Biological Conservation 197 (2016) 40–46

Contents lists available at ScienceDirect

Biological Conservation

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

Mind the cat: Conservation management of a protected dominant scavenger indirectly affects an endangered apex predator

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ARTICLE INFO

Article history:
Received 28 July 2015
Received in revised form 11 January 2016
Accepted 19 February 2016
Available online xxxx

Keywords:
Wildlife management
Interspecific interaction
Kleptoparasitism
Cascading effects
Lynx lynx
Ursus arctos

ABSTRACT

Interspecific interactions are among the key factors influencing the structure of animal communities and have high relevance for conservation. However, managers, conservationists and decision-makers rarely consider the potential side-effects of single-species carnivore management for the conservation of other carnivores. We studied how management of protected brown bears (*Ursus arctos*) affected interspecific interactions with an endangered apex predator, the Eurasian lynx (*Lynx lynx*) in Slovenia. Due to large body size and superb olfactory abilities, bears are one of the most important dominant scavengers and regularly usurp kills from other large predators, a process known as kleptoparasitism. At the same time, bears throughout the world are usually actively managed through zone-specific culling regimes, supplemental feeding, and translocations. This can considerably alter bear densities and activity patterns and in turn influence interactions among carnivores. Overall, we observed that bear scavenging pressure resulted in substantial energetic losses for Eurasian lynx. The probability of lynx losing kills to bears ranged from 8 to 74% and strongly depended on local bear densities and monthly bear movement rates. Kleptoparasitic interaction intensity differed almost 3-fold between different bear management zones. Furthermore, the presence of a bear feeding site increased the odds of lynx losing kills by 5-fold compared to areas > 1000 m from these sites. We suggest that existing bear-feeding regimes should be reconsidered in order to reduce unwanted side-effects of this controversial practice on endangered apex predators. We also call attention to the importance of considering impacts of interspecific interactions in wildlife management and conservation.

1. Introduction

Interspecific interactions have profound effects on ecosystem function and community structure (Begon et al., 2006). Understanding the underlying mechanisms that influence interspecific interactions is increasingly an important aspect of animal conservation (Creel et al., 2001; Moleón et al., 2014). Despite the potential to alter entire communities, wildlife managers rarely consider possible negative side-effects of management decisions on interspecific interactions (Linnell and Strand, 2000; Ordiz et al., 2013; Selva et al., 2014). More empirical knowledge is needed for better conservation and management that accounts for interactions across multiple levels of ecosystems (Lozano et al., 2013; Périquet et al., 2015). This is particularly true for strongly interacting species, such as large mammalian carnivores due to their cascading effects on numerous species and terrestrial ecosystems worldwide (Estes et al., 2011; Ripple et al., 2014).

Researchers are increasingly concerned about unwanted or unexpected impacts of specific management actions involving large carnivores. For example, hunting increases infanticide in African lions (*Panthera leo*; Loveridge et al., 2007; Whitman et al., 2004) and brown bears (*Ursus arctos*; Gosselin et al., 2015; Swenson et al., 1997), decreases pack stability in wolves (*Canis* spp.) and increases their hybridization with domestic dogs (Moura et al., 2014; Rutledge et al., 2010). For cougars (*Puma concolor*) and African lions, hunting changes their distribution and movement patterns (Davidson et al., 2011; Maletzke et al., 2014). Hunting also changes brown bear activity and foraging behaviour (Ordiz et al., 2012). Changes in abundance, sociality, foraging, spatial distribution and movement patterns have also been reported as a consequence of carnivores exploiting readily available human-provided foods (Newsome et al., 2015; Oro et al., 2013). On the other hand, much less is known about the effects of these measures beyond the managed species (Périquet et al., 2015). Consequently, carnivore management programmes rarely consider the indirect effects on other apex predators via changes in interspecific interactions.

Interspecific interactions among carnivores frequently occur at kill sites (Atwood and Gese, 2008). The stealing of kills or kleptoparasitism is recognized as an important part of large carnivore ecology with the potential to change entire ecological communities (Allen et al., 2014). High levels of kleptoparasitism can directly threaten predators (Carbone et al., 1997; Gorman et al., 1998). Kleptoparasitic interactions among bears and solitary felids provide an opportunity to study these

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http://dx.doi.org/10.1016/j.biocon.2016.02.019

interactions. Solitary felids that kill large prey are characterized by a prolonged consumption process of their kills (Jobin et al., 2000; Stander et al., 1997) and are regularly exposed to kleptoparasitism in their ranges worldwide (Krofel et al., 2012a). As the largest terrestrial scavengers with superb olfactory abilities, bears are one of the most important dominant scavengers and kleptoparasites in the Holarctic region (Allen et al., 2014; Krofel et al., 2012a; Murphy et al., 1998). At the same time, ursids are often actively managed either through hunting and management removals (Kaczensky et al., 2013; Nielsen et al., 2004) or, in case of endangered populations, through reintroductions (Clark et al., 2002). In addition, bear movements, local densities, diet and other life history traits can be greatly altered through human-caused changes of habitat and food availability (Apps et al., 2004; Güthlin et al., 2011; Kavčič et al., 2015; Penteriani et al., 2010). However, it is poorly understood how management of dominant scavengers like bears affect their interactions with other predators.

Our research focuses on how management of protected brown bears in Slovenia influences interspecific interactions with a sympatric apex predator, the Eurasian lynx (*Lynx lynx*). The highly endangered Dinaric lynx population is impacted by kleptoparasitism from brown bears, through substantial energetic losses and potential reduction in reproductive success. On average, bears usurpe one third of lynx kills and despite increasing their kill rate, lynx are not able to fully compensate the losses (Krofel et al., 2012a). These kleptoparasitic interactions were highest during the bear mating season and lowest in the denning period (Krofel et al., 2012a). Brown bears in the region are intensively managed through a zoning system of culling and supplemental feeding, which was shown to considerably alter bear distribution, local densities, diet and activity patterns (Jerina and Adamič, 2008; Jerina et al., 2013; Kavčič et al., 2015; Steyaert et al., 2014). We speculated that these management actions could influence interactions between bears and the lynx (Krofel et al., 2012a). Here we tested this hypothesis. We predicted that the proportion of lynx kills usurped by bears would cumulatively increase with: 1) higher local bear densities, 2) higher bear movement rates, and 3) proximity to bear feeding sites.

2. Material and methods

2.1. Study area and study species

The study was conducted in the Northern Dinaric Mountain Range in Slovenia (45°25′–45°47'N, 14°15′–14°50'E) in mixed temperate forests dominated by fir and beech (Omphalodo-Fagetum s. lat.). The altitudes range from 200 m to the peak of Mount Snežnik at 1796 m. The climate is a mix of influences from the Alps, the Mediterranean sea and the Pannonia basin with annual temperature averaging 5–8 °C, ranging from average maximum of 32 °C to a minimum of −20 °C, and average annual precipitation of 1400–3500 mm.

The study area encompasses the north-western part of the transboundary Alps-Dinaric–Pindos brown bear population. Here bears are under strong influence of various human activities and management measures, which created a large gradient in bear densities. Bears were nearly extirpated in the late 19th century, but since the 1940s, their numbers and distribution increased due to conservation measures, including establishment of the Core Bear Protective Area (CBPA) of 3500 km^2 within the Dinaric Range in 1966, where bear hunting was strictly regulated (Simonič, 1994). In contrast, bears outside this area (mostly dispersing individuals) experienced higher harvest rates and consequently bear densities there have remained low (Jerina and Adamič, 2008; Krofel et al., 2010). Currently, bears are present in approximately half of the country, although the majority (95%) of bears are concentrated in 19% of Slovenian territory. The average density of brown bears in most of the lynx range in Slovenia is estimated at 12 bears/100 km^2, with local densities exceeding 40 bears/100 km^2 (Jerina et al., 2013).

Today the most important bear management practices are hunting and supplemental feeding. In Slovenia, 75% of bear mortality is human-caused (Jerina and Krofel, 2012) and 20% of the brown bear population is removed annually through legal hunting (Krofel et al., 2012b). Supplemental feeding in the central part of the CBPA is intensive, with high-energy supplemental food, especially corn, available to bears year-round and in high quantities (on average, 12,500 kg/100 km^2 annually) at numerous feeding sites. Supplemental food represents 34% of dietary energy content ingested by bears in this area (Kavčič et al., 2015). Locally intensive supplemental feeding likely increases carrying capacity and may result in some of the highest recorded densities and reproduction rates of brown bears worldwide (Jerina et al., 2013; Kavčič et al., 2015; Reding, 2015). It has also been observed that intensive supplemental feeding affects habitat use of bears in Slovenia (Jerina et al., 2012) and likely shortens bear denning periods by as much as 20% compared to areas without supplemental feeding; currently average denning period for bears in Slovenia lasts 75 days (Krofel et al., 2013a).

Eurasian lynx are the largest felid in Europe and along with the grey wolf (*Canis lupus*), the main predator of wild ungulates on the continent (Jedrzejewski et al., 2011). In most of Europe, lynx specialize in hunting European roe deer (*Capreolus capreolus*), which they typically consume in a course of several days (Breitenmoser and Breitenmoser-Würsten, 2008). Lynx in Slovenia are part of the Dinaric lynx population, one of the most threatened populations in Europe (Kaczensky et al., 2013; Sindičić et al., 2013). The population is rapidly declining in Slovenia with estimated 15–25 residential animals (Kos et al., 2012). In the study area, lynx hunt mainly wild ungulates, which together represent 88% of biomass consumed (Krofel et al., 2011). Roe deer is the main prey species (79% of consumed biomass), with edible dormouse (*Glis glis*) and red deer (*Cervus elaphus*) as important alternative prey, each representing approximately 7% of consumed biomass.

2.2. Locating kills and telemetry

We measured lynx predation, lynx prey consumption, and bear movements using telemetry. During 2005–2011, eight lynx (five females and three males) and 33 bears (14 females and 19 males) were captured and equipped with telemetry collars (five lynx and all bears with GPS–VHF collars and three lynx with VHF collars) using standard protocols (see Krofel et al. (2013b) and Jerina et al. (2012) for details on capture and immobilization of lynx and bear, respectively). GPS collars were scheduled to attempt 7–8 GPS fixes per day for lynx and 12–24 fixes per day for bears.

We used snow-tracking and GPS location cluster analysis of lynx telemetry data to locate kill sites with prey remains of ungulates killed by lynx (see Krofel et al., 2013b for details). At each kill site we checked for signs of bear presence (footprints, hair, scat, or characteristic signs of consumption — e.g. large broken bones or crushed skull) or monitored the carcass consumption with the use of automatic infra-red video cameras with motion detectors (Fig. 1; Krofel et al., 2012a). Only carcasses of roe deer, the main lynx prey, were included in this study. Kleptoparasitic interaction (i.e. kill being found by bears) was noted only when bears usurped the kill during the time while lynx were still feeding on them. Lynx pin the study area fed on roe deer for 4.4 days on average if kills were not usurped by bears (Krofel et al., 2012a). We typically visited the kill sites the day after lynx abandoned the kill site (median time of visit: 4.5 days after the kill was made), but on some occasions ($n = 13$) we arrived earlier to install the video system at the kill site. When a kill site was too old to reliably asses it, these data was not included in the analysis.

2.3. Analysing effects of bear densities, movement rates and supplemental feeding sites

For each lynx kill site we determined the local bear density. We used raster map of local bear population densities in Slovenia with 1 km^2 resolution, which was produced using voting classifications method based