from their perception of ranchers as a privileged group, receiving more help and consideration in decision-making processes. Farmers also gave more importance to the jaguar's right to live than ranchers while discussing jaguar management. However, they made a parallel with the situation of ranchers regarding jaguar management in describing their own difficulty with wild herbivores consuming and destroying their crops: "*They*

[herbivores] are also affecting me, and it can become a tremendous problem to protect my property. Right now, I don't have anything to defend myself, so the animal should not live. What is the most valuable? The life of the animal or the life of my family? (F1)". For those detrimental herbivores, farmers were less inclined to talk about their right to live.

Variability in the criteria according to whom participants perceived to be responsible

Attribution of responsibility at different institutional levels also impacted participants' construction of justice appraisal and the magnitude of their feelings of (in)justice. For example, local actors were generally aware of international efforts and projects for forest protection, and perceived the Mexican government as the authority in charge of this resource: mistrust, non-neutrality, disrespect, and lack of representation or consistency between individuals were strongly responsible for their feelings of injustice toward how the government handles forest management. The following quote represent their perception of international help: "*We agree on protecting trees; it costs us dear to fell trees. But they receive millions of dollars and supposedly this money is for those who protect trees, but that money never gets here, we don't receive it (R1)*". Water management was perceived to be the responsibility of regional authorities and allegations of mistrust were less common. Which government entity is responsible for wildlife management seemed uncertain, and people often mistook those in charge of different programs: the reserve, for example, was thought to be in charge of the compensation scheme for depredation, and frustration against the program was then redirected toward the reserve. Such confusion can explain why the levels of collaboration with the reserve did not appear to affect people's construction of justice appraisal, as they did not know to whom they should attribute responsibility for the costs and benefits of conservation.

Perceptions regarding procedural justice were also dependent on the role of individuals: some actors who were currently or had been a village head spoke more about unfairness at higher institutional decision levels. Overall, differences between actors did not create much dissent within the focus groups. Even in the multi-actor group, actors seemed to reach consensus and share perspectives of justice built on a common identity, as *campesinos* with little income and education, from isolated communities in Mexico, having

as a common 'enemy' the government that does not take their concerns into consideration. In fact, one participant said: "*They [the government] should recognize our right, and come here to see [our] reality. Governments are not interested in this right; what interests them is to get the power, enjoy [it], and take everything they can, and leave (M.A)*".

Discussion

Our study addresses recent calls to integrate the notion of fairness into conservation practice (Gross, 2011), and aims to develop a framework to support practitioners in assessing justice in conservation that is sensitive to the local context (Martin et al., 2015) and useful in managing biodiversity conflicts.

Dimension of justice, criteria, and source of variation

To improve biodiversity conflict management, it is important to understand strategic and local prioritization of criteria (Sikor et al., 2014). In this research, we identified different criteria associated with how people build their feelings of justice regarding the management of different resources. The majority of those criteria are similar to justice principles documented in previous research, including in other fields (see Appendix C1 for a list of references). Our qualitative approach gives deep insight into actors' perceptions of justice and allows us to explore the definitions of criteria by our participants, which is critical to understand typical variations in local context (Martin et al., 2014, 2015; Sikor et al., 2014). We show how their different perceptions of natural resources call for different approaches to answer to their claim for justice. For instance, water management could be addressed by a basic needs threshold approach (see Martin et al., 2015) to reflect the moral imperative that focus groups articulated toward this resource. Forest management might be addressed by a market-based approach, though the issue of inequality among community members will have to be tackle (*ejidatario* vs. non-*ejidatario*; see Navarro-Olmedo et al., 2016). In addition, while it is possible to extract some general criteria on which people build their perception of justice, the conception of these criteria might differ among people. Consequently, while criteria are useful to understand the construction of justice, we warn against using our criteria

list as a pre-established set of criteria to evaluate justice in other contexts. We agree with Sikor and colleagues (2014) that context matters and we emphasize the need for more empirical casework on local and global conceptions.

Our research allows identifying some of the contextual sources of variation among the different criteria used by our participants, such as the social scale of focus and whom they perceive as responsible for the injustice. In fact, the debate on environmental justice has evolved from a focus on individual interest to one that addresses justice at both the individual and community level (Gross, 2011; Martin et al., 2016; Müller, 2011; Schlosberg, 2013). Our results support previous suggestions (Kahn et al., 1982) that the social scale of focus influences criteria: while at an individual level some criteria prevail, in situations where people identify at the community level, they will opt for other criteria that seem fairer for the collective. Furthermore, at an individual level, who they principally identify with, and who they blame for injustice also leads to differences in arguments over justice that might result in biodiversity conflict (Clayton, 2000).

Broadening the scope of procedural justice: from procedure to process

Procedural justice is usually investigated under one particular environmental decision-making process (e.g., Gustavsson et al., 2014; Lauber, 1999). In this study, we rather focused on multiple issues, and people expressed justice concerns about the general process of environmental management and the resulting biodiversity conflicts. For example, criteria of trust and respect applied on an everyday basis to all interactions between actors involved in environmental management. Contrary to other studies, where interpersonal treatment was related to interactional justice as a dimension of justice independent from others (Bies et al., 2001), our participants directed their anger not toward individuals, but against institutions; interpersonal treatment then still related to procedural justice (Cohen-Charash and Spector, 2001). For example, in the case of corruption, our participants agreed that it is the administration that should not allow corruption to happen, instead of individuals. People's perception of the level of corruption and lack of integrity and neutrality in administration and decision-making influences how people construct their perception of justice. We are not trying to establish an argument for the need to make a distinction between

interactional and procedural justices, and while the former might be pertinent in other cases, concerns toward interactional justice were not articulated by our participants. Feelings of (in)justice toward interpersonal treatment were related mostly to the enactment of environmental management processes, which occupies the area of procedural justice (Mikula et al., 1990).

We propose instead to broaden the scope of claims relative to procedural justice not only to procedure, which refer to established and official ways of taking decisions (Madden and McQuinn, 2014), but to every process of environmental management. Processes, as proposed by Madden and McQuinn (2014), refer to "the series of actions to achieve a goal", in this case environmental protection, and allow for more flexibility to incorporate participants' concerns. For example, whilst the process and outcome could be fair, implementation of the decision might be perceived unfair (Ohl et al., 2008). One farmer criticized the "lack of action" of other local actors: "*The problem is that if you come here, see my needs and help me, and come back to see that nothing has changed, it is not fair either that I did not do my part. It is important to respect the decisions made (F2).*" Compliance, i.e. respect of decisions and their further enforcement, was thus an important criterion to further explain people's feelings of justice. This conceptualization of procedural justice corresponds more to an adaptive form of management where decisions are continually questioned and revised (Plummer, 2009). Defining procedural justice as the overall fairness of the processes of environmental management allows us to consider not only the decision-making processes but also decision implementation and appeal, particularly when corruption, or perceived corruption, exists.

Ecological justice and justice-as-recognition as distinctive dimensions

This research is innovative in the way that it both explores literature considering ecological justice as a dimension of justice that stand alone (Clayton, 2000) and literature on justice-as-recognition that incorporates the notion of ecological justice (Jacobsen and Linnell, 2016; Martin et al., 2016; Schlosberg, 2007). In fact, the right to live of animals might be fully recognized in some cultures, and ecological justice could then overlap with justice-as-recognition. In our study, participants had migrated from other states and did not

articulate specific cultural identity based on ethnicity, but rather identity in relation to roles and agrarian livelihoods (as in Martin et al., 2014). Recognition was then mostly articulated around the need to acknowledge a particular lifestyle (e.g. rural lifestyle versus urban lifestyle) and see current land holders as "good stewards of the land" (Olive, 2016). This is well captured by this participant's memory: "*I think of my father a lot; he was a hunter and a fisherman. It wasn't a crime to commercially sell fish and meat, or nothing of this kind at the time. (...) And the animals never went extinct. And it was a way of life. And what has happened now? Now, as everything is a crime, we can't live (M.A.)*". Their claims for fairness stand in recognizing their knowledge and practice as relevant and potentially compatible with environmental management and refusing a dominant conception of conservation that potentially prevents them from natural resource utilisation.

However, claims for more recognition did not always coincide with claims of ecological justice, such as intrinsic rights for nature or personal responsibility for its conservation. Attributing intrinsic value to the natural environment has led people to acknowledge macro-justice arguments that emphasize societal concerns, interdependence and responsibility (Clayton et al., 2016); it also influences attitudes toward environmental protection (Opotow, 1994). It needs not to be associated with a particular culture or way of living and seeing the world; care for nature has been proposed as a "unifying common dominator" among different perceptions of the world (see the notion of stewardship in Lute and Gore, 2014). Ecological justice should then be addressed differently than justice-as-recognition: environmental managers can encourage people to think collectively about their relationship to the natural world.

Conceptualisation of conditional and practical justices

Our combined deductive and inductive empirical approach allowed us to understand local perceptions of justice and propose a framework representing how people construct their feelings of justice regarding environmental management in the region of Calakmul (figure 4.2). While there is no causal link between the dimensions of justice and each dimension can interact with each other, we propose to distinguish two broad categories of justice: conditional justice (justice-as-recognition and ecological justice) and practical justice

(distributive and procedural justices). We do not consider justice-as-recognition to be on the same analytical level as the other dimensions of justice, but rather one that underpins every other dimension. In fact, recognition allows for questioning whose values matter in the perception of costs and benefits, whose knowledge counts in the decision-making process (Martin et al., 2013), and generally who is a legitimate source of justice norms (Whiteman, 2009). Justice-as-recognition allows to acknowledge the different ways of knowing nature and prevents us from imposing a dualist thinking between society and nature (Martin et al., 2013). Additionally, we advocate to conceptualize ecological justice as a distinct conditional justice in order to support collective thinking about our relationship to nature. How people perceive the rights of species and the responsibilities towards the natural world and future generations will determine who they include in their scope of justice (Opotow, 1994; Parris et al., 2014). By placing ecological justice as a condition of distributive and procedural justices, we widen the perspective on social justice by also including consideration of justice for 'nature' itself. Procedural and distributive justices, in turn, address more the question of environmental management in practice, and what can be fair in the daily process of environmental management and the distribution of its costs and benefits.

In other words, justice-as-recognition allows not to determine what is fair or unfair, but to acknowledge that there are different conceptions of justice among individuals that reflect different ways of knowing the world (Martin et al., 2013); then, ecological justice is about how to incorporate the natural world in the scope of justice (Clayton, 2000), while practical justice, procedural and distributive, interact in order to define fair procedures and distribution. The arrangement in Figure 4.2 of the dimensions of justice recognises their interaction, so that the fulfilment of one dimension will not compensate for the lack of consideration of another (Schlosberg, 2007). This framing could avoid negative effects found previously, in which attempts to reach a compromise in procedural and distributional fairness failed because the relevant actors were not included, new power-imbalances were introduced, or compromises were not implemented at the appropriate scale (Martin et al., 2013, 2015; Neumann, 2004). Furthermore, supporting interventions that reinforce values and attachment to nature could help reconcile environmental integrity and social justice, and demonstrate how environmental considerations are fundamental in creating the conditions for social justice.

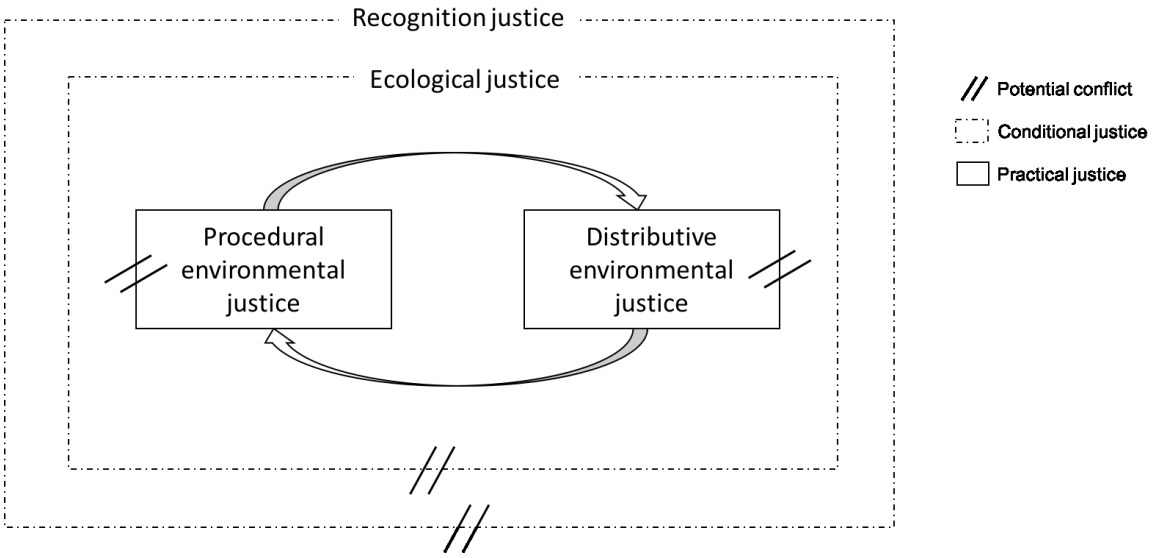

Figure 4.2 Framework representing the construction of justice appraisal in association with biodiversity conflicts.

Conclusion: the importance of the plurality of justice perceptions

This study offered innovative insights on the feelings of justice and their implications for environmental management. Perceptions of justice have been recognized to affect environmental attitudes and behaviour, and it has been proposed that different perceptions could be at the origin of most biodiversity conflicts (Whiteman, 2009). Our findings demonstrate that practitioners and researchers working in conservation must be aware of competing fairness perceptions, to avoid some actors feeling excluded and developing animosity against environmental managers. In Calakmul area, the criteria of justice and the basis for their variation we identified could help local practitioners modify their approach to environmental issues in order to improve the perception of justice in environmental management. For example, clarity over authority for the depredation compensation program or transparency regarding international funding for ecosystem services could assist in addressing some of the frustration that participants expressed against the Reserve. However, these feelings are so situation dependent and complex that we believe using our predetermined set of criteria in other contexts would be counterproductive. There is no

simple tool box that will allow us to address justice concerns everywhere; thus, empirical qualitative approaches should be reproduced as a starting point. In doing so, our major research outcome was to open a space for dialogue among local actors and to support the process of developing a mutual understanding.

Our pluralist approach led us to develop a broad framework offering a realignment of principles, and context for practical action, which can guide practitioners and researchers in understanding and accommodating the place that 'feelings of justice' occupies in addressing biodiversity conflicts. Future studies could use this broad framework to compare the construction of justice and the origin of the variation of people feelings of justice which might lead to further modifications or incorporation of other justice dimensions (e.g., interactional justice; Bies et al., 2001; cognitive justice; Coolsaet, 2016). Our framework recognizes the importance of people' feelings of fairness, but also of the need to consider the natural environment when undertaking 'fair' environmental management. It thus reemphasizes that sustainable development should not be perceived as a goal but rather as a process that recognizes the "interconnectedness of environmental integrity and social justice" (Ferraro et al., 2011, p. 72). The pursuit of sustainable development will then include examination of what different justice perspectives represent, how to adjudicate among them, and how to reconcile conflicting perspectives in democratic processes. Acknowledging justice-as-recognition and developing a sense of ecological justice among groups will help to develop strategies that align with fair procedural and distributive justices for communities and their natural surroundings.

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CHAPTER 5

FACTORS AFFECTING FEELINGS OF JUSTICE IN BIODIVERSITY CONFLICTS: TOWARDS FAIRER JAGUAR MANAGEMENT IN CALAKMUL, MEXICO

Description of the article and contribution

This fourth chapter builds on chapter 3's qualitative work to achieve a comprehensive analysis of the dimension of justice regarding jaguar management, and proposes a systematic investigation of the determinants of feelings of justice. Using a new statistical approach (BTLLasso), I addressed the external factors that influence people's feeling of justice, how criteria of justice can converge and diverge, and how this can support 'fair' solution for jaguar management. Again, this chapter highlights the variability among people's perceptions of justice. Our main finding is that experience of attacks does not have a strong influence on an actor's perception of fairness, which is mostly driven by questions of identity and responsibility of others and intra-group interaction. To answer to people's various claims for justice, we emphasize the need to engage in constructive dialogue with multiple actors, acknowledging differences and allowing mutual understanding and trust to develop.

For this article, I developed the initial idea. I developed the questionnaire and the sampling strategy with the support of Sophie Calmé, Rehema White and Birgit Schmook. I collected data during interviews with the help of Maria Manzon Che. I performed the statistical analyses with the help of Guillaume Blanchet. I wrote the main text of the manuscript. Sophie Calmé, Rehema White, Birgit Schmook and Guillaume Blanchet commented on previous versions of the manuscript, helping me with English editing and with the clarification of the manuscript. This manuscript will be submitted shortly to the journal "Biological Conservation" although some modifications could still occur.

Factors affecting feelings of justice in biodiversity conflicts: towards fairer jaguar management in Calakmul, Mexico

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Abstract

Conservation usually focuses on environmental objectives, but neglecting social concerns can lead to a feeling of injustice among some actors and thus jeopardise conservation aims. Through a case study on a biodiversity conflict around jaguar management in the Calakmul region of Mexico, we explored actors' feelings of injustice and their associated determinants. We employed a novel framework distinguishing four dimensions of justice: recognition, ecological, distributive and procedural. By conducting and analysing 235 interviews with farmers and ranchers, we investigated what might drive their feeling of injustice, namely their perceptions of the injustice itself (i.e. location, intentionality, stability), individual characteristics (i.e. socio-economic status, motivation, environmental identity), and interactions with their environment (i.e. natural and social). We also asked the participants to make paired comparisons across 18 statements that characterized their feeling of justice toward jaguar management based on different criteria. Using a pioneering statistical analysis, BTLLasso, we showed the complexity of the drivers of feeling of justice. Experience of attacks on livestock somewhat explained actors' feelings of justice, but these feelings were influenced mostly by factors related to actors' relationships (e.g. the coherence perceived in the group to which they feel they belong, a positive perception of responsibility at a collective level). Our analyses also allowed comparison of the effects of different factors on the assessment of criteria by diverse actors. It is possible, for example, to compare how differences in the organisations and groups perceived as being responsible for jaguar management modify a participant's perception of fairness. This nuanced understanding of how people build their perception of justice can inform practitioners, who seek fairer and

more effective conservation approaches. Whilst details will be context specific, supporting relationship building and enabling debate over ecological responsibilities are important and conservation efforts should go beyond merely offering financial compensation for livestock depredation. We conclude that perception of justice is a neglected, but important aspect to include in integrative approaches to managing biodiversity conflicts and that novel mixed methods can advance both conceptual and applied understanding in this area.

Keyword: fairness, paired comparison, Bradley-Terry-Luce Lasso, self-interest motivation, group identity.

Introduction

The conservation of large charismatic species can involve biodiversity conflicts in which disagreements between actors must be addressed (Marshall et al., 2007; Redpath et al., 2017; White, 2013). Biodiversity conflicts are driven partly by competing visions of fairness (Müller, 2011; Redpath et al., 2013), and feeling of justice can be a good predictor of people's attitudes and behaviours regarding conservation (Martin et al., 2015, 2014; Sikor et al., 2014)[5]. Someone perceiving a lack of fairness might resist conservation rules (Dawson et al., 2017) or limit their endorsement of pro-environmental action (Kals and Russell, 2001). Similarly, perceived unfairness can result in profound resentment and social conflict (Schlosberg, 2007; Whiteman, 2009). Conversely, positive feelings of justice increase trust in decision-makers (Lauber, 1999), acceptance of decisions by locals (Davenport et al., 2007), overall effectiveness of conservation actions (Oldekop et al., 2016), and reduce conflict (Lind and Tyler, 1988). Consequently, research focusing on, and policies supporting, the incorporation of justice into environmental issues has been increasing, especially the ones related to climate change (Agyeman et al., 2016), payments for ecosystem services (Martin et al., 2014), protected area management (Dawson et al., 2017), and large carnivore conservation (Bredin et al., 2018; Jacobsen and Linnell, 2016). In this study, we adopted a justice approach to jaguar management around the Calakmul reserve, Mexico. Specifically, we used an empirical approach to identify factors affecting the feeling

[5] Fairness and feeling of justice here are both used as synonym to talk about subjective justice.

of justice in local farmers and ranchers. In doing so, we offer new insights for theoretical considerations of justice while proposing practical steps to manage biodiversity conflicts.

Feelings of justice represent actors' positions on particular issues, at a specific time and in a particular context (Martin et al., 2014; Schlosberg, 2007; Sikor et al., 2014). Those feelings are based on a plurality of views of justice that calls for an approach encompassing several dimensions of justice. We used a framework that accounts for four dimension of justice: distributive justice (fair distribution of the costs and benefits of conservation), procedural justice (fair decision-making process), ecological justice (fair treatment of the natural world), and justice-as-recognition (fair integration of group identity, lifestyle, knowledge and viewpoints) (Lecuyer et al., 2018). While recent studies have often proposed frameworks where justice-as-recognition includes ecological justice (e.g., Jacobsen and Linnell, 2016; Martin et al., 2016; Schlosberg, 2007), we have previously shown that ecological justice can be a distinct dimension that can be addressed differently from justice-as-recognition (Lecuyer et al., 2018). These four dimensions of justice enable us to broadly frame local actors' perception of justice and to explore variability among the dimensions.

Divergent viewpoints on fairness may be a major obstacle for mutual understanding (Müller, 2011), the latter being necessary to manage biodiversity conflict. It is thus important to test empirically how the factors influencing the feeling of justice vary among individuals. The issue itself (characteristics of the conflict, i.e. location, intentionality, stability), the individual (i.e. socio-economic status, motivation, environmental identity), and the context (i.e. natural and social) can all influence one's feelings of justice (see Table 1 for full definition and references). People might perceive the dimensions of justice differently and employ different criteria to explain their perception of it (e.g. Lauber, 1999; Martin et al., 2014; Zafra-Calvo et al., 2017). In the example of jaguar management, perception of distributive justice might depend, for instance, on socio-economic status or previous experience of jaguar attack on livestock. According to their own subjective judgment, individuals could thus adopt different criteria to achieve perceived justice.

In this paper, we employed a novel mode of analysis that uses a mixed-method approach to achieve a comprehensive analysis of all justice dimensions and to propose a

systematic and quantitative investigation of the determinants of feelings of justice that accounts for the multi-dimensional facet of the justice and its perception. Research on the plurality of, and individual variation in, justice perception has in many cases been qualitative (Coolsaet, 2016; Martin et al., 2014; Smith and McDonough, 2001; but see Zafra-Calvo et al., 2017), while studies using a quantitative approach often focused on a single dimension of justice, usually procedural justice (e.g. Lauber, 1999). Here, we used an enhanced version of the Bradley-Terry model (Bradley and Terry, 1952; Schauberger and Tutz, 2017) where the selection of factors included in the model is carried out using a LASSO penalty (Tibshirani, 1996). Using the Bradley-Terry model permitted us to develop interdisciplinary enquiry around the concept of justice and to inform future research using sophisticated quantitative methods in combination with qualitative data to reveal patterns of feelings of justice.

We explored factors affecting feelings of justice held by different actors involved in the management of the jaguar around the Calakmul Biosphere Reserve in Mexico. We investigated the jaguar conflict in Calakmul to examine factors influencing feelings of justice within a theoretical framing of multiple dimensions of justice. This study complements the work of Lecuyer et al. (2018) who showed that feelings of injustice in local communities are exacerbated by jaguar management in Calakmul. Here, we aimed to (1) identify factors influencing local actors' perceptions of justice; (2) assess how the criteria local actors used in the description of their feelings of justice cluster; (3) offer practical advice on strategies to achieve 'justice' and support 'fair' management actions; and (4) present a novel methodology for the analysis of empirical data on local perceptions of justice. We thus contribute to the theorization in this area, but also offer practical recommendation for biodiversity conflict management. By helping to develop mutual understanding and foster an open dialogue among actors, our research facilitates fair and effective conservation action.

Table 5.1. External factors of justice: factors are extracted from the literature and divided according on whether they depend on the resources or injustice considered, on the individual, or on the context in which the situation take place.

Category of external factor	External factor	Definition	Reference
Related to the injustice itself	Responsibility	Who/what is held responsible for the injustice: an individual, an organization or intangible factors	Ohl et al., 2008; Utne and Kidd, 1980
	Intentionality	Whether the injustice is caused voluntarily or not by one (or more) actors.	Collett, 2008; Della Fave, 1986; Ohl et al., 2008; Utne and Kidd, 1980
	Duration	Whether the injustice and its cause(s) are temporary or long lasting.	Ohl et al., 2008; Utne and Kidd, 1980
Related to the individual	Individual characteristics	Socio-economic and demographic attributes, and previous experience of the actors.	Clayton and Opotow, 2003; Hegtvedt, 2006; Kellerhals et al., 1997
	Motivation	The actors' objectives and expectations regarding the situation.	Parris et al., 2014
	Environmental identity	Whether and how the environment plays an important part in of someone's identity.	Clayton et al., 2016; Clayton and Opotow, 2003; Müller, 2011; Parris et al., 2014; Stets and Biga, 2003
Related to contextual factors	Physical environment	The physical environment influence how an actor perceives place identity and connects to the natural world.	Agyeman et al., 2016; Kahler, 2003; Marques et al., 2015; Parris et al., 2014

Intra-group relationships	Observation of others' behaviour in the group is used to interpret if one's behaviour is appropriate in a given situation. Social norms to which members of a social group state adherence are likely to strongly benefit or legitimize that group.	Biddle et al., 1980; Clayton et al., 2016; Clayton and Opotow, 2003; Colvin et al., 2015; Lute and Gore, 2014; Marques et al., 2015; Parris et al., 2014
Inter-group relationships	Perception of the legitimacy of an external group that promotes a certain behaviour. Such legitimacy influences how people act in accordance with each other and supports a legitimated norm or set of behaviours.	Clayton et al., 2016; Clayton and Opotow, 2003; Colvin et al., 2015; Hegtvedt, 2006; Lauber, 1999; Lute and Gore, 2014; Parris et al., 2014; Schroeder and Fulton, 2017

Methods

Species of interest and study area

The jaguar is a focal species for environmental protection and biodiversity conservation as it is a top predator and a flagship species (Sanderson et al., 2002). However, it also represents a threat to livelihoods because of livestock depredation (Polisar et al., 2003; Zarco-González et al., 2013). This has resulted in hunting and poisoning of jaguars, representing a significant threat to the survival of certain jaguar populations (Inskip and Zimmermann, 2009). In Mexico, the jaguar is considered an endangered species (SEMARNAT, 2010). Recent studies showed that the Yucatán peninsula, especially the Calakmul region, hosts one of the largest continuous areas highly suitable for jaguars (Rodríguez-Soto et al., 2011). In recognition of the region's biological importance, a Biosphere Reserve covering 723,185 ha across the largest tract of tropical forest in Mexico was created in 1989.

The Calakmul municipality is also home to 28,424 people, living in 62 *ejidos* distributed around the reserve (INEGI, 2015). An *ejido* is a land tenure system often combining both individual and communal land rights and in which decisions affecting *ejido* life are taken collectively among the *ejidatarios*, the land-tenure right holders (Warman and Warman, 2001). A large influx of people arrived in Calakmul between the 1960's and the mid 1990's mainly from the Gulf coast and central regions of Mexico. In Calakmul, people engage in a wide range of activities, including honey production and logging, although most depend on subsistence maize agriculture (Haenn et al., 2014; Turner et al., 2004). In addition, many families in the region own livestock, mostly cattle and sheep. Government programmes have sponsored sheep production, hence there has been a recent increase in families owning small flocks of sheep as a complementary income (Schmook and Radel, 2008).

The co-occurrence of livestock and jaguars and pumas makes Calakmul a high-risk zone for large felid depredation on livestock. Marshall et al. (under review) found that over 30% of the ranchers suffered at least one attack between 2010 and 2015 in the Calakmul

region. This widespread jaguar depredation is mainly experienced by sheep owners, partly because of livestock husbandry practices (Lecuyer et al., in prep). To compensate for economic losses from predators, a national compensation scheme was created. The scheme is funded through the National Confederation of Livestock Organizations (Confederación Nacional de Organizaciones Ganaderas), and is accessible to any livestock rancher who can provide evidence of ownership, without any insurance cost to the claimant. Furthermore, the Reserve and a local non-governmental organization (PRONATURA) have been helping local ranchers to complete and submit the required report after an attack. The Reserve also plays a role in jaguar management through biological monitoring, including monitoring undertaken by local groups trained by the Reserve. Additionally, the Reserve sporadically delivers technical and financial support to communities to implement mitigation measures, like electric fences, to limit the risk of attack. PRONATURA has been providing camera traps to ranchers to identify the predator in case of an attack; PRONATURA also carried out an awareness campaign, and was involved in multiple events regarding jaguar (Pers obs). Despite these efforts, jaguar management is causing a latent and sometimes strong biodiversity conflict among the region's actors, leading to feelings of injustice in local populations (Lecuyer et al., 2018).

Data collection

We conducted a survey of 45 *ejidos* located near the Calakmul Biosphere Reserve where we interviewed both ranchers (i.e. people primarily practising livestock production) and farmers (i.e. people primarily practising agriculture and not owning livestock). We supposed that ranchers might perceive fairness toward the jaguar differently from farmers as they are directly affected by predation; while farmers could offer an outsider perspective, which may react similarly to ranchers, but tend to reflect greater concerns for the community (Parris et al., 2014). Farmers were selected randomly, while ranchers were selected with a snowball technique (Coleman, 1958), where we randomly chose a house in each community to ask members of the household if they could provide us with the names of livestock owners in the community. This approach was used due to the limited number of ranchers in the communities. As the main interest of this study is to understand ranchers' perceptions of justice, we interviewed more ranchers (n=144) than farmers (n=91).

Our questionnaire used both closed and open-ended questions and was divided into two sections. The first section comprised a series of demographic and categorical questions to investigate external factors that can influence feeling of justice. We adapted factors identified in the literature as shown in Table 1, for the specific case of jaguar management as show in Table 2. While some were simple to adapt, others required an understanding of the region and several iterations after pilot interviews with local actors (see appendix 1). Because of the limited number of variables we could include in the analysis, in Table 2 we only present the questions from which we extracted the variables included.

Table 5.2. Questions to assess external factors regarding jaguar management.

Category of external factor	External factor	Question asked
Related to the injustice itself	Responsibility	• Who do you think is responsible for jaguar management in the region? 1) Individuals, 2) Government, 3) Reserve, 4) NGOs, 5) *Ejido* authorities • Do you think, the responsible (chosen above) is 1) Making enough effort to prevent jaguar attacks on livestock? 2) Does not care about jaguars attack on livestock? 3) No opinion
	Intentionality	• Do you think jaguar attacks are 1) Controllable? 2) Non-controllable?
	Duration	• How do you perceive jaguar attacks? 1) Uncommon, 2) Frequent • In your opinion, in which order (from most to least) do these predators perpetrate attacks? Jaguar, Puma, Dogs, Coyotes, Other (If no risk was associated with a species, a zero was written)
Related to the individual	Individual characteristics	• Activity: 1) Rancher, 2) Farmer • Gender • Age • Education • Number of sheep • Farmers only: Did any jaguar attack on livestock ever occur in your community? • For ranchers only: Have you ever experienced a jaguar attack on your livestock?
	Motivation	• In light of the current situation surrounding the jaguar, would you like to: 1) Permit an equilibrium between jaguar protection and livestock production? 2) Increase livestock production?
	Environmental identity	• *Choice of propositions to categorize their environmental identity (see Stet and Biga, 2003)* Creation of an index centred on 0, from -1 to 1.
Related to contextual factors	Physical environment	• How often do you go in the forest? 1) Every day, 2) Once a week, 3) Once a month, 4) Once a year • How often do you see wild animals? 1) Every day, 2) Once a week, 3) Once a month, 4) Once a year
	Intra-group relationships	• How do you best identify yourself? 1) By your activity (rancher or farmer), 2) By your status in your community (*ejidatario* or non *ejidatario*), 3) By the community in which you live (name of the community) • Within the group you best identify yourself, regarding jaguar management, do you: 1) Share the same opinion? 2) Have a different opinion?
	Inter-group relationships	• Which of the following actors do you think have the right to be involved in jaguar management? (several answers possible) 1) Government, 2) Reserve, 3) NGOs, 4) Ejidos, 5) Individuals • Do you think the jaguar management actions implemented by this/these actor(s) have been adequate? 1) Yes, 2) No

The second section of the questionnaire was an assessment of participants' feelings of justice. During previous research in the region, we identified 16 criteria people used to build their perceptions of justice according to the four dimensions of justice considered here (Lecuyer et al., 2018). Those criteria were described in 18 statements (Table 3, Appendix 1). We first asked participants if they agreed or disagreed with these statements to confirm our framing of the criteria of justice. Following, we asked them to select the 10 most important statements for them, without ranking. Out of those 10 statements, participants had to make choices of the most important statement for each pair of statements (45 paired comparisons in total). We chose paired comparisons because it is easier for people to compare pairs of objects than rank a list of items (Cattelan, 2012). The interview ended with open questions about how respondents felt about the criteria and justice toward jaguar management in general.

Table 5.3. Statements that were the object of paired comparison and representing different justice criteria that are associated with different justice dimensions.

Theme	Criterion	Statement
Distributive environmental justice: the fair distribution of costs and benefits related to jaguar management	i. Need-Benefit	Support should be provided to the livestock breeders who need it most
	k. Equality-Benefit	The same support should be provided to everyone
	m. Merit-Cost	Conservationists should pay for the cost of living with jaguars
	o. Merit-Benefit	Support should be provided to those who take measures to coexist with, and protect, jaguars
	r. Equality-Benefit	The cost of living with the jaguar should be distributed among all
Procedural environmental justice: the fairness of the processes of jaguar management (daily based operation)	c. Compliance	Everybody should respect the decisions taken
	d. Consistency	There should be no interest group favoured during the decision-making process
	j. Opportunity for revision	If I disagree with a decision, I should be able to give my opinion
	l. Trust	People in charge of making decisions should be people I trust
	p. Representation	Everyone should have the opportunity to give their opinion during the decision-making process
	q. Respect	Those responsible for jaguar management should treat me with respect
Ecological justice: the fair and respectful treatment of jaguar	a. Right of the environment	Jaguars have the right to live
	f. Responsibilities towards other species	I am responsible for not putting jaguars and their habitat at risk
	n. Responsibilities to future generation	I want to protect the jaguar for my children and grandchildren to be able to know it
Justice as recognition: acknowledging land-use rights, values and knowledge systems	b. Plurality of interest	Those responsible for jaguar management should recognize the importance of everyone's interest
	e. Land-use right	I should have the right to do what I want, if a jaguar is on my land
	g. Neutral approach	Those responsible for jaguar management should be neutral
	h. Knowledge	Jaguar management should be based on what we know about the jaguar

Data analysis

Our analysis presupposes that study participants make choices between different criteria of justice to build their overall perception, and that those choices will be influenced by external factors (covariate) related to the injustice, the individual and the context. These choices can be analyzed with the Bradley-Terry-Luce model using paired comparisons (Bradley and Terry, 1952). However, the Bradley-Terry-Luce model assumes that the strengths of the objects compared are equal for all subjects selecting them (Cattelan, 2012). Schauberger and Tutz (2017) propose a methodology that allows us to account for heterogeneity of both the subject (person) making the comparison, and the object (criteria) being compared. They recently incorporated a LASSO penalty to select subject-specific or criteria-specific covariates into the Bradley-Terry-Luce model. By using a penalized likelihood approach, the Bradley-Terry-Luce model with LASSO penalty (BTLLasso) allowed us to 1) compare pairs of criteria from choices made by different participants; 2) identify clusters of criteria influenced similarly by a covariate; and, 3) assess the subject-covariate that influenced choices among pairs of criteria (Schauberger and Tutz, 2017). In short, the BTLLasso proposes the modulation of justice criteria by subject-specific covariates selected using a LASSO penalty weighted by a tuning parameter. Because the importance of the LASSO penalty may vary depending on the data in question, we used a cross-validation to choose the tuning parameter and thus a penalty level adequate for the data for which the model was constructed. By choosing an appropriate penalty level, we can visualize justice criteria that share the same strength as well as the ones that can be distinguished from other justice criteria (Schauberger and Tutz, 2017). To evaluate the quality of the models obtained, we randomly sampled the data with replacement (bootstrap) 200 times and used these bootstrap iterations to build 95% confidence intervals. By using BTLLasso, we represented 1) how external factors influenced the perception of the subjects between justice criteria and 2) the influence that specific external factors have on the different justice criteria. All Bradley-Terry-Luce models were constructed using the BTLLasso R package. More details about the Bradley-Terry-Luce model and the R package can be found in Supplementary material 2.

In addition, we explored how justice criteria were affected similarly by external factors. We thus built a matrix of estimated effects (from the values given for the effect on each criterion for the optimal model from the BTLasso analysis) for each criterion of every group of external factors and for every external factor. We then used K-means partitioning (Legendre and Legendre 2012, section 8.8) to group criteria based on how similarly that are influenced by external factors. K-means partitioning assigns each criterion to a specific cluster and optimizes the assignment through an iteration process. In K-means partitioning, the number of clusters is defined *a priori*. Here, we tried to group criteria in 2 to 10 clusters. To find the optimal number of clusters we used the Calinski-Harabasz criterion (Calinski and Harabasz, 1974). To perform this analysis, we used the cascadeKM function available in the vegan (Oksanen et al. 2017) R package.

Results

General result on external factors

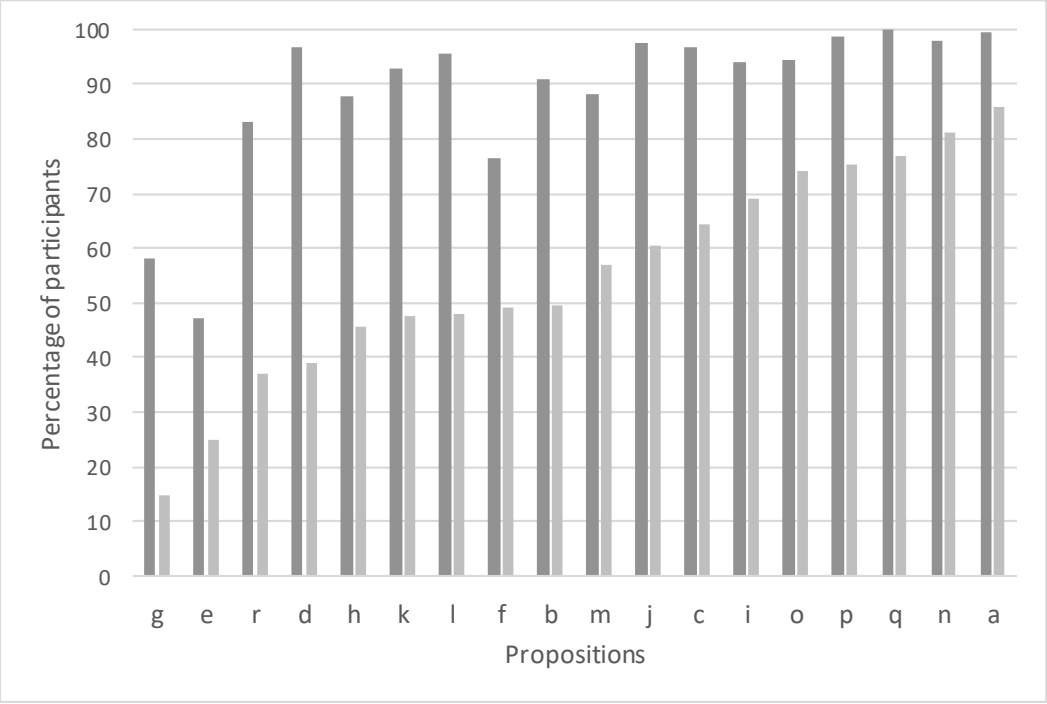
Our interviews provide information on the participant and also allows us to explore people´s perception of both the injustice itself and their interaction with their social and natural environment (Table 4).

Table 5.4. Result to the questions to assess external factors regarding jaguar management.

Category of external factor	External factor	Results
Related to the injustice itself	Responsibility	• Ejido = 12 (+ = 8, - = 3, No Opinion = 1) Everyone = 22 (+ = 5, - = 13, No Opinion = 4) Government = 75 (+ = 24, - = 45, No Opinion = 6) ONG = 20 (+ = 7, - = 12, No Opinion = 1) Reserve = 106 (+ = 32, - = 64, No Opinion = 10)
	Intentionality	• Jaguar attacks are: Controllable = 73; Non-controllable = 162
	Duration	• Frequency: Uncommon = 124; Frequent = 111 • Perception or risk (average score): Jaguar = 0,9**;** Puma = 0,4
Related to the individual	Individual characteristics	• Activity: Rancher = 144; Farmer = 91 • Gender: M= 160; W = 75 • Age: Range = 19-83; Mean = 47; SD = 15 • Education (number of years): Range = 0-15; Mean = 6 ; SD = 4 • Number of sheep: Range = 2-300; Mean = 32; SD = 27 • Farmers only: Attack in community= 54; No attack in community = 37 • For ranchers only: Attack = 100; No attack = 44
	Motivation	• Equilibrium between jaguar protection and livestock production =126 Increase livestock production = 109
	Environmental identity	• Environmental identity index: Range = -0,66-1; Mean = 0.28; SD = 0.45
Related to contextual factors	Physical environment	• Number of day they go to the forest and see wild animals per years: Range= 2-730; Mean= 258 ; SD = 237
	Intra-group relationships	• Activity = 44 (Same Opinion =17; Various opinion =27) Status = 84 (Same Opinion =31; Various opinion =53) Community = 107 (Same Opinion =33, Var opinion =74)
	Inter-group relationships	• Government: No adequate = 95, No involved = 30, Adequate = 110 Reserve: No adequate = 63, No involved = 26, Adequate = 146 ONG: No adequate = 65, No involved = 38, Adequate = 132 Ejido: No adequate = 57, No involved = 29, Adequate = 149 Everyone: No adequate = 37, No involved = 30, Adequate = 168

Criteria selection

The first part of the interview indicated if participants (n=235) agreed with the statement related to each criterion (dark shaded column, Figure 1) and which ones they selected as their 10 most important (light grey column, Figure 1). Some criteria (*a, n, o, p, q*) stood out as almost 95% of the participant agreed with these statements and because they were often chosen in the ten most important criteria (> 74%). Conversely, a few criteria showed lower levels of agreement (45-60%) among participants (*e, g*) or had lower importance (10-40%) (*d, e, g, r*).



a. Right of the environment
b. Plurality of interests
c. Compliance
d. Consistency
e. Land-use and land-right
f. Responsible for other species
g. Neutral approach
h. Knowledge
i. Need – Benefit
j. Opportunity for revision
k. Equality - Benefit
l. Trust
m. Merit - Cost
n. Responsibility to future generation
o. Merit - Benefit
p. Representation
q. Respect
r. Equality - Cost

Figure 5.1. Agreement with the criteria presented (dark grey) and criteria selected among the 10 most important (light grey) by participants (n=235). Criteria data are organized according to the percentage of participants that select this criterion as one of the 10 most important in order to clearly demonstrate the different of importance given to the different criteria.

Importance of external factors

The BTLLasso data analyses resulted in 43 plots (see Appendix 2) that we summarized in Table 4 to facilitate interpretation and presentation. Figure 2 and 3 present examples of one plot obtained from a BTLLasso analysis..

Injustice itself – Looking at factors related to the injustice itself allowed us to explore the effects of the nature of the injustice in question on participants' perception of justice (Table 4a). First, we found that the effect of whom participants perceived to be responsible is not straightforward; the positive perception of entities deemed responsible for jaguar management sometimes had a stronger effect than when only responsibility was attributed to a given entity. Second, the positive perception of responsibility at the collective/global (including themselves) or community level had a larger influence on their feeling of justice than attributing responsibility to particular entities, such as the Reserve or NGOs[6]. Third, the perceived control and temporality of attacks were important in determining the feelings of justice of participants.

Individual - At the individual level (Figure 2, Table 4b), environmental identity was the factor, which mostly influenced participants' perception of fairness. Fairness was followed by gender, personal motivation regarding jaguar management (i.e. more livestock or an equilibrium between jaguar protection and livestock production), and farmers' knowledge of jaguar attack occurrence in their community. However, factors related to the ranchers themselves were relatively unimportant (e.g. previous experience of attacks, number of sheep owned). External factors such as education and age were not very important either.

[6] External factors highlighted as influential were not necessarily selected by a majority of participants. For example, only 22 participants perceived individuals as responsible for jaguar management, against 135 who perceived the Reserve as responsible. Moreover, the way the 22 participants perceived individuals as responsible led them to perceive and prioritize the criteria of justice differently in comparison to the other participants.

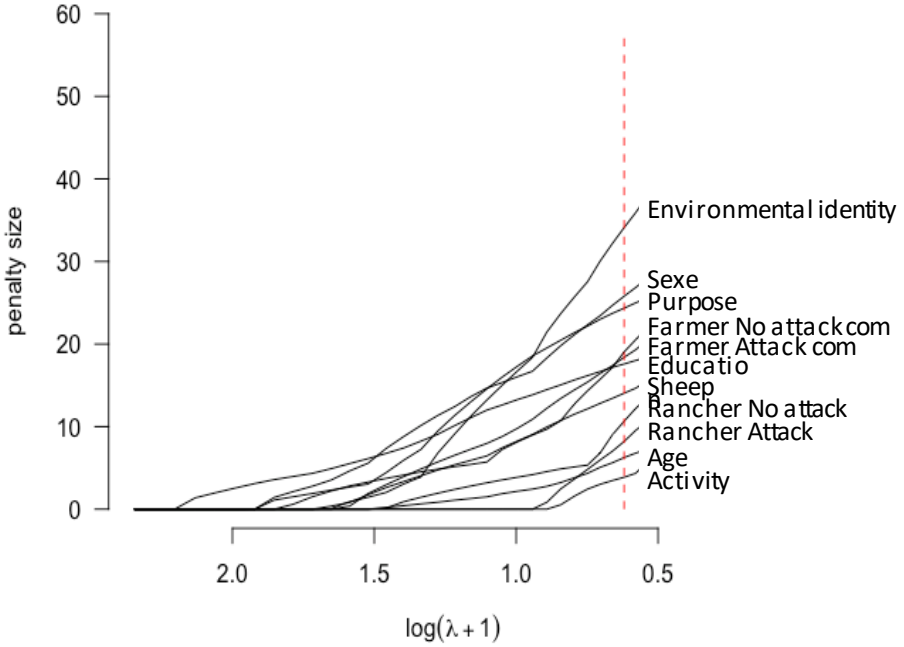


Figure 5.2. Penalty paths for individual factors. The dashed red line represents the optimal model following a 10-fold cross-validation. Subject-specific covariate "environmental identity" had the largest penalty for the single model component at the optimal value of the tuning parameter; hence, it was the covariate that most influenced the choice of participants between the different criteria.

Context - Coherence in the group to which participants felt they belong to (i.e. intra-group relationships) was the most important factor explaining feelings of justice, especially if they thought they had divergent opinions regarding jaguar management (Table 4c). Inter-group relationships had a lower influence on feeling of justice, but allowed us to evaluate how the perception of entities actions as adequate, differently influenced their feeling. Interaction with the physical environment had a minor effect on people's perception of justice. Finally, group affiliation of participants appeared to have no effect on their perception of justice.

Table 5.5. Ranking of the most influential external factors and their effect on the criteria at three levels: (a) injustice, (b) individual, and (c) context. We ranked the external factors from most to least influential on participants' perception of justice. Criteria in the left columns were influenced negatively by the external factors, while those in the right columns were influenced positively by the external factors. We selected only the criteria with estimates > |0.7| at optimal value threshold, i.e. on those most influenced by external factors. Colours correspond to justice dimensions: ecological (a, f, n; in green); recognition (b, e, g, h; in orange); procedural (c, d, j, l, p, q; in brown); distributive (i, k, m, o, r; in blue)

a. Right of the environment
b. Plurality of interests
c. Compliance
d. Consistency
e. Land-use and land-right
f. Responsible for other species
g. Neutral approach
h. Knowledge
i. Need – Benefit
j. Opportunity for revision
k. Equality - Benefit
l. Trust
m. Merit - Cost
n. Responsibility to future generation
o. Merit - Benefit
p. Representation
q. Respect
r. Equality - Cost

-	(a) External factors: Injustice	+
e, q, h, c, n	Everyone responsible (+)	m, g, f, b, o
	Ejido responsible (+)	e
f, a, g, n, l	Attack frequency (Frequent)	h, k, d, o, p, e, c, b, m, q, r,
g, m, r	Attack control (No Control)	q, e, p, l, j, f, c
m, n, o, k, d	Reserve responsible	g, c, p, a, i, b, j, e
e, h, q, g, a	Ejido responsible	**
g, e, h, j	Everyone responsible	f
h, b, g	Risk jaguar	**
b, d	Government responsible (+)	f, a
b, c, d, f	NGO responsible	h, k, i, n, q
l	Government responsible	a, e,
b, l, e, f, n, r	Risk puma	g
	Reserve responsible (+)	k, i
	ONG responsible (+)	h

-	(b) External factors: Individual	+
g, m, a, i, o	Environmental identity (+)	k, e, l, b
e, k, p, h, j, l, q	Sex (Men)	d, g, o, f
p, r, i , f, l , d, c, o, g	Purpose (+ livestock)	n, q, e, m, j
j, b, q	Farmer/ No attack comm	r, o, g, f
g, r	Farmer/ Attack comm	a, i, n
b, i, g, k, d, l, p, c	Education	h, r, e, n
e, h, n, g, m	Number of sheep	f, d, p, c, b
h, g, e	Rancher/ No attack	j
l, k, d, b	Rancher/ Attack	a
k	Age	h, i
h, e, b	Activity (Rancher)	o, n, j, i, a, p, m

-	(c) External factors: Context	+
a, e, g, h, p, j	Group identity Activity/Variable	All other criteria
f, r, k,	Group identity Comm/Similar	**
j, m, g	Group identity Comm/Variable	a *,f, h, o, r, k
d, e, o, h, l	Adequate/ Yourself	c, i, k, m, f
f, e, h, a, n	Group identity Status/Variable	p, j, i, g
e	Adequate/NGO	g, k i, o
g, f, l, m	Adequate/Gov	e, d
g	Physical environment (+)	b
b, g, i, f, n	Adequate/Ejido	r, q, e, h
	Adequate/ Reserve	f, l
	Group identity Status/Similar	f, n
	Group identity Activity/Similar	
	Group identity Community	
	Group identity Activity	
	Group identity Status	

External factors influence on criteria

The BTLLasso analysis made it also possible to study the effect of external factor on the studied criteria. For example, participants' gender influenced how they perceived the criteria of justice (Figure. 3). Relative to women, men preferred an approach to jaguar management that should be *consistent* across actors (*d*) and *neutral* (without any preconception) (*g*), held that *benefits* should be given based on *merit* (*o*), and felt more inclined towards *individual responsibility* regarding jaguar management (*f*). On the other hand, women were more interested in being *directly involved* in jaguar management (*p*), in the possibility to *review decisions (j),* in sharing *benefits equally* (*k*), in having their *knowledge* taken into consideration (*h*), and in *being able to do whatever they want on their land* (*e*).

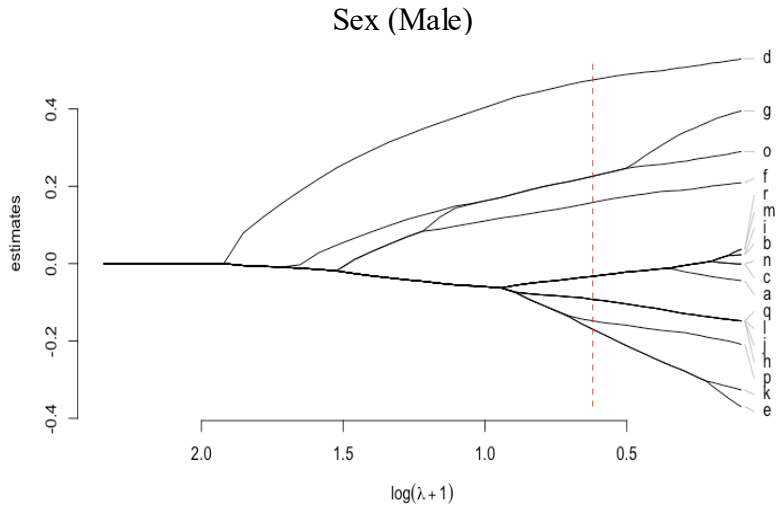


Figure 5.3. Parameter paths for the subject-specific variable, here "gender (male)". The dashed red line represents the optimal model following a 10-fold cross-validation. The plot is centered on 0 on the Y–axis. Parameter paths with a positive (negative) value indicate a positive (negative) relationship of the criteria for the variable of interest. For the optimal model (dashed red line), some criteria follow the same paths (e.g. *g* and *o*), they should be given equal importance in the interpretation of this result.

The effect of the single external factors (n=43) are shown in detail in Appendix 2. In this paper, we explore specifically how some external factors influence criteria in comparison to others. For example, the participants who expressed a strong sense of belonging to their community and who perceived they shared the same opinion regarding jaguar management with others in their community were less inclined toward an *equal distribution of costs and benefits (k,r)*, and more towards help for people with greatest *needs (i*) (Figure. S3). These participants also considered *individual responsibility* to be less important in jaguar management. On the other hand, participants who expressed a strong sense of belonging to their community, but said opinions regarding jaguar management diverged within their community, perceived things differently. Criteria they felt were important included: *equal distribution of costs and benefits (k, r)*, recognition of efforts to coexist with jaguars (*merit, o*), and recognition of their *knowledge (h)*.

We could also compare the criteria used to assess fairness across the different entities people perceived to be responsible for jaguar management. Perceiving individuals to be responsible for jaguar management decreased the importance of the criterion that one should be able to do what they want with jaguars on their land (*land-use rights, e*), while perceiving the *ejido* as responsible increased the importance of the criterion "*land-use rights*".

Grouping patterns of criteria

The K-mean partitioning did not identify a clear number of groups using the Calinski-Harabasz criterion (see Appendix 3). However, it was when the criteria were partitioned in four groups that the Calinski-Harabasz criterion yield the largest increase. Using these four groups we compare our initial division of the criteria among the four dimensions of justice. We explored the effect of each group of external factors and of every external factor on each criterion, allowing us to identify trends (Table 5). The external factors related to injustice suggest that there may be specific influences, for example, on how people perceive their *land-use right (e)* and on how they perceive the importance of a *neutral approach (g)*, representing a plurality of interest, but also on criteria related to the *right to live of the jaguar (a)* and their *own*

responsibility for its survival (f). Furthermore, with this analysis we were able to compare our initial grouping of the criteria (according to procedural, distributive, ecological and recognition forms of justice) with the final grouping of the criteria according to the influence of external factors (injustice, individual, context): 1. Each criterion of distributive justice (merit, *m, o,* need, *i,* equality, *k, r*) is represented in a different group. 2. Every criterion of procedural justice (*c, g, l, p, q*) is influenced similarly by the external factors of justice except for the *consistency* criteria *(d)* that were more associated with criteria related to justice-as-recognition: *neutrality (g)* and the *plurality of interests (b)*. 3. *Knowledge* criteria *(h)* that were associated with justice-as-recognition seem to be affiliated to procedural justice concerns and perceived more at the decision-making process level. 4. *Land-use rights (e)* criteria responded differently than all other criteria to the influence of external factors. 5. Ecological justice was divided in two: while *the rights of the species (a)* and *responsibilities to future generations (n)* seem to go hand in hand with people's concerns regarding procedural justice and *the need (i)* for criteria of distributive justice, *individual responsibility (f)* for jaguar management seemed to be influenced differently and related to the *equality* criteria *(k, r)* of distributive justice.

Table 5.5. **Grouping patterns of criteria according to the external factors evaluated (injustice, individual, and context). The table shows the groups formed at level 4 of the K-mean partitioning. Our original grouping of criteria included four dimensions of justice: ecological (a, f, n; in green); recognition (b, e, g, h; in orange); procedural (c, d, j, l, p, q; in brown); distributive (i, k, m, o, r; in blue).**

External factor	Group 1	Group 2	Group 3	Group 4
Injustice	n h, c, d, j, l, p, q, i, k, m, o, r,	a, f	b, g,	e
Individual	a, n, e, h, j, q, i, m	f, b, c, l, p, k	g, d, o	r
Context	a, e, h, j, p,	n b, c, d, l, q, i m, o,	g	f, k, r
All external factors together	a, n, h, c, j, l, p, q, i	g, b, d, m, o	e	f, k, r

Discussion

This study aimed at exploring participants' perception of justice. However, it is important to note that our analysis did not identify the dominant perception of justice (e.g. Sikor et al., 2014), but instead highlighted the variability among people's perception of justice. Although initially we were interested in assessing the overall feeling of justice regarding jaguar management in the Calakmul region, this was impossible to achieve and not meaningful as people's description of their perception of justice varied too widely. For instance, for some, unfairness lay in the killing of jaguars, while for others, unfairness lay in the losses of livestock

experienced by ranchers. Therefore, we focused on revealing the varied nature of justice perception by making explicit the various criteria at play in local actors' perceptions of justice surrounding jaguar management, and linking them to social parameters. Our main finding was that a personal experience of jaguar attack had a weak influence on actors' perception of fairness; rather, perception of fairness was driven mainly by questions of identity and assessments of inter and intra-group relationships. We also showed how some criteria (e.g. *land-use rights*) are influenced in various ways by different external factors, and how others (e.g. *the jaguar's right to liv*e) are potentially critical to reach fairer jaguar management. Through our analysis, we were able to highlight patterns and relationships amongst criteria affecting perceptions of justice, enabling us to contribute to a holistic perspective on feelings of fairness in conservation.

Group identity and self-interest influences on feelings of justice

We assessed the importance of three groups of factors towards feelings of justice: the first related to the injustice in question, the second to the individual expressing their feelings, and the third to the context of the situation. These factors enabled us to explore the role of self-interest and group identity. The self-interest assumption implies that people's main motivation is to maximize their reward (Skitka et al., 2010). However, we found that being a rancher and having suffered an attack had a weak influence on one's perception of justice. This finding supports previous research that the role of previous experience has a limited influence on fairness perception (Clayton et al., 2016) and that feelings of justice might not only be related to the object of the injustice (Kellerhals et al., 1988). More surprisingly, experience of attack at the individual and community levels, respectively for ranchers and farmers, increased the perceived importance of the jaguar right to live. This does not support the assumption of the role of people's self-interest in their perception of fairness. However, perceiving attacks as frequent did negatively influence the ecological justice criteria. One finding that might support self-interest was that actors who called for more livestock protection were more inclined to claim that conservation organisations should pay for the cost of jaguar protection. Other individual external factors also indicated concerns regarding sharing of the costs and benefits of jaguar

conservation. However, whilst most perceptions of justice did not reflect self-interest, they did not necessarily reflect a concern for society either. Instead, people seemed to base their feeling of fairness on a common peasant-farmer *campesino* identity, across *ejidos* and farmer/rancher roles, expressed through their desire of being able to live a decent life in Calakmul. This finding reinforced our previous finding that local actors aspire justice for those sharing the *campesino* identity (Lecuyer et al., 2018).

Our results also supported the group identity assumption that relationships within and between groups are potent determinants of fairness judgments (Lind and Tyler, 1988; Skitka et al., 2010). Actors not only took into consideration their own judgments, but also the conduct and opinions of group members while evaluating fairness (as shown by Clayton et al., 2016; Hegtvedt et al., 2003; Lauber, 1999; Ohl et al., 2008). More importantly, our results indicated that rather than the group with which they identified, it was the perception of the coherence in the opinions toward jaguar management within the group that mattered. In the case where participants identified with their local community, perceived coherence across the opinions on jaguar management resulted in participants supporting sharing the costs and benefits based on need and merit. Meanwhile, perceived variability of opinion toward jaguar management privileged individual responsibility for jaguar conservation, and equal sharing of the costs and benefits of coexisting with jaguars. A lack of coherence within a given group also hinders the willingness of its members to participate in decision-making, because of the lack of a united front to present and defend ideas (Lind and Tyler, 1988). In our study, participants who identified as *ejidatarios* (i.e. owners of land rights) were less willing to support ecological justice if they perceived that other *ejidatarios* had divergent opinions toward jaguar management. The comparison between the different group memberships allowed us to uncover some of the groups' values and the dynamics of group influence on their perception of fairness.

Both self-interest and group identity were important assumptions to take into consideration for carnivore conservation. In effect, past actions emphasized technical measures to reduce losses caused by depredation, if concern for self-protection was driving the surrounding conflict (Treves and Karanth, 2003). On the other hand, recent studies proposed

that relational aspects are among the principal drivers of biodiversity conflicts (Redpath et al., 2013). Here, we showed that external factors did not have a straightforward effect: while some individual factors led people to choose criteria that represent justice for all, including jaguars, external factors related to relationships with others sometimes influenced their choice of criteria in relation to self-interest. Participants modified their perception of justice not only according to the costs and benefits to be distributed and to whom, but also according to who is in charge of the distribution and how others act regarding jaguar management. Looking at the influence of external factors on criteria that Calakmul ranchers and farmers used to build their feeling of justice supported others' finding that everyone cares for both self-interest and group identity (Clayton and Opotow, 2003; Lind and Tyler, 1988).

Recommendations for jaguar conservation

We believe acknowledging and exploring the variability in the criteria used by people to assess fairness in jaguar management can provide guidance to implement management plans that encompass various perceptions of justice. One of our main findings was that the vast majority of local actors, ranchers included, recognized the intrinsic right of the jaguar to live and the importance of its survival for future generations. Even more importantly, we uncovered alternative narratives to those currently circulated by conservationists in Calakmul. For instance, even ranchers who had suffered attacks and consequent losses reaffirmed jaguar' right to live. Furthermore, people shared the same perception of procedural justice and perceived a clear distinction between the criteria of distributive justice, i.e. need and merit. Additionally, some of the criteria that were marginally important, such as individual responsibility for jaguar survival and land-use rights, should not be ignored as they might play an important role in people's frustration and in explaining potential retaliation.

Our results can inform practitioners of specific factors that can positively influence a change in people's perception of the criteria. For example, both the perception of frequency of attacks and control over jaguar depredation influenced people's perception that they should be able to act freely on their land. Current programmes to reduce livestock predation should be

reinforced to discourage people to do what they want with jaguars on their land. Furthermore, cooperation of ranchers might be improved by acting on those factors that influence the perception of individual responsibility toward jaguar management. In Calakmul, perceiving the Reserve's actions as adequate was related to an increased sense of personal responsibility toward jaguar management. This was not the case if a NGO or the government carried out actions that were positively perceived; rather, this led to the unwanted result that people reduced their own sense of responsibility. We believe this result shows the relevance of programmes that directly involve communities, such as the temporal employment programme of the Reserve, where a contract between the Reserve and local actors is established, leading local actors to feel responsible for their actions.

Organizations and institutions could use the perception that locals have of their actions to induce changes in their management practice in order to support positive feelings of fairness. For example, consideration of their knowledge seems more important if they perceived NGOs were responsible for jaguar management (it was far less important if they perceived their community or individuals were responsible). This highlighted that people felt their knowledge had been ignored in previous NGO interventions. Imposition of dominant conceptions of knowledge can increase people's feelings of injustice and decrease support for a particular organization (Coolsaet, 2016). On the other hand, people stressed that the Reserve should adopt a neutral approach. This might reflect concerns that managers do not listen to local actors, even when consulting them, because their minds are made up in advance and they only support a conservation agenda (Lauer et al., 2017; Smith and McDonough, 2001). It is important to consider those feelings of justice, since even minority groups can be vocal and lead conflict around species conservation (Lute and Gore, 2014).

Approaches to fairness in environmental management

Our novel and sophisticated quantitative approach allowed us to demonstrate the power of using criteria selection to achieve a nuanced understanding of how people build their perceptions of justice. Using an enhanced version of the Bradley-Terry model, we analyzed

the plurality of justice perception and how it is influenced by different covariates. The strength of this statistical analysis is that it reveals complex patterns of perceptions of fairness. Rather than assessing the dominant views of justice, our approach showed the importance of the variability in people´s description of fairness. In addition, it highlighted the complexity of the criteria by which people construct their perception. This specialized statistical analysis might not be useable for every biodiversity conflict study, but understanding that this complexity exists, as well as the importance of identity and relationships are likely to be relevant to other conflicts.

People have diverse views of justice and justify their positions using criteria from all dimensions of justice. Importantly, these dimensions are not mutually compensable (Zafra-Calvo et al., 2017), and success in addressing one dimension will not reduce the potential impact of failure to comply with another dimension. Moreover, results are highly context-specific, so criteria should be based on local people's construction of justice. In addition, criteria can represent various points of view (e.g. representation can be a desire to voice their concerns or a wish to participate directly through voting; Smith and McDonough, 2001). This variability can add a layer of complexity in interpreting and translating the results into action, making it necessary to accompany such an approach with qualitative research allowing a deeper understanding of the situation. Whilst results from this study offer important new insights, it is the combined knowledge from both our qualitative understanding of the situation (Lecuyer et al, 2018) and the quantitative results showed here that allowed us to develop specific recommendations to support conservation efforts.

Our recommendations might help address particular feelings of justice and play a role in succeeding in conservation. Besides, we also agree with researchers who claim that there will be no single solution that will address everyone's feeling of justice (Jacobsen and Linnell, 2016; Law et al., 2017; Martin et al., 2014; Müller, 2011). However, the complexity of the feeling of justice should not prevent us from seeking routes toward enhancing fairness in environmental management. The importance of group relationships supports the need to develop collaborative approaches (Lauer et al., 2017; Sikor et al., 2014; Dawson et al., 2017).

However, approaches that only aim to aggregate local actor preferences to legitimate specific and predetermined conservation goals will not be sufficient to acknowledge people's multiple perceptions of fairness (Durand et al., 2014). To agree on conservation practices that will appear just to different actors, researchers and managers must engage in a difficult dialogue, where local actors openly verbalize their notion of justice, acknowledge their differences, build mutual understanding and trust, and try to help groups of actors develop common identities (Durand et al., 2014; Müller, 2011). The value in having such diverse perceptions of justice is that it opens the door for extensive debate and collective reflection, thus developing relationships among actors, which we believe is itself a step toward more sustainable solutions for jaguar conservation, and indeed conservation more widely.

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CHAPTER 6

GENERAL DISCUSSION AND CONCLUSION

This thesis proposed an innovative approach to studying biodiversity conflicts, placing them in the context of sustainable development to find alternative solutions that differ from traditional technical measures to improve the conservation of jaguars (*Panthera onca*) in the Calakmul region. The Calakmul region was very well suited to conduct our empirical studies. While still being a well-conserved landscape, it also represents a place of livelihood to numerous actors who hold different concerns towards environmental management, including jaguar conservation. I decided to adopt an interdisciplinary approach that incorporates social justice, specifically people's feelings of justice toward environmental management, with the goal of supporting environmental integrity. This research aimed at answering three principal questions: (1) What is the relationship between biodiversity conflicts and biodiversity impacts? (2) How is the concept of social justice related to biodiversity conflict and how might its consideration offer new approaches or solutions to strengthen environmental integrity? And (3) Can dialogic and collaborative approaches contribute to managing biodiversity conflicts? By doing so I did not only question the relationships between humans and jaguars but shed light on the relationships between actors and how it might influence our capacity to manage biodiversity conflicts fairly.

The first chapter showed that livestock attacks by large cats in Calakmul have affected about one third of the ranchers in the region, livestock species being the first determinant of attacks with sheep being particularly at risk. I found then that functional landscape characteristics best explain the spatial distribution of attacks in the region. However, the region of Calakmul is a very well preserved landscape resulting in a widespread risk of attacks in the whole region. The second chapter contextualized environmental management concerns, including human-wildlife interaction, by exploring the common ground and importance among

multiple issues expressed by local representatives. I propose that common ground can represent a positive way to approach conflicts and support the first stages of collaborative processes. The third and fourth chapters focused on the central notion of social justice, and more specifically about how people build their feelings of justice and which external factors determine variation in those feelings. Chapter 3 explored feelings of justice surrounding the management of three resources (forest, water and jaguar) and proposed that people articulate their feeling of justice around four dimensions of justice: justice-as-recognition and ecological justice, which are presented as conditional to the other two dimensions, and distributive and procedural justice, considered as practical justice. Chapter 4 used criteria identified in Chapter 3 to assess the influence of external factors on the feeling of justice. Using a pioneering statistical analysis (BTLLasso), I was able to identify what influences people's perception of fairness on the issue of jaguar management in the region of Calakmul. Personal experiences of livestock losses have a limited effect, while relationships among local actors, such as intra-group interaction, or attribution of responsibility were very important in explaining variation in local actors' perception of justice.

Overall, my research integrates both social and natural sciences' perspectives to provide, for each chapter, specific recommendations that can improve environmental management, and more specifically jaguar management in the region of Calakmul. It also uses deep qualitative analysis and novel quantitative approaches that allow us to support the development of methods and framework in an innovative way, in order to open a new understanding of biodiversity conflicts. While the different chapters offer answers to specific objectives, I want to develop here how my entire interdisciplinary work answers the three questions of the general inquiry. I present how my research reveals the complexity of the links between biodiversity impacts and biodiversity conflicts, and how social justice can bring new understanding to both concepts. Finally, I propose that my project helps bring new understanding on the form of the collaborative approaches needed. It also shows how science and researchers can contribute to the management of biodiversity conflicts, by adopting a research process that emphasizes the importance of the relationships among disciplines, researchers and actors.

Social justice an overarching concept to address relationships between biodiversity impacts and biodiversity conflicts

Biodiversity conflicts have attracted increasing interest by researchers and practitioners in recent years (Peterson et al., 2013; Redpath et al., 2015; White et al., 2009). Over the duration of my project, a large number of publications have recognized the need to not restrict investigations to the ecological context, but to acknowledge that the relationship between biodiversity impacts and biodiversity conflicts is neither simple not linear (Pooley et al., 2017; Redpath et al., 2015; Young et al., 2016b). My research contributes to the argument that while biodiversity conflict might stem from biodiversity impact, biodiversity conflicts are more complex and embedded in specific socio-economic contexts (Kansky and Knight, 2014; Young et al., 2010). The interviews conducted for Chapter 2 revealed that large cat attacks on livestock were the second ranked cause of livestock loss in the region, which is not negligible (see appendix E, Marshall et al., in prep). The level of risk in the region was found to be widespread over the landscape and the impacts also influenced how people addressed the criteria related to their feelings of justice in the following chapter Livestock losses and the resulting distribution of support or compensation were part of the concerns addressed under the dimension of distributive justice. However, our focus on the broad notion of social justice demonstrates that non-material social needs, and unmet psychological needs, such as trust or acknowledgement for the *campesino* way of living, are also at the root of the conflicts. Additionally, our results show that personal experience of loss (biodiversity impact) has a limited effect on people's perception of justice in comparison to intra- or inter-group relationships. Only addressing the conservation issue of jaguar management by proposing technical solutions may not address local actors' calls for recognition, respect, trust, transparency, and participation. Biodiversity conflicts "do not occur in a vacuum" as Young and colleagues (2010) stated, and it is important to acknowledge the diverse interacting factors including biological, economic, social, and cultural issues.

In this research, I focused principally on the instrumental benefits for conservation of pursuing fairness. One of the important contributions is the proposition that social justice, as

represented in the scope of environmental management, can address issues related to both biodiversity impact and biodiversity conflict. I suggest that the perception of distributive fairness can be related to the perception of biodiversity impact, such as the cost of depredation, distribution of help for mitigation measures, and efficiency of the compensation scheme; while procedural fairness judgment emerges from the wish of local actors to be involved, to have a voice and control over the process of environmental management. Justice-as-recognition, on the other hand, allows issues involving deep-rooted conflicts such as belonging and connectedness or social and cultural security, and freedom of behavior to be addressed (see also Madden and McQuinn, 2014; Pooley et al., 2017). While conservation is sometimes regarded as imposing external perceptions of the world upon local actors (Howitt and Suchet-Pearson, 2006; Schlosberg and Carruthers, 2010), justice-as-recognition addresses power imbalance and the multiple beliefs and forms of knowledge (Martin et al., 2016). Finally, ecological justice recognizes the different ways to think about a given animal species, for instance, and the moral value intrinsic to the natural environment itself. It allows one to address how people perceive the relationship between humans and nature, an important aspect of biodiversity conflict (Linnell et al., 2015), and eventually to integrate mutual concerns for animals and local actors into environmental management process and outcomes. The framework I propose in Chapter 3 allows the coverage of a large variety of the issues brought up by biodiversity conflicts and biodiversity impacts.

Furthermore, the inquiry of the factors affecting feelings of justice provides insight into the complexity of potential drivers of biodiversity conflicts. First, personal interests and experiences were insufficient to explain peoples' perceptions of justice and potential reasons for conflict. This result highlighted the importance of peoples' relationships and their perceptions of themselves, others, and their place in the group and larger society (Hegtvedt et al., 2003; Lute and Gore, 2014; White et al., 2009). Other researches have shown, for example, that shepherds in Europe show strong resentment towards city-dwellers who, according to them, impose wolf protection (Skogen et al., 2008) and develop the stereotypes that people living in cities have no knowledge about nature (Mounet, 2006). Negative perception might influence the willingness of each party to enter into a negotiation and try to reach an agreement, amounting to highly

polarized debates (Hickey, 2009; Miller et al., 2011; Peterson et al., 2002; Stoll-Kleemann, 2001). Secondly, the drivers behind feelings of justice investigated in my research address the perception of the animal itself, shedding light on how predators and their attacks are perceived, i.e. how their impacts are perceived, which is an important aspect of human-carnivore relations (Pooley et al., 2017). Are they controllable? How do people perceive the level of risk? External factors allow exploring both relationships among actors involved in environmental management, and the relationship of those actors with the natural environment itself.

While my research gives a comprehensive view of the feeling of justice, there is still a lot to explore in future research in order to improve biodiversity conflict management. Numerous aspects proposed in this research would deserve, for example, deeper and more targeted research, such as done by Young and colleagues (2016a) on the notion of trust. I also recognize that many other aspects might influence the successful management of biodiversity conflicts (e.g. legislation and institutional support, see Plummer, 2009), which were not explored in this project, and that other interesting frameworks have been proposed to explore biodiversity conflicts (Madden and McQuinn, 2014; Redpath et al., 2013; White et al., 2009; Young et al., 2016b). Furthermore, I investigated the feeling of justice among local farmers and ranchers, as they are the local residents whose livelihoods are affected by environmental management decisions and who effect the local environment through their actions. It would be interesting in future studies to examine feelings of justice in other groups of actors (e.g. local authorities, conservationists), and to see how local perceptions of justice might interact with global visions of sustainable development and imperatives of justice. Nevertheless, I think that approaching biodiversity conflict under the scope of social justice allows a broadening of the debate, investigating numerous issues that are normally approached individually under different disciplines, paradigms or concepts. It brings multiple points of views together and can create mutual understanding among actors, which will help to reconcile environmental integrity and social justice.

The importance of collaborative approaches and relationships

One of the constant recommendations that emerges from my investigation is the need for conservation to engage in collaborative approaches that emphasize dialogue and recognition. This is nothing new, as co-management and participation have both attracted the attention of international institutions, researchers, and practitioners. Protocols and international commissions have proposed a shift towards more public participation, taking the stand that conservation approaches should not disadvantage local people, who should be given a political voice in decision making (Antunes et al., 2006; Messner et al., 2006; Reed, 2008; Treves, 2009). In the Brundtland Report, it was stated that equity in resource allocation would be more easily achieved through public involvement in decision making (Bruntland, 1987). Protected area guidelines also include themes such as "governance, participation, equity and benefit sharing" (CBD, 1992). It has been even more strongly emphasized in the following policies with the Sustainable Development Goals that propose to move beyond the focus of participation to promote partnership (UN, 2015). Involvement of local communities has been described as being a solution to prevent negative consequences of conservation, to increase its effectiveness and to reduce its costs (Orlove and Brush, 1996; Reed, 2008). However, past attempts of public participation have struggled to obtain the expected results of effectively taking each point of view into consideration (Ohl et al., 2008). The issue regarding biodiversity conflict is the impossibility to fulfill everyone's interests, and people are then tied up in finding a solution that does not always involve optimizing costs and benefits under an economic perspective (Paavola, 2004). Collaborative approaches are challenging, and this project allows us to recognize some important aspects to consider in collaborative strategies.

First, we propose to move from approaches that focus on differences (see research that focuses on positions "for" or "against" carnivores; Dressel et al., 2015; Slagle et al., 2017) to one that tries to find common ground. My second chapter reveals how to identify, measure, and use common ground to support collaboration, and stresses the importance of acknowledging the variety of positions among actors who share the same occupational activity (e.g., NGO representative, farmer). Categorization can polarize actors and highlight their differences and

how they compete, which does not promote conflict resolution. Secondly, focusing on a single issue can also antagonize actors who have divergent opinions on a given issue. It might then be useful for future collaborative approaches to explore multiple issues in order to identify and act on commonalities in people's perspectives and find areas of negotiation among contentious issues. Broadening the context by considering the variability between individuals and a multiplicity of issues will support the identification of potential solutions to manage biodiversity conflicts. Without advocating the objective of full consensus, which can have negative consequences (see Peterson et al., 2005), the search for common ground allows us to envision and implement new strategies to understand and support forms of conservation practice that use a positive and forward-looking approach incorporating increased societal negotiation and the acknowledgement of wider contexts.

Second, we agree on the need to move away from the idea that "one size fits all" solutions exist (Sunderland et al., 2009), or even solutions that will satisfy everyone (Jacobsen and Linnell, 2016; Law et al., 2017; Martin et al., 2014; Müller, 2011). Exploring feelings of justice highlights the importance of adopting a plurality of approaches that recognize people's highly diverse views of fairness. Furthermore, perceptions of fairness can change according to different factors such as the resources in question, or who is perceived to be responsible. It is a messy and complicated affair. Collaborative approaches should be open to (1) Engage in difficult dialogue that addresses issues of power, interest, and representation (Young et al., 2010): (2) Take into account deeper social conflicts (Madden and McQuinn, 2014) and the historical contexts of particular conflicts (Pooley et al., 2017); and (3) Explore people's differences to find the best form of adjudication and reconciliation when facing conflicting perspectives, in a democratic process. This might be challenging as collaborative approaches often necessitate time, as well as the willingness of the different parties and the required resources to engage in such process (Davies and White, 2012).

Collaborative approaches should not be seen as a panacea and there is still strong debates regarding solutions to coexistence with carnivores (Lute et al., 2018). Regarding carnivore conservation, Treves and colleagues (2017) recently suggested a protectionist approach where

the state should be fully responsible for their conservation, whereas Redpath and colleagues (2017) underlined the importance of collaborative approaches, especially in the developing world. More generally, given the urgency of biodiversity protection, some authors have called for more drastic protection measures (Oldekop et al., 2010). Furthermore, collaborative approaches can fail when conflicts between parties already exist and are not acknowledged (Armitage et al., 2009). I thus agree that collaborative approaches might not always be the appropriate answer and that the best approach will be context-dependent. However, I would like to raise some concerns regarding the biodiversity crisis context in which this protectionist discourse emerges. While I understand the necessity for emergency action to protect some species, I found during my fieldwork a growing frustration in local actors striving for conservation, as they feel that they are left behind and neglected. They ask why they should keep doing conservation when other places where people have perpetuated more destruction receive more attention and more financial support. Whilst I have not verified this claim, this perception is dangerous as it might discourage people from engaging in conservation until it becomes indeed a crisis. In places such as Calakmul, a well-conserved tropical forest with a viable jaguar population, I believe that it is important to develop collaborative approaches in order to maintain people's motivations to secure the health of the environment they live in and willingness to coexist with jaguars.

The complexity of biodiversity conflicts and potential difficulties to develop effective collaborative approaches, however, should not be an excuse to give up. It should lead us to be more reflexive and to wonder when collaborative approaches are appropriate (Young et al., 2016b) and what makes them effective (Gutiérrez et al., 2016). For example, participatory interventions that only aim to aggregate people's preferences regarding a predesigned conservation plan might fail to recognize people's claims for more recognition and procedural justice (Durand et al., 2014). Furthermore, evaluation of collaborative approaches will have to replace objective standards, such as how many people participate, by subjective points of evaluation (Haider, 2001), such as those that account for the evolution of relationships between the actors involved. Future research should continue to try to understand in more details the importance of social (individual and group) identity or legitimacy in relationship to

environmental management, following the work by different authors (Colvin et al., 2015; Lute and Gore, 2014; Skitka et al., 2010). In the case of jaguar management in Calakmul, social relationships came out as important in different parts of this research project. I believe then that collaborative strategies that recognize the potential conflict in all justice dimensions used in our framework will be beneficial and allow more effective management of biodiversity.

Recommendations to support environmental integrity and jaguar conservation in Calakmul

While specific recommendations are given in the different chapters, here I want to summarize some of the main proposals to support jaguar conservation that arose from my project. These proposals derive both from the results of my own research and from ideas developed during the time spent actors in the field and during the workshops organized within fieldwork. We conducted two workshops with multiple actors, including ranchers from several different areas in the region, local NGO representatives, government representatives, and one representative of the compensation scheme in order to discuss how to improve the compensation scheme and explore other possible solutions. An additional workshop was organized with several ranchers from the region, researchers who were active locally, staff from Calakmul Biosphere Reserve and PRONATURA, and the veterinarian in charge of the compensation scheme in the region in order to develop a more fruitful dialogue among actors and establish the basis for a stronger relationship in the future. This second workshop had a further objective, as it was also open to graduate students seeking to learn about facilitation and participatory processes through a real-world case. Finally, programs worldwide that have shown how it is possible to co-exist with large carnivores (e.g. snow leopard in India) also inspired these ideas.

Some recommendations are based on the notion that synergies among multiple issues could potentially occur (see Chapter 3). For instance, providing assistance to ranchers because they are co-existing with jaguar and are deemed key actors in the success of its conservation could increase positive feelings, as it would give them recognition as good stewards of the land.

In Calakmul, the kind of support that would benefit ranchers might be equipment to install water tanks in pastures, facilitating access to veterinary care, or systematically providing camera traps to ranchers located in areas where depredation by large cats is common. Furthermore, such programs should be implemented as contracts between communities and the organisations or institutions providing the support, in which it should be stated clearly that the support is contingent on them not killing jaguars. A slaughtered jaguar in a given community would thus jeopardize or cause suspension of the support for a period of time. This would ensure that individual and group responsibilities are not ignored, and would increase community vigilance.

Another emerging recommendation that will require additional research to assess its feasibility is to create local cooperatives of sheep breeders and implement a short direct supply chain distributing Calakmul mutton and lamb meat to the tourist areas of the Yucatan Peninsula. Today in Calakmul, more people want to own sheep, but many own only a small flock and cannot invest to protect their livestock against depredation. Since *ejidos* are communal land, one plot could be dedicated to sheep breeding using good husbandry practices and enabling co-existence with jaguar and other predators, for example, by implementing mitigation measures such as electric fences. Producers using this communal plot could be organized as a cooperative to divide the work and money invested. Such a cooperative would also facilitate application to subsidies and increase the potential to have a voice and participate in decision-making. Regarding current modes of marketing and distribution, today the animals in the region are sold to intermediaries who dictate the price of the product. Cooperatives could help facilitate distribution directly to restaurants in the tourist area. This would allow producers to sell meat at a better price, especially if the meat is branded as "jaguar friendly". This type of approach would require support and may demand a new certification scheme. Again, this proposal permits local actors to receive recognition for their contributions toward jaguar conservation.

One other important aspect that came out of my research is the importance of the relationship between and among groups. Perception of responsibility plays an important role and wrong information and blurred understanding of organisations' roles can lead to negative perceptions among local actors. Information campaigns should not just focus on disseminating

information regarding jaguar ecology and management, but also provide a clear picture of the actors involved in the region, their roles and responsibilities and potential ways to contact them and should use participatory and dialogical two way modes of knowledge exchange to permit actors to contribute to ideas for management. Another important factor related to the relationships among actors were the notions of trust, respect, and transparency. It is thus critical who disseminates information and facilitates knowledge exchange. In the region, I believe a network of local informers should be developed, including local ranchers knowing, for example, about prevention of jaguar depredation and the compensation scheme. Furthermore, face to face exchanges between ranchers who do not manage their livestock to avoid jaguar depredation and the few ranchers who have implemented good practices should be organized. This will give recognition to those who have implemented these practices, and for the others, demonstrated examples of how it is possible to implement those measures. Finally, on a more formal level, we worked on the creation of a livestock producer committee that would represent all ranchers of the region in decision-making processes. This committee should be invited to participate in the main collaborative efforts organized in the region (sustainable development through the CMDRS, conservation through the Calakmul Biosphere Reserve, etc.). Efforts should be pursued to make this committee effective and a real partner in decision-making processes in the region.

Overall, Calakmul is an area where the conflict surrounding jaguar management has not yet escalated to the stage that it has created divisions between groups that are not able to talk to each other (see wolf management in some places in Europe: Jacobsen et al., 2016). Almost all actors engaged in this research (except one out of almost 250 individuals) recognized the importance of ensuring jaguar survival. This does not mean that a status-quo for jaguar conservation would be acceptable, but highlights that it is still possible for local actors to work together to find solutions. My research helped to make local actors more aware of the importance of collaboration and of the potential solutions that can come from collaborative approaches. It supported the development of projects that put at the forefront the participation of local actors and consideration of the social aspects surrounding the conflict regarding jaguar management.

A shift in conservation science and researcher's positions

Within the context of biodiversity conflict, several authors are beginning to acknowledge the role of scientists and the possible bias arising from their position as environmental conservation supporters and their occasional involvement in advocacy groups (Haller and Gerrie, 2007; Lawton, 2007; Oreskes, 2004; Redpath et al., 2013; Scott et al., 2007; Scott and Rachlow, 2011; White et al., 2009). Scientists, specifically natural scientists, while thinking that they are only providing neutral scientific facts, often fail to recognize that their own motivation and sometimes the goal of their study rest on achieving conservation oucomes (White et al., 2009). Consequently, when looking into biodiversity conflicts related to species conservation, this underlying goal may result in scientists interested in conservation imposing their interests in order to improve species protection instead of minimizing the main conflict (Haller and Gerrie, 2007; Redpath et al., 2013). This is usually pushed through legislation and enforcement (Rastogi et al., 2012). 'Success stories' in conservation often relate, therefore, to the level of protection given to a species or to its potential population recovery without paying attention to the resulting level of conflict with local populations (Chan et al., 2007; Madden and McQuinn, 2014; Negi and Nautiya, 2003). Although I do not believe that it is always possible, or even necessary to avoid conflict, it is important to be aware of it and of its potential consequences.

More generally, scientific information included in debates on environmental controversies is presented as being neutral and value-free (Vallance et al., 2011). However, when science is placed at the center of the debate, it is common that both parties will justify their views using competing scientific positions or by invoking scientific uncertainty, putting into question the usefulness of science in managing conflicts, and suggesting it may even reinforce those conflicts (Nelkin, 1995; Sarewitz, 2004). By making this observation, one has to reconsider the assertion that scientific information is devoid of any interest and impartial. Some authors go further, acknowledging that the scientific and political contexts interact, resulting in a co-production of scientific knowledge by scientists and the society which scientists are a part of (Jasanoff, 1996). The boundaries between science and policy or politics are then always renegotiated as part of the political process. From my experience through my research

and the literature written on this subject, I propose to conclude here by presenting what I believe would be a necessary shift in the position of conservation science and the researcher in order to better address biodiversity conflicts.

To reach the normative goal of preserving the different forms of life on Earth, conservation biologists need to operate under a different mode, whereby they engage and interact with other societal actors. Through direct interaction with local actors and the adoption of an interdisciplinary approach that integrates social sciences, conservation research could help bridge knowledge gaps and develop common problem definitions (Giller et al., 2008; Jasanoff, 2009; Mascia et al., 2003). Conservation biology needs to become a boundary science, one that both develops scientific understanding and supports conservation practice on the ground (Cook et al., 2013). Researchers will need to distance themselves from the traditional top-down and technocratic approaches (Brand and Karvonen, 2007), and instead: (1) investigate local communities to use them as a leading force of their research projects; (2) acknowledge that solutions will not only be technical and will involve negotiation among actors who have different values and knowledge; (3) develop interactional expertise (see Carolan, 2006), representing the capacity to interact in a meaningful way with others who possess relevant expertise of another form. In this context, conservation science shifts from being a process of information production to being integrated within social processes and being used to help structure debates about policies and decision making (Patterson et al., 2003). Conservation science thus potentially becomes part of societal negotiations and contributes to the exploration of future options that can facilitate collaboration for sustainable and equitable development (Giller et al., 2008).

I propose here that the research process can play an important role in this. Social scientists and more specifically social constructionists have long acknowledged that during qualitative research, research becomes a joint product between the researcher and the researched (Cunliffe, 2003; Finlay, 2002; Riley et al., 2003). They co-constitute meanings that have the potential "to transform the very phenomenon being studied" (Finlay, 2002, p.531). In other words, the research process has the potential to change both the researcher and the researched

by involving them in a form of mutual learning. In the process of my own research, a lot of time was spent in the form of open discussion through interviews, focus groups and workshops, with different actors who allowed the creation of common experience and knowledge. I also spent time coming back to communicate my results to the communities and local actors in charge of conservation and sustainable development, as advised by Young and colleagues (2016b), allowing the development of follow-up projects. This can help building bridges between divergent points of view, developing trusting relationships, and supporting the development of commonalities between the researcher and the researched, and among the researched (see the case of elephant management in Madden and McQuinn, 2014). Moving away from the hegemonic approach of natural science where subjectivity is denied, allows one to acknowledge the importance of the research process as a potential first step to manage conflict. Furthermore, I believe it allows each actor, researchers included, to reflect on their position and build confidence in their will to participate toward collaboration, which might represent one of the major outcomes of my project.

Of course, this shift of conservation science and researcher's positions remains challenging and important contributions are also done every day under "the traditional approach". Obstacles to interdisciplinarity have long been documented (Bennett et al., 2017; Campbell, 2005; Delibes-Mateos, 2017; Endter-Wada et al., 1998; Hicks et al., 2010; Marzano et al., 2006; Mascia et al., 2003; Pooley et al., 2014; Sandbrook et al., 2013; Sievanen et al., 2012), and also occured during my research process. Poor understanding from natural scientists of what social sciences represent and how they can contribute to conservation have led to obstacles in the pursuit of successful interdisciplinary projects (Campbell, 2005; Moon and Blackman, 2014). There is also no consensus on whether training in environmental fields, such as my Ph.D., should mainly focus on natural science or incorporate other disciplines (Adams, 2016; Newing, 2010). Additionally, there is a debate regarding whether it is necessary to incorporate other actors and forms of knowledge into the research process (Carolan, 2006). Overall, researchers have emphasized that investing in collaboration, communication, mutual learning, and interpersonal relationships (Campbell, 2005; Marzano et al., 2006) is necessary for successful interdisciplinary work. I believe that, to achieve this goal, more social ties will

have to be created where stereotypes are broken so that each key interest group develops more empathy toward the others (empathy being defined here as the ability to understand and share another person's experience and emotions). In the future, the role of researchers and the intent of their research regarding biodiversity conflicts might thus be to allow ties to be created and relationships between people and disciplines to be reinforced.

APPENDICES A

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APPENDIX TO CHAPTER 1

Content:

Table A.1. List of variables considered and associated justifications

Table A.1 List of considered and associated justifications

Variable	Definitions	Justifications	References
Percentage of upland mature forest (selva alta/ mediana/baja) / P_matFor_r	Percentage of mature forest in the landscape within a given radius around the attack/non-attack point in 2015	Mature forest is known to be the principal type of vegetation used by jaguar. It has been shown to influence the occurrence of attacks by carnivores in other places	(Chávez, 2010; Conde et al., 2010; Michalski et al., 2006; Zarco-González et al., 2013)
Percentage of inundated short-stature forest/ P_indFor_r	Percentage of inundated short-stature forest in the landscape within a given radius around the attack/non-attack point in 2015	Inundated short-stature forest is used differently by male and female jaguar and during the year. It is selected by females, especially with cubs, while males tend to avoid it.	(Chávez, 2010; Conde et al., 2010)
Percentage of secondary forest P_SecFor_r	Percentage of secondary in the landscape within a given radius around the attack/non-attack point in 2015	Secondary forests seemed to be avoided by jaguars, which might influence the occurrence of jaguar attack	(Chávez, 2010; Conde et al., 2010)
Percentage of upland mature forest in 2000 (selva alta/ mediana/baja) / P_matFor_2000_r	Percentage of mature forest in the landscape within a given radius around the attack/non-attack point in 2000	Past forest condition can be important to understand jaguar presence and biodiversity pattern, which might influence the occurrence of jaguar attack	(De Angelo et al., 2013; Ewers et al., 2013)
Percentage of inundated short-stature forest/ P_indFor_2000_r	Percentage of inundated short-stature forest in the landscape within a given radius around the attack/non-attack point in 2000	Past forest condition can be important to understand jaguar presence and biodiversity pattern, which might influence the occurrence of jaguar attack	(De Angelo et al., 2013; Ewers et al., 2013)
Percentage of secondary forest P_SecFor_2000_r	Percentage of secondary in the landscape within a given radius around the attack/non-attack point in 2000	Past forest condition can be important to understand jaguar presence and biodiversity pattern, which might influence the occurrence of jaguar attack	(De Angelo et al., 2013; Ewers et al., 2013)

Percentage of perforated forest Perforation_r	Degree to which edge effects are introduced into the core forest area, representing non-forest patches within primarily compact forest patches within a given radius around the attack/non-attack point	The perforation of mature forest can affect the quality of the jaguar habitat and potential number of prey influence the occurrence of jaguar attack	(Olsoy et al., 2016; Rogan et al., 2016; Soille and Vogt, 2009; Watkins et al., 2015; Zanin et al., 2015)
Artificial or natural water holes WatPA	Presence or absence (NO) of artificial (AP) or natural pools (NW) with water or both (B) in the pasture area	The presence of water has been shown to positively influence attacks by jaguars. In the study area, surface water is scarce during the dry season. Therefore, water holes located within pastures may attract jaguars, increasing the probability of attacks.	(Abade et al., 2014; Michalski et al., 2006; Soh et al., 2014)
Density of minimum patch size Dens_MinP_r	Number of minimum patch size within a given radius around the attack/non-attack point	The presence of patches of a minimum given size has been shown to change landscape connectivity and jaguar movement. Minimum patch size has been evaluated to be 2 km^2	(Ramirez-Reyes et al., 2016)
Distance to breeding patch* Dist_BreedP	Euclidean distance to the closest edge of a breeding patch to the attack/non-attack point	The distance to a patch of mature forest large enough to sustain a breeding event (i.e. patch of mature forest the size of annual home range of jaguar female in the area, in the area 203 km^2) could influence the occurrence of jaguar attack	(de la Torre et al., 2016)
Distance to habitat patch* Dist_HabP	Euclidean distance to the closest edge of a habitat patch to the attack/non-attack point	The distance to a patch of mature forest large enough to sustain a viable population (i.e. in the area, 1515 km^2) could influence the occurrence of jaguar attack	(Behdarvand et al., 2014; Dar et al., 2009; Thorn et al., 2012)

Percentage of Bridge Bridge_r	Percentage of structural connectivity between core forest patches within a given radius around the attack/non-attack point	Connectivity between patch allow jaguars to move freely across the landscape and coud influence the occurrence of jaguar attack	(Olsoy et al., 2016; Rogan et al., 2016; Soille and Vogt, 2009; Watkins et al., 2015; Zanin et al., 2015)
Percentage of Branch Branch_r	Percentage of forest pixels that are not core forest and are connected at one end only to a forest patch within a given radius around the attack/non-attack point	"False" corridor that do not connect one jaguar habitat patch to another can act as a trap, but also allow jaguar to come closer to pasture area while being under forest cover	(Olsoy et al., 2016; Rogan et al., 2016; Soille and Vogt, 2009; Watkins et al., 2015; Zanin et al., 2015)
Percentage of agriculture P_Agr_r	Percentage of agriculture in the landscape within a given radius around the attack/non-attack point	Agricultural areas are not considered a favorable cover type for jaguars, and are significantly avoided by female jaguars while have a lower impact on male jaguars who sometimes venture in agricultural area	(Chávez, 2010; Conde et al., 2010; De Angelo et al., 2013)
Percentage or pasture P_Past_r	Percentage of pasture in the landscape within a given radius around the attack/non-attack point	Pasture areas are not considered a favorable cover type for jaguars, and are avoided by females.	(Chávez, 2010; Conde et al., 2010; De Angelo et al., 2013)
Population Index Human_ind_r	Index representing human density across the study area so that the contribution of the population of each point for a given location would gradually decrease with distance according to an exponential function. Three functions were created so that the contribution of a given locality would represent 10% of the population size at distances of 2, 4 and 8 km. For a given location (point of attack), these contributions were summed over all localities.	Human activity and human settlement has been shown to have a negative effect on jaguar presence, and then influence the probability of occurrence of attacks. However, the distance at which population size might have an effect also probably taper off (at an unknown distance in the region).	(Behdarvand et al., 2014; Carvalho et al., 2015; De Angelo et al., 2013; de la Torre et al., 2016; Rabinowitz and Zeller, 2010; Soh et al., 2014; Zarco-González et al., 2013)

Distance to paved road Dist_road	Euclidean distance from nearest paved road to the attack/non-attack point	Presence of roads in the landscape influences jaguar movement as female jaguar tend to avoid paved roads. Paved road is also an indication of human pressure on the landscape, which can negatively influence carnivores attacks	(Conde et al., 2010; Soh et al., 2014; Zarco-González et al., 2013)
Livestock species Liv_Sp	Livestock species: cows (C), sheep (S), both (B)	Adult cows are less vulnerable to jaguar attack than calves and sheep.	(Rodríguez-Soto et al., 2011; Zarco-González et al., 2013)
Livestock density (total, cows, sheep) Dens_Liv	Livestock density in the pasture area calculated as the size of the flock divided by the pasture area (expressed in heads per ha)	Livestock density can influence jaguar movement as male jaguars venture more easily into low intensity cattle ranches, while female avoid them. Previous studies have also shown that cattle density can influence positively the occurrence of attacks	(Carvalho et al., 2015; Conde et al., 2010; Zanin et al., 2015; Zarco-González et al., 2013)
Livestock management practice index Liv_Mgmt	Score given to evaluation of livestock management practice regarding jaguar attack: Level of surveillance: Daily (3) Every two day (2), twice a week or less (1); Type of fencing: electric fence (2), wire net (1), no fence (0); Surveillance at night: Yes (6), Sometimes or when I have attack (3), No (0). The score ranges from 1 to 11.	Livestock management influences the occurrence of jaguar attacks, as good fencing, especially at night, as well as night watches or human presence might prevent attacks	(Ceballos et al., 2002; Jackson et al., 1996; Rodríguez-Soto et al., 2011; Soto-Shoender and Giuliano, 2011; Zarco-González et al., 2013)

* Breeding patches are areas sufficiently large enough to support a breeding event (de la Torre et al., 2016), and the minimum size of breeding patches is determined by the mean annual activity area of female jaguars in the study area, i.e., 203 km^2 (Chávez, 2010). We also calculated the smallest continuous area to maintain a viable population of 50 individuals (de la Torre et al., 2016, Rodríguez-Soto et al., 2011), the habitat patch. If we assume a minimum density of 3.3 jaguars for each 100 km^2 in Calakmul (Chávez, 2010), the minimum continuous area to maintain 50 individuals would be 1515 km^2. Only one breeding patch (i.e., forest patches larger than 203 km^2) and one habitat patch (i.e., forest patches larger than 1515 km^2) were identified, as the study landscape was mainly covered by one large forest patch of 24,541 km^2, while the second largest forest patch dropped to 43 km^2. We thus discarded distance to breeding patch, and only kept distance to habitat patch.

APPENDICES B

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APPENDICES TO CHAPTER 2

Content:

Supplementary material B1. The coding scheme
Supplementary material B2. Cluster analysis

Supplementary material B1. The coding scheme

Table B1.1 The coding scheme

Theme level	Topic level	Sub-Topic level	Perspective Level
I. Productive activities	1.Natural Resource dependent activities	1.1. Training capacity	Capacitation in veterinary care
			Capacitation in livestock management
			Capacitation for local variety of maize
		1.2. Financial solvency	Issue with middleman
			Request for financial support
			Subsistence vs commercial agriculture
			Development of sheep production
			Potential profit from timber certification
		1.3. Pollution & unsustainable extraction	Use of chemical for agriculture
			Use of chemical for chili production
			Advancement of the agricultural boarder
			Practices in livestock management
		1.4. Technical improvement	Livestock nutrition
			Livestock genetics
			Extensive vs intensive livestock management
			Agricultural mechanization
		1.5. Environmental constraints	Non-productive soil
			Temporal agricultural production
			Lack of water
			Depletion of commercially valuable trees

2. Alternative activities	2.1. Development opportunities	Derived products from the natural resources available in the region
		Handcraft production
		Awareness of the potential for these activities (lack of)
		Not a vocation for everyone
	2.2. Financial solvency	Tourism not a trigger for economic development
		Lack of administrative structure to manage profits
		Handcraft not viable as the only household activity
	2.3. Training capacity	Training center for tourism
		Capacitation for business management
	2.4. Infrastructure requirements	Develop service industries (restaurant and hotel)
		Access to emergency care
		Equipment to produce more sophisticated handcraft
	2.5. Commercialization	Tourism certification
		Tourism strategy
		Expand market for handcraft
	2.6. Economic benefits	Potential of ecotourism
		Potential for cultural tourism
		Job opportunity for young people
	2.7. Environmental integrity	Risk of massive tourism
		Re-use of branches and wood for handcraft production
		Support awareness and willingness to protect the environment
3. Perceived Sustainable activities	3.1. Access & Authorization	Availability of license and permits
		Legal access to secondary forest exploitation
		Modification of reserve limits
		Bureaucratic process
	3.2 Development and promotion	Promote honey production and derived products
		Promote organic activities and label
		Commercialization of secondary forest products
		Financial support and equipment for allspice production

		3.3. Environmental integrity	Support reforestation
			Increase biodiversity
			No use of agrochemicals
II. Biophysical process	4. Climate change	4.1. Drought	Hinders crops and livestock production
			Wild animal death
		4.2. Heavy rainfall	Inundation
			Excess of water not good for allspice production
		4.3. Adaptation	Develop adaptive strategies
			Lack of international investment
			Budget for emergency measures
	5. Biodiversity loss	5.1. Management procedures	UMAS (hunting units)
			Improve forest fire management
			Law enforcement
		5.2. Habitat loss	Deforestation
			Open access through new road
		5.3. Habitat fragmentation	Road kills
			Lack of corridor
			Road enlargement
		5.3. Water body conservation	Conservation of natural water body
			Competition between wildlife & human for water
		5.4. Monitoring & evaluation	Rangers program
			Research
			Community vigilance
			Biological monitoring
	6. Environmentally derived benefits	6.1. Realized conservation benefits	Reforestation
			Resilient ecosystem
			Abundant wildlife
			No alarming impact
		6.2. Importance of nature	For future generation
			Importance of emblematic species
			Responsibility for the world as Calakmul is one of the largest forest

		6.3. Potential conservation benefits	To control fire
			More forest means more rain
			To develop tourism
			For hunting
		6.4. Ecosystem payment program	Short-term and not sustainable
			Positive income for the community
	7. Human-animal interactions	7.1. Animal impacts	Herbivores and birds on crops
			Snakes and bats on livestock
			Jaguar depredation on livestock
			Compensation scheme
			Retaliation
		7.2. Animal proximity	Fear of carnivores
			Wild animal sighting near villages
		7.3. Hunting	Illegal hunting
			Subsistence hunting
			Animal traffic
III. Community development	8. Human health	8.1. Access to health services	Health center
			Lack of doctor and nurse
		8.2. Pollution	Domestic waste
			Human waste
			Agrochemicals
		8.3. Nutrition	Food in school
			Access to meat
			Diversified nutrition
	9. Water access	9.1. Water quality and quantity	Develop water treatment
			Risk from water pollution
			Rare and temporal
		9.2. Water infrastructure	Drinkable water network
			Water tank
			Drainage systems
		9.3. Price of water	Disorganized price systems
			Expensive to import water

	9.4. Water management	Reduce consumption
		No management committee
		Lack of consciousness
		Need for integral management
10. Economic development	10.1. Difference within & between *ejido*	Status between *ejidatarios* (right owners) and *pobladores*
		Different communities have different vocations
		Size of the *ejido* and access to resources
	10.2. Employment	Migration
		Temporary jobs
		Land abandonment
		Lack of alternative economics activities
	10.3. Basic needs & minimal income	Economic self sufficiency
		Material to build home
		Need of an income
11. Cultural identity	11.1. Diversity of cultural background	Variability in people origins and culture
		Different mentality of work
	11.2. Maintenance of cultural heritage	Rescue local knowledge
		Respect people values
	11.3. Culture & nature	Mayan culture of caring for the environment
		Cultural perception of water
		Difference of perception between indigenous and non-indigenous
12. Environmental education	12.1. Environmental education (school-age population)	Regarding garbage management
		Regarding local crops and medicinal plants
		Regarding honey production and bees
	12.2. Environmental education (adult population)	Information campaign on the importance of the environment
		Exchange program on good practice for the environment

		12.3. Environmental awareness	Understanding the interconnection between nature and human wellbeing
			Importance of wildlife to maintain a healthy ecosystem
IV. Political process	13. Governmental capacities	13.1. Program development	Technical assistance to have access to programs
			Change from agricultural politics to conservation politics
			Lack of coherency between regional and state level programs
			Program access highly centralized in the head town
			Unfair and uneven programs between activities / communities
		13.2. Program management	Corruption
			Lack of personal
			Lack of program follow-up
			Management too institutional
		13.3. Program subsidies	Negative effect of the subsidies on the environment
			Help is not appropriate and has low efficiency
	14. Actor relationships	14.1. Level of collaboration	Develop local network
			Positive initiative to have a board working on sustainable development (CMDRS)
			Heads of *ejidos* and representative of productive groups have different objectives
			Importance of developing productive dialogue to build collaboration
		14.2. Science policy interface	No follow-up from researchers on the results and recommendations
			Collaboration with scientists to inform the decision-making process
			No appropriate language for the audience
			Lack of information on what researchers do

Supplementary material B2: Cluster analysis

We wanted to know if common ground between actors at the two levels showed a grouping pattern across the different groups of actors. Cluster analysis is used to identify discontinuous subsets in an environment: in our case, the existence of a grouping pattern across actors. Clusters are computed from association matrices; to do so, we built distance matrices using Jacquard distance, because it does not account for situations where neither party mentions an issue (pairs of absence data). We then ran a cluster analysis using hierarchical clustering for each level of categorization. To minimize within-group dispersion, we used the Ward2 clustering method (Murtagh & Legendre, 2014). We ran the analysis using the vegdist and hclust functions of the vegan package in R version 3.2.2.

Hierarchical methods will impose a division of group in the data: the members of smaller, inferior-ranking clusters are then agglomerated to larger, higher-ranking clusters. It is then the responsibility of the authors to determine if there are interpretable clusters and to define the level of division into the initial data (Murtagh & Legendre, 2014). Dendrograms were obtained to represent our hierarchical result as well as fusion level graph (see figures B1 and B2 for an example at the topic level). Fusion level values of a dendrogram represent "the dissimilarity values where a fusion between two branches of a dendrogram occurs" and can provide further information to determine how many clusters should be considered in the data (Legendre & Legendre, 1998).

We first analyzed the groups formed with a cutting level of 4, as we pre-determined 4 groups (EG, PG, GI, NG). Because no pattern arose based on our predetermined groups (Figure B2.1.), we explored our data further using the data from the graph of fusion level values (Figure B2.2). The graph shows clear jumps after each fusion between 2 to 5 groups. However, on the dendrogram, each of these cutting levels did not allow to find interpretable clusters according to our predetermined group assignment.

Legendre, P. and L. Legendre. 1998. Numerical ecology. 2nd English ed. Elsevier, Amsterdam

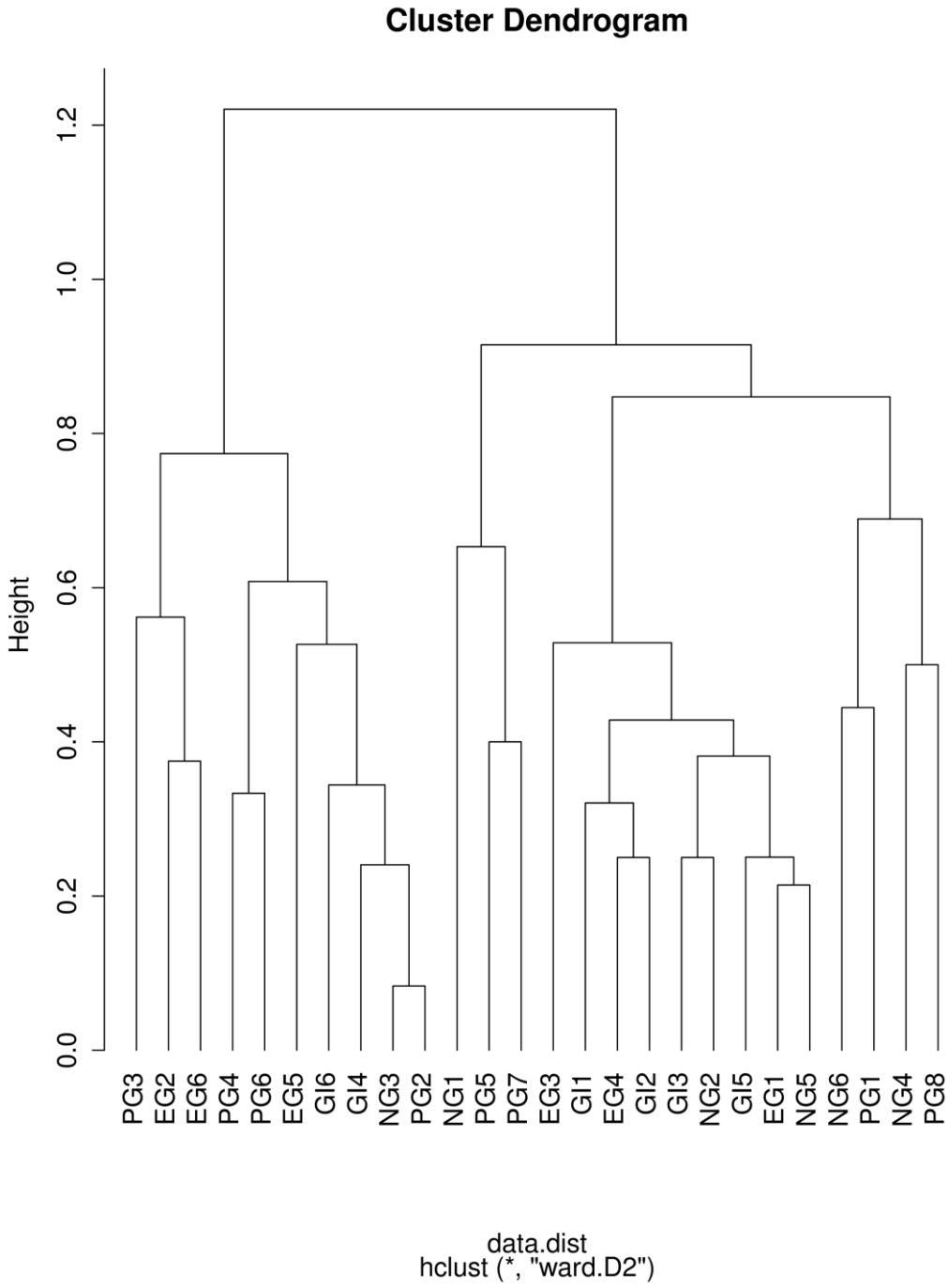

Figure B2.1 Dendrogram of a Ward2 clustering of a matrix of Jacquard distances among actors at the topic level

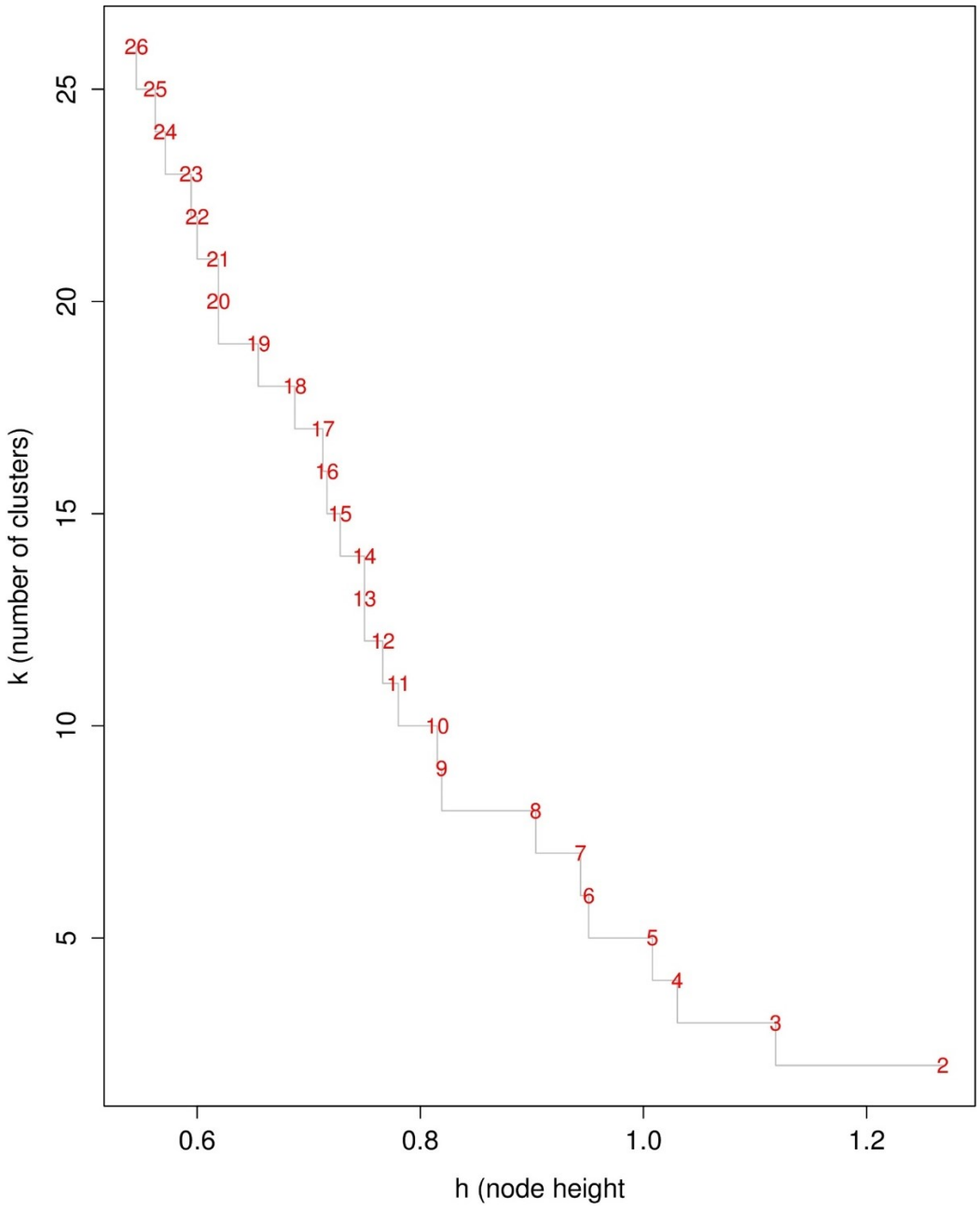

Figure B2.2 Graph of the fusion values of the Ward2 clustering at the topic level

APPENDICES C

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APPENDICES TO CHAPTER 3

Content:

Appendix C1. Coding manual elaborated to analyse the discourse of focus groups' participants.

Supplementary material C1. Details of the methodology

Supplementary material C2. Additional indexing: parallel coding of relational and directional aspects of feelings of injustice

Appendix C1. Coding manual elaborated to analyse the discourse of focus groups' participants

Table C1.1. Coding manual elaborated to analyse the discourse of focus groups' participants. In the Code column, modified definitions are in italics, and new definitions that emerge from our empirical data are in bold. References indicate previous literature identifying certain definitions of justice. Quotes are examples from our empirical data illustrating the forms of justice appraisal.

Theme	Code	Description	References	Quote
Distributive environmental justice: the fair distribution of costs and benefits related to environmental management	Merit	The higher the individual contribution to the common goal, the greater the individual benefit should be and vice versa, such that individual inputs and outputs are balanced.	Ittner and rawl , 2005; Kellerhals et al., 1997; Ohl et al., 2008	*"The person with most [forest] is the one who should receive more [benefits] from conservation (F1)"*
	Equality	All people should be treated alike, disregarding their differences in need or merit, such that a uniform distribution of the cost and benefits is achieved.	Ittner and Ohl, 2005; Kellerhals et al., 1997; Ohl et al., 2008	*"The money paid for environmental services to [protect] the forest should be the same for all ejidatarios, regardless of their [specific] needs (F1)"*
	Need	A higher contribution should be given to the people who are the most dependent on the resource in question, or a smaller contribution should be offered to those who have more resources.	(Ittner and Ohl, 2005; Kellerhals et al., 1997; Ohl et al., 2008)	*"It depends on the needs of those who need it the most."* While another participant added *"It depends on how big the family is. (R2)"*
Procedural environmental justice: the fairness of the processes of environmental management (decision-	Representation	Representation of different point of view in the decision-making process	(Leventhal, 1980; Tyler, 1988)	*"The campesino should be asked to say something and the ejidos' opinions should be taken into account.* [...] *They take decisions without knowing and are outsiders. Decisions should be taken here [in the region] (R2)"*

making, action implementation)	Consistency	The consistency with which a procedure is applied across time and individuals.	(Barrett-Howard and Tyler, 1986; Leventhal, 1980)	*"There is a lot of favouritism, they [government] agree with the ejidal commissary (apart) and they say, we're gonna give you that much today. Or, the ejidal commissary brings together the majority of his followers; for example, if there are 20, he brings 11 persons together and splits the money among them, and the other people who should also benefit are not taken into account. (MA)"*
	Respect	*The respect with which participants are treated by the authorities responsible.*	(Tyler, 1988)	*"They [the government] do not respect the information we give them; they decide everything over there (R2)"*
	Trust	*The trustworthiness of the authorities responsible.*	(Tyler, 1988)	*"Let's take the decisions the way we are doing it right now, face to face, looking into the eyes, feeling that there is trust, that you are talking with the truth and not planning little truculent projects. (F1)"*
	Opportunity for revision	**The existence of opportunities to appeal or modify a decision after it is taken.**		*"And what do we do if we do not agree with the decision? We cannot do anything. (R1)"*
	Compliance	**Acquiescence to the decision made**		*"The problem is that if you come here, see my needs and help me, and come back to see that nothing has changed, it is not fair either that I did not do my part. It is important to respect the decisions made (F2)."*
Ecological justice: the fair and respectful treatment of the natural environment.	Right of the environment	Intrinsic right of every part of the environment to exist.	(Clayton, 2000)	*"It is unfair to the animal, wild animal… It would be unfair to kill them, there are free too (F2)."*
	Responsibilities to other species	Human obligations to fairly treat non-human species in a way that does not threaten their survival in their natural world.	(Clayton, 2000)	*"When we fell trees from the forest to cultivate, it is unfair for animals; we harm them (F2)."*

	Responsibilities to future generations	Human obligations to maintain a world where future generations will have the same opportunities to benefit from natural resources as the current generation.	(Clayton, 2000)	*"It is unfair if jaguars disappear, because, for instance, we are here today but young people, children are following. Maybe they won't know it. it is unfair to the next generation [to see jaguar] on a picture or on the internet (R2)".*
Justice-as-recognition: acknowledging individuals' rights, values, cultures and knowledge systems	**Land-use and land rights**	**The ability to make decisions over land use on one's own land, or if restricted to be given alternative land**		*"Justice for me it to be able to do what I want if I am on my land, because we leave him his house [the jaguar], what they call protected area. If we are in the protected area, get us out of here and give us another place to live". (R1)*
	Knowledge	**The recognition of different knowledges, including local knowledge**		*"It's important the information they use, because who knows best about its own house that those who live here. I know the knowledge I have that people from the city don't have."* While another precise example was: *"We need a technician from here, who can get information more true, who know the people, who know what is happening here. This will give information more reliable and more complete" (F1)*
	Plurality of interests	**Recognition of the validity and equality of different interests**		*"In reality, them, if you don't negotiate with them, others will come to negotiate larger project, and the teeny weeny one who no one will defend, is not going to have anything." (MA)*
	Neutral approach	**No preconceived idea of what the decision should be**		*"Sometimes, they come and say they're going to listen, but they already know what is going to be the final decision." (R1)*

Supplementary material C1. Details of the methodology

Communities choice

Two communities in the area surrounding the Calakmul Biosphere Reserve were selected based on their level of collaboration with the reserve. We hypothesized that their relationships with local conservation authorities affected their feelings of fairness toward environmental management, in order to explore more largely the feeling of justice. To evaluate their level of collaboration, we collected information on 75 *ejidos* from 2010 to 2015, from documentation available at the reserve: the number of years they had reserve-sponsored projects in the community, total number of projects, duration of each project, total number and type of beneficiaries, as well as the funding and area covered for each project.

For each variable, we created community rankings and chose one community that scored highly across combined categories and one community that scored poorly. We are aware that our numerical ranking might not fully coincide with the perception people have of the level of collaboration with the reserve, but our data and the personal experience of the authors (MLL, SC, BS) make us confident that we selected two communities with a high difference in their level of collaboration with the reserve.

Justification for the use of focus group

Individual interviews with local actors were challenging as cultural and linguistic norms made it difficult to articulate feelings of justice in line with the theories articulated above. We therefore decided to explore feelings of justice regarding environmental issues within focus groups. Focus groups can be less threatening to participants, with face-to-face interactions enabling them to discuss more easily about their perceptions, thoughts and opinions (Krueger, 2014). Furthermore, focus groups provide an opportunity for participants to query each other and explain themselves (Morgan, 1997; Rabiee, 2004). Focus groups also enable researchers to investigate group interactions, identify areas of consensus, and highlight potential differences between the researcher and participant's perspectives (Morgan et al, 2010). Potential weaknesses of focus groups include the influences of group interactions on conforming behaviours and censoring of some group participants (Carey and

Smith, 1994; Morgan, 1997; Onwuegbuzie et al., 2009). Because we were interested in the variability in feelings of justice rather than in the interactions between group participants, we decided to adopt a hybrid approach (see Theory-Building Focus Group by Ryan et al., 2014). The facilitator (MLL) thus led the discussion, mindful of interactions between participants, while an assistant took notes recording who spoke and non-verbal interactions (Kitzinger, 1994). This enabled us to highlight potential influences and assist in the decision of which interactions between actors should be included in the data collection and analysis, in line with recommendations by (Ryan et al., and colleagues (2014).

Step by step data analysis process

Stage 1. Familiarization

We listened to the focus group recordings 2-4 times to familiarize with the data. We did partial transcriptions of commentaries relating to actors' feeling of justice. Transcripts were subjected to primary coding against the dimensions of justice identified from the literature: distributive environmental justice (including distribution of cost and benefits), procedural environmental justice (including decision-making process) and ecological justice (including concerns expressed regarding fair treatment of the environment or 'nature'). We developed an additional code for fairness concerns that was not in the pre-identified dimensions.

Stage 2. Identifying Deductive and Inductive coding of criteria of justice

Secondly, we explored the criteria against which people assessed dimensions of justice. A coding manual (see Appendix C1) was developed (Saldaña, 2015) including the main criteria that have been proposed to define justice appraisal and text was deductively coded. Inductive analysis led to the expansion of a secondary code or the creation of additional codes to describe new criteria (Boyatzis, 1998). For example, trust and respect were initially criteria coded under the procedural justice dimension, representing the need for these attributes during decision-making. However, participant concerns expressed in relation to respect and trust were actually broader and included not only decision-making, but also implementation and follow-up. Hence, codes description were modified to enlarge our understanding of procedural justice: procedural justice includes not only specific decision-making process, but also every social interaction in environmental management. Participants also differed in

their perception of the criteria; for example, representation in the decision-making process meant for some to be in charge of the decision while for others it meant merely having their point of view heard. Indicative quotes were assigned against criteria to inform the variation of criteria definition (Bazeley, 2013). We did not aim for quantitative textual assessment, and all text in relation to justice was included in the coding identification analysis.

Stage 3. Contextualization and pattern of justice construction

The criteria used to support feelings of justice were then located within context, including linguistic description and the order of presentation. Relational sequencing of text preceding or following the discussion of different criteria and overall dimensions of justice was recorded (Bazeley, 2013). Importance and interest in relation to different criteria were assessed through noting criteria recurrence and depth of feeling expressed. This stage helped us connect our codes to discover patterns of justice construction and explore if our data supported our initial framework and how criteria that did not fit against dimensions of justice described above could be interpreted. The investigation of text, codes, and themes in this study involved several iterations before the analysis proceeded to an interpretive phase.

Stage 4. Additional indexing: parallel coding of relational and directional aspects of feelings of injustice

We then indexed data, to investigate relational and directional aspects of feelings of injustice. We then created a parallel coding characteristic for each text segment of each criteria indicating if that segment was allocated to individual or collective intention ('I' or 'we'). The adoption of an individual or a collective identity was one reason the criteria used to assess justice seemed to vary. Additional identifiers included allocated responsibility for resource management when participants discussed feelings of justice. For example, who they perceived to be in charge of the compensation program for livestock depredation (the government, the reserve, the NGO) seemed to influence their perception of justice.

Stage 5. Charting to compare feeling of justice among individuals, groups, activities, and communities

We used then comparative strategies (Bazeley, 2013) to identify under what condition the perception of criteria varies and how it shifts in definition and use in different contexts: at

the individual level, at the group level and between the focus groups. We examined the connections and interdependencies but also contradictions between our criteria and systematically checked for associations among our codes. We worked iteratively through our data, comparing and interpreting data at the individual unit, group unit, between activities (rancher and farmer), and between communities to understand how perceptions vary and impact feeling of justice.

Stage 6. Analysis of group interactions

In this last stage, the interactive nature of focus groups was explored. We principally aimed to explore what participants expressed regarding their feeling of justice, prioritizing the individual unit of analysis, but we recognized the importance of interaction analysis (see Kidd and Parshall, 2000; Morgan, 2010 for discussion of the unit of analysis and inclusion of interaction data). Mainly, we wanted to ensure we represented the groups, and recorded disagreements, forms of consensus, infrequent inputs from almost silent members (Onwuegbuzie et al., 2009). We used the guiding questions from Steven (1996, p. 172) to analyse group interactions by listening to the entire transcript alongside a reading of notes taken on group dynamics: "How closely did the group adhere to the issues presented for discussion? Why, how and when were related issues brought up? What statements seemed to evoke conflict? What were the contradictions in the discussion? What common experiences were expressed? Were alliances formed among group members? Was a particular member or viewpoint silenced? Was a particular view dominant? How did the group resolve disagreements? What topics produced consensus? Whose interests were being represented in the group? How were emotions handled?" (Stevens, 1996, p. 172). Only interactions that might change the interpretation of the result were added to the previous interpretation.

We are aware that one limitation of our analysis is that the analysis process was undertaken by the first author only, and therefore did not ensure agreement about the coding among several people. However, the data were subject to a member-check at the end of the focus group and discussion about the analysis among the co-authors was occurring regularly during the process.

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Supplementary material C2. Additional indexing: parallel coding of relational and directional aspects of feelings of injustice

Table C2.1. Example of additional indexing for the code *Representation*, i.e., the representation of different points of view in the decision-making process

Focus group	***Representation***	**Natural resource example**	**With whom they identify** Individual Community	**Who they perceived responsible** International community Federal government State government Local government Reserve Compensation Fund
R1	*"We are no fools. It [the government] sets the rules and we cannot say anything."*	Forest	Community	Federal government
	"I suppose they [government representatives] have meetings, assemblies, where they talk and decide all, but this never makes it to the community."	Water	Community	State government
	"We fight each other because we do not understand them [government representatives] and they do not understand us."	Water	Community	State government
	"Those who have access [opportunity to representation] are leaders or authorities, other people do not. Other people mean nothing. You have to be village leader, [local] authority etc. They can express their opinion. It is not sufficient that only they can have access to the decision-making process. But, I am not prepared to take decisions for a village, so it is important to listen to the government's proposals, bring the communities in and decide together. Because we are not prepared to take the kind of decisions."	Water	Individual, then community	State government, Local government

	"Authorities do not take into consideration [local] people, we do not participate directly. [Even] if we do not agree, we have to be united."	Water	Community	State government
	"That the way it is, we are Mexicans, the voice of others is more important, has more value, and is more heard. Our voice is a little more hidden even though we tell the truth."	Jaguar	Community (country level)	International community
F1	*"All these agreements and decision making should not happen in [government] institutions."*	Forest	Community	Federal government
	"There should be representatives who actually represent the ejido, who could take decision more equitably."	Forest	Community	The reserve
	"Let's take the decisions how we are doing it right now, face to face, looking into the eyes, feeling that there is trust, that you are talking with the truth and not planning little truculent projects. Because many times things are invented, for example how to protect the tapir, and well, in the field is not viable."	Jaguar	Individual	The reserve
	"The government does not listen to the grassroots, and who are they? It's people from the community who know how people in the community live."	Jaguar	Community	Federal government
F2	*"They must take the decisions; those who live here."*	Forest	Community	Federal government
	"They should take into account the opinion of each person". While another refutes *"People have no interest in doing something. There is a lack of involvement, and so we should try to find unity because where there is unity, there is strength."*	Forest	Individual / Community	Local government
	"That the government do as it wishes is unfair. They should come and know how things happen here in order to do their project and then it will be fair."	Forest	Individual	Federal government
	"We should hold meetings to have rules over how we should share water."	Water	Community	State government
R2	*"The campesino should be asked to say something and the ejidos' opinions should be taken into account. How much work it is, how*	Forest	Individual	Federal government

	much it costs. They take decisions without knowing and are outsiders. Decisions should be taken here [in the region].”			
	“When they [state government] take decisions, they should consider our authorities, the decisions from the [ejidal] assembly.”	Water	Community	State government
	“They [state government] should take into account the opinion of people who suffered damage. Everyone has a voice, because how do we decide that an animal is nice, an endangered species, but it’s dangerous and harmful for sheep or cattle production.”	Jaguar	Individual	State government
MA	*“Here we have to make decisions together, with everyone, but then they [federal government] don’t change anything in the law, they don’t take into consideration our decisions.”*	Forest	Community	Federal government
	“Why can’t I decide how much they [compensation fundl] should help me with my livestock? There are different things that can be done, like electric fence or other, but I can’t say anything.”	Jaguar	Individual	Compensation Fund

APPENDICES D

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APPENDICES TO CHAPTER 4

Content :

Supplementary material D1. Adaptation of external factor and criteria for data collection
Supplementary material D2. Data analysis: BTLLasso
Supplementary material D3. K-mean partitioning result

Supplementary material D1. Adaptation of external factors and criteria for data collection

Adaptation of external factors to jaguar management

Responsibility was based on how people perceive other entities involved in jaguar management. Those entities included the Reserve, the government, local and regional NGOs, the *ejido*, and everyone. While the Reserve is a governmental agency, local actors maintain a different discourse toward the Reserve and the rest of state and federal government agencies. *Ejidos*, while not directly involved in jaguar management, are involved in the management of natural resources such as timber or game or in conservation-related programs such as payments for ecosystem services).

Intentionality, which normally considers if the injustice is caused voluntarily or not, has been modified here to know if people perceive attacks are controllable or not. If they perceive attacks as being controllable, making no effort to control them could be perceived as unfair.

The notion of *duration* was represented here by how people perceived the frequency of attacks on livestock and the associated level of risk.

Individual experience focused on socio-demographic characteristics, such as age, sex, and education. Other characteristics were related to potential vulnerability to large cats' attack (number of sheep) and past experience with attacks (knowledge of attacks within the community or personal experience with attacks).

Motivation related to the goal of people toward livestock production or conservation.

Environmental identity was a numerical index built from the 11 paired statements proposed by Stets and Biga (2003), choosing for each pair the proposition they agree with (e.g in competition with the natural environment vs. in cooperation with the natural environment). Propositions favoring the environment count as 1, while opposite propositions count as -1; the index ranges from -11 to 11.

Intra-group interaction here is adapt to evaluate to which group they feel they affiliated the most and if they perceive a certain coherency into this group regarding jaguar management. . In Calakmul, people interact in different types of groups, in which attitudes might influence their perception of fairness. They can feel mainly part of the "*ejido*" and

define themselves as ejidatarios, or can also feel they belong the to the group of livestock producers and rely on this membership to evaluate themselves and other actor's behaviors. Finally, they can also interact with other actors at the community level and feel like they belong mostly to the community at large. How people identify with different groups and perceive their peer's environmental attitudes and identities has to be investigated to assess the impacts of peers on individual's feeling of justice (Parris et al., 2014).

Finally, intergroup interactions relate to the perception of the legitimacy of an external group that promotes a certain behaviour. We modified these variables after the pilot interviews. We first asked how they perceived the legitimacy of the actors involved in jaguar management; however, the term legitimacy was not clear to participants. Because legitimacy is a complex concept and relates to propriety, validity, endorsement, and authorization (see Hegtvedt et al., 2003), we modify it here according to the discussion with locals actors during pilot interviews and develop two questions around the right to participate in decision-making and the adequacy of actions. The questions were asked for every entity as in the first question on responsibility, with the exception of "everyone" that was changed by "yourself" to focus on the perceived adequacy of individual actions (Parris et al., 2014).

Adaptation of the criteria of distributive and procedural justice to statements regarding jaguar management

The statements reflecting distributive justice included aspects related to costs and benefits sharing. Four statements were created regarding criteria of merit and equality, one regarding how to share benefit and the other about sharing the costs. The statements were deliberately phrased positively (e.g. 'People in charge of the decision-making should be people I trust', instead of 'I do not trust people in charge of the decision-making') to avoid influencing negatively people's perceptions of jaguar management.

For the statement regarding procedural justice, we did not focus on one specific management topic and collaborative process such as undertaken in previous studies (Lauber, 1999; Smith and McDonough, 2001). We showed previously that people express concerns regarding the daily-based management of the environment and every-day interactions with decision-makers (Lecuyer et al., in press). Ranchers in the region do not all have direct contact with the different entities during the decision-making process and we thus wanted to

evaluate their feelings of justice in a wider context, in line with approaches taken in other studies (e.g. Schroeder and Fulton (2017). No statement gives a precise description of *those responsible for jaguar management* or of the *decision-making process*.

Supplementary material D2. Data analysis and result BTLLasso

BTLLasso allowed us to account for heterogeneity in participants (subject), and assess the external factors (subject-covariate) that determine the choice between alternative criteria (object) in people's construction of justice. We could not build a full model for all the variables (we were unable to estimate the unpenalized model to get the adaptive weight for the penalty) due to too many variables. Therefore, we performed the analysis using the three categories of subject covariates: injustice, individual, context. Furthermore, we had to increase the initial tuning parameter for ridge penalty on all coefficients, to stabilize the results. We tested the effect of changing this parameter, which was small as long as it did not exceed 1; thus, we set ridge penalty at 1 for all subsequent models. We then performed a cross validation and estimated the confidence intervals (see R code).

The visualization function allowed creating graphs that plot the coefficient path and represent the importance of the external factors in explaining the variation in criteria choices, and the effect of each external factor on the criteria. BTLLasso function generated a graph with one path per covariate to explore the effect size and importance of each covariate (Figure S1). The second type of graph plot showed the effect of a given subject-specific covariate on object selection (Figure S2). It is also possible to plot the bootstrap result to visualize if a given subject-specific covariate had a positive or negative effect on the object attractiveness (figure S3). Objects situated at the same distance from 0 were effected similarly by that subject-specific covariate.

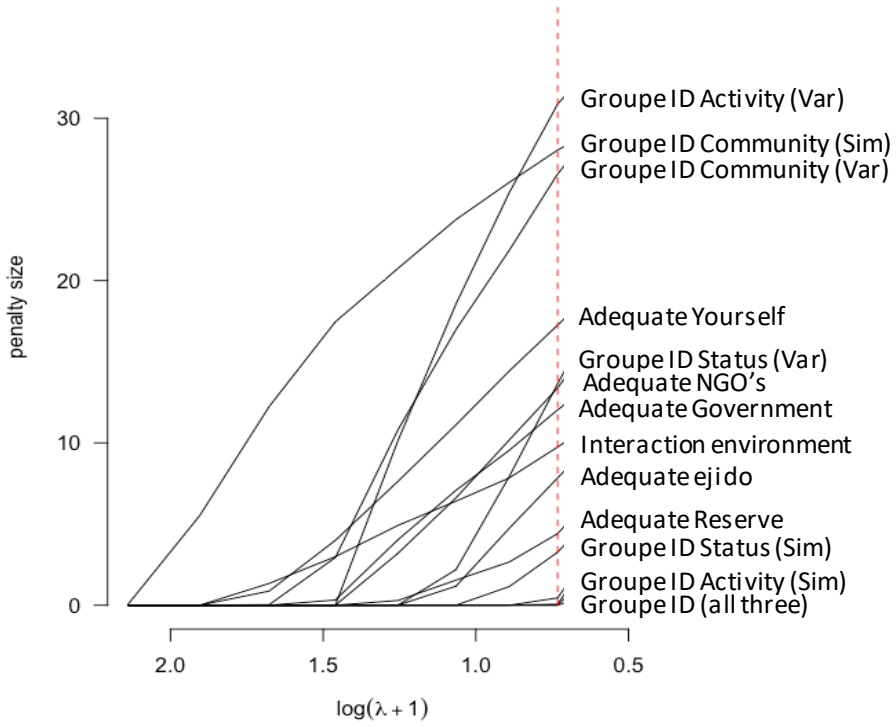


Figure D2.1. Penalty paths for subject-specific variables (here contextual factors). The dashed red line represents the optimal model according to a 10-fold cross-validation. Subject-specific covariates that have the largest values of penalty term for the single model component at the optimal value of the tuning parameter; hence they are those that influence most the choice between the different objects.

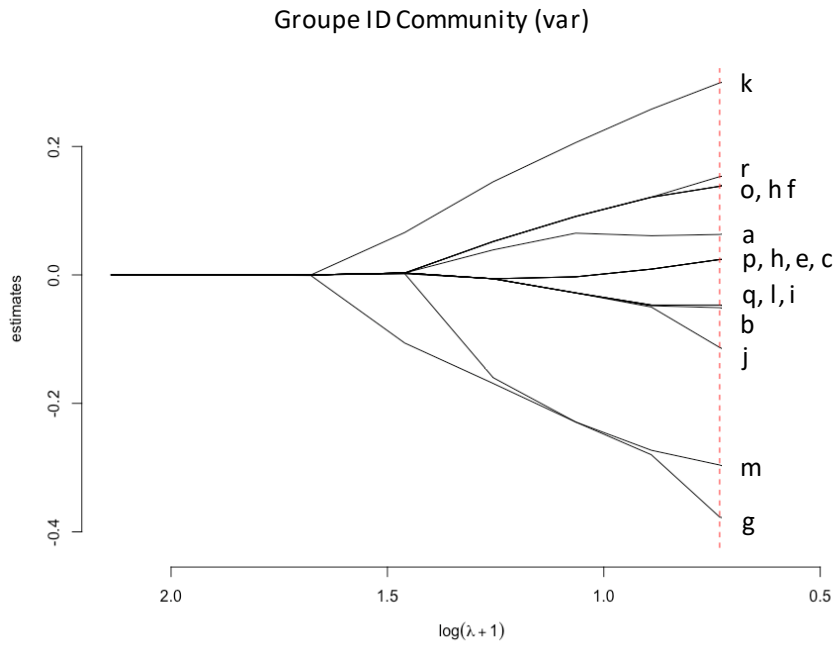


Figure D2.2. Parameter paths for subject-specific variables (here Group identity = community, with diverse opinions within the group). The graph is centered on 0 on the Y–axis. Object coefficient paths that have a positive value at the optimal value of the tuning parameter indicate that this object attractiveness is influenced positively by this specific covariate. On the contrary, object coefficient paths that have a negative value at the optimal value of the tuning parameter indicate that this object attractiveness is influenced negatively by this specific covariate.

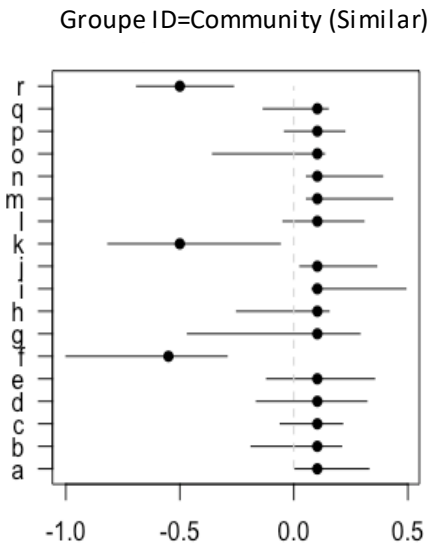


Figure D2.3. Confidence intervals for subject-specific variables (here Group identity = community, with similar opinions within the group), based on 200 bootstrapped samples.

R script for BTLLasso.cv

```
#########################################################
#  BTLLasso#
#########################################################

##CHARGING DATA

library(BTLLasso)
criteria <- read.csv("./Data_base_Lou_fairness_BTLasso.csv",sep=";", header = TRUE, fill = FALSE, stringsAsFactors = FALSE)


##FORMATING DATA

nb_prop <- 18 ##Number of proposition that were used for the paired comparisons
nb_test <- dim(raw)[2]/2 ##the result of the test was written in two column (prop i / prop j)
nb_pers <- dim(criteria)[1] ## number of participants

## FORMAT DATA TO FIT THE PARAMETER OF THE FUNCTION RESPONSE.BTLLASSO
object.names = c()
for(i in 1:nb_prop) {object.names <- c(object.names, sprintf("Prop %d", i))} ##We called each proposition by its index

response = c(); ##raw result of the paired comparison
first.object = c();## the first proposition of the paired comparison
second.object = c();## the second proposition of the paired comparison
subject = c(); ## the participant who compare the proposition

##SETTING THE DATA
for(i in 1:nb_pers) {
  for(j in 1:nb_test)
  {
    first.object = c(first.object, prop[,2*j-1]);
    second.object = c(second.object, prop[,2*j]);
    subject = c(subject, names[i]);
    response = c(response, raw[i,2*j-1]);
  }
}

first.object = first.object
second.object = second.object
response2 = as.factor(response)

## CREATION OF THE OBJECT Y FOR BTLLasso
Y = response.BTLLasso(response = response, first.object = first.object, second.object = second.object, subject = subject)
```

```
##SET SEED
set.seed(1988)

##BTLLASSO FUNCTION FOR THE EXTERNAL FACTOR RELATED TO THE INJUSTICE ITSELF

Criteria_injustice= criteria2[,c(14, 15, 18, 19, 27, 28, 29,30,31, 44, 45, 46, 47, 48)]

##CV.TEST

cv.test.Criteria_injustice_lam10=cv.BTLLasso(Y, X = Criteria_injustice, control=ctrl.BTLLasso(scale=FALSE, l.lambda = 10,
 lambda.min = 0.6, lambda2 = 1, penalize.X=TRUE), fold=5, cores=5, trace = FALSE,trace.cv = FALSE)

plot(cv.test.Criteria_injustice_lam10)
par(mar=c(5.1,4.1,4.1,25), xpd=TRUE)
paths(cv.test.Criteria_injustice_lam10)

##BOOTSTRAP
boot.cv.test.Criteria_injustice_lam10=boot.BTLLasso(cv.test.Criteria_injustice_lam10, B=200, cores=5)
plot(boot.cv.test.Criteria_injustice_lam10)


##BTLLASSO FUNCTION FOR THE EXTERNAL FACTOR RELATED TO THE INDIVIDUAL

Criteria_individual= criteria[,c(1,2,7,11,12,20,21,52,53,54,55)]

##CV.TEST

cv.test.Criteria_individual_Lam10=cv.BTLLasso(Y, X = Criteria_individual, control=ctrl.BTLLasso(scale=FALSE, l.lambda = 10,
 lambda.min = 0.6, lambda2 = 1, penalize.X=TRUE), fold=5, cores=5, trace = FALSE,trace.cv = FALSE)

plot(cv.test.Criteria_individual_Lam10)
par(mar=c(5.1,4.1,4.1,25), xpd=TRUE)
paths(cv.test.Criteria_individual_Lam10)

##BOOTSTRAP
boot.cv.test.Criteria_individual_lam10=boot.BTLLasso(cv.test.Criteria_individual_Lam10, B=200, cores=5)
plot(boot.cv.test.Criteria_individual_lam10)


##BTLLASSO FUNCTION FOR THE EXTERNAL FACTOR RELATED TO THE CONTEXT


Criteria_context=criteria[,c(10,22,23,24,25,26,49,50,51,61,62,63,64,65,66)]


##CV.TEST

cv.test.Criteria_context_lam10=cv.BTLLasso(Y, X = Criteria_context, control=ctrl.BTLLasso(scale=FALSE, l.lambda = 10,
 lambda.min = 0.6, lambda2 = 1, penalize.X=TRUE), fold=5, cores=5, trace = FALSE,trace.cv = FALSE)

plot(cv.test.Criteria_individual_Lam10)
par(mar=c(5.1,4.1,4.1,25), xpd=TRUE)
paths(cv.test.Criteria_individual_Lam10)


##BOOTSTRAP
boot.cv.test.Criteria_individual_lam10=boot.BTLLasso(cv.test.Criteria_individual_Lam10, B=200, cores=5)
plot(boot.cv.test.Criteria_individual_lam10)
```

A. Factors related to the injustice itself

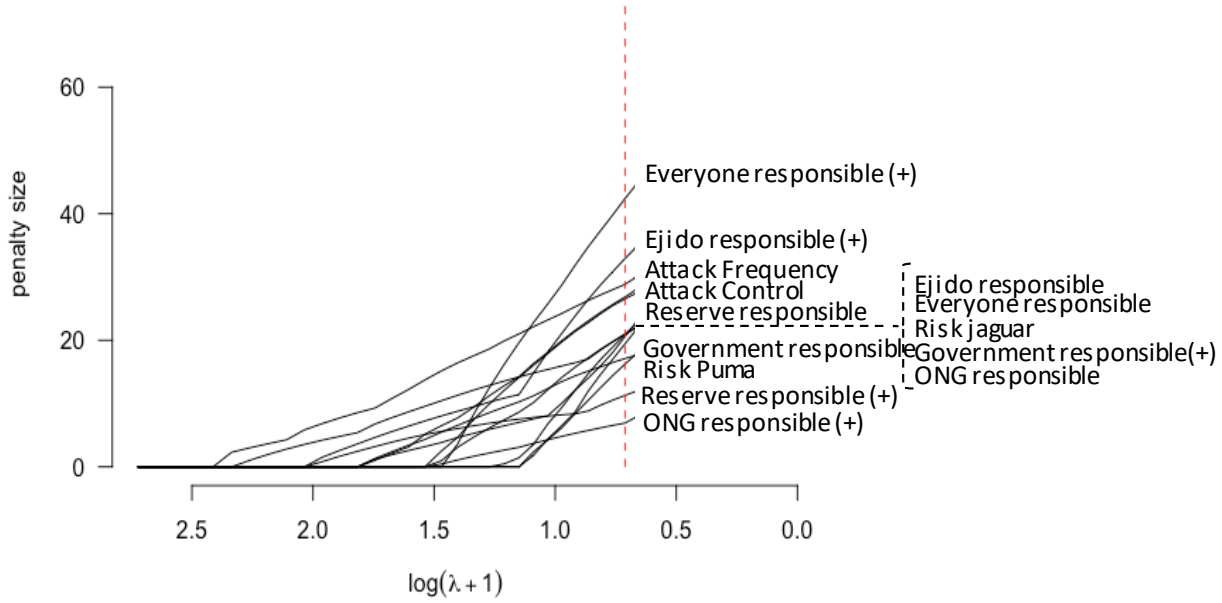
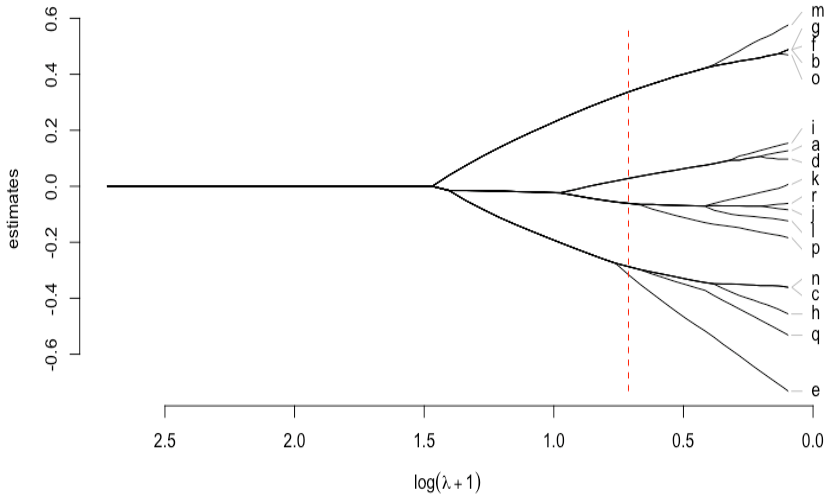
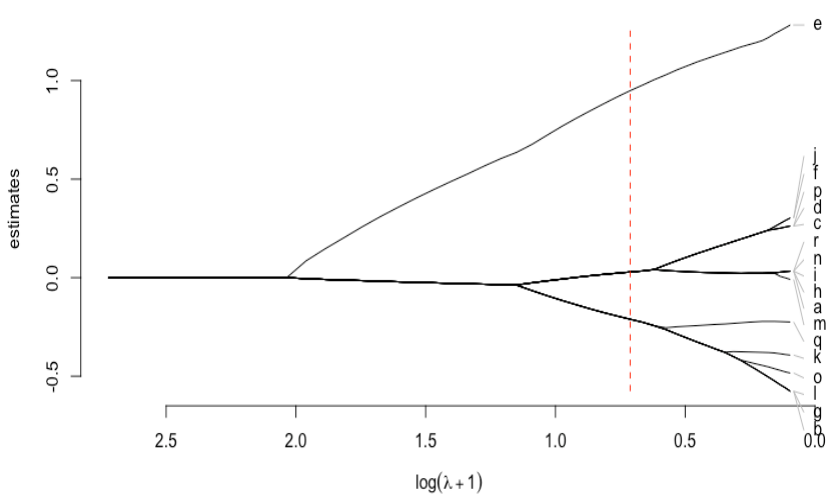


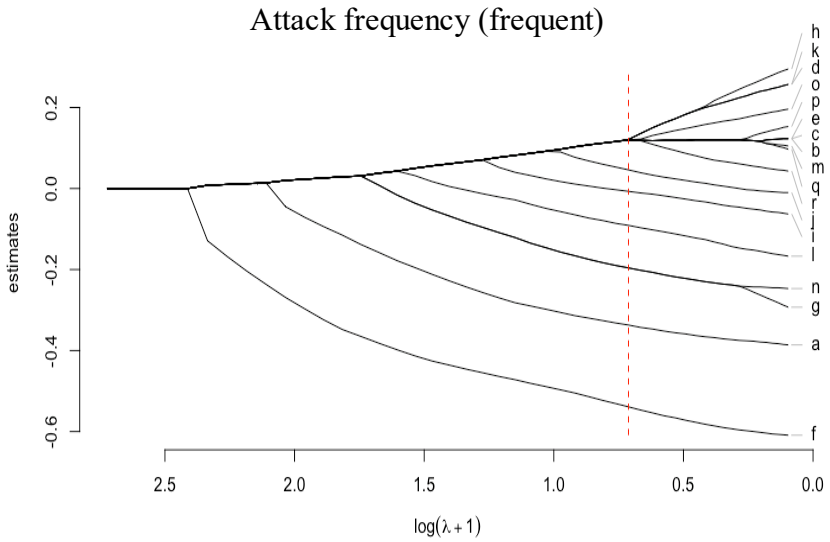
Figure D2.4. Penalty paths for the factors related to the injustice itself. The dashed red line represents the optimal model according to a 10-fold cross-validation. Subject-specific covariates that have the largest values of penalty term for the single model component at the optimal value of the tuning parameter; hence they are those that influence most the choice between the different objects.

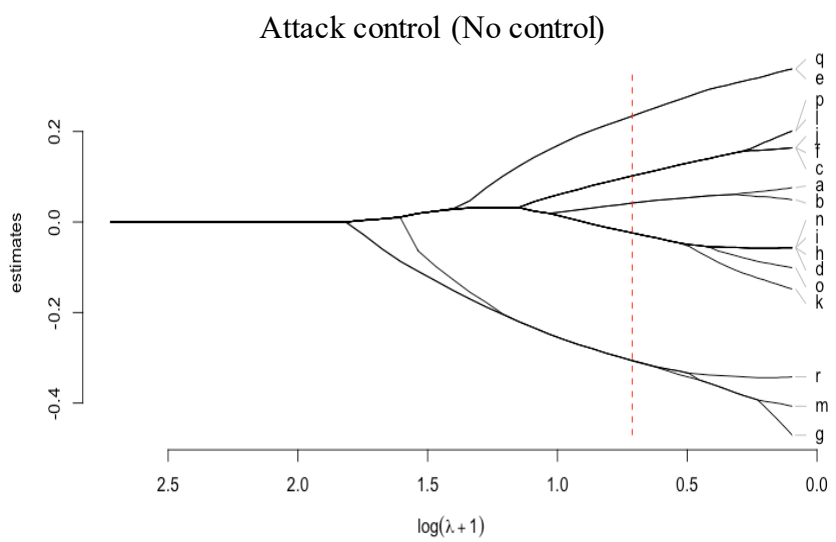
Everyone responsible (+)



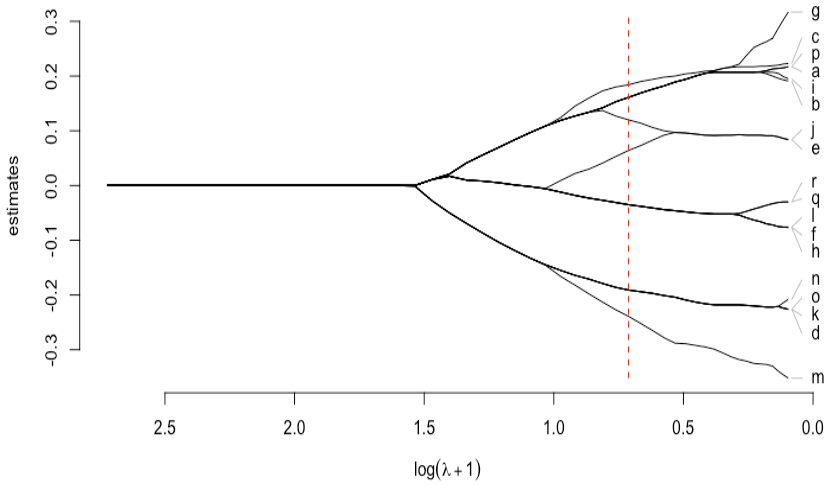
Ejido responsible (+)



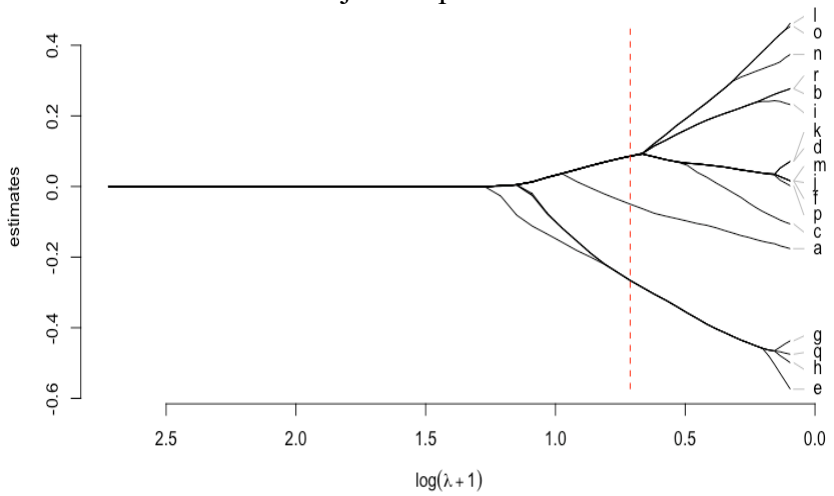

Attack frequency (frequent)
estimates
0.2
0.0
-0.2
-0.4
-0.6
2.5
2.0
1.5
1.0
0.5
0.0
log(λ+1)
h
k
d
o
p
e
c
b
m
q
r
i
l
n
g
a
f

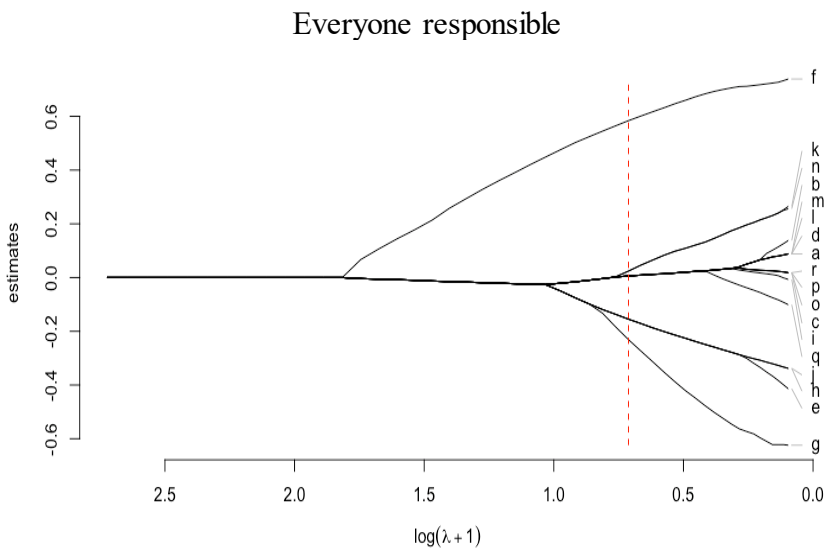

Attack control (No control)
estimates
0.2
0.0
-0.2
-0.4
2.5
2.0
1.5
1.0
0.5
0.0
log(λ+1)
q
e
p
i
f
c
a
b
n
h
d
o
k
r
m
g

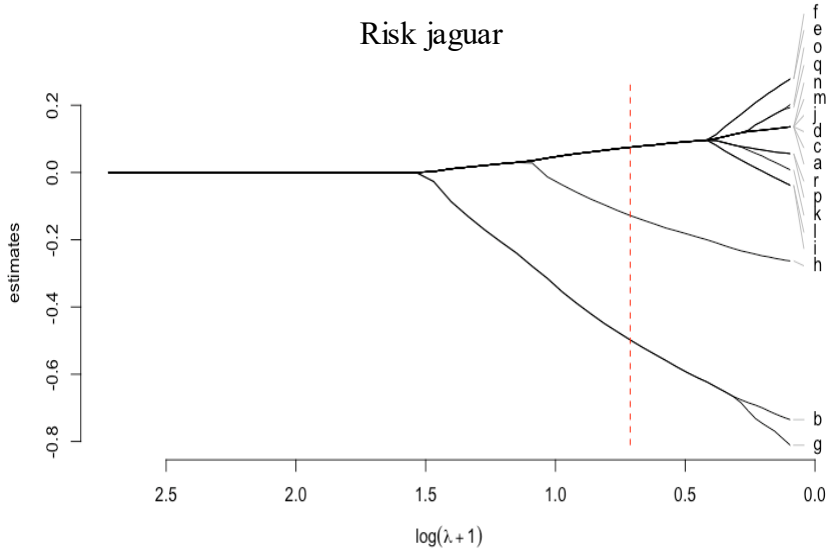
Reserve responsible



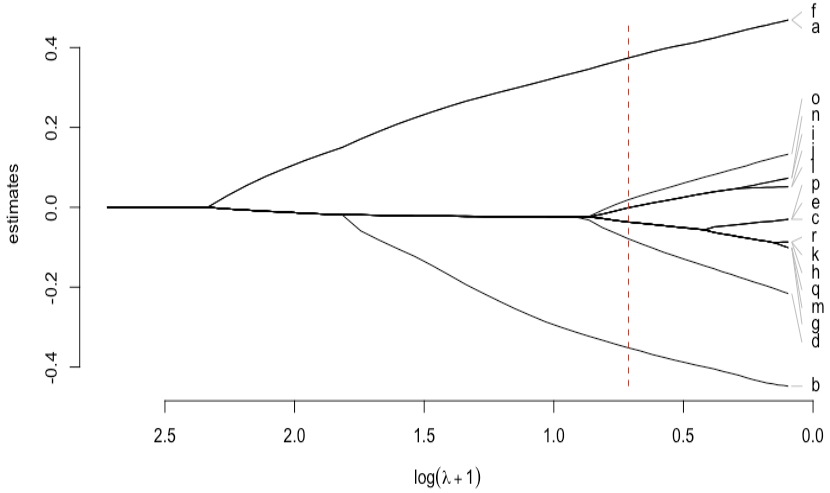
Ejido responsible



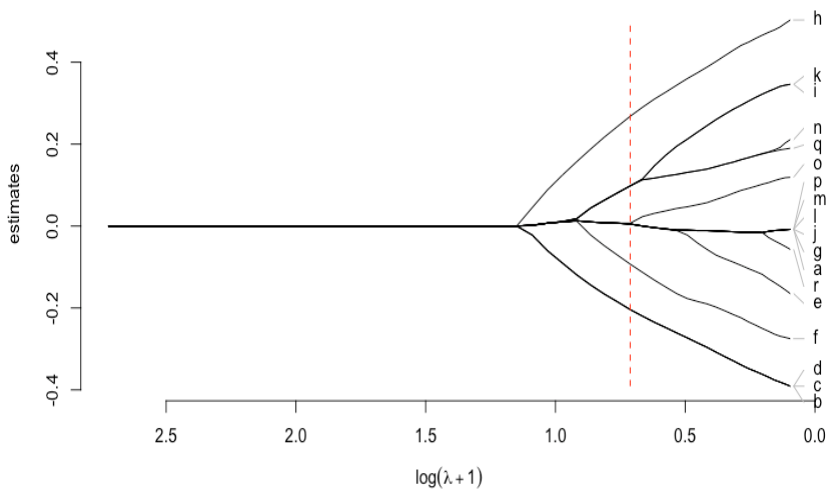

Everyone responsible
estimates
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
2.5
2.0
1.5
1.0
0.5
0.0
log(λ + 1)
f
k
n
b
m
d
a
r
p
o
c
i
q
l
h
e
g


Risk jaguar
estimates
0.2
0.0
-0.2
-0.4
-0.6
-0.8
2.5
2.0
1.5
1.0
0.5
0.0
log(λ + 1)
f
e
o
q
n
m
l
d
c
a
r
p
k
i
h
b
g

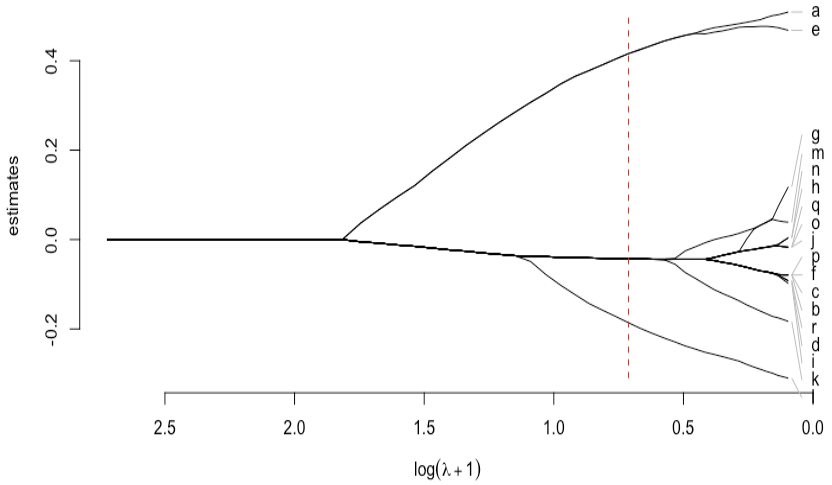
Government responsible (+)



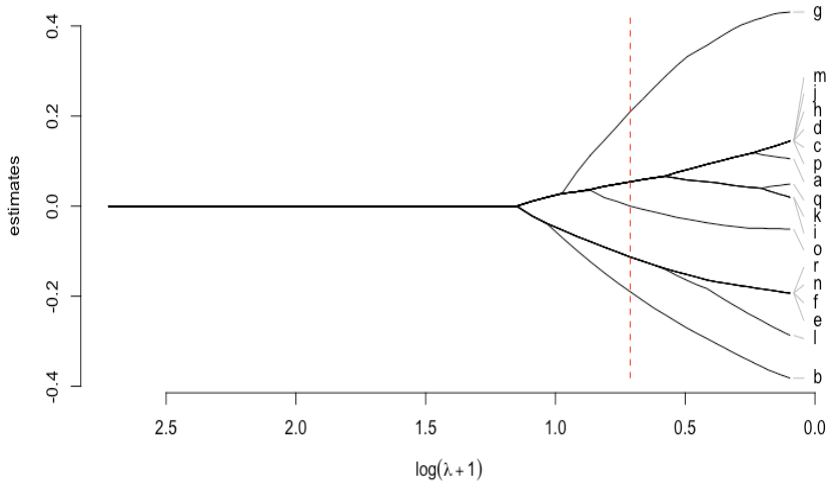
ONGs responsible



Government responsible



Risk puma



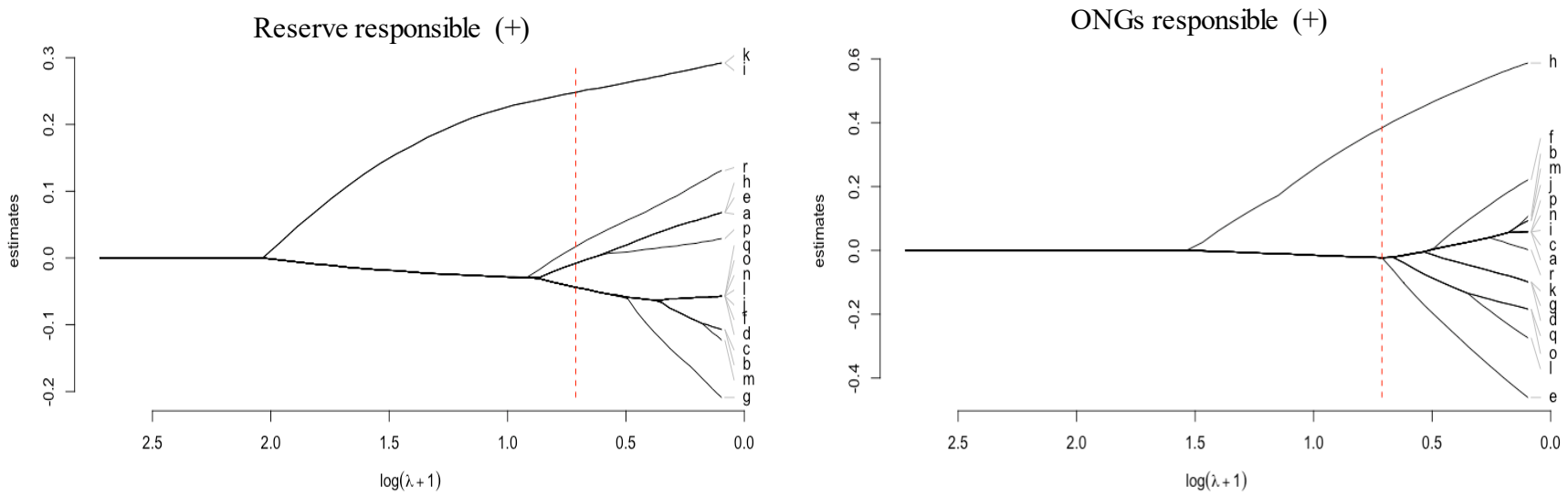


Figure D2.5. Parameter paths for subject-specific variables (i.e. factors related to the injustice itself). The dashed red line represents the optimal model according to a 10-fold cross-validation. The graph is centered on 0 on the Y–axis. Object coefficient paths that have a positive value at the optimal value of the tuning parameter indicate that this object attractiveness is influenced positively by this specific covariate. On the contrary, object coefficient paths that have a negative value at the optimal value of the tuning parameter indicate that this object attractiveness is influenced negatively by this specific covariate.

B. Factors related to the individual

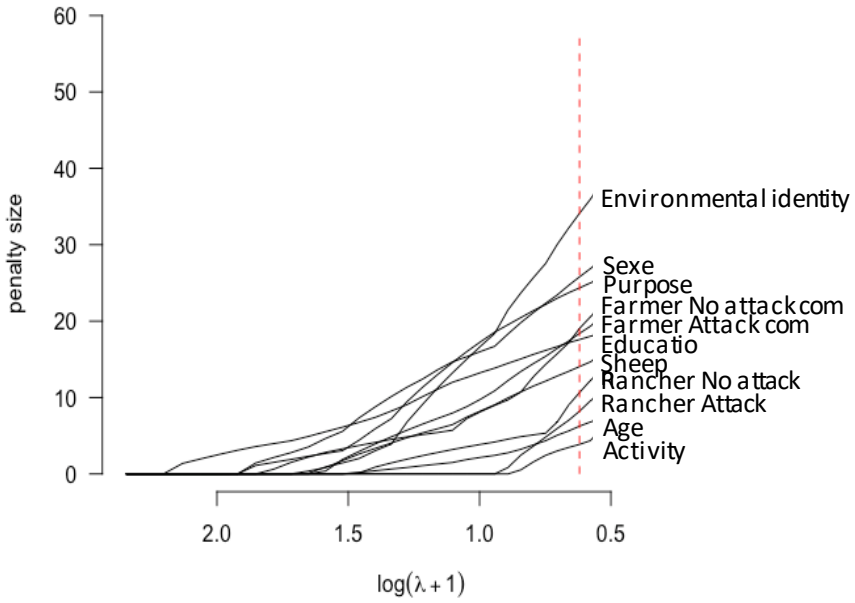
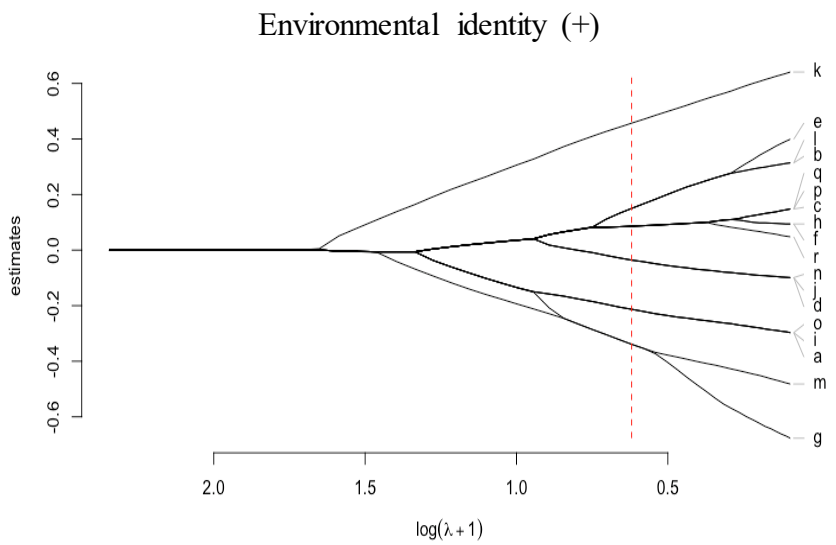
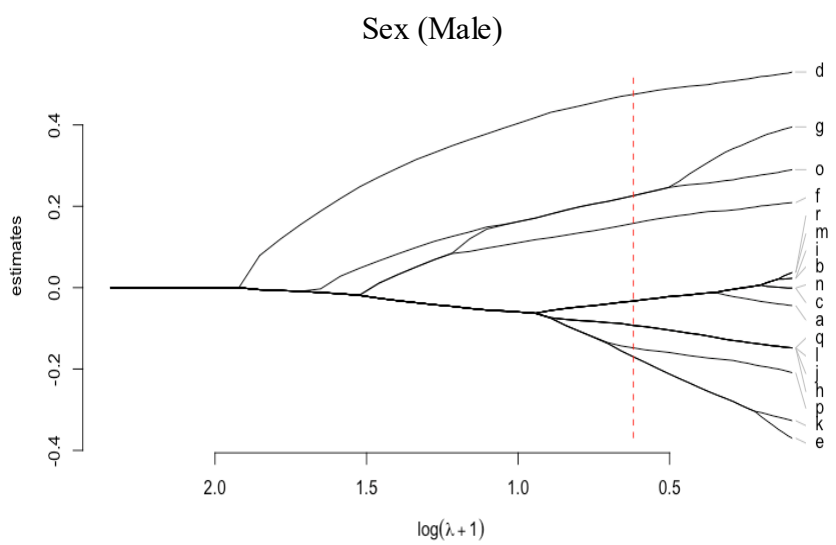
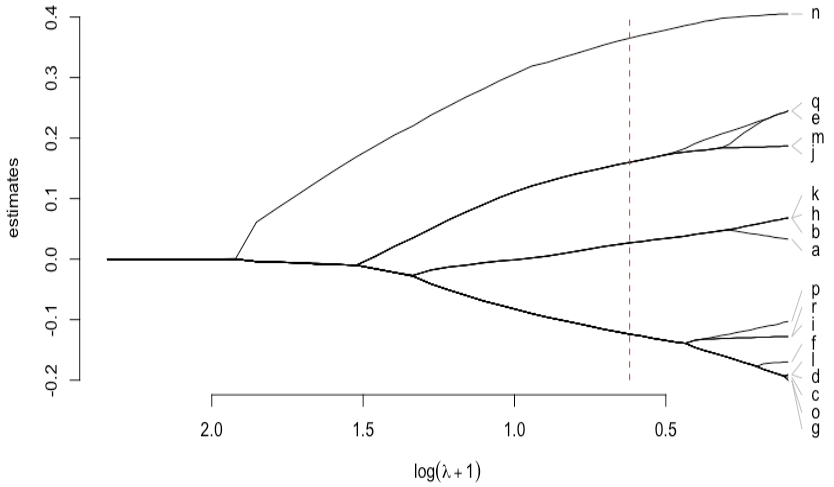


Figure D2.6. Penalty paths for the factors related to the individual. The dashed red line represents the optimal model according to a 10-fold cross-validation. Subject-specific covariates that have the largest values of penalty term for the single model component at the optimal value of the tuning parameter; hence they are those that influence most the choice between the different objects.

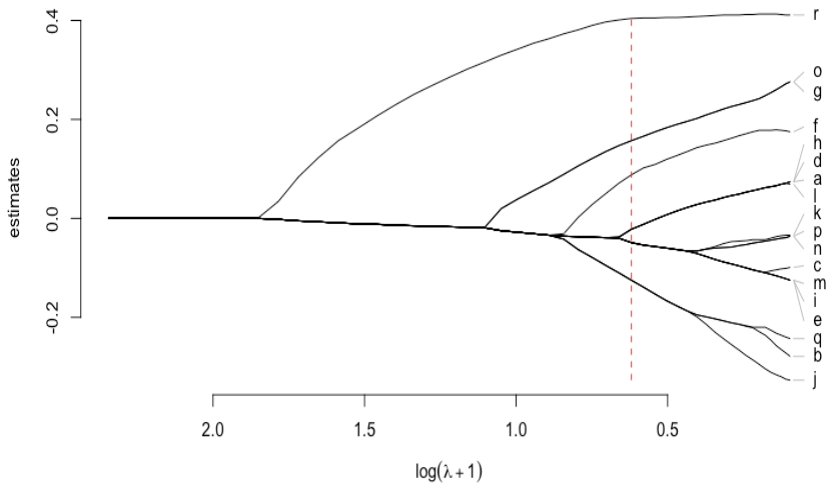

Environmental identity (+)
estimates
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
k
e
b
q
p
c
h
f
r
n
j
d
o
i
a
m
g
2.0
1.5
1.0
0.5
log(λ + 1)

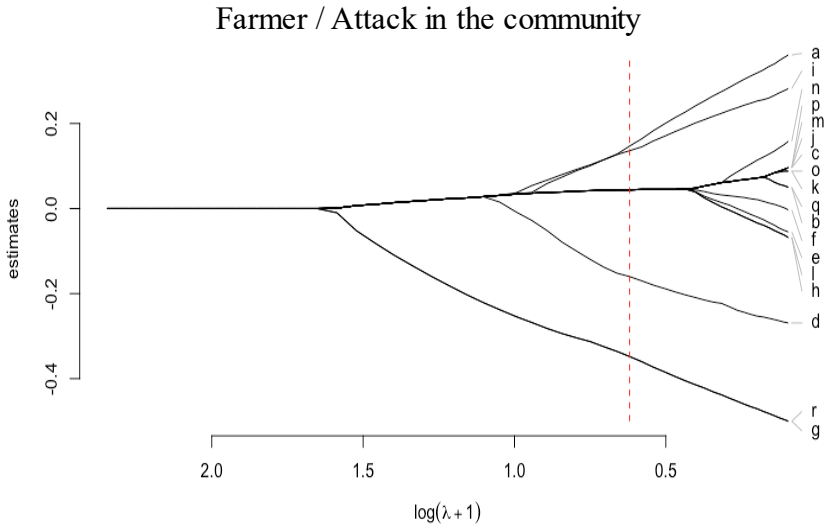

Sex (Male)
estimates
0.4
0.2
0.0
-0.2
-0.4
d
g
o
f
r
m
l
b
n
c
a
q
i
j
h
p
k
e
2.0
1.5
1.0
0.5
log(λ + 1)

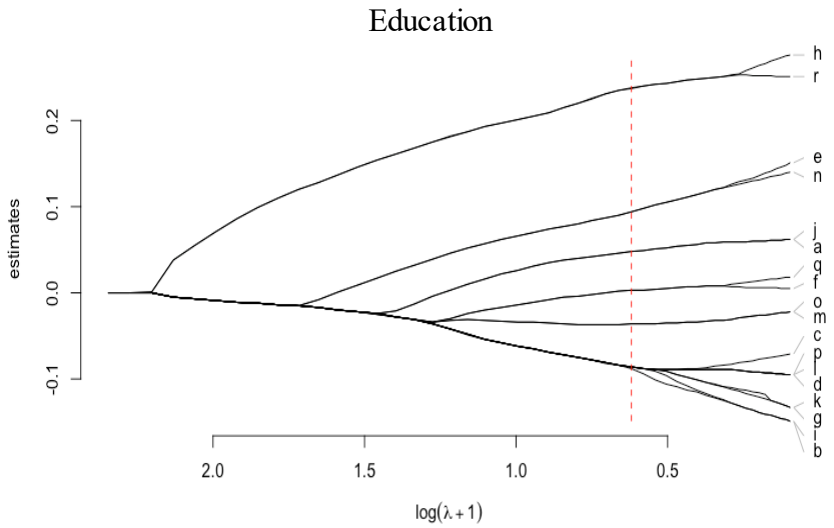
Purpose (+ Livestock)

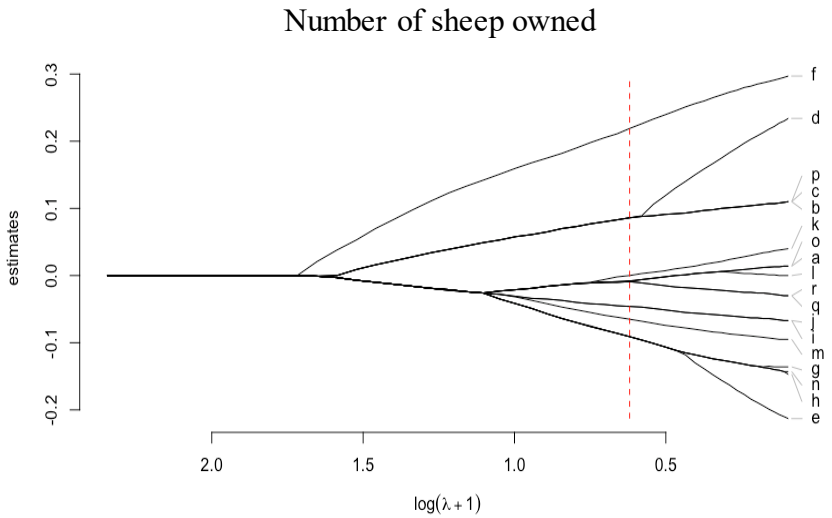


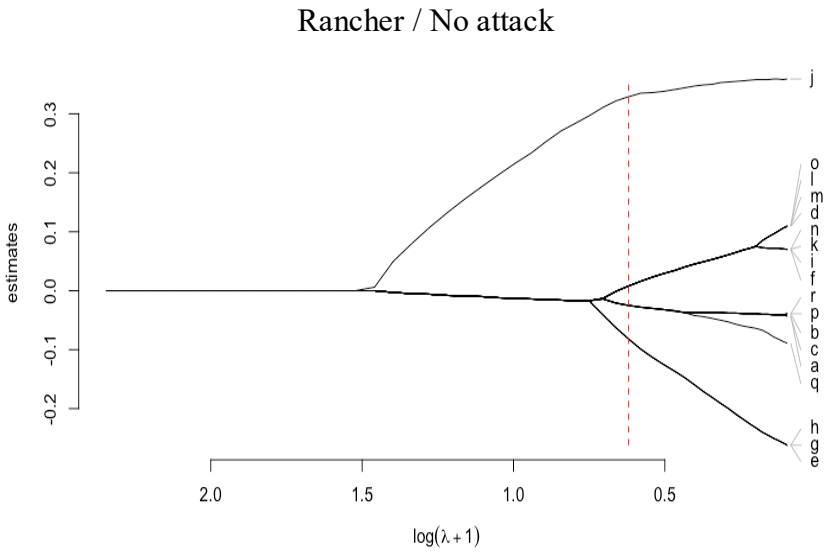
Farmer / No attack in the community



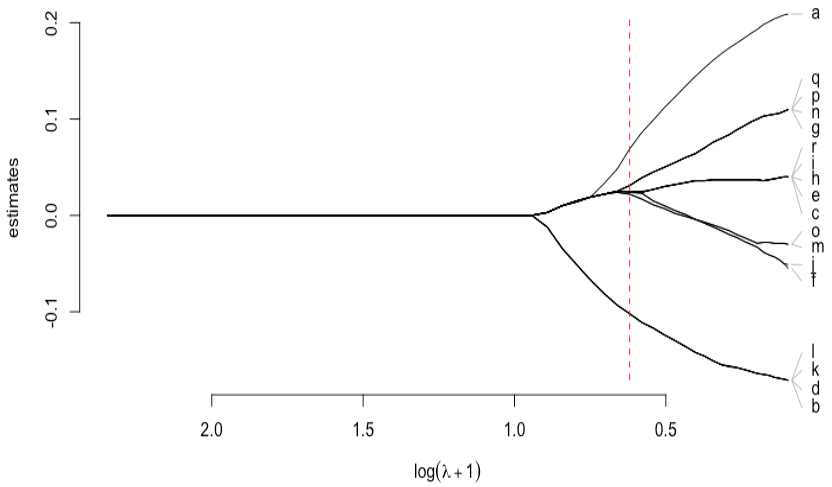

Farmer / Attack in the community
estimates
0.2
0.0
-0.2
-0.4
2.0
1.5
1.0
0.5
log(λ + 1)
a
i
n
p
m
j
c
o
k
q
b
f
e
l
h
d
r
g


Education
estimates
0.2
0.1
0.0
-0.1
2.0
1.5
1.0
0.5
log(λ + 1)
h
r
e
n
j
a
q
f
o
m
c
p
l
d
k
g
i
b

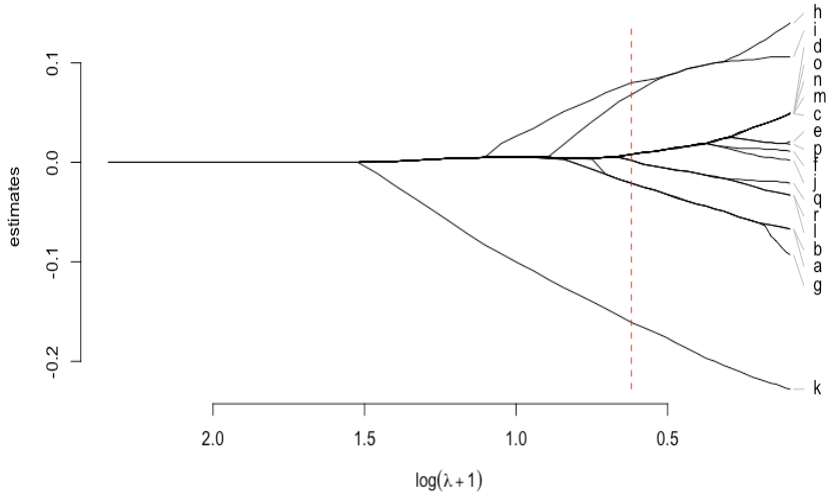

Number of sheep owned
estimates
0.3
0.2
0.1
0.0
-0.1
-0.2
f
d
p
c
b
k
o
a
l
r
q
j
i
m
g
n
h
e
2.0
1.5
1.0
0.5
log(λ + 1)


Rancher / No attack
estimates
0.3
0.2
0.1
0.0
-0.1
-0.2
j
o
l
m
d
n
k
i
f
r
p
b
c
a
q
h
g
e
2.0
1.5
1.0
0.5
log(λ + 1)

Rancher / Attack



Age



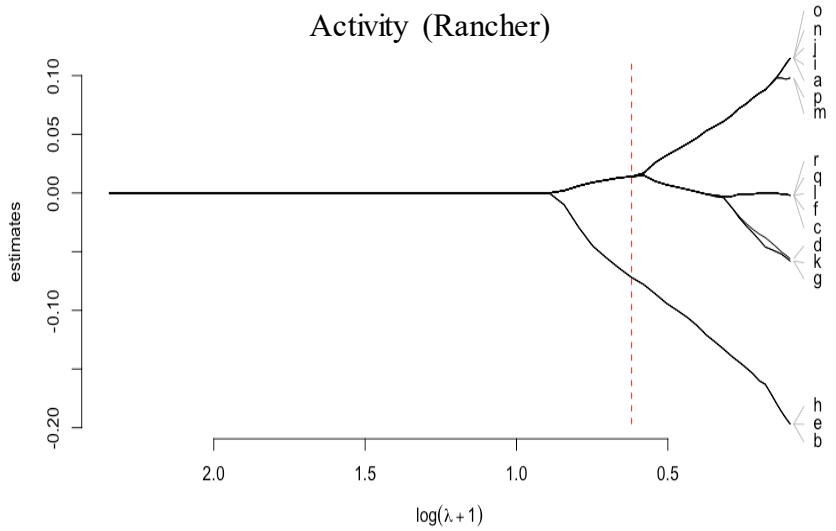


Figure D2.7. Parameter paths for subject-specific variables (i.e. factors related to the individual). The dashed red line represents the optimal model according to a 10-fold cross-validation. The graph is centered on 0 on the Y–axis. Object coefficient paths that have a positive value at the optimal value of the tuning parameter indicate that this object attractiveness is influenced positively by this specific covariate. On the contrary, object coefficient paths that have a negative value at the optimal value of the tuning parameter indicate that this object attractiveness is influenced negatively by this specific covariate.

C. Factors related to the context

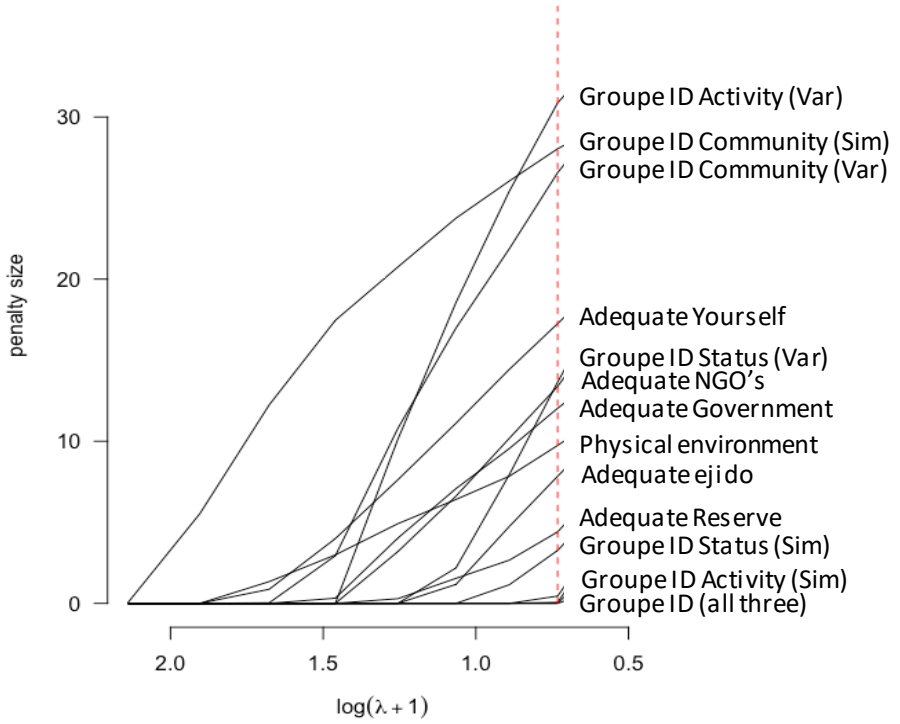
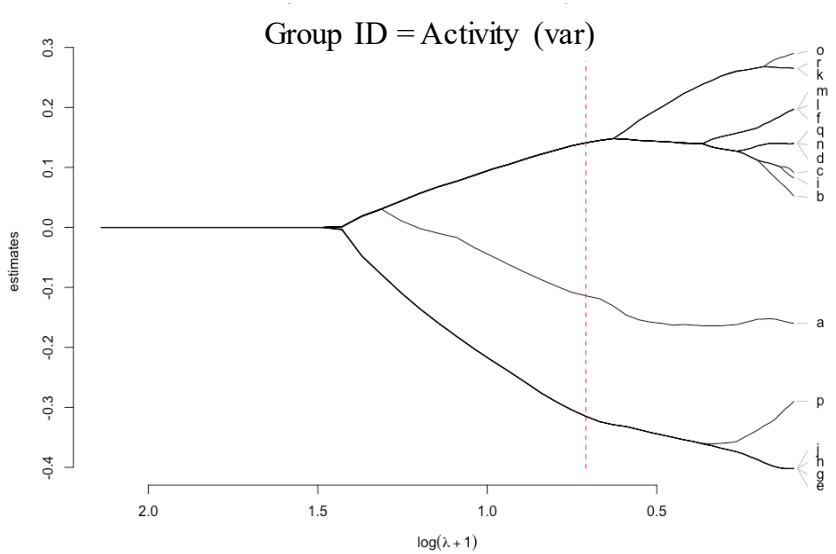
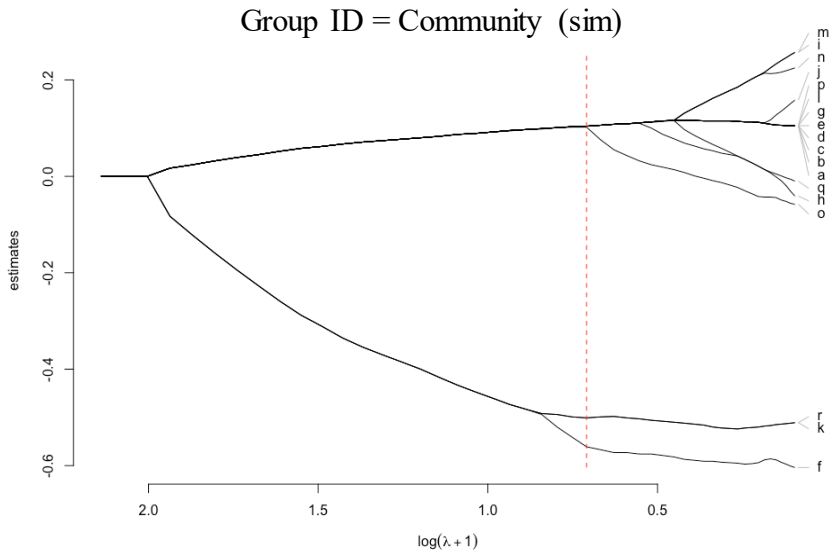
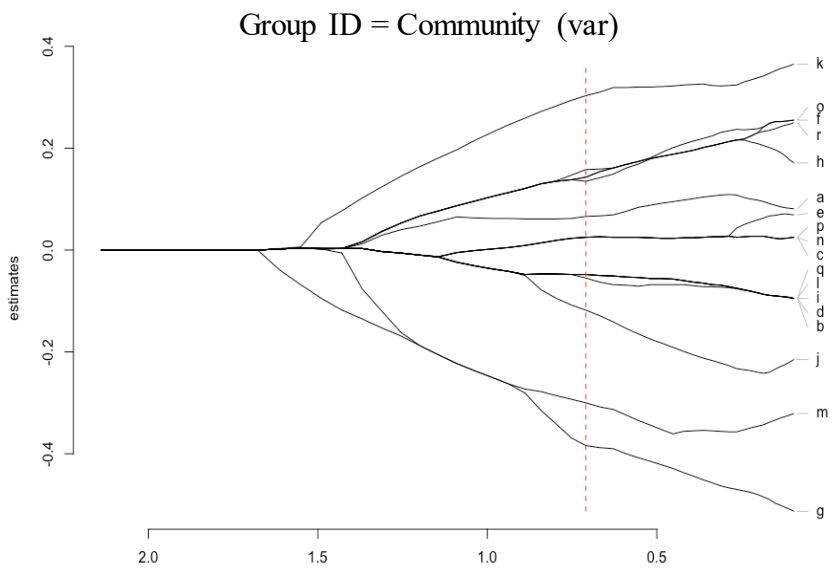
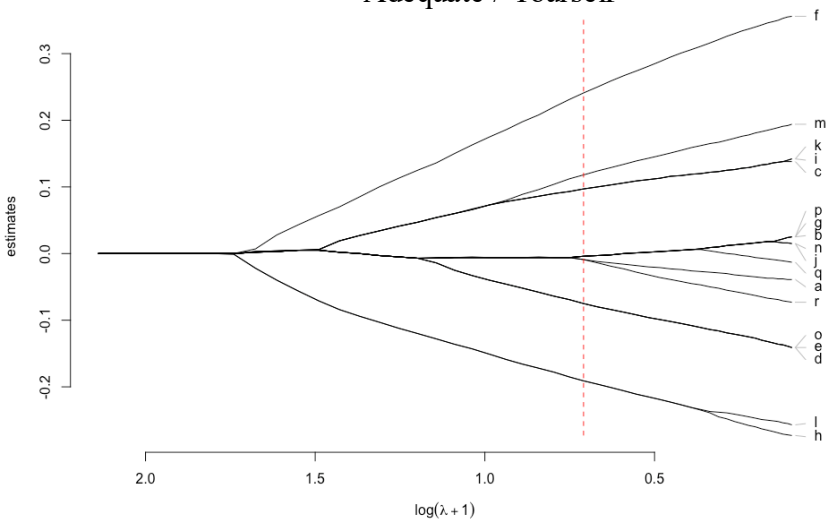


Figure D2.8. Penalty paths for the factors related to the context. The dashed red line represents the optimal model according to a 10-fold cross-validation. Subject-specific covariates that have the largest values of penalty term for the single model component at the optimal value of the tuning parameter; hence they are those that influence most the choice between the different objects.

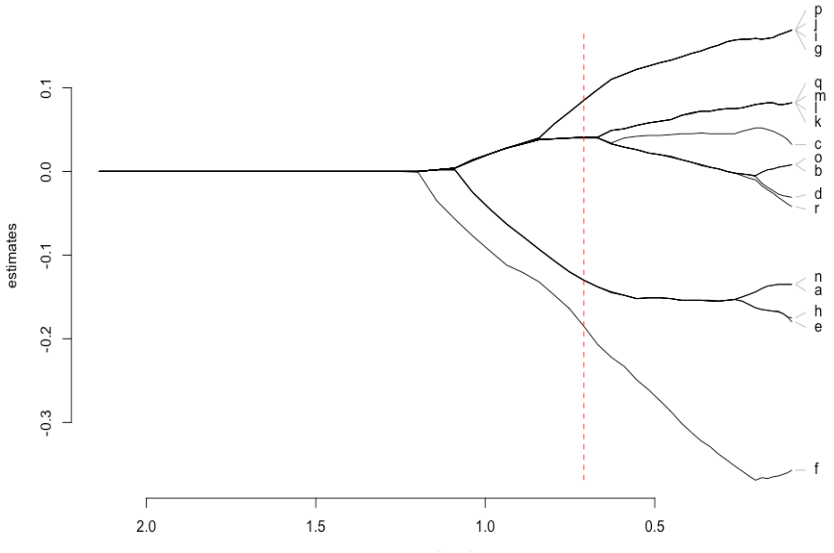

Group ID = Activity (var)
estimates
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
2.0
1.5
1.0
0.5
log(λ + 1)
o
r
k
m
l
f
n
d
c
i
b
a
p
j
h
g
e


Group ID = Community (sim)
estimates
0.2
0.0
-0.2
-0.4
-0.6
2.0
1.5
1.0
0.5
log(λ + 1)
m
l
i
p
j
g
e
d
c
b
a
n
h
o
r
k
f

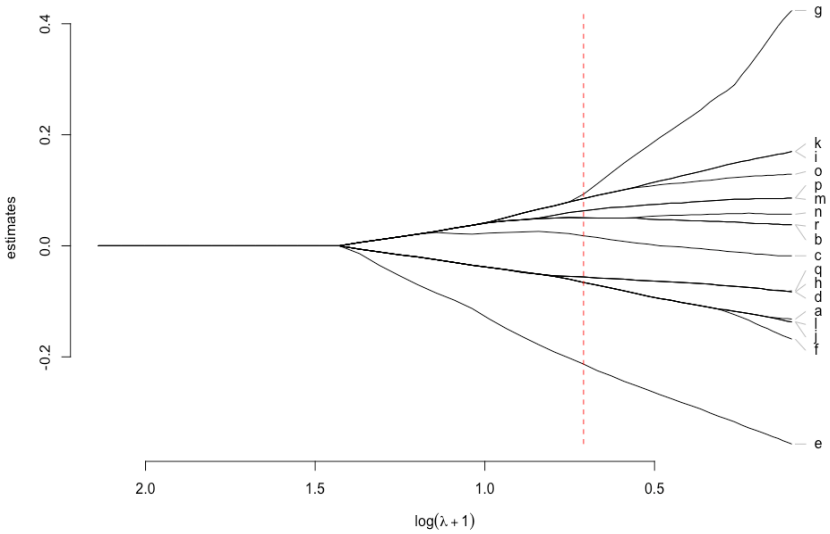

Group ID = Community (var)
estimates
0.4
0.2
0.0
-0.2
-0.4
k
o
f
r
h
a
e
p
n
c
q
i
d
b
j
m
g
2.0
1.5
1.0
0.5

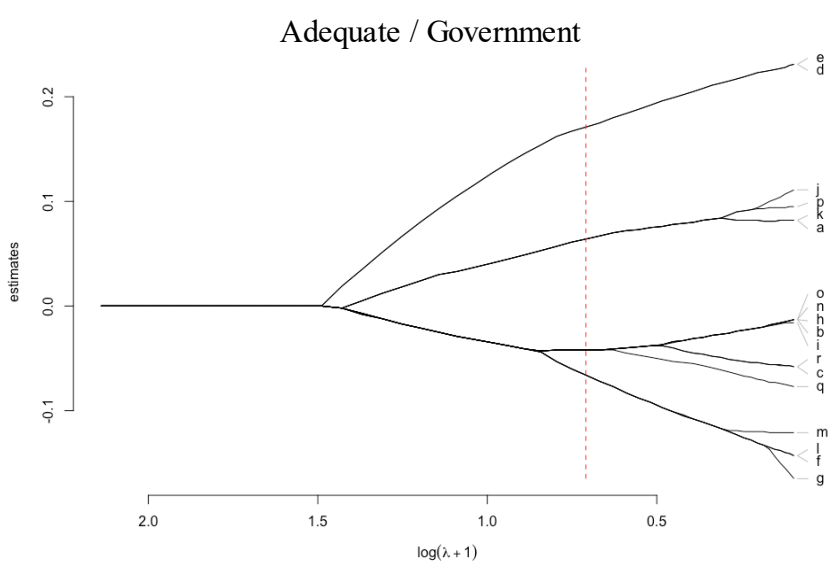

Adequate / Yourself
estimates
0.3
0.2
0.1
0.0
-0.1
-0.2
f
m
k
i
c
p
g
b
n
j
q
a
r
o
e
d
l
h
2.0
1.5
1.0
0.5
log(λ + 1)

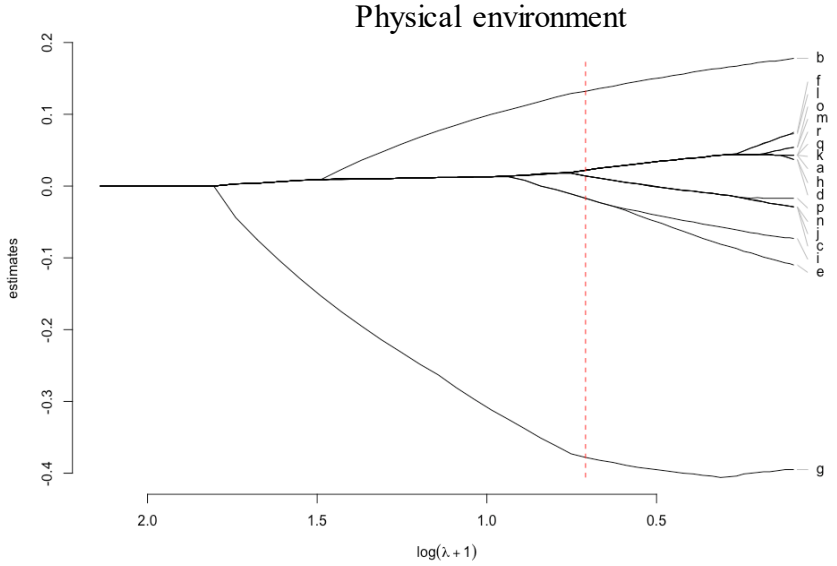
Group ID = Status (var)

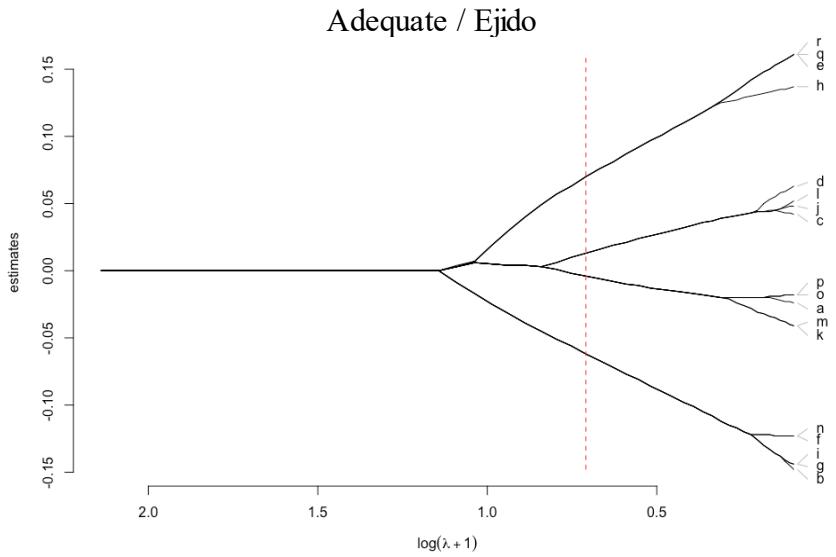


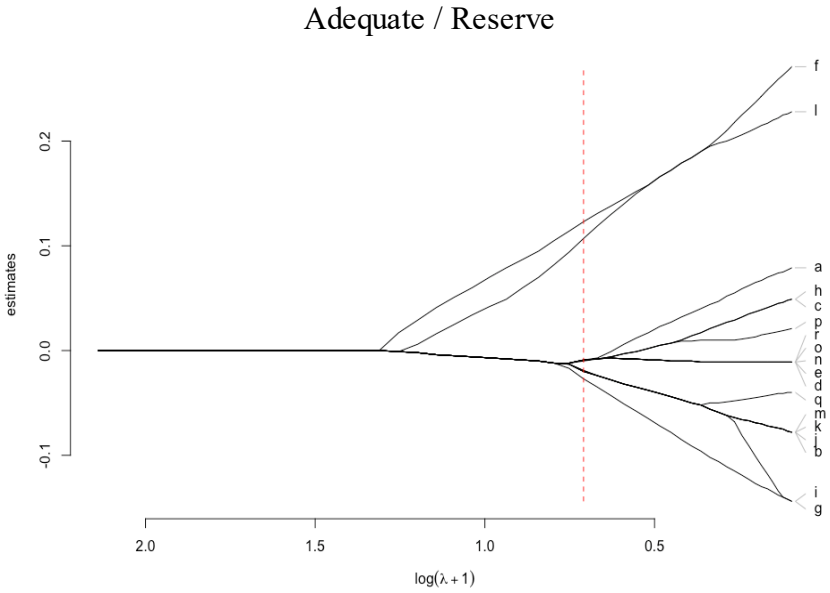
Adequate / NGOs

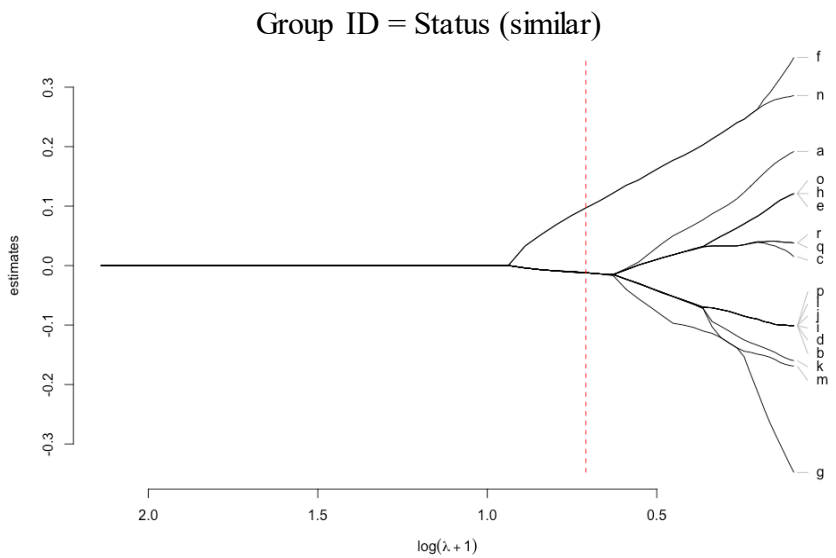


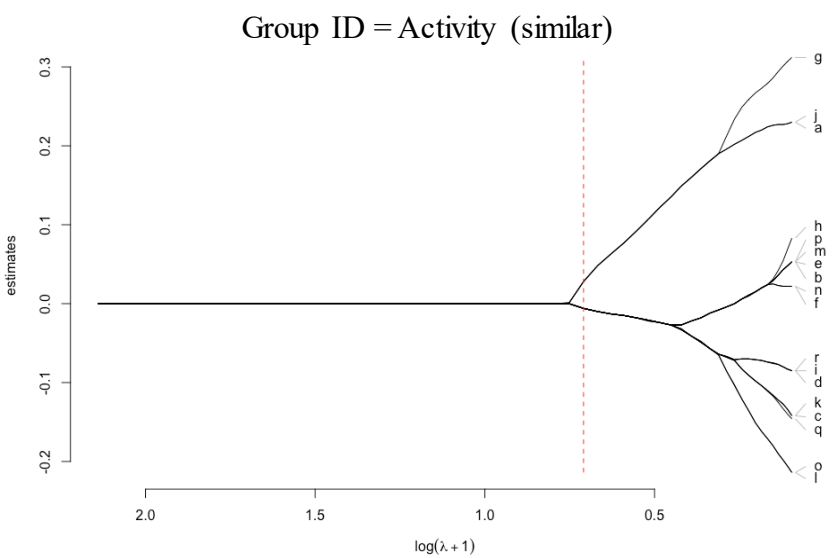

Adequate / Government
estimates
0.2
0.1
0.0
-0.1
2.0
1.5
1.0
0.5
log(λ + 1)
e
d
j
p
k
a
o
n
t
i
r
c
g
m
l
f
g

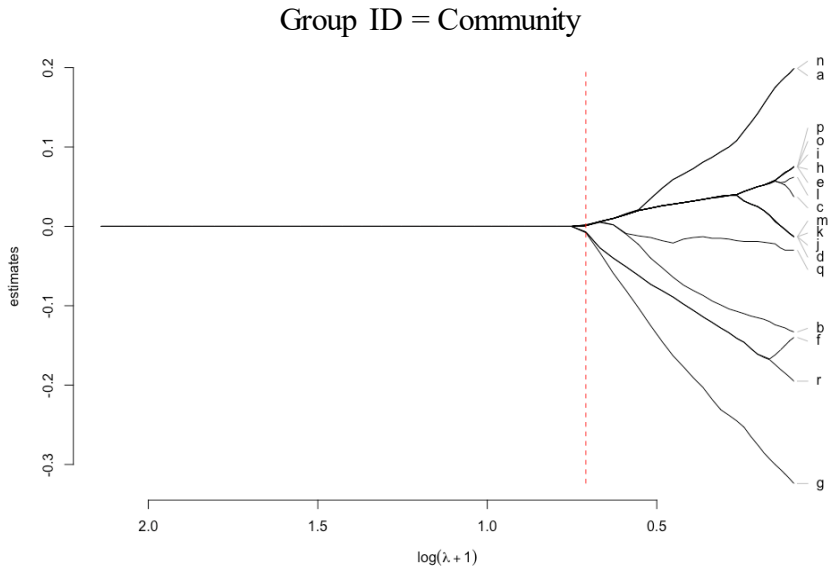

Physical environment
estimates
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
2.0
1.5
1.0
0.5
log(λ + 1)
b
g

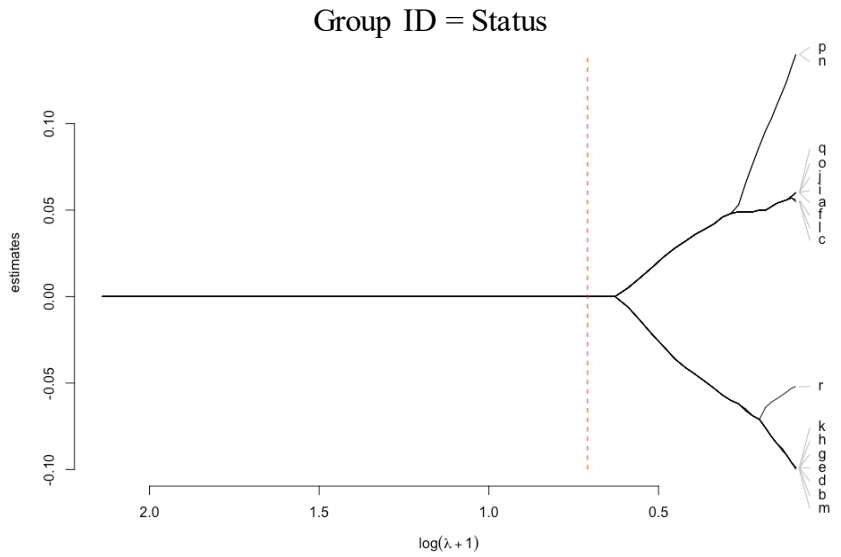

Adequate / Ejido
estimates
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
2.0
1.5
1.0
0.5
log(λ + 1)
r
q
e
h
d
l
j
c
p
o
a
m
k
n
f
i
g
b


Adequate / Reserve
estimates
0.2
0.1
0.0
-0.1
2.0
1.5
1.0
0.5
log(λ + 1)
f
l
a
h
c
p
r
o
n
e
d
q
m
k
j
b
i
g


Group ID = Status (similar)
estimates
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
2.0
1.5
1.0
0.5
log(λ + 1)
f
n
a
o
h
e
r
q
c
p
l
i
d
b
k
m
g


Group ID = Activity (similar)
estimates
0.3
0.2
0.1
0.0
-0.1
-0.2
2.0
1.5
1.0
0.5
log(λ + 1)
g
j
a
h
p
m
e
b
n
f
r
i
d
k
c
q
o
l


Group ID = Community
estimates
0.2
0.1
0.0
-0.1
-0.2
-0.3
2.0
1.5
1.0
0.5
log(λ + 1)
n
a
p
o
i
h
e
l
c
m
k
d
q
b
f
r
g


Group ID = Status
estimates
0.10
0.05
0.00
-0.05
-0.10
2.0
1.5
1.0
0.5
log(λ + 1)
p
n
o
i
a
t
l
c
r
k
h
g
e
d
b
m

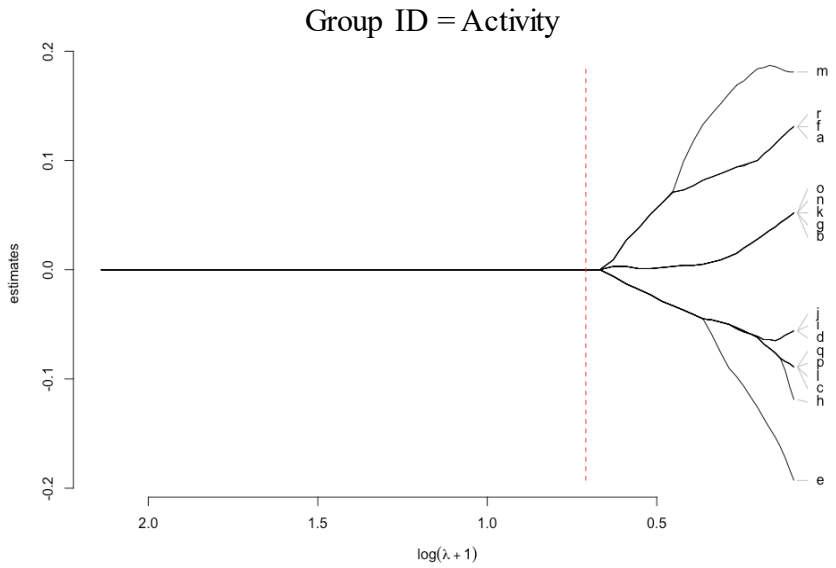


Figure D2.9. Parameter paths for subject-specific variables (here, factors related to the context). The dashed red line represents the optimal model according to a 10-fold cross-validation. The graph is centered on 0 on the Y–axis. Object coefficient paths that have a positive value at the optimal value of the tuning parameter indicate that this object attractiveness is influenced positively by this specific covariate. On the contrary, object coefficient paths that have a negative value at the optimal value of the tuning parameter indicate that this object attractiveness is influenced negatively by this specific covariate.

Supplementary material D3. Results: K-mean partitioning result

We used a K-mean partitioning to assess if some criteria were influenced similarly by the external factors. To do so, we used a matrix built on the values of the estimated effects (for the optimal model) for each criterion for every group of external factors and for every external factor. We performed the analysis using the Calskinki-criterion for each sub-group of external factors (injustice itself, individual, context) and for every external factor.

External factors related to the injustice itself

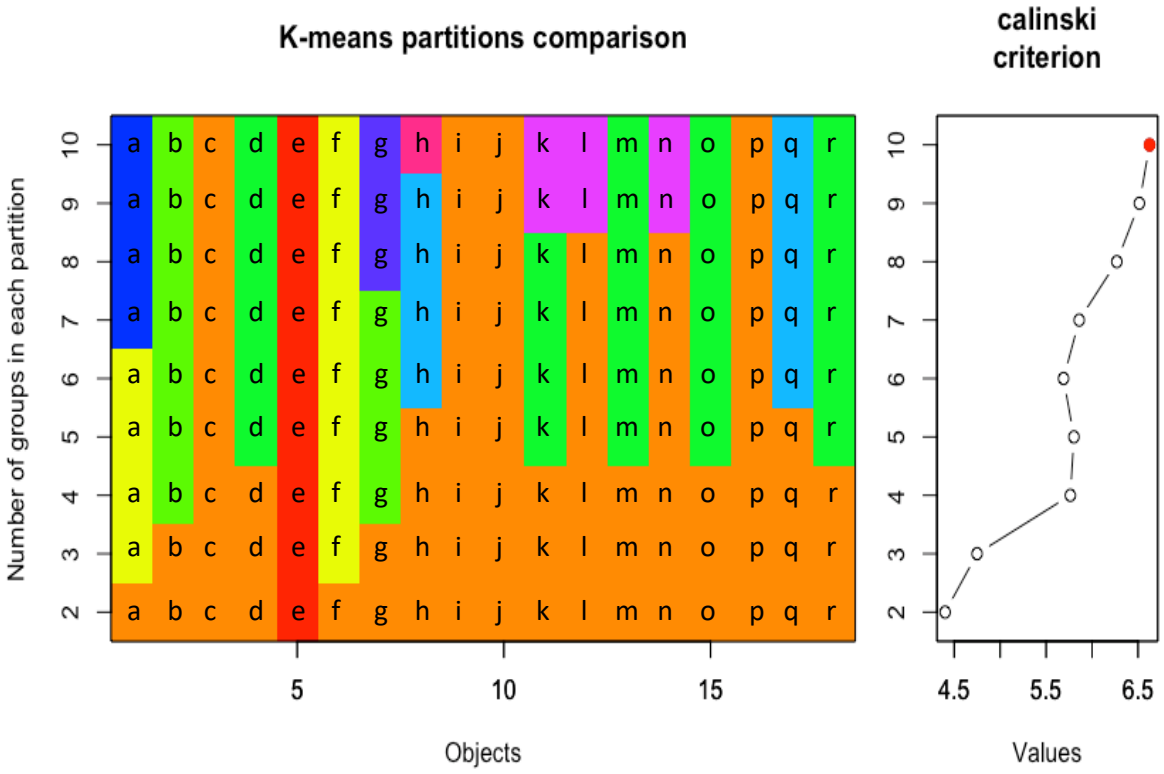


Figure D3.1. K-mean results for external factors related to the injustice itself

External factors related to the individual

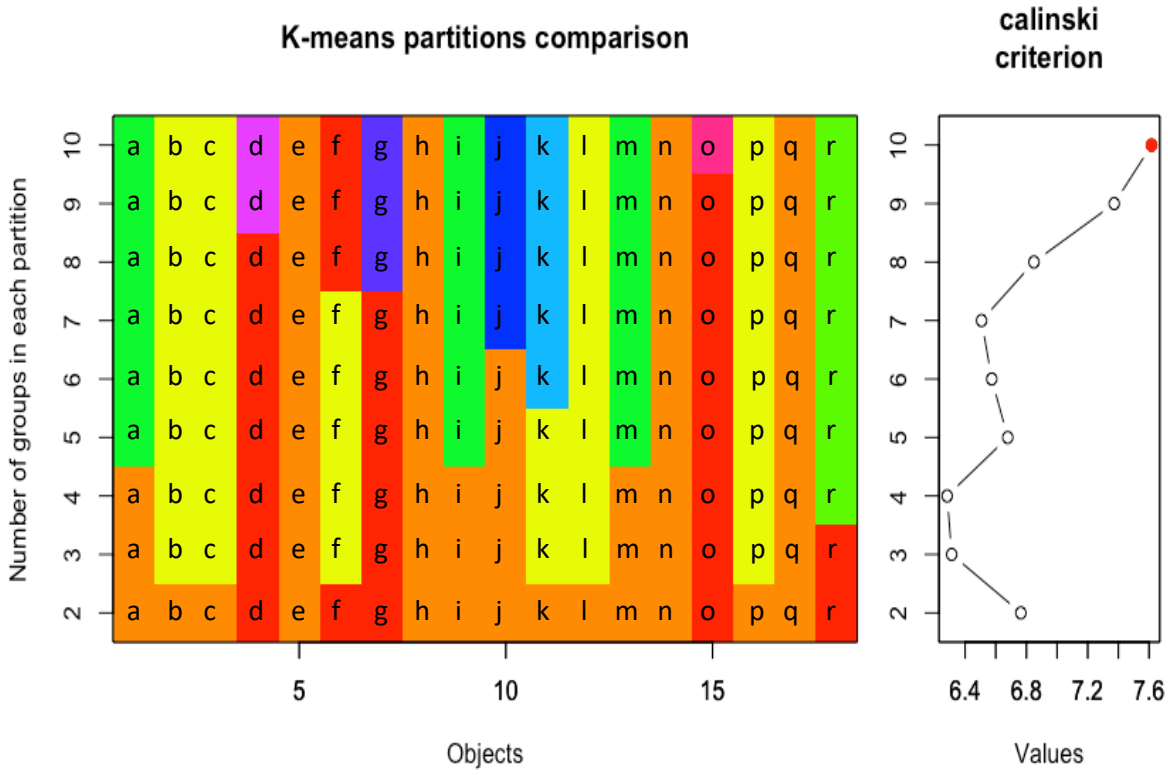


Figure D3.2. K-mean results for external factors related to the individual

External factors related to the context

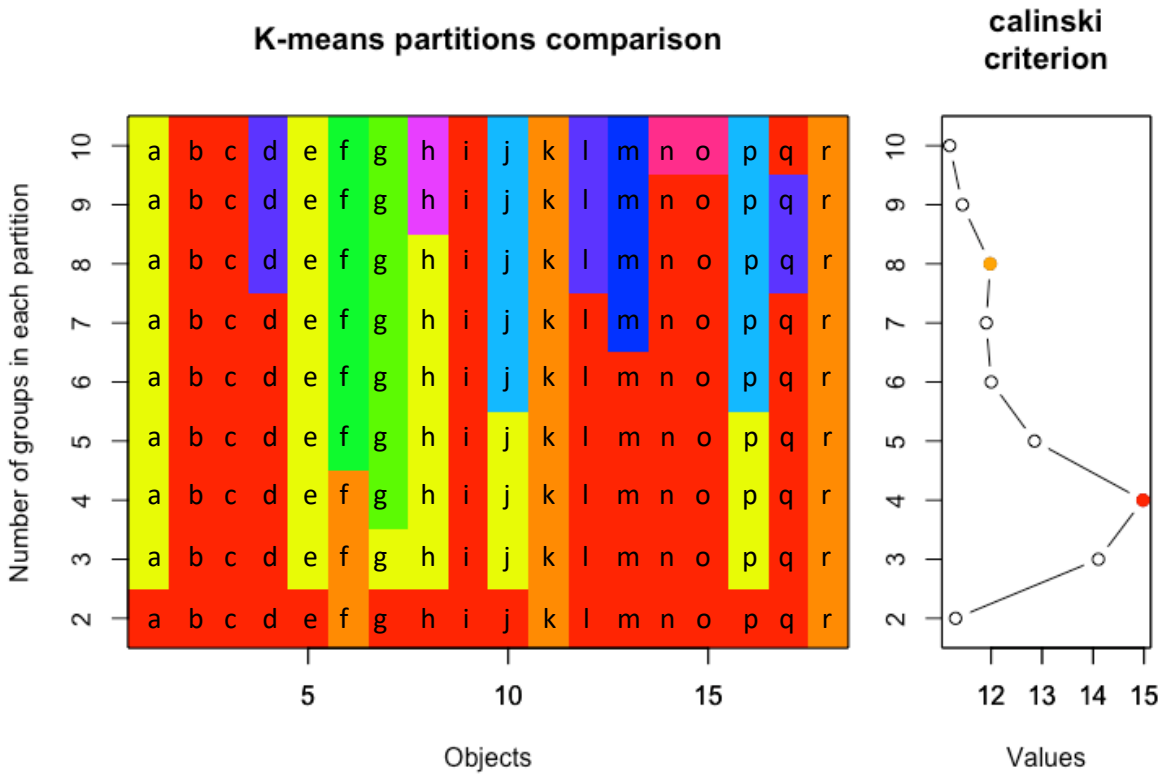


Figure D3.3. K-mean results for external factors related to the context

All external factors

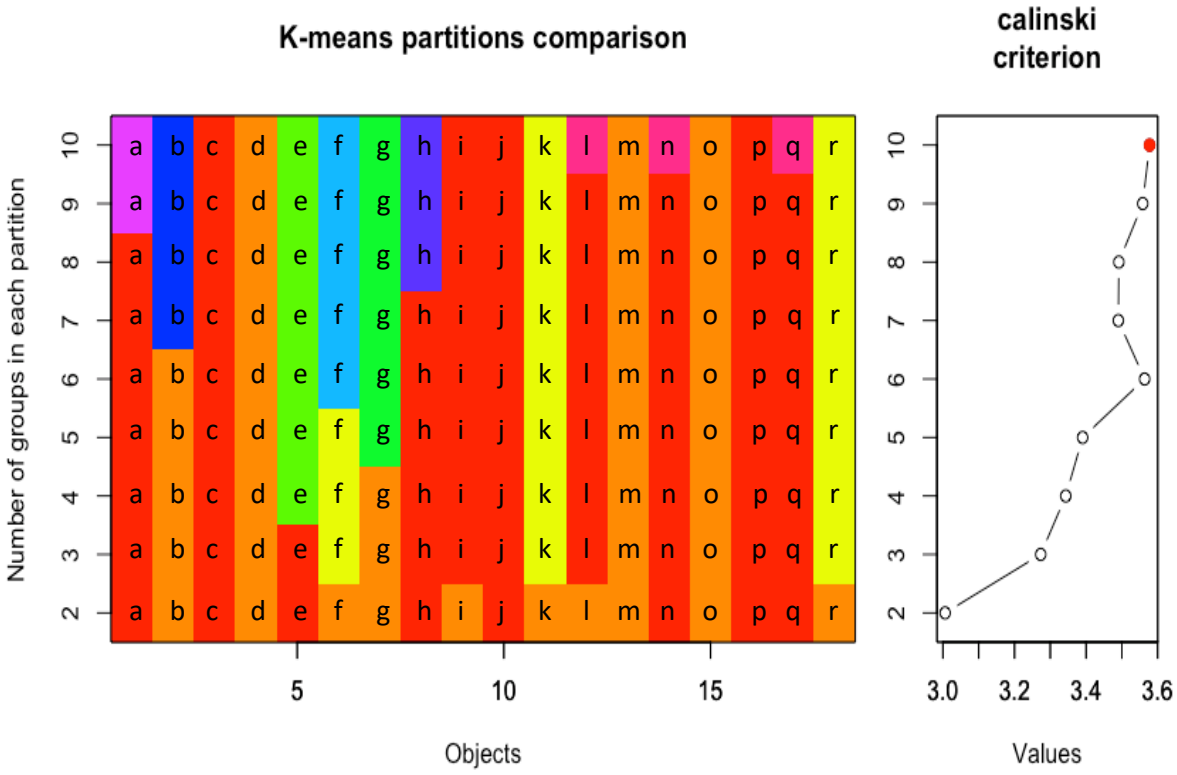


Figure D3.4. K-mean results for all external factors

APPENDICES E

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THE IMPORTANCE OF GROUND LEVEL PERSPECTIVES IN ASSESSING THE EFFICIENCY OF A CONSERVATION TOOL: THE CASE OF THE MEXICAN COMPENSATION SCHEME FOR DEPREDATION

Harry Marshall, Lou Lecuyer and Sophie Calmé

Abstract

The use of compensation schemes as conservation tools that counteract losses of crops or livestock by wildlife of conservation concern has been widely implemented to settle disputes between conservationists and local people. To assess a compensation scheme implemented to support jaguar conservation in Mexico, we focused on ground-level perceptions of local actors as the main determinant of their acceptance and attitudes towards it. We carried out 165 semi-structured interviews to obtain livestock breeders' perceptions of both depredation and the scheme. Criteria were developed to cover every aspect of the scheme (accessibility, relationships, efficiency, transparency), and were measured through 5-point Likert items. Among those individuals who had yet to claim compensation, responses regarding the reputation of the scheme were mixed, where their level of education and number of livestock lost were respectively positively and negatively associated with reputation. More individuals who had used the scheme rated it positively, with trust and the accessibility of information being the criteria most closely associated with positive perceptions. Last, ranchers' satisfaction levels with the scheme were related to the ease of application process, the brevity of time spent waiting, and the transparency of the decision-making process. A deeper understanding of local actors' perceptions allowed us to uncover criteria that were used to shape their evaluations, which were not found in biological or economic assessments. Our assessment, based on social data, was

developed to be easily accessible to managers, practitioners, and scientists, with a capability of delivering answers on how to improve the compensation tool.

Keywords: perception; monitoring and evaluation; participatory management; social approach; large carnivores; jaguars.

Introduction

Financial compensation is a common tool that is used to reduce the impacts of negative interactions between people and wildlife, with numerous schemes being set in place to compensate livestock breeders when their livestock is attacked (Maheshwari et al., 2014; Nyhus et al., 2003). The relative success of compensation schemes varies, with the efficacy of ex-post compensation programs as tools for conservation being called into question across countries and species (Boitani et al., 2011; Nyhus et al., 2003). It has been suggested that the receipt of compensation creates a disincentive regarding the protection of livestock so as to avoid depredation (Hemson et al., 2009; Isaksen, 2014). Further, the offer of compensation can provide incentives that inadvertently lead to further negative interactions through land conversion to agricultural use (Bulte and Rondeau, 2005). The capacity of compensation to increase tolerance towards wildlife has been questioned (Nyhus et al., 2003). Yet, at the same time, there is much support for its continuation in support of conservation efforts (Agarwala et al., 2010; Naughton-Treves et al., 2003).

The evaluation of such programs is vital in ensuring their value to conservation (Nyhus et al., 2003). However, common operational issues are associated with compensation schemes that include 1) low levels of trust between producers and officials (Ogra & Badola, 2008), 2) complicated application processes (Agarwala et al., 2010; Maclennan et al., 2009), 3) long reimbursement waiting times (Karanth et al., 2013), and 4) undervaluing capital (Chen et al., 2013; Pechacek et al., 2013; Wagner et al., 1997). The relative success of a compensation scheme is defined by the perspective from which it is being analyzed; this is an important point

of which researchers should be aware. Within the conservation literature, three main analytical perspectives have been used to evaluate compensation schemes: ecological, economic, and social.

The ecological approach to evaluating compensation schemes focuses mainly upon the effects that compensation imposes on wildlife populations (Hazzah et al., 2014; Maclennan et al., 2009). These studies typically ignore the practical and social realities of applying for and obtaining compensation. Further, this approach overlooks the importance of non-biological factors, such as perceived risk of danger, which may lead to retaliation against "problem" individuals, regardless of the real impact of these animals (Boyd et al., 1999; Treves et al., 2009). Therefore, the recommendations of these studies tend to favor priorities of conservationists, such as the imposition of fines or punishments for retaliation against wildlife that have damaged property or livestock (Maclennan et al., 2009). Indeed, this approach tends to neglect the potentially large differences in the perceptions, opinions, and priorities of academics versus laypeople (Bruyere et al., 2009; Treves et al., 2009), while prioritizing conservation-oriented academic knowledge over the perceptions of those who are directly affected by depredation.

Numerous studies have taken an economic approach to the evaluation of compensation schemes, by focusing on the cost-efficiency of a scheme's operation (Boitani et al., 2011; Fourli, 1999; Mishra, 1997; Okello et al., 2014; Yoder, 2000). Here, the assumption is that the value of conservation tools is intrinsically linked to their economic efficiency and attractiveness to decision-making actors (Wagner et al., 1997). For example, Boitani et al. (2011) concluded that compensation was an unwise strategy for alleviating negative interactions between humans and wolves (*Canis lupus italicus*) in Italy, as it became economically unsustainable when a large wolf population was present. This focus on the economic sustainability of compensation programs ignores the fact that social viability is a key factor in determining a conservation tool's utility (Montag et al., 2003).

Socially based approaches to evaluating conservation processes, outcomes and programs can be based on empirical evidence, while also focusing at the same time on human perceptions

(Bennett, 2016; Ogra and Badola, 2008). People's perceptions are the ways in which they view reality, and are a combination of socio-cultural constructions and prior experience (Conforti & de Azevedo, 2003). Understanding people's perceptions opens the door to understanding the heterogeneity of their realities, which cannot always be seen using other approaches (Hill, 2010). Perceptions of interactions between humans and wildlife are important, as perceived risk to losses can be greater than actual risks (Dar et al., 2009), or they can even be attributed to another species instead of the actual culprit (Lucherini and Merino, 2008; Rasmussen, 1999). Further, perceptions of human-human conflicts that are related to conservation issues can also lead to negative perceptions of wildlife (Dickman, 2010; Naughton-Treves and Treves, 2005). Thus, perceptions influence the outcomes of conservation initiatives and, ultimately, may help to ensure the support of local constituents, thereby facilitating the long-term success of conservation (Bennett, 2016).

The use of perception in the evaluation of compensation schemes can shed light upon underlying issues that other approaches do not or cannot take into account. For instance, previous negative experiences with compensation schemes can reduce tolerance towards wildlife, by passing frustration with the compensation program along to the wildlife in question (e.g., Rodriguez, 2008; Vynne, 2008). Evaluations that pay attention to the perceptions of those involved in human-wildlife interactions can provide insights into how and why compensation schemes may not be achieving their objectives (Milheiras and Hodge, 2011; Mishra et al., 2003). For example, a more socially focused approach has revealed that social status can be a factor that is instrumental in access to compensation (Ogra and Badola, 2008). Because these studies directly involve those who use compensation schemes, they tend to have practical implications, which can be acted upon to ensure the proper use of available schemes (Montag et al., 2003; Vynne, 2008).

The present study follows the socially based approach, using a ground-level perspective to understand ranchers' perceptions in the assessment and evaluation of a compensation scheme. We followed previous research analyzing perceptions using a practical method that was designed to determine upon which criteria ranchers would base their evaluations of the scheme,

so as to make recommendations about how to improve the scheme. We used the specific example of a compensation program that covers livestock ranchers for losses due to depredation in Mexico. The program was created six years ago in an attempt to resolve the increasing problem of livestock depredation across Mexico by charismatic species such as the jaguar (*Panthera onca*). However, the program has never been evaluated or assessed externally since its creation, thereby providing an excellent case study with which to explore the study's premise. Our study area in southern Mexico, Calakmul, has a relatively recent history of livestock production by the rural poor and is famously home to a large jaguar population. The conditions have led to wildlife and humans impinging upon one another over the availability and use of resources.

Material and Methods

Study area

The Calakmul municipality is situated in the Mexican state of Campeche (figure E.1). It is home to the Calakmul Biosphere Reserve, which covers a total area of 723 185 ha. The entire region encompassing the municipality is of significant interest to jaguar conservation, as it has been declared a Jaguar Conservation Unit (Sanderson et al., 2002). This designation is due to the relatively high estimated density of 6.0 individuals/100 km^2 (Carrillo et al., 2011).

Over the last 50 years there has been a steady increase in the human population of Calakmul due to governmental allocation of land through the granting of *ejidos*, i.e., settlements of communal lands with specific property rights for members. Up until the 1990s, the area was considered an agricultural frontier, despite the awarding of these grants, with a recent and large increase in population due to migration from neighboring states (Keys and Chowdhury, 2006). Across the municipality, there are 77 settlements that contain about 27 000 people (INEGI, 2010). The majority of the population practices subsistence *milpa* farming (producing typical foodstuffs such as maize, beans, and squash), livestock husbandry, and forestry for both timber

and non-timber products (Monzón-Alvarado et al., 2014). A total of 11 330 head of cattle was reported in the most recent census made available from the Calakmul municipality (Censo Agropecuario, 2007). Agricultural activities are subsidized by the state, and most of the population now relies on these subsidies for their livelihoods (Ericson, 2006; Haenn et al., 2014).

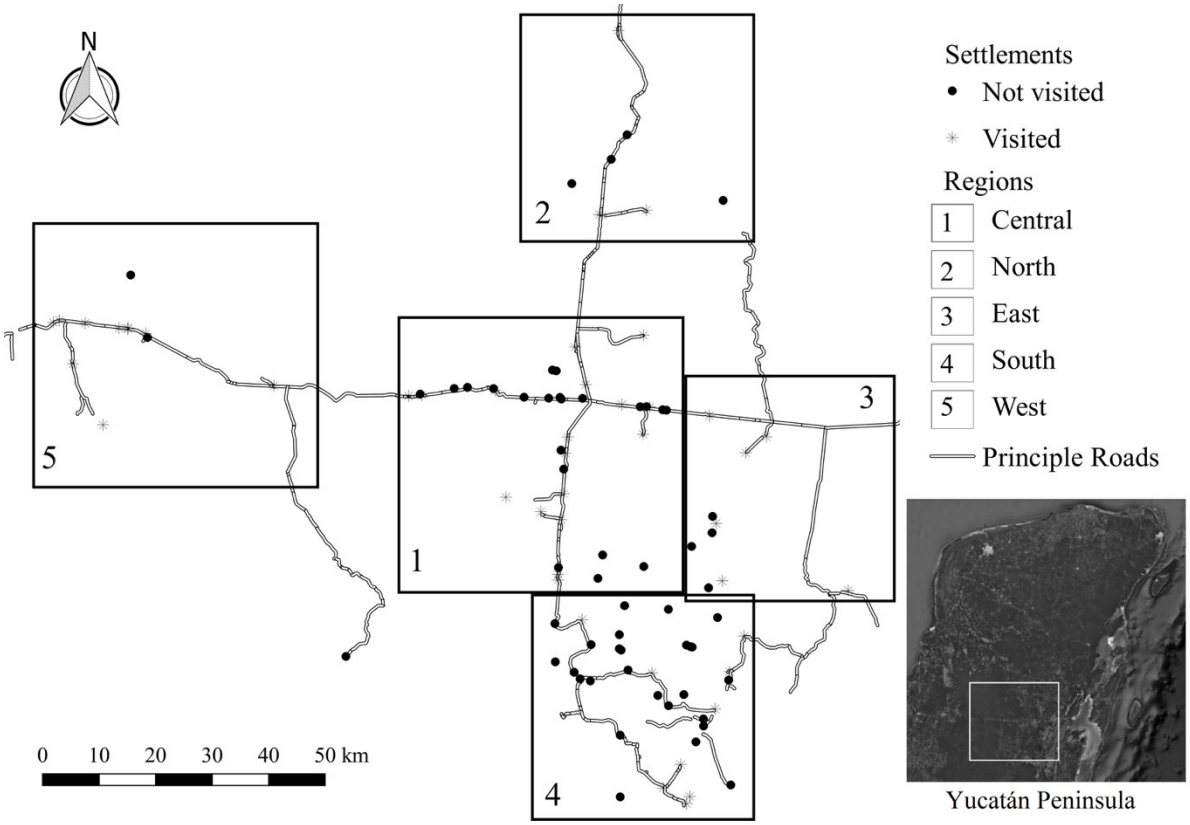

Figure E.1 Settlements within the study area were divided among the regions used for analysis. Black dots represent settlements that were not visited for interviews; white dots represent settlements that were visited. Regions are numbered as follows: 1, Central; 2, East; 3, South; 4, West; and 5, North.

Compensation scheme

The *Fondo de Aseguramiento Ganadero* (FAG) is a national compensation scheme that covers livestock losses to predators such as the jaguar, puma (*Puma concolor*), and feral dogs

(*Canis familiaris*), among others. The FAG is accessible to any livestock breeder who can provide evidence of ownership, without any insurance cost to the claimant. This scheme is funded by the national confederation of livestock producing organizations (*Confederación Nacional de Organizaciones Ganaderas*, CNOG). CNOG represents the interests of livestock breeders in seeking to develop the livestock production industry and maintaining the integrity of its producers, while also improving the quality of life of livestock breeders nationwide. CNOG is funded both by large livestock breeding companies and by smaller scale breeders.

Surveys

A snowballing technique (respondent-driven sampling; see, Faugier and Sargeant, 1997) was used to select participants, using local livestock breeders' associations, known livestock breeders, and a list of ejidos that reportedly suffered high levels of depredation as starting points. We sought out known livestock breeders and attempted to find as many as possible within each settlement that we visited. The study area was divided into regions, based on accessibility to administrative centers and natural vegetation (figure E.1). The central region is based around Xpujil, which is the administrative center for the municipality of Calakmul. The eastern region uses Chetumal as their administrative center, while the western region is closer to the capital of the next municipality, Escarcega. The southern and northern regions are more isolated from any administrative center, with the southern region being covered by evergreen tropical forest, whereas the northern region lies within the dry-tropical forest zone.

Our study used semi-structured interviews, which were divided into five sections. First, profile information was gathered on the interviewee (i.e., age of the rancher, his or her level of education, membership in an association, number of livestock owned). Second, livestock management practices were documented (e.g., frequency of livestock monitoring, fencing). Third, a profile was created regarding livestock losses, the impact of depredation on livelihoods, general experience with depredation, and knowledge of the compensation scheme. Fourth, an evaluation of the scheme was conducted based on the perceptions of the interviewee. Only those who had sufficient experience or knowledge of the scheme answered this section. Last, open-

ended questions were directed to the respondent that centered on his or her perception of wildlife within the Calakmul biosphere reserve, and on their tolerance towards jaguars.

The questions in the fourth section were split into four categories, each referring to a particular aspect of the compensation scheme: Accessibility, Relationships, Efficiency, and Transparency. These categories each contained questions about certain criteria upon which ranchers were expected to base their perception of the scheme. These criteria questions were 5-point Likert-scale items rating a criterion from highly negative through to highly positive. To check the appropriateness of our definitions, we included 2-4 sub-criteria (Likert items) for each criterion that reflected several aspects of our definition of the criterion (see supp. mat. E1). For example, the definition of trust that we used was based on correlations between respondents' agreement to the following set of statements (referring to the FAG staff): I feel they tell me the truth; I feel they believe what I said; and I feel they use the information that I give. To test the suitability of these definitions, we looked at Spearman's rank correlations (r_s) of responses to the 2-3 sub-criteria with the main question relating to the criterion. If a sub-criterion was not significantly correlated with its main criterion, we did not use that sub-criterion to interpret the responses. We asked the participants to rate the scheme's overall quality (hereafter, referred to as "evaluation"), their satisfaction with experiences associated with the scheme (hereafter, referred to as "satisfaction"), and experiences with external sources of help (e.g., the Biosphere Reserve staff) in the application process (see supp. mat. E1). These questions were all single 5-point Likert items following the same method used for rating the criteria.

Data analysis

We summarized the variables relating to socio-economic profile, livestock losses (in the last two years), and obstacles to livestock production using standard descriptive techniques. We fitted ordinal logistic regression models to the data to investigate 1) the influence of potential determinants on the level of knowledge of the scheme, 2) reputation of the scheme, 3) evaluation of the scheme's overall quality, and 4) satisfaction with the scheme. For each response variable,

we included all potentially important predictor variables in the original model (saturated model) and used a backward, stepwise elimination to produce a final model (Harrell, 2015). The predictor variables included in modeling the first two response variables (knowledge and reputation of the scheme) consisted of age, number of other sources of income, total livestock, losses to depredation, losses to illness, total losses, total area of pastures (ha), membership to an association, region, and level of education. The last variable was excluded from the model for knowledge as its inclusion violated the assumptions of the tests; this was similarly the case for region with respect to modeling reputation.

In the analysis of which factors were associated with participants' evaluation of the scheme's overall quality, together with satisfaction with their experiences with the scheme, eight predictor variables were included using criteria addressing different aspects of the scheme. The eight criteria included 1) access to information about the scheme, 2) accessibility of the application process, 3) facility of contacting the scheme's staff, 4) trust in the scheme's staff, 5) the cost of the application process, 6) compensation received, 7) amount of time waiting for the scheme's staff, and 8) transparency of the scheme. Additional criteria, i.e., use of external help from the Reserve and from a local conservation NGO, could not be used due to low response rates. Two further criteria were excluded from the analysis due to high collinearity when considering variance inflation factors, quality of the communication with the scheme's staff, and time invested in the application process. A predictor variable was determined to have a significant effect at the 5 % level. All analyses were run using SPSS v. 20 (Field, 2013).

Results

Profile of ranchers and losses

In total, we interviewed 165 ranchers from 46 settlements in the Calakmul area (Figure E.1). Of these respondents, 13 were female and the rest (n = 152) were male, with an average age of 52 years (SD = 14.5; range 19-87 years). Most respondents had completed a minimum of primary education. One hundred fifty-eight respondents were currently still farming livestock, with a high degree of variation in the number of head that were owned (range 1-318

animals), with a mean and standard deviation of 58.9 ± 59.1 head. Most participants (n = 145; 88 %) participated in at least two forms of subsistence farming, usually livestock herding and *milpa* cultivation, and to a lesser extent, beekeeping. Our sample accounted for a total of 9060 animals across Calakmul, with cattle (n = 5276) and sheep (n = 2960) representing the majority.

A total of 2266 livestock losses were reported over the past two years. One-third (n = 725; 32 %) could be attributed to disease, which affected 69 ranchers, while depredation accounted for 588 losses (26 %), affecting 51 ranchers. More ranchers had suffered depredation (n = 101) than not (n = 62), with the number of depredation events that were attributed to jaguar (n = 69) totaling more than all remaining predator species in the region combined (n = 30). A variety of responses were given to the question: "What are the greatest obstacles to your livestock production?" The most frequently reported obstacles were lack of money (24 %), lack of water (18 %), lack of resources (18 %), and depredation (12 %). Most participants (76 %) believed compensation to be a good measure in helping to reduce the effects of livestock depredation on livelihoods.

Correlates of knowledge, reputation, perception of, and satisfaction with the scheme

Many more people had at least heard of the scheme (75 %; n = 124) than those who had not (25 %; n = 41). Of those who knew of the scheme, only 53 % (n = 66) had sufficient understanding, whereas 47 % (n = 58) had only heard of it. The final model explaining the differences in the level of knowledge included three variables: region; total number of livestock lost to depredation; and total number of livestock that were owned (Table E.1). Two regions appeared to show large differences in terms of respondents who had sufficient knowledge of the scheme (i.e., North) and those who did not (West). Individuals with larger herds were more likely to know more about the scheme, but were also more likely to have lost more livestock.

Table E.1 Predictor variables that were significantly associated with the dependent variables in ordinal logistic regression of a) people's knowledge of the scheme, b) scheme's reputation according to those who had not used it. *P*-values are for the associated Wald-χ^2 statistics.

Response variable	Explanatory variable	Odds ratio (Lower – Upper)	*P*-Value
Knowledge	Depredation losses	1.007 (1.000 – 1.014)	**0.030**
	Total livestock	1.058 (1.016 – 1.119)	**0.021**
	Region		
	Central	2.511 (0.988 – 6.495)	0.051
	North	0.699 (0.207 – 2.316)	0.555
	East	2.530 (0.849 – 7.727)	0.105
	South	2.381 (0.884 – 6.537)	0.088
Reputation	Depredation losses	1.007 (1 -1.014)	**0.001**
	Level of education		
	Preparatory school	25.633 (1.245 – 1050.76)	**0.049**
	Secondary	5.972 (0.609 – 80.438)	0.141
	Primary	0.486 (0.059 – 3.854)	0.489

The scheme's reputation among those who had not used it received mixed ratings at similar levels (positive, n = 13; negative, n = 11), while 5 individuals rating the scheme neutrally. The final model that explained differences in the reputation of the scheme included two variables: level of education; and number of losses due to depredation (Table E.1). Higher ratings of the scheme were associated with individuals who were educated beyond primary school. Lower ratings were assigned to the scheme as livestock losses to depredation increased.

Among those individuals who had used the scheme, more rated its overall quality positively (n = 13) than negatively (n = 1), with 10 respondents rating the scheme neutrally. The final model explaining differences in the general perception of the scheme included two variables: trust, and the accessibility to information about the scheme (Table E.2; see sup. mat.E1 for full definitions). If participants had positive experiences with access to information and felt that they could trust the scheme's staff, they were more likely to rate the scheme's overall quality positively.

Table E.2 Predictor variables that were significantly associated with the dependent variables in ordinal logistic regression of a) the evaluation of the scheme by those who had used it, and b) people's satisfaction with their experiences with the scheme. *P*-values are for the associated Wald-χ^2 statistics.

Response variable	Explanatory variable	Odds ratio (Lower – Upper)	*P*-Value
Evaluation	Accessibility of information	3.507 (1.469 – 10.776)	**0.009**
	Trust	4.686 (1.802 – 15.963)	**0.006**
Satisfaction	Ease of application	3.338 (1.398 – 9.323)	**0.011**
	Time Waiting	2.828 (1.017 – 9.007)	0.065
	Transparency	2.139 (1.016 – 5.198)	0.063

Accordingly, a greater number of interviewees responded that they were satisfied (62 %; $n = 18$) rather than dissatisfied (38 %; n = 11) with their experiences with the scheme. The final model explaining differences in satisfaction with the program's operation included three variables: ease of the application process; time spent waiting; and transparency of the decision-making process (Table E.2; sup. mat.E1 for full definitions). The relationship between people's experiences and each aspect of the scheme correlated positively with their satisfaction. The easier the application, the shorter the waiting time, and the more transparent the decision-making process determined the degree to which respondents felt more satisfied with the process.

Contingency tables comparing knowledge (see supp. mat. E2, Table a), reputation (see supp. mat. E2, Table b), evaluation of the scheme (see supp. mat. E2, Table c) and satisfaction with the application process (see supp. mat. E2, Table d) with key predictors can be found in the supplementary materials.

Discussion

The motivation for conducting this study was based on personal observations, which in turn led to the concern that the compensation scheme in its current form might be worsening,

rather than ameliorating the conflict between actors. Individuals had heard about the potential for compensation, but were not able to access it. Using a ground-level perspective of the situation and the scheme allowed for a deeper understanding of people's perceptions of it. This led to proposals for solutions that would improve the scheme by broadening its appeal and potentially ensure more effective conservation of the jaguar over the long-term.

Our study first assessed depredation in the region, and how local actors perceived losses in relation to other obstacles barring livestock production. While livestock breeding did not always represent the principal activity of our participants, it remained an important economic asset for many households. Local actors purchase livestock opportunistically as part of an asset strategy for improving their livelihoods (Ellis, 2010), for example, by investing in education or covering unexpected expenses (e.g., funerals). Thus, livestock losses that are incurred by predators are viewed from a more emotional perspective, given that they reduce people's ability to deal with stochastic life events (Dickman, 2010). Further, the lack of money and resources was reported as the biggest obstacle to production. Breeders believed that with additional materials, such as medicines and fences, they could limit the damage caused by the most common kinds of losses, i.e., disease and depredation. Accordingly, the majority considered compensation to be an adequate and appropriate remedy against depredation. This view, which was shared by both our participants and stakeholders, globally implies that financial compensation for losses should mitigate to some extent the damage and could be perceived as an appropriate and necessary response to depredation (Fourli, 1999; Isaksen, 2014).

The scheme is an initiative that was instituted by the livestock industry to support human-jaguar co-existence and is a progressive move from a traditionally conservative industry. However, the success of efforts to reduce the negative effects of crop and livestock losses through compensation fundamentally depends upon whether the intended beneficiaries are actually aware of its existence (Ogra and Badola, 2008). While most people in our study area had heard of the scheme, differences in response among breeders still suggest that the dissemination of information could be improved. Having prior experience with depredation was associated with a higher level of knowledge regarding the scheme, indicating that breeders

learned on a need-to-know basis. In known hotspots of depredation, such as the southern region of Calakmul, people are more aware of the scheme, because of reactive interventions that have been made by conservation actors (the Calakmul Biosphere Reserve and a local conservation NGO) to aid breeders in gaining access to compensation. Information about the scheme should be made available before the onset of depredation, given that the lack of adequate prior knowledge could prove costly. For example, claimants must adhere to specific requirements to actually obtain compensation, such as guidelines for the protection of depredated livestock. Breeders with more livestock appeared to be more aware of the compensation scheme, given that they tended to be members of breeder associations that share information and resources on a regular basis. Efforts should then focus on information reaching those in areas where breeders are less aware of the scheme, and to develop efficient communication channels to include those with smaller herds.

People's experience is important to consider when deconstructing how perceptions are formed and is relevant to exploring the effect of reputation (Conforti and de Azevedo, 2003). This is why our study examined both the perception of the scheme by those who had used it and its reputation by those who had not. Individuals who had never used it had a slightly lower appreciation of the scheme, with participants' level of education being an associated factor. People with higher levels of education are often more capable of seeking information, and involve themselves to a greater degree in organizational/political processes (Mirowsky and Ross, 2003), thereby making them more aware and able to understand the functioning of the scheme. Negative perceptions were also associated with a higher number of attacks; the more animals that farmers lose without asking for compensation, the more negative a perception they are likely to have. The potential for misinformation regarding the scheme and for negative perceptions to spread could actually reduce the willingness of potential participants to use the scheme, and drive ranchers to use other means to tackle depredation (Dickman, 2010; Naughton-Treves and Treves, 2005).

Positive local perceptions of conservation initiatives are fundamental to the success of conservation (Bennett, 2016). Our study uncovered the underlying criteria that influence the

perception of the compensation scheme by those who used it. Far from what economic and biological evidence-based evaluations can show (e.g., Ferraro and Pattanayak, 2006; Maclennan et al., 2009), our results highlighted the importance of trust in the staff and the accessibility of information. Trust has been shown to be a vital aspect of successful environmental management (Beierle and Konisky, 2000; Davenport et al., 2007; Gray et al., 2012). The importance of trust in our study was key to how participants believed information transferred by other actors. An example of great concern that we observed on numerous occasions involved people believing stories of how the scheme did not operate fairly, and that applying for compensation would not lead to reimbursement, particularly in areas where the reputation of the scheme was poor. Perception of the overall quality of the scheme was thus related mainly to social factors and allowed our evaluation to obtain a more complete picture upon which conservation management decisions could be based.

Livestock breeder satisfaction with the process and outcomes of their compensation claims highlighted different criteria that influenced local actors' perceptions. The associated criteria convey crucial details about the social acceptability and appropriateness of the compensation scheme. Our analysis emphasized how simplifying the application process to suit a livestock breeder's level of education is paramount, as this could restrict the claimant's ability to understand and comply with requirements. Time spent waiting was also a key factor in determining people's satisfaction, which seems obvious considering that there were examples of people who waited more than six months for a decision and even longer for the money, all the while fearing refusal. There were cases when people did not know how the scheme came to a decision or how many animals were going to be compensated. This was evidenced by the strong association between satisfaction and the transparency of the decision-making process. All three criteria that were associated with people's satisfaction were aspects of the scheme that were only observable when using a social-based approach, again highlighting the relevance of using perception to evaluate conservation tools. Knowing the specific criteria upon which people base their perceptions and satisfaction can thus lead to management that focuses efforts on improving particular aspects of a program's functioning (Milheiras and Hodge, 2011).

Our study was designed to answer a call in conservation for more rigorous, robust and easy- to-use evaluations such that practitioners and managers can improve conservation activities in an ever changing world (Mascia et al., 2014; Sainsbury et al., 2015). We incorporated a recent move in conservation science towards realizing the importance of perception-based research to practice more dynamic conservation and environmental management (Bennett, 2016). The strength of this study lies in the design of a methodology that produces results, which are easily obtainable, respectful of local understanding of criteria, and more easily interpreted by a wider audience (Sainsbury et al., 2015). The speed with which recommendations from evaluations can be generated is also a key aspect in determining the willingness of managers and practitioners to use them (Mascia et al., 2014). Our study was completed over a short period (three months) and employed a combination of qualitative and quantitative methods, which allowed quick analysis and generation of targeted recommendations. Perceptions were presented here as an essential part of the information necessary to carry out effective monitoring and evaluation to drive the development of conservation tools (Bennett, 2016; Jenks et al., 2010). This case study, therefore, demonstrates how using a ground-level perspective can lead to evaluations that are relevant to those affected by interactions with carnivores, while generating practical recommendations that are both internally and externally valid to the situation.

Conservation implications

To have an impact on conservation practice it is essential to go beyond simply understanding perceptions and apply results of research to the real world (Bennett, 2016). In aiming for positive development of the scheme and solutions at a larger scale that would support jaguar-livestock breeder coexistence, we moved from research to action. We organized a three-day workshop in collaboration with the Calakmul Biosphere Reserve and a local conservation NGO (PRONATURA). We invited actors from the compensation scheme, local government, and the NGO sector. Various studies have shown that public participation can be used to build trust between managers and laypeople, by targeting those who have previously had negative

experiences (Beierle and Konisky, 2000; Davenport et al., 2007; Gray et al., 2012). During the workshop, we presented the results of this study and used them as the basis for building our discussion toward possible solutions. The main foci of the workshop were to improve the spread of information about the scheme and the application process, and to discuss a broader incentive program. We had thought about which form of information would be useful, to whom it should be directed, and through which channel. We also discussed the creation of a network of locals who could help and support potential compensation claimants. Last, a group was created that would include breeders in the decision-making process at the regional level, and who would be included in future work with the reserve in a potential incentive program. Our study and subsequent workshop align with a social approach that leads to a more humane management style, which engages those who are affected and involved in conservation initiatives more effectively (Milheiras and Hodge, 2011).

There is still much debate about how to carry out effective evaluation and monitoring of conservation processes, goals and outcomes with a wide array of perspectives and their respective supporters (Bottrill et al., 2011; Ferraro and Pattanayak, 2006; Kleiman et al., 2000; Mascia et al., 2014; Stem et al., 2005). We believe that our work contributes to the debate surrounding compensation schemes. While financial compensation could address the economic losses that are experienced by most of the breeders following instances of predation, we suggest that incentive programs should incorporate other concerns to promote protective livestock management. Our results highlight that disease was the main cause of losses in the region and that breeders perceived the lack of water and resources as the main obstacles to the success of their activities. Further, few breeders currently use husbandry techniques that are known to effectively aid in protecting livestock against predators (Mishra et al., 2003). Veterinary care, technical tools, and training could be provided under a larger incentive program that is aimed at jaguar protection, including a more context-adapted conservation contract, similar to one that was developed in Mongolia for conserving the snow leopard (*Panthera uncia*) (Mishra et al., 2003). In the case of multiple attacks, restrictions or reductions to the amount of compensation available should be enforced on the condition that breeders adopt better husbandry practices. Such incentive programs should be rigorously monitored and evaluated to confirm their

efficacy, while avoiding detrimental impacts that are associated with their misuse (Bulte and Rondeau, 2005).

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Supplementary material E1. Criteria and sub-criteria (statements) used to evaluate the scheme. Sub-criteria significantly correlated with their corresponding criterion are indicated with an asterisk.

The scheme's quality	
1. How would you rate the fund?	X[1]
Accessibility of information	
2. How would you rate the fund's diffusion campaign?	X
2a. I believe it is easy to find information about the fund*	O[2]
2b. I believe it is easy to understand information about the fund	O
Accessibility of application process	
3. How would you rate the application form?	X
3a. I think it is easy to report an attack to the fund*	O
3b. I think it is easy to fill out the form*	O
3c. I think it is easy to obtain the required documents	O
4. How would you rate the facility to contact staff from the fund?	X
4a. I believe they are available when I need*	O
4b. I think they take the necessary time to attend me*	O
Relationships	
5. How would you rate your communication with the fund's staff?	X
5a. I feel they treat me with respect*	O
5b. I feel they listen to my problems*	O
5c. I feel that it is easy to speak with the fund's staff*	O
6. How would you rate the trust you have in the fund?	X
6a. I feel they tell me the truth*	O
6b. I feel they believe what I say*	O
6c. I believe the information I give comes to something*	O
Role of external help (Reserve staff)	

7. How would you rate the Reserve's help?	X
7a. Without the Reserve, I would not know of the fund	O
7b. The Reserve helps me contact the fund*	O
7c. The Reserve helps me to fill out the forms*	O
7d. The Reserve helps me obtain evidence*	O
Role of external help (PRONATURA)	
8. How would you rate PRONATURA's help?	X
8a. Without PRONATURA, I would not know of the fund	O
8b. PRONATURA helps me contact the fund*	O
8c. PRONATURA helps me to fill out the forms*	O
8d. PRONATURA helps me obtain evidence*	O
Efficiency	
9. How would you rate the money you invested in the application process?	X
9a. The cost to go and make the call to report an attack is acceptable*	O
9b. The cost of the telephone call to make a report is acceptable*	O
9c. The cost to go and get my money is acceptable*	O
10. How would you rate the compensation received?	X
10a. The compensation covers all the animals lost in the attack*	O
10b. The compensation covers the expenses made in reporting the attack*	O
10c. The compensation covers damages caused during the attack	O
10d. The compensation is sufficient to let me continue my business*	O
11. How would you rate the time invested in the application process?	X
11a. Going to make the report didn't take much time*	O
11b. The call didn't take much time*	O
11c. Filling the report didn't take much time*	O
11d. The time spent preserving the carcass is acceptable*	O
12. How would you rate the waiting time?	X
12a. The fund's staff came quickly*	O
12b. The time spent making a decision was reasonable*	O
12c. The time taken to receive my money was reasonable*	O
Transparency	
13. How would you rate the justification of the fund's decision?	X
13a. They gave me an explanation*	O
13b. It is easy to obtain an explanation*	O
13c. I understood the explanation*	O
Satisfaction	
14. I am satisfied with the application process	O
15. I am satisfied with the result	O

[1] X indicates a statement with the possible responses being: Very good, Good, Okay, Bad, Very bad.
[2] O indicates a statement with the possible responses being: Totally agree, Somewhat agree, Neither agree nor disagree, Disagree, Totally disagree.

Supplementary material E2. Contingency tables

Table a. Contingency tables of predictor variables in final model for knowledge of the scheme.

Livestock owned	Knew nothing	Heard about it	Knew it well	Total interviewees
1 – 15	9	7	11	27
16 – 29	12	15	12	39
30 – 49	7	12	7	26
50 – 70	3	11	9	23
70 +	8	10	23	41

Livestock lost to depredation	Knew nothing	Heard about it	Knew it well	Total interviewees
No losses	30	46	36	112
0 - 10	8	10	15	33
11 +	3	2	13	18

Table b. Contingency tables of predictor variables in final model for reputation of the scheme.

Reputation	Preparatory	No education	Primary	Secondary	Total interviewees
Very bad	0	0	0	2	2
Bad	0	1	6	2	9
Okay	0	2	2	1	5
Good	1	1	3	3	8
Very good	2	0	0	3	5

Reputation	No losses	1 – 10 losses	11 + losses	Total interviewees
Very bad	1	2	0	3
Bad	4	8	3	15
Okay	2	4	3	9
Good	7	2	0	9
Very good	2	6	0	8

Table c. Contingency tables of predictor variables in final model for the evaluation of the scheme.

Evaluation	Accessibility of information Very bad	Bad	Okay	Good	Very good
Very bad	0	0	0	0	1
Bad	0	4	1	0	0
Okay	1	1	4	4	0
Good	0	1	3	6	4
Very good	1	0	0	2	3

Evaluation	Trust Very bad	Bad	Okay	Good	Very good
Very bad	0	1	0	0	0
Bad	4	1	0	0	0
Okay	0	2	5	2	1
Good	0	0	7	3	4
Very good	0	0	1	3	2

Table d. Contingency tables of predictor variables in final model for breeder's satisfaction with the application process.

Satisfaction	Ease of application Very bad	Bad	Okay	Good	Very good
Very dissatisfied	0	0	0	1	0
Dissatisfied	0	3	0	1	0
Neither satisfied or dissatisfied	0	1	3	3	1
Satisfied	0	1	4	2	1
Very Satisfied	0	0	0	1	2

Satisfaction	Time spent waiting Very bad	Bad	Okay	Good	Very good
Very dissatisfied	0	1	0	0	0
Dissatisfied	2	2	0	0	0

Neither satisfied or dissatisfied	3	1	3	1	0
Satisfied	0	3	4	1	0
Very Satisfied	0	0	1	2	0

	Transparency				
Satisfaction	**Very bad**	**Bad**	**Okay**	**Good**	**Very good**
Very dissatisfied	1	0	0	0	0
Dissatisfied	0	3	1	0	0
Neither satisfied or dissatisfied	3	2	1	2	0
Satisfied	1	1	1	3	2
Very Satisfied	0	0	0	1	2

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