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"Conflicto carnívoro-ganadería: una revisión global bajo una perspectiva ecológica"

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"Conflicto carnívoro-ganadería: una revisión global bajo una perspectiva ecológica"

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Dedicado al fascinante mundo de los carnívoros

Por un planeta de coexistencia entre la naturaleza y sus agregados seres humanos.

BIOGRAFÍA

Carolina Susana Ugarte Caraball

Desde siempre he sentido curiosidad y fascinación por la naturaleza, mis padres siempre incentivaron el gusto por adquirir conocimiento y entender el mundo. Así desde niña me interesé por las ciencias y por saber cómo funcionaba este planeta, lo que junto con mi pasión por el mundo silvestre, me llevó por un largo camino de descubrimiento y análisis que me guió a estudiar Biología Ambiental. Durante mis estudios me incorporé al Laboratorio de Conservación Biológica, donde realicé esta tesis y realizaré la maestría, con la cual espero continuar aprendiendo y aportar a la conservación de carnívoros silvestres.

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RESUMEN
Un tercio de las especies de carnívoros a nivel mundial se encuentra amenazadas debido a conflictos con humanos. Las áreas protegidas no han sido suficientes para conserver a este grupo, debido a su amplio rango de hogar. Paradójicamente, su conservación se debe llevar a cabo en áreas que también se destinan a agricultura. Sin embargo, emerge un desafío debido a los conflictos entre carnívoros y la ganadería, ya que la depredación sobre el ganado implica pérdidas socioeconómicas y la eliminación de los carnívoros por retaliación. Para reducir estas pérdidas se usan múltiples técnicas de manejo y se incluyen atributos del paisaje y de los depredadores, aún así el conflicto no ha disminuido. En este marco conceptual, se llevó a cabo un revisión bibliográfica sobre el conflicto entre ganadería y carnívoros con el fin de analizar la incidencia de atributos biológicos y ecológicos de los depredadores y la efectividad de distintas técnicas de manejo del ganado para reducir su depredación. A lo largo del tiempo el número de especies involucradas en el conflicto han ido en aumento. Las especies que se involucran con mayor frecuencia presentan mayores rangos de hogar y mayor pérdida de sus rangos de distribución, en comparación con las especies que se involucran con menor frecuencia. La depredación aumenta en lugares con vegetación más densa, más cercanos a bosques y en épocas secas. El control letal es ampliamente usado, pero no reduce la depredación del ganado. En cambio, técnicas no letales como el uso de perros de guardia, cercados y la presencia de pastores disminuyen las pérdidas. Existe una exitosa reducción de la percepción de depredación al usar múltiples técnicas no letales simultáneamente. Para lograr la conservación de carnívoros es necesaria una estrategia *land-shearing*, lo que implica una necesidad de constante manejo orientado a la coexistencia de los carnívoros y la industria

ganadera. Nuestra investigación destaca opciones requeridas para evitar o reducir conflictos, y así contribuir a la conservación de los carnívoros y cumplir las metas Aichi.

ABSTRACT
A third of carnivores' species worldwide is threatened as a consequence of conflicts with humans. Protected areas are not enough to conserve them because of their wide home range. Paradoxically, their conservation must rely on areas devoted to agricultural uses as well. However, a challenge emerges due to conflicts between carnivores and domestic animals, as predation upon livestock implies socioeconomics losses and retaliatory killings. To reduce losses many management techniques are used, including landscape and predators' features, but conflicts remain unabated. Within this framework, we carried out a literature review about carnivore-domestic animal conflict to analyse the incidence of biological and ecological attributes of carnivores, and the effectiveness of different management techniques to reduce domestic animals' predation. Through time, the number of species engaging in conflict is increasing. Species frequently involved in conflicts show larger home ranges and greater loss of range' distribution that species less frequently involved in conflicts. Predation increases in locations with dense vegetation cover, close to forest and during dry seasons. Lethal control is widely used but does not reduce predation. Instead, non-lethal methods like guarding dogs, fencing and the presence of herdsman diminish losses. Successful reduction of predation is achieved when multiple non-lethal tools are implemented simultaneously. To successfully reach carnivores' conservation, a land-sharing strategy is needed, this implies constant manage oriented to achieve coexistence by carnivores and ranchers. Our research highlights options required to avoid or reduce conflicts, contributing to conservation of wild carnivores and attain Aichi targets.

GENERAL INTRODUCTION

Land use changes has caused significant impact on biodiversity and is one of the main causes of species loss, either reducing habitat availability or triggering contacts, therefore conflicts, between wildlife and domestic species (Ellis and Ramankutty 2008; Krauss et al. 2010). A leading strategy used to remedy these losses have been to rely on protected areas. Despite its widespread use and coverage, protected areas are not enough to reduce biodiversity decline worldwide. Several species, particularly carnivores, requires large areas to keep viable populations than the ones provided by protected areas (Simonetti and Mella 1997; Mora and Sale 2011). In this scenario, to improve the efforts to conserve biological diversity outside protected areas is imperative. In fact, the Convention of Biological Diversity proposed in the seventh goal on its Strategic Plan for Biodiversity 2010-2020 that by 2020, areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity (CBD 2010).

Conflicts among humans and wildlife is one of the most pressing problems to biodiversity conservation and there is an expanding research on human-wildlife conflict, with a significant rise since 1998 (Dickman 2010). These conflicts emerge when an action by either humans or wildlife has an adverse effect on the other (Redpath et al. 2013). Among these, conflicts between carnivores and humans emerge from predation of poultry and livestock (hereafter domestic animals) by wild carnivores and their elimination as a retaliatory action (Treves and Karanth 2003; Woodroffe and Frank 2005).

Almost two thirds of large carnivores are threatened with local or total extinction, 77% of carnivores' populations are in continuous declining and, in average, these species are occupying just 47% of their historic range (Ripple et al. 2014). This group has a large home range, that is why they require more space than offered by protected areas to maintain viable populations over time (Noss et al. 1996). Therefore, their conservation will depend on agriculture and forestry areas.

The conservation of carnivores in human-dominated landscape depends on ecological, environmental and social factors. To avoid predation, farmers usually applied lethal and non-lethal methods without enough evidence of their effectiveness (Treves et al. 2016). Further, predation might depends on biological attributes like body size and ranging-behaviour and landscape features such as vegetation cover that can conceal ambushing predators (Winterbach et al. 2013; Kuijper et al. 2015). However, a systematic review of the available evidence regarding the role of these factors is spending.

Our general aim was to critically analyse the current state of carnivore-human conflict derived from domestic animal predation. To achieve this, we set two specific objectives; (1) critically characterize the extent of the conflict across carnivores' taxa, biome, continent and prey, as well as the biological and ecological attributes of the species involved in conflicts; (2) review the reliance on different management techniques and its effectiveness in reducing predation upon domestic animals, particularly non-lethal techniques; and assess the usefulness of management techniques.

CHAPTER 1

Abstract

Conflicts between humans and carnivores due to domestic animals' predation and retaliatory killing has become a serious threat to carnivores. To reduce or prevent predation upon domestic animals, multiple action has been taken, lethal and non-lethal techniques has been carried out and landscape and predators' variables has been studied, despite this, human-carnivore conflict is non-resolve and it is increasing. To analyse the extent of the conflict through predators' biological and environmental variables we carried out a review about human-carnivore conflict. We found that "conflict-prone" carnivores' species are increasing worldwide, preying mostly upon cattle, sheep and goats. Carnivores' home range and declines of their distribution are associated to the grade of conflict, vegetation cover, seasonality and domestic prey' age also influence in domestic animal predation. Other biological attributes did not show effect. Predation depends on lands use changes and the increase of encounter probability with carnivores. Further, as more wildlands are infringed, more likely new species with smaller home ranges or restricted distributions will engage in conflict. To prevent or reduce conflict, temporal and spatial scale must be considered, and trough land-shearing strategies achieve coexistence of humans and carnivores on productive-lands.

Introduction

Human-carnivore conflict arise due to livestock predation by wild carnivores and their elimination as a retaliatory action because of their negative effect on local and regional economy (Treves and Karanth 2003; Woodroffe and Frank 2005). These clashes are one of the most expanded and difficult problems facing carnivores conservation today (Dickman 2010). Examples of conflicts include a wide range of carnivores such as wolfs (*Canis lupus*), bears (*Ursus spp.*) and lynx (*Lynx spp.*) in North America, Europe and Asia (Thorn et al. 2013; Smith et al. 2014; Miller 2015), tigers (*Panthra tigris*), snow leopards (*Panthera uncia*) and leopards (*Panthera pardus*) in Asia (Miller 2015), hyenas (*Hyaena spp.*), wild dogs (*Lycaon pictus*), jackals (*Canis mesomelas* and *Canis auereus*), lions (*Panthera leo*) and cheetahs (*Acinonyx jubatus*) in Africa (Thorn et al. 2013) and jaguars (*Panthera onca*) and pumas (*Puma concolor*) in Central and South America (Palmeira et al. 2008; Soto-Shoender and Main 2013). These carnivores prey on a diverse array of domestic animals, including poultry, sheep, goats and cattle. The frequency of attacks and the monetary losses due to predation is increasing (Treves and Karanth 2003).

In order to prevent or reduce domestic animal predation, producers apply lethal and non-lethal techniques including aversive devices, fences to enclose herds, guarding dogs, night confinement, vigilance by herdsmen, among others (Dickman 2010). These actions are expected to benefit both the conservation of carnivores and the domestic animal's industry, but despite the implementation of these measures, human-carnivore conflict is a pending conservation problem (McManus et al. 2014).

To avoid or resolve this conflict requires understanding the importance of ecological and management variables in domestic animals predation, as well as the efficacy of control measurements used to reduce the losses (Treves et al. 2016). The engagement in preying upon domestic animals may relate to biological attributes of carnivores such as body size, social structure, home range, fecundity and behaviour flexibility, which in term is influenced by brain mass (Sol et al. 2008; Winterbach et al. 2013). Conflict may also emerge from changes in the abundance of native compare to domestic prey and habitat loss, which facilitate the encounters between carnivores and domestic animals (Baker et al. 2008). To unravel biological and ecological variables that impinge on whether a carnivore specie is "conflict-prone" might contribute to set evidence-based management approaches to avoid or reduce conflict. These approaches are required to achieve sustainable livestock rearing as expected by the Aichi target 7 from the Strategic Plan 2010-2020 from the Convention of Biological Diversity (CBD 2010). Within this context, our aim was to critically characterize the extent of the conflict across carnivore' taxa, biome, continent and prey as well as the biological and ecological variables of the species involved in conflicts.

Methods

We surveyed ISI Web of Knowledge database using the keywords "carnivore-livestock conflict", "human carnivore interaction" and "predation risk". We included every publication dealing with predation of a wide range of domestic animals (from cattle to poultry) by native carnivores and excluded reviews and commentaries. We consider factors that could affect domestic animal predation, including site's characteristics and ecological factors considered in every case study. We tallied: country, continent, Holdridge's life zone, habitat type, predators, domestic prey, percentage of predation for every prey and from each carnivore, time of the day and season when predation occurs (Inskip and Zimmermann 2009). We also collected data on the age of livestock preyed, livestock abundance and landscape variables as natural prey abundance, distance to protected area, nearest forest and human settlement. In order to test if the number of species per family engaging in conflicts differs from the expected from species' richness pf each family we used a G-test. Similarly, to test if the frequency of predation upon each species of domestic animal differs from what to be expected from its abundance we used a χ^2-test.

Regarding carnivores, we analyzed: (1) home range because species with largest home ranges may have higher probabilities of encounter with humans (Winterbach et al. 2013); (2) Body mass that could impact on the severity of losses (Baker et al. 2008); (3) litter size was included in the analysis because larger litter sizes demands more energy hence more food (Gittleman 1989); (4) Social behavior as social carnivores might hunt larger prey than solitary (Gittleman 1989); (5) Activity period was included as nocturnal predators could ravage more secretively on pasture lands (Cozzi et al. 2012); (6) Species with flexible behavior can the ability to explore novel habitats as pasture lands. We used cephalization (brain mass, corrected by body mass) as a surrogate of behavioral flexibility (Gonzalez-Voyer et al. 2016). Biological data were obtained from the global database PanTHERIA (Jones et al. 2009), The Handbook of the Mammals of the World (Wilson et al. 2009) and published literature (Sol et al. 2008; Barton and Capellini 2011). We used data provided by the IUCN to calculate the current and historic carnivores' distribution ranges of 36 carnivores using QGIS 2.16. We then obtained decline distribution index of each species by calculating the ratio between both current and historic ranges. Values were ranged between 0 (no lost distribution range) and 1 (maximum lost distribution range). To analyze if the frequency of species' engagement in conflicts correlates to species' attributes, we used Spearman rank correlation.

To test if different ecological factors impact on domestic animals' predation we calculated a ratio between preyed animals' age (young/adult), seasons (dry/wet), the moment of attacks (day/night), natural prey densities (high/low), vegetation cover (dense/open) and distances from forest, protected areas and human settlements (far/near). We added 0.1 to every value and apply ln, so if the ratio was zero there was not difference among compared predation. Predation upon domestic animals was obtained as the number of animals lost to carnivores, percentage of the stock preyed or predation rate. We conducted a t-test to assessed the significant effect of these factors. All statistical analyses were conducted using R-package (R Core Team 2016).

Results

We obtained 191 publications that fit our criteria. Of these, 124 papers included quantitative information about predation. Studies were carried out in all continent except Antartica, 31.8% were conducted in Asia, 31.8% in Africa, 17.7% in Europe, 10.4% in North America, 5.2% in South America, 1.6% in Central America and 1% in Oceania. Carnivore-livestock conflict ocurr in all Holdridge's life zones including Subtropical (35% of cases), Cool Temperate (19%), Tropical (15%), Boreal (15%), and Warm Temperate (13%) zones, Polar and Subpolar zones conformed only 3% of study cases.

The number of carnivores involved in concflicts is increasing over time, particularly after 2013 (Figure 1). Felidae and Canidae were the most involved families in the conflict (52.5% and 26.8%, respectively). Other families involved were Hyaenidae (10.9%), Ursidae (5.2%), Musteliade (2.6%), Viverridae (1%), Eupleridae (0.5%) and Herperstidae (0.5%). The frecuency with wich some carnivores' families are involved in the conflict differs from expected by chance (log likelihood ratio test $G=30.2$, $p<0.05$). A *posteriori* test reveals that Felidae (log likelihood ratio test $G=24.73$, $df=6$), Canidae ($G=27.7$, $df=6$, $p<0.05$) and Hyenidae ($G=8.7$, $df=3$) are involved more often than expected by random, while Mustelidae and Viverridae are less frecuently mentioned conflicts ($G=12.7$, $df =4$, $p<0.05$) ($G=6.69$, $df=2$, $p<0.05$) (Figure 2). Species more frecuently mentioned were *Canis lupus*, *Panthera pardus*, *Panthera leo*, *Crocuta crocuta*, *Lynx lynx*, *Panthera tigris* and *Acinonyx jubatus*, which made up 55.8% of the total number of named species.

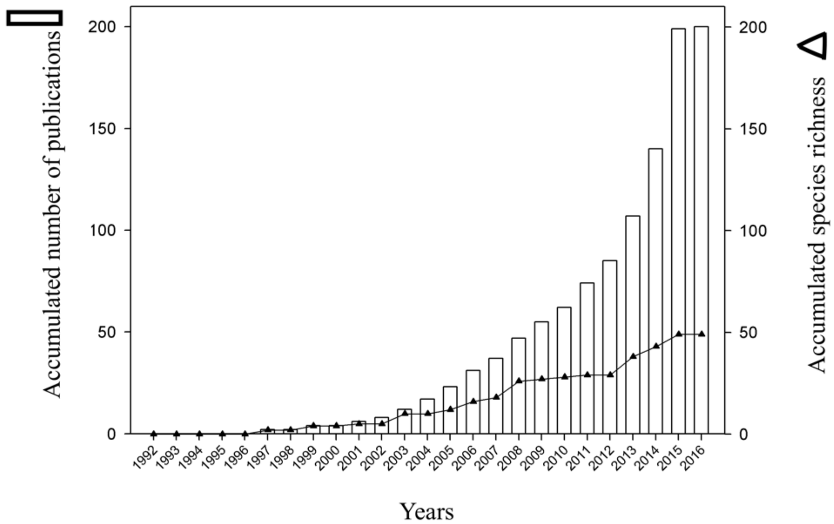

Figure 1: Acumulated number of publications (bar) and species involved (triangle) in conflict with livestock, over period 1992-2016.

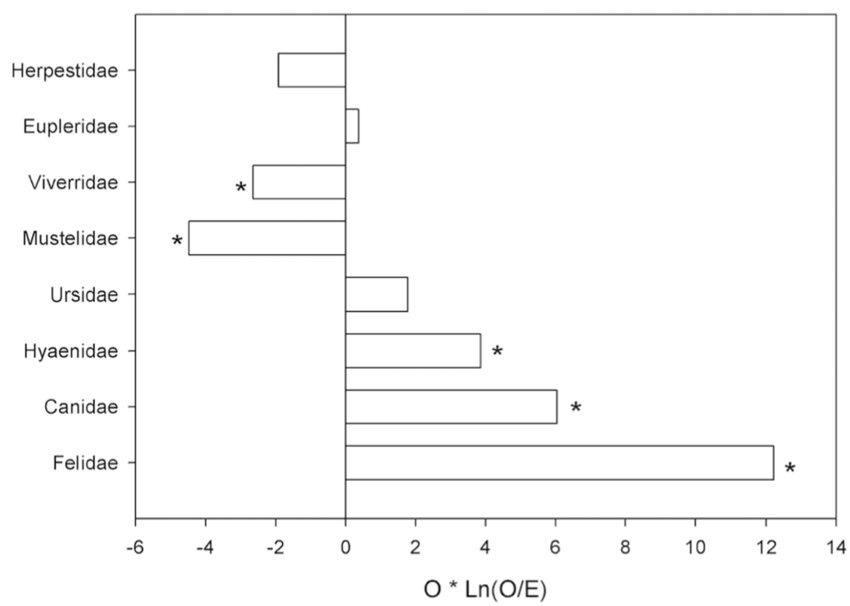

Figure 2: Biases in the number of species involves in human-carnivore conflicts among carnivores' families. Bar size denote contribution of each family to the overall G value. * indicates significant difference at p<0.05.

Domestic animals involved in the conflict include 23 species. Cattle account for 21.9% of reported cases, sheeps and goats account 21.7% and 18.2% of reported cases, respectively, horses (8.4%), donkeys (5.9%), dogs (5.3%), poultry (4.9%), yaks (2.7%) and pigs (2.5%) are resported less often. The frecuency with which domestic animals are involved in the conflict differs from expected by chance (chi square test χ^2=1672.5, $p<0.05$). Cattle and smallstock (sheep and goats) were involved in conflicts more frecuently than expected by their relative global abundance (χ^2=370.28, df=3, $p<0.05$ and χ^2=1068.9, df=3, $p<0.05$, respectively) while poultry was involved less often than expected by its global abundance (χ^2=232.31, df=3, $p<0.05$).

Carnivore species more often involved in conflict exhibit larger home ranges and body masses. The amount of distributional range was also positively related with the species' grade of conflict, but neither litter size nor cephalization had a significant effect on species conflictiveness (Table 1). Twenty-nine point one percent of the cases include species strictly nocturnal, 10.1% diurnal and 60.8% crepuscular or cathemeral. In addition, 55.3% of cases involve solitary carnivores.

Table 1: Results of the correlation between sepecies' attributes of carnivores and their relation with the grade of conflict.

Carnivore attribute	rho	p
Home range	0.640	<<0.01
Body mass	0.699	<<0.01

Litter	0.013	0.94
Range lost	0.566	<<0.01
Residual brain	-0.004	0.98

Regarding environmental factors, prediction of domestic animals was positively related to vegetation cover (t=35.8, p<0.01), whereas it was negatively related to distance to forest (t=-2.0, p=0.1). Predation was not related either to distance to human settlement (t=2.0, p>0.05), distance to protected areas (t=0.2, p>0.05) or density of native prey (p=-0.4, p>0.05) (Figure 3). Other variables mentioned such as predator abundance, elevation, distance to roads, distance to water corses and slope could not be assesed due to low sample sizes.

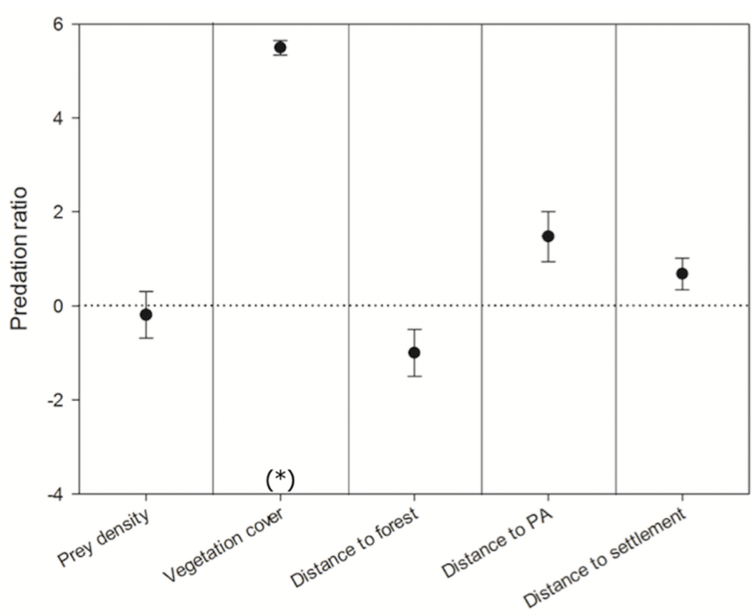

Figure 3: Predation ratio as response of native prey abundance (high/low), vegetation cover (open/dense) and distance to forest patch, protected area and human settlement (far/near). (*) Significant effect at p < 0.05.

Young animals are preyed more often than adults, albeit difference is marginaly significat (t=-1.91, p=0.07). Predation was higher in dry season (t=-2.2, p=0.05) and occur similarly at day and night (t=1.2, p>0.05) (Figure 4).

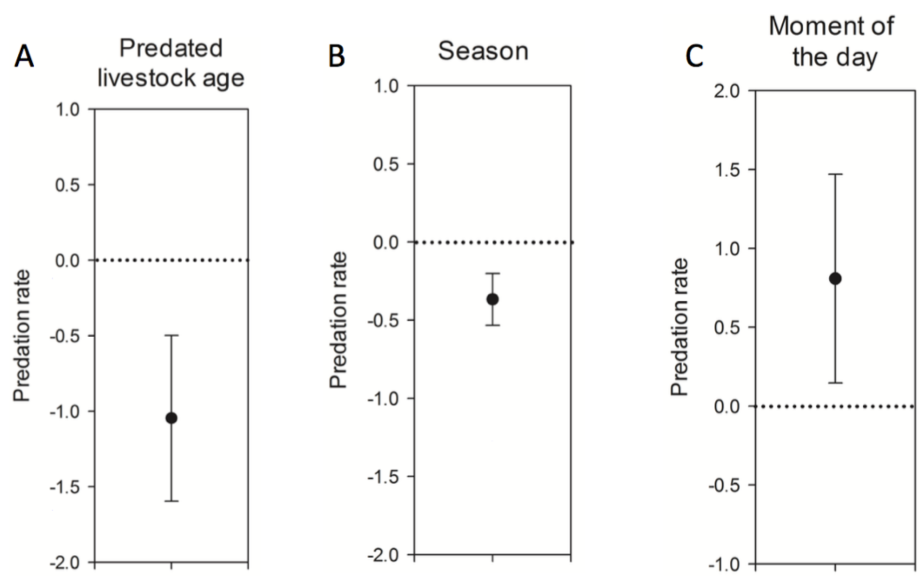

Figure 4: Predation rate: A) ln (adults preyed/youngs preyed), B) ln (predation in dry season/predation in wet season), and C) ln (predation at day/predation at night). (*) Significant effect at p<0.05.

Discussion

Human-carnivore conflicts are a worldwide and increasing phenomena that need to be tackled as 30% of terrestrial carnivores are threatened by retaliation (UICN 2016). The likelihood of this scenario worsen over time is expected. Land use changes remains unabated, which implies that chances for carnivores to run into human-dominated landscapes continues to be high (Ripple et al. 2014). Particularly affected are large bodied animals that require larger areas, such as *Panthera pardus*, *Canis lupus*, *Panthera leo*, *Panthera tigris,* as they have an increasing probability to encounter with domestic animals, to predate them, and therefore to engage in conflicts (Winterbach et al. 2013). Further, larger animals tend to kill larger and more valuable livestock (Baker et al. 2008) therefore they are persecuted.

Biological attributes have a low weight in determining whether species are “conflict-prone”. Litter size, that could determine energetic needs (Gittleman 1985) or cephalization, which might affect hunting behavior (Sol et al. 2008) do not influence the chances to become conflictive. Similarly, neither social organization, that would be associated to hunting strategies (Gittleman 1989), nor activity period were determinant, although it could stablish the moment of attack (Cozzi et al. 2012). On the other hand, predation of domestic animals depend on vegetation cover (Stahl et al. 2002), but it does not appear to be influenced by the availability of native prey *per se*. In effect, a low ratio between availability of native prey compared to the abundance of domestic animals could account for increased predation on domestic prey (S. Crespin, personal communication).

Thick vegetation cover could be increasing hunting success due to a reduction in visibility to detect predators (Thorn et al. 2012).

Landscape-level variables on the other hand, do increase the likelihood of a carnivore to be consider “conflict-prone”. Land use changes including raising domestic animals in formerly wildland increase the probability of encounters between domestic animals and predators (Ripple et al. 2014). In fact, the closer to a wildland domestic animals are raised, they tend to be more preyed upon. Therefore, as more habitat is encroached, more likely new species with restricted distributions or smaller home ranges will engage in conflict. Therefore, available evidence suggests that management techniques to avoid or reduce conflict should be allocated toward landscape management incorporating spatial and temporal scale (Miller 2015). This approach should consider explicitly seasonality and the mosaic of different type of vegetation where to allocate domestic animals to reduce risk (Chapter 2, this thesis).

To achieve the conservation of carnivores will require a land-sharing strategy as smaller natural habitats remains and should rely on human-dominated landscapes. This approach will demand to avoid human-carnivore conflicts. As available suggest managing predation risk across time and space will contribute to minimize this conflict therefore satisfying coexistence of carnivores in production-oriented lands.

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CHAPTER 2

Management tools to reduce human-carnivore conflicts: current gap and future challenges

Abstract

Domestic animal predation by carnivores is a triggering factor in human–wildlife conflicts across production-oriented landscapes. A wide range of management tools to limit predation has been invoked. However, their effectiveness must be demonstrated. Using a quantitative framework and local evaluation of perceived predation, we identify knowledge gaps and research needs related to the effectiveness of management techniques to reduce domestic animals' predation. Lethal control is largely mentioned across literature in comparison to non-lethal forms. Yet, the effectiveness of both approaches remains poorly evaluated (33.8% of studies). Lethal control and night confinement of domestic animals would have no effect on reducing predation, whereas the use of livestock-guardian dogs, fencing or herdsman may significantly reduce animal losses. This reduction may even increase if multiples non-lethal tools are combined. Effectiveness of management techniques and integration of multiples tools across different spatial and temporal scales have to be research priority to promote coexistence between carnivores and livestock activity.

Introduction

Carnivore predation upon domestic animals is of conservation concern (Treves and Karanth 2003; Woodroffe et al. 2005). Although the number domestic animals lost annually to predators tend to be small relative to the number of animals raised (<1–5%; Baker et al., 2008), these losses might be significant in term of livestock biomass (Novaro et al. 2004) or economically sizeable for local economy and owner's well-being (Knowlton et al. 1999). As consequence, numerous carnivore populations have declined, some to the extent of being locally extirpated due to human retaliation (Thirgood et al. 2005; Dickman 2010).

Management of human-carnivore conflicts ought to be evidence-based (Sutherland et al. 2004). Although the reduction of predation upon domestic animals has traditionally relied on lethal methods of control (Treves and Karanth 2003), the effectiveness and acceptability of lethal methods are still controversial (Baker et al. 2008; Treves et al. 2016). For instance, the elimination of "problem" predators at local scale might be buffered by re-colonization of individuals migrating from adjacent areas (Novaro et al. 2005) or by the individuals' compensatory reproduction at regional scale in subsequent years. Thus, even though the elimination of animals could reduce the domestic animal losses in the short term (i.e. during lambing season), little or no effect may be apparent in the long term (Blejwas et al. 2002). More important, the extirpation of native carnivores as a management technique is socially regarded as undesirable on ethical and ecological grounds (Treves and Naughton-Treves 2005; Dickman 2010).

In turn, effectiveness and efficiency of non-lethal techniques to reduce domestic animals predation at the same time to conserve carnivores ought to be demonstrated in order to replace the reliance on lethal control techniques (Treves and Karanth 2003; Baker et al. 2008). This is particularly important if conservation of biodiversity is to be achieved in lands devoted to agriculture including livestock raising, as expected under the Aichi Biodiversity Targets (CBD 2010). For instance, presumed non-lethal techniques such as the translocation, requires critical appraisal, as they have turned to trigger higher mortality among translocated individuals, being equivalent to lethal control (Fontúrbel and Simonetti 2011). Despite the increasing rate of conflicts between carnivores and livestock activity, there is no systematic analysis of the more efficacy techniques to reduce them, which implies more pressure upon native carnivores (Treves et al. 2016). In addition, if the utilization of non-lethal techniques is also perceived to effectively decrease predation, then the willingness to use these methods by ranchers is expected to increase, enhancing the survival of native carnivores in production-oriented lands (Redpath et al. 2013). Here, we review the reliance on different management techniques and its effectiveness in reducing predation upon domestic animals. We focused particularly on non-lethal techniques. We also assessed the perceived effectiveness of management techniques by analyzing empirical data from sheep ranchers in Chilean Patagonia.

Methods

We searched the Web of Science (Science Citation Index Expanded) for papers using the following search terms: carnivore-livestock conflict* OR human-carnivore interaction* OR predation risk*. We reviewed peer-reviewed literature dealing with predation of a wide range of domestic animals (from poultry to cattle) by native carnivores and excluded studies that did not explicitly mention management approaches to prevent animal losses. We also excluded studies presenting only review, opinion or meta-analysis.

In order to characterize the diversity of published studies in term of management approaches, we considered those techniques previously mentioned: lethal control, livestock-guardian dogs, predation risk models, night confinement, livestock fencing, the presence of herdsman, carnivores' translocation and aversive devices (Breitenmoser et al. 2005; Baker et al. 2008). We classified the studies as: i) those where the specific method was used or mentioned but not tested its impact to reduce animal losses (e.g. across study area and discussion sections); and ii) studies which the aim was explicitly to evaluate the success of the method used.

Based on those publications that present quantitative information regarding predation with and without the use of a particular technique, we tested if the technique use indeed reduces predation comparing the response ratio as natural logarithm (post-measurement predation /baseline predation or with technique implemented/without technique implemented). If the technique does reduce predation, the response ratio ought to be negative, with lower frequencies after implementing that method compared with the baseline frequency.

In order to assess if the reliance on non-lethal techniques is perceived as effective for reducing domestic animal losses, we applied a semi-structured questionnaire to sheep ranchers during May 2014 in Rio Verde district in the Region of Magallanes, Chilean Patagonia. This region reaches high annual sheep predation (up to 10.8%) by native carnivores with 76% of ranches affected by predation (Soto 2001). The questionnaire was applied prior to a workshop carried out in the community. Only eighteen ranchers attended the meeting and they were asked about (i) the perceived annual loss of sheep in their ranches and (ii) to indicate the number of current management techniques they used to reduce animal losses. To test whether variances of the mean number of animals lost to predation differ pending on the number of techniques used to reduce predation, we run a Leven test.

Results

A total of 191 papers were retrieved, of which117 studies published between 1990 and 2016 fulfilled our inclusion criteria (Appendix 1). Fifty-nine studies mentioned or evaluated two or more techniques to reduce animal predation. Lethal control was the method more frequently mentioned (42.5%) compared to non-lethal techniques: livestock fencing (34.9%), livestock-guardian dogs (34.0%), reliance on predation risk models (33.0%), night confinement (30.1%), the presence of herdsman (28.3%), carnivores' translocation (11.3%) and the use of aversive devices (6.6%) (Fig.1). The effectiveness of different management techniques was explicitly assessed only in 33.8% of cases. Whereas the success of livestock fencing and livestock-guarding dog appears more frequently evaluated (18% and 17%, respectively; Fig. 1) studies dealing with the effectiveness of aversive devices and predation risk models to reduce predation are scarce (6% and 1%, respectively; Fig. 1). Examining effectiveness within each technique, aversive devices and livestock fencing have been largely evaluated (85.7% and 51.3% of cases, respectively, Fig. 1), whereas lethal control and predation risk models appear poorly tested (22.2% and 2.9% of cases, respectively, Fig. 1).

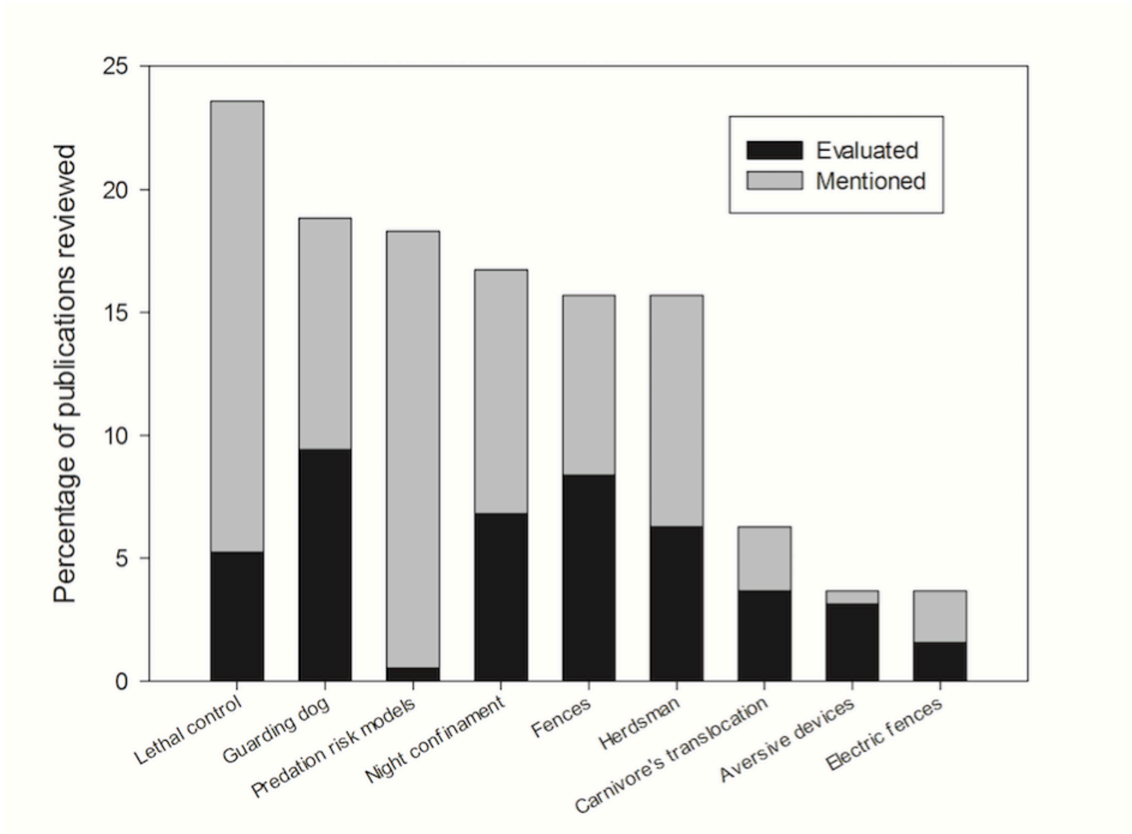

Figure 1. Management techniques mentioned and evaluated to reduce domestic animal predation by native carnivores (N=234 cases in117 publications).

Twenty-nine studies reported quantitative measurement of animal losses with/without a particular management technique. Lethal control and night confinement do not reduce predation rates ($-1.78 < t < -0.34$, $p > 0.05$; Fig. 2), whereas animal losses were on average 2.3,1.4 and 1.7 times lower in cases where livestock-guardian dogs, fencing and the use of herdsmen were applied ($t = -3.12$, $p < 0.02$; $t = -3.31$, $p < 0.02$ and $t = -2.34$, $p < 0.05$, respectively; Fig. 2). Even though aversive devices appear to reduce domestic animal losses, statistical inference was not possible due to low sample size (N=2).

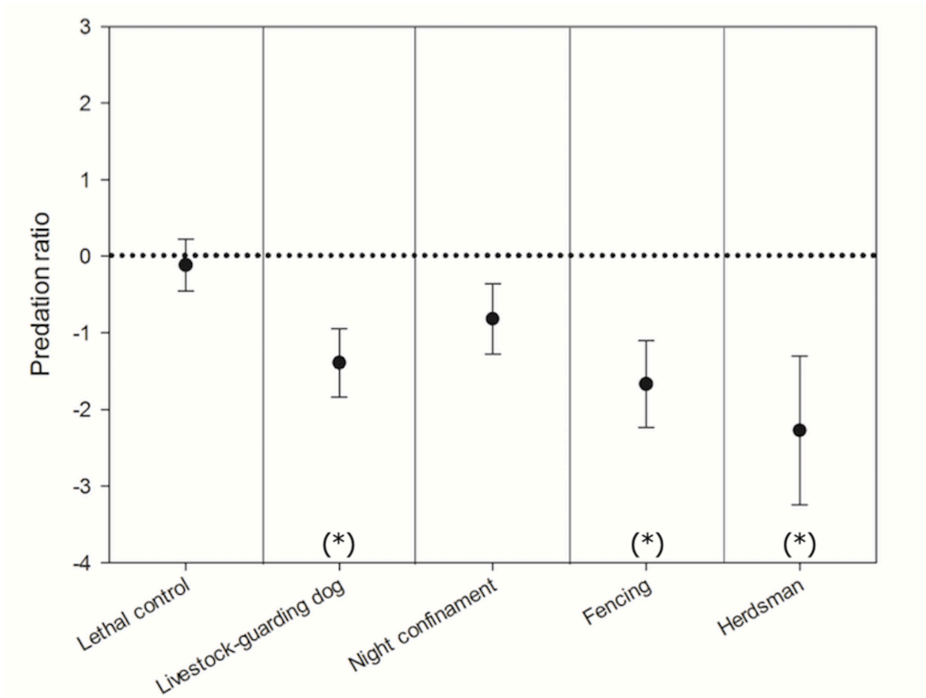

Figure 2. Predation of domestic animal by carnivores in presence of different management techniques. Values are the ratio ln (post-measurement predation /baseline predation) (mean and SE). Samples sizes were: 10 cases for lethal control, 9 for livestock-guarding dog, 7 for night confinement, 14 for fencing and 11 for herdsman. (*) Denotes significant effect at $p<0.05$.

At Patagonia, ranchers would use up to three non-lethal methods simultaneously including more commonly livestock-guarding dogs and nocturnal confinement. Perceived predation was up to four times lower among ranches using more techniques that those who relied on just one (Fig. 3). Interestingly not only the average losses decrease but also the variability, suggesting that the use of more technique tend to reduce more predictably losses (Levene test 3.2 df=2 p=0.08; Fig. 3).

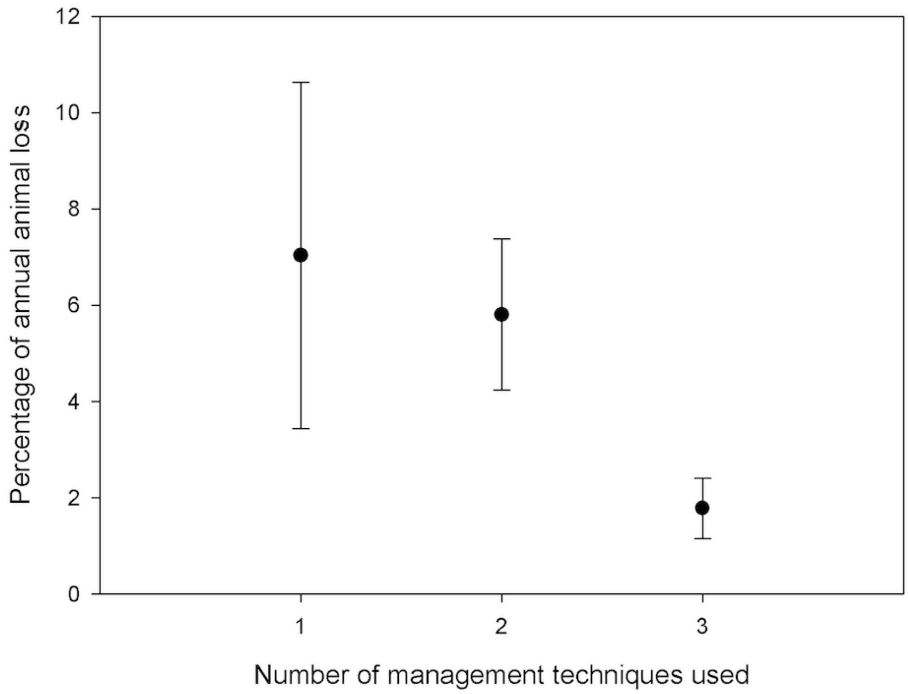

Figure 3. Relationship between perceived annual predation (mean percentage of sheep and SE) and the number of non-lethal techniques used by local ranchers to reduce animal loss in Magallanes Region, Chilean Patagonia (N=18).

Conclusions

Predation on domestic animals by carnivores is a persistent problem wherever carnivores and livestock co-occur. As such, predation on domestic animals is a triggering factor of human-wildlife conflicts worldwide (Woodroffe et al. 2005). Consequences of this conflict are not only circumscribed to the negative effects on economy or food production of local and regional communities but also to the long-term persistence of many carnivore populations across the globe (Baker et al. 2008).

Despite the importance of preventing domestic animal's predation would have to reduce human-carnivore conflicts, there still is a substantial paucity of data on the effectiveness of lethal and non-lethal control forms. In fact, the implementation of predator control often lacks rigor regarding its effectiveness (Treves et al. 2016). This is particularly noticeable in the case of lethal forms of control, which appears largely invoked to prevent animal losses but only a fifth of studies does effectively evaluate its success. Based on people's perception, non-lethal techniques would be more effective than lethal ones. Our appraisal pinpoints that lethal control seems to have no effect in reducing animal predation by native carnivores when compared to non-lethal techniques such as livestock-guarding dogs, fencing and the use of herdsmen. The success of lethal control technique in reducing domestic animal predation is likely to be dependent on carnivores' population at larger spatial and temporal scales (Knowlton et al. 1999; Novaro et al. 2005) as well as the rise of subordinate predators that may also prey on domestic animals (Treves and Naughton-Treves 2005; Prugh et al. 2009). In addition, the extirpation of carnivores from human-dominated landscapes is clearly in conflict with ethical concerns and the efforts to achieve land-sharing as a conservation approach (CBD 2010).

Alternative non-lethal approaches are called to prevent domestic animal losses at the same time of promoting the conservation of carnivores in production-oriented lands (Breitenmoser et al. 2005). Yet, quantitative evaluation must be undertaken to identify the relative effectiveness of management practices aimed at reducing domestic animal losses. This validation will be ultimate essential part of demonstrating the success of these management techniques as tools for informed conservation decision-making (Larrosa et al. 2016). Even in novel spatial approaches as predation risk models, field validation is needed to build a bridge between theory and practice.

The combination of multiple non-lethal techniques is perceived to increase the success in reducing livestock predation. Thus, the benefits of more integrated approaches involving multiples management techniques across different spatial and temporal scales must be evaluated. This is a keystone issue for systematic conservation planning, where the effectiveness strongly depends on accounting for natural and anthropogenic dynamics (Pressey et al. 2007). Furthermore, although costly and/or logistically difficult to implement, estimates of predation reduction should not be based on producers' perception only but also supported by field quantifications.

Carnivores' persecution and destruction due to livestock predation is becoming the main factor of global carnivores decline, and this conflict will increase as more natural landscapes turn into production-oriented lands and encroaches remnant carnivore populations. Urgent attention of conservation biologist and wildlife managers should then be directed to promote the coexistence of predators and human activities throughout ecologically and socially acceptable and also effectively demonstrable approaches, resulting in the recovery of many carnivore’s populations. A corollary to the decision-making processes and public policy is that lethal techniques are unfounded about their effectiveness to reduce animal loss while the complementation of non-lethal techniques appears to be effective to reduce livestock predation. To promote the reliance on non-lethal techniques will contribute to achieve carnivore conservation in human dominated landscapes.

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GENERAL DISCUSSION

Current efforts to conserve biodiversity are being oriented toward achieving it in human-modified landscapes (Sanderson et al. 2002; Chazdon et al. 2009; Ellis et al. 2010). In these modified lands, conflicts between humans and carnivores arise, as predators inhabiting productive lands, encounter and prey upon domestic animals. As a consequence predators are persecuted and hunted in retaliation (Baker et al. 2008). Further, as agricultural boundaries are expanding, more carnivores are becoming conflict-prone. These facts represent a challenge, since carnivores´ conservation increasingly depends on human dominated lands` management.

On this scenario, conservation strategies of carnivores ought to be supported by empirical evidence to render efficient and effective management approaches (Sutherland et al. 2004). Our review of available evidence shows, first, that to rely on biological, ecological and landscape attributes could be used to develop management techniques of domestic animals that might avoid conflicts. Second, that the simultaneous consideration of these attributes is more effective than to rely on lethal techniques. Third, that the combination of non-lethal techniques could favor the persistence of carnivores and effectively reducing the predation of domestic animals.

Regarding the effectiveness of techniques used to reduce predation, it is largely assessed through producers' perceptions (75% of cases where evaluation was conducted), lacking quantitative and independent field-ground evaluations. This validation is required to objectively demonstrate the success of different management techniques, hence better informing conservation decision-making (Larrosa et al. 2016). This assessment should be carried out regardless how costly or logistically difficult is to implement. If losses occur, despite the use of non-lethal techniques, public agencies ought to consider in order to compensate ranchers for those losses which is equivalent to invest in the conservation of involved carnivores (Fontúrbel and Simonetti 2011). In this way, the coexistence of carnivores and livestock will be based on approaches technically robust and socially accepted in human dominated landscapes, fulfilling the Aichi target of the Convention of Biological Diversity.