Rangeland Ecology & Management xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Rangeland Ecology & Management

journal homepage: http://www.elsevier.com/locate/rama

Management Tools to Reduce Carnivore-Livestock Conflicts: Current Gap and Future Challenges☆

Darío Moreira-Arce [a,b,d,*], Carolina S. Ugarte [a], Francisco Zorondo-Rodríguez [b,c], Javier A. Simonetti [a,b]

[a] Biological Conservation Laboratory, Department of Ecological Sciences, Faculty of Ciencias, University of Chile, Santiago, Chile
[b] Association of Kauyeken, Santiago & Isla Riesco, Chile
[c] University of Santiago of Chile, Department of Gestión Agraria, Santiago, Chile
[d] Departamento de Manejo de Bosques y Medio Ambiente, Facultad de Ciencias Forestales, Universidad de Concepción, Casilla 160-C, Victoria 631, Concepción, Chile

ARTICLE INFO

Article history:
Received 7 October 2017
Received in revised form 22 January 2018
Accepted 13 February 2018
Available online xxxx

Key Words:
carnivora
carnivore management
human–wildlife conflicts
livestock predation
production-oriented lands

ABSTRACT

Predation on domestic animals by carnivores is a persistent problem wherever carnivores and livestock co-occur. A wide range of management tools to reduce predation has been invoked. However, the evidence of their effectiveness is still limited for a broader range of species and conditions. Using a global analysis of domestic animal predation by native carnivores under a "before-after/control-impact" framework, we assessed the effectiveness of management techniques used to reduce domestic animal predation identifying knowledge gaps and research needs. We reviewed 291 predation cases in 149 studies published between 1990 and 2017 involving 47 carnivores. Lethal control is the most common method to reduce predation in comparison with nonlethal techniques. Yet the effectiveness of both approaches remains poorly evaluated (30.1% of study cases) and largely based on producers' perceptions (70% of cases where effectiveness was evaluated). Lethal control and night confinement of domestic animals would have no effect on reducing predation, whereas the use of livestock-guarding dogs, fencing, or herdsmen may significantly reduce domestic animal losses. When the effectiveness of each technique to reduce predation was assessed by large and mesocarnivores, fencing significantly reduced predation of domestic animals by the former. Despite little scientifically published material, our findings indicate lethal control would have no effect in reducing animal predation by native carnivores when compared with nonlethal techniques. Our study also indicates the effectiveness may vary depending on the type of carnivore involved in the conflict with livestock activity. The use of an evidence-based framework to measure and assess the differential effectiveness of nonlethal techniques and the use of complementary tools at different spatial and temporal scales must be research priorities to prevent livestock predation while promoting the conservation of carnivores in production-oriented lands as encouraged by the Convention of Biological Diversity.

Introduction

Carnivore predation upon domestic animals is a matter of conservation concern (Treves and Karanth 2003; Woodroffe et al. 2005). Although the number of domestic animals lost annually to predators tends 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 the local economy and owner's well-being (Knowlton et al. 1999). As a consequence, due to human retaliation, numerous carnivores' populations have declined, some to the extent of being locally extirpated (Thirgood et al. 2005; Dickman 2010).

Effective management of the conflict derived from the predation of domestic animals would benefit from the explicit use of verifiable scientific evidence obtained from both experimental research and the disemination of routinely systematic reviews (Sutherland et al. 2004; Treves et al. 2016). Although the reduction of predation upon domestic animals has traditionally relied on lethal methods (Treves and Karanth 2003), the effectiveness and acceptability of lethal approaches 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 recolonization of individuals migrating from adjacent areas (Novaro et al. 2005) or by the individuals' compensatory reproduction at regional scale in subsequent years (Knowlton et al. 1999). 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 achieved in the long term (Blejwas et al. 2002). More importantly, the

☆ This work was supported by CONICYT FONDECYT/Postdoctoral Grant No. 3160056 and Proyectos Basal USA 1555-Vridei O91775ZR PUBLIC Universidad de Santiago de Chile.

* Correspondence: Darío Moreira-Arce, Biological Conservation Laboratory, Department of Ecological Sciences, Faculty of Ciencias, University of Chile, Casilla 653, Santiago, Chile. Tel.: +56 9 9927896.
E-mail address: moreira.dario@gmail.com (D. Moreira-Arce).

https://doi.org/10.1016/j.rama.2018.02.005
1550-7424/

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, the effectiveness and efficiency of nonlethal techniques to reduce predation upon domestic animals while conserving carnivores have to be demonstrated in order to replace the reliance on lethal control techniques (Treves and Karanth 2003; Baker et al. 2008; Treves et al. 2016). 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 nonlethal techniques such as the animals' translocation, requires critical appraisal, as they have turned to trigger higher mortality among translocated individuals, being equivalent to lethal control (Fontúrbel and Simonetti 2011).

In response to the increasing rate of conflicts between carnivores and livestock, recent review studies have documented the relative effectiveness of conflict-mitigation strategies on a global scale (Miller et al. 2016; Van Eeden et al. 2017; Eklund et al. 2017). Although the evidence provided by research suggests that nonlethal strategies may reduce domestic animal predation, the focus on large carnivores-livestock conflicts, as well as the use of predation cases reporting statistic metrics, limit our understanding above the success of nonlethal techniques under a wider range of species and conditions. Consequently, from a conflict management perspective, important insights can be gained by assessing if the effectiveness of each technique varies between carnivore species and environmental conditions. Furthermore, to demonstrate this effectiveness, confident and accurate methods to quantify domestic animal predation should also be considered in order to avoid the overestimates/underestimations of animals' losses under different management strategies. This is particularly important if replacement animals or financial payments schemes are used by public agencies to compensate those losses (Baker et al. 2008).

If the utilization of nonlethal techniques is not only perceived but also demonstrated to effectively decrease predation, then the willingness to use these methods by producers is expected to increase, enhancing the survival of native carnivores in production-oriented lands (Redpath et al. 2013). The success of techniques has been mostly evaluated individually (e.g., Andelt 1992; Woodroffe et al. 2007; see examples in Eklund et al. 2017), and little evidence is known about the additive or synergic effects of combined strategies (Espuno et al. 2004; Garrote et al. 2015). Here, we examined the effectiveness of lethal and nonlethal management techniques in reducing predation upon a wide range of domestic animals and carnivores. As a new aspect of this research, we have disaggregated the predation by carnivores with different body sizes in an attempt to identify patterns of used techniques that might facilitate more informed selection by potential users. To do so, we reviewed published cases of predation of domestic animals that quantified effectiveness of a given management technique as the change in domestic animal losses (as reported by different sources) after/with the applied technique.

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 a wide range of terrestrial native carnivores and excluded studies that did not explicitly mention management techniques to prevent domestic animal losses. We also excluded avian carnivores from our search since the carnivores-livestock conflict has been primarily related to carnivore taxon occurring in production-oriented lands (Baker et al. 2008).

In order to characterize the diversity of published studies in terms of management approaches, we considered those techniques mentioned in recent studies (Miller et al. 2016; Van Eeden et al. 2017; Eklund et al. 2017): lethal control, livestock-guardian dogs, night confinement, livestock fencing, the presence of herdsman, carnivores' translocation, and aversive devices. We also included the use of decision support tools such as predictive spatial models since they can be used as a complementary approach to reduce domestic animals' predation, operating to larger spatial scales, and their results can be validated (Treves et al. 2011; Treves and Rabenhorst 2017). We classified the studies as 1) those where the specific method was used or mentioned but not tested for its impact to reduce animal losses (e.g., across methods or discussion sections) and 2) those aimed explicitly at evaluating the success of the technique used. Of the later set of studies, we identified the source used to assess or quantify the effectiveness of each technique.

On the basis of those publications that presented quantitative information regarding predation, we used a "before-after/control-impact" (BACI) framework to test if the technique used indeed reduced predation (Treves et al. 2016). To do that, we compared the response ratio (postmeasurement predation/baseline predation or with technique implemented/without technique implemented) and standardized it by using ln in order to avoid overdispersion (Simonetti et al. 2013). If the technique does reduce predation, the response ratio will be negative, with lower frequencies after implementing that method compared with the baseline frequency. A Student's *t*-test (Zar 1974) was performed to determine if the average of the response ratio for each used technique was different from 0 (i.e., no change in predation before-and-after technique implementation). We performed the analyses in two steps. First, we assessed the effectiveness of different techniques by accounting for the whole diversity of carnivores included in the study cases that presented quantitative information regarding predation. We then disaggregated the predation cases involving mesocarnivores and large carnivores. To separate between these two groups of species, we used the median of body sizes of involved predators (20.9 kg) obtained from (Jones et al. 2009). Those cases for which it was not possible to separate the predation by mesocarnivores or large carnivores were included in the first analysis only.

Results

A total of 255 papers were retrieved, of which 149 studies published between 1990 and 2017 fulfilled our inclusion criteria completing a total of 291 study cases involving 47 carnivore species (Appendix 1). We considered a study case as an event of predation on individuals of domestic animal species by a particular carnivore. Lethal control was the method most frequently mentioned across the study cases (19.2%) compared with nonlethal techniques: livestock fencing (15.8%), livestock-guarding dogs (15.4%), reliance on predation risk models (15.0%), night confinement (13.7%), the presence of herdsman (12.8%), carnivores' translocation (5.1%), and the use of aversive devices (3.0%) (Fig. 1). The effectiveness of different management techniques was explicitly assessed only in 30.1% of study cases. Whereas the success of livestock fencing and livestock-guarding dogs appeared most frequently evaluated (8.1% and 7.6 of total study cases; see Fig. 1), studies dealing with the effectiveness of carnivores' translocation and predation risk models to reduce predation were scarce (<1% of studied cases; see Fig. 1). When examining the effectiveness within each technique (i.e., considering as the total of study cases those available for each technique), the use of aversive devices has been mostly evaluated (60% of studied cases for this technique; see Fig. 1), whereas predation risk models appear poorly tested (4.3% of studied cases for this technique; see Fig. 1). The effectiveness of techniques used to reduce animal losses was largely evaluated through producers' perceptions conducting surveys (70% of total cases where evaluation was conducted), whereas the use of diet analyses, reports of claims provided by local agencies, and the use of direct observations of preyed animals were rarely used (1.1%, 14.4%, and 14.5%, respectively; Fig. 2).

Thirty-eight publications (25.5% of studies published) reported 87 study cases (30.1% of total study cases considered) with quantitative

Please cite this article as: Moreira-Arce, D., et al., Management Tools to Reduce Carnivore-Livestock Conflicts: Current Gap and Future Challenges, (2018), https://doi.org/10.1016/j.rama.2018.02.005