Biological Conservation 224 (2018) 170–177

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Review

Discordant scales and the potential pitfalls for human-carnivore conflict mitigation

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ARTICLE INFO

Keywords:
Human-carnivore conflict
Lion
Panthera leo
Prediction
Scale

ABSTRACT

Floral and faunal biodiversity are jeopardized by a number of ecological, environmental, and anthropogenic factors. Increasingly however, an evident disconnect between the science and policy spheres problematizes efforts to conserve biodiversity. One of the issues that informs this research-implementation gap is discordance among the scales at which: *i*) the research objective is devised, *ii*) the data are collected, and *iii*) the inferences are applied. This issue might be influential among human-carnivore conflict research where applied results are intended to optimize the implementation of interventionist activities. Using human-lion (*Panthera leo*) conflict research as a novel case study, we reviewed papers studying patterns of conflict from 1990 to 2016. Despite the fact that the majority (70.5%, 62 of 88) of these papers devised their research objectives at broad spatial scales (i.e., either landscape or regional), most (64.8%, 57 of 88) envisioned their inferences at fine scales (i.e., either household or community). Mismatches between the coarsest reported scale of data collection and the finest reported scale of inference were also evident. For instance, 24 of 79 papers (30.4%) had potentially problematic mismatches given that the scale of inference was at a finer scale than the scale of data collection. We infer that scale discordance in human-lion conflict research is common and derives, in part, from the lack of fine-scale geospatial data describing the systems in which humans and lions interact. Efforts to develop more resolute geospatial libraries across biodiverse regions will help to make conservation research more effectual by narrowing the research-implementation gap.

One sentence summary: Discordance between the scale of data collection and the scale of prediction problematize efforts to devise interventions for human-carnivore conflict.

1. Introduction

Global biodiversity loss is one of the most pressing conservation challenges of the 21st century (Butchart et al., 2010; Rands et al., 2010; Reich et al., 2012; Tittensor et al., 2014). A broad array of floral and faunal species is imperiled by dynamic processes including climate change, urbanization, habitat degradation/fragmentation, trophic guild disruption, disease, invasive specification, and hunting (Sala et al., 2000; Clavero et al., 2009; Krauss et al., 2010; Lenzen et al., 2012; Pimm et al., 2014; Macdonald, 2016). Dramatic population declines threaten the persistence of species of conservation concern and, given the connected and integral role that many of these species play in the trophic systems in which they reside, the structure of ecosystems and human health, more broadly (Daszak et al., 2000; Tilman, 2000; Adams et al., 2004; Cardinale et al., 2012; Hooper et al., 2012; Reich et al., 2012). Estimates suggest that as much as 52% of global biodiversity has been lost in the last 40 years alone (McLellan et al., 2014) with future predictions that depict even steeper rates of decline (Raven, 2011, Ceballos et al., 2015). Many have suggested that these rates indicate that we are in the midst of the sixth mass extinct event on earth (Magurran and Dornelas, 2010; McLellan et al., 2014; Cafaro, 2015) and the first that has been principally accelerated by human action (Brook et al., 2008; Barnosky et al., 2011; Bellard et al., 2012).

Conservation research has largely focused on documenting the ways in which species are affected by the biotic and abiotic processes that threaten population persistence (Blaustein and Kiesecker, 2002; Naeem, 2002; Cardillo et al., 2005). Via this research, we have an improved understanding of the consequences of climate change or disease, for example, on species abundance and distribution, but we have only a modest appreciation of how to apply and implement interventionist

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https://doi.org/10.1016/j.biocon.2018.05.018
Received 6 March 2018; Received in revised form 30 April 2018; Accepted 18 May 2018

activities capable of benefiting these species (Ferraro, 2001; Loreau et al., 2001; Kuussaari et al., 2009; Pereira et al., 2010). This divide, referred to as the *research-implementation gap* (also called the *knowing-doing gap*, Pfeffer and Sutton, 1999), affects not only research into biodiversity loss, but spans every sector of science (Bero et al., 1998; Opdam et al., 2001; Haines et al., 2004; Higgs, 2005; Knight et al., 2008; Wandersman et al., 2008). This gap exists for many reasons. For example, many scientific fields have largely theoretical roots (i.e., not applied in origin), are often lacking transdisciplinary collaboration between STEM scientists and political scientists, and exist within structural systems that do not explicitly incentivize research that is actionable (Ehrenfeld, 2000, Salafsky et al., 2002, Cowling et al., 2004, Balmford and Cowling, 2006, Chapron and Arlettaz, 2008, Cook et al., 2013, Montgomery et al., 2018). While all of these factors can impede science, the research-implementation gap can be devastating for conservation biology as species can go extinct during the time in which the science and policy realms are attempting to navigate this divide (Pimm et al., 1995; Vitousek et al., 1997; Groves et al., 2002). Thus, for the field of conservation biology to become more effectual, the research-implementation gap must be narrowed so that the results of this work can inform action that promotes the recovery of species of conservation concern.

The conservation of large-bodied terrestrial carnivores (order *Carnivora*) provides a particularly relevant case study for examination of the research-implementation gap. There are 31 species of large carnivores remaining on the planet and over three-quarters of these have populations that are declining (Ripple et al., 2014; Bauer et al., 2015; Chapron and López-Bao, 2016). These are species that tend to be fierce, charismatic, and iconic (Linnell et al., 2000, Karanth and Chellam, 2009, Macdonald, 2016). Furthermore, given that they typically inhabit apex predator positions with life histories that are often predicated upon the consumption of mobile prey species, large carnivores can exert strong effects on trophic system dynamics (Schmitz et al., 2000, 2010; Beschta and Ripple, 2009; Schmitz et al., 2010; Ripple et al., 2014, 2016). For these and other reasons, broad-scale conservation efforts are underway to preserve large carnivore populations (Weaver et al., 1996; Weber and Rabinowitz, 1996; Woodroffe and Ginsberg, 1998; Chapron et al., 2014). In addition to the aforementioned causes of biodiversity loss, large carnivore persistence is negatively affected by conflict with humans (Treves and Karanth, 2003, Berger, 2006, Inskip and Zimmermann, 2009, Redpath et al., 2013). Conflict tends to be associated with real or perceived depredation of livestock by carnivores (Patterson et al., 2004, Graham et al., 2005, Dickman, 2010, Millspaugh et al., 2015). Carnivores kill people's livestock and people respond by killing carnivores. This is not a specific problem, as it occurs in every habitat around the world where people and carnivores come into contact (Linnell et al., 2000). Thus, in an effort to mitigate conflict, research is often oriented to yield applied impacts, such as the development of risk maps which depict the predicted spatial patterns in carnivore depredation of livestock (Marucco and McIntire, 2010, Treves et al., 2011, Meena et al., 2014, Miller, 2015). Risk maps are used to communicate with stakeholders and prioritize interventionist activities capable of decreasing conflict. However, a recent review of 18 human-carnivore conflict risk map studies found that only one of them evidentially impacted policy formation (see Miller et al., 2015). This suggests that the research-implementation gap is an important concern for human-carnivore conflict research in particular.

One understudied issue that contributes to the research-implementation gap is discordance among the scale of the research objective (the objective level), the scale at which the data is collected (the data collection level), and the scale of the prediction or management action (the inference level; Root and Schneider, 1993, Hurlbert and Jetz, 2007, Wiens et al., 2009; Fig. 1). Mismatching scales is a problem that confounds interpretation of research results across a number of disciplines (Hurlbert and White, 2005; Cumming et al., 2006; McPherson and Jetz, 2007; Hurlbert and Jetz, 2007; Wiens and Bachelet, 2010) and there is good reason to believe that it may be pervasive among carnivore conservation research. For example, for management action to be effective, it is often necessary to document carnivore space use patterns or develop interventions at fine spatial scales (Treves et al., 2004; Ericsson et al., 2006; Gorini et al., 2012; Angerbjörn et al., 2013). Thus, to match the scale of the research objective with the scales of data collection and/or inference, fine-scale geospatial information describing the system would need to be acquired. However, remote-sensing data has, since its inception, produced data that is typically too coarse (10's to 100's of m^2) for meaningful assessments of species occurrences (Turner et al., 2003). Recent advancements have facilitated image processing at much finer resolutions, but these data are often not depicted across broad spatial scales and typically not associated with developing nations, where large carnivores often tend to occur (Carter et al., 2012; Mora et al., 2014; Ripple et al., 2014). Thus, the impact of scale discordance in the research-implementation gap might be magnified for human-carnivore conflict research.

Here we conducted a survey of the literature to determine the extent to which scale discordance occurs among the field of large carnivore conservation. To frame our analysis, we centered the assessment on research of human-lion (*Panthera leo*) conflict. We selected lions because they are a species of special conservation concern, that are highly-studied, regularly conflict with people, and have experienced dramatic population declines in recent decades (Bauer et al., 2015, 2016; Riggio et al., 2016). Further, the conservation of lions is embroiled in a broader dialogue relating to the species' protected status (see Nelson et al., 2013; Henschel et al., 2014; Bouché et al., 2016; Di Minin et al., 2016). Thus, the research-implementation gap could be particularly influential for the persistence of lion populations and for human-lion conflict research. We discuss the implications of this assessment on the: *i*) research-implementation gap, *ii*) conservation of large carnivores, *iii*) efficacy of conflict mitigation efforts, and *iv*) the potential for more robust integration of geospatial information among this research effort.

2. Methods

2.1. Literature survey

In April of 2017 we conducted a survey of the literature to identify papers that assessed human-lion conflict across the period of 1990 to 2016. To capture as much of the literature as possible, we conducted our survey using four different databases. These included Wildlife and Ecology Studies Worldwide (WESW), Google Scholar, Scopus, and Web of Science (WoS) Core Collection. We anticipated variation in the number of papers returned from each database. Such variation should be expected given prevailing search mechanisms and the relative size of the indices associated with each engine. For instance, WoS has the largest index with Scopus next and then WESW (Adriaanse and Rensleigh, 2011). While Google Scholar does not advertise the size of their index, they have the capacity to search every document on the internet (Mayr and Walter, 2008) to form a corpus larger than any existing index. Across each database, we conducted primary, secondary, and tertiary literature searches. We used the terms 'human lion livestock' and '*Panthera leo*' during the primary search. We then added the term 'conflict' in the secondary search and finally 'depredation' at the tertiary level. Given the inherent bibliographic limitations of the Google Scholar search engine, we had to structure our survey in a slightly different fashion. At the primary level, we introduced the terms 'human lion conflict' as a bound phrase. Then in the secondary search we added the term '*Panthera leo*' and 'depredation' in the tertiary search.

2.2. The scales of human-carnivore conflict

We assessed the resultant literature to identify those papers that