Ecological Economics 143 (2017) 188–198

Contents lists available at ScienceDirect

Ecological Economics

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

Analysis

Costs of Livestock Depredation by Large Carnivores in Sweden 2001 to 2013

Marit Widman [1], Katarina Elofsson *

Swedish University of Agricultural Sciences, Box 7013, SE-750 07 Uppsala, Sweden

ARTICLE INFO

Article history:
Received 31 January 2017
Received in revised form 29 May 2017
Accepted 8 July 2017
Available online xxxx

Keywords:
Wildlife compensation
Livestock depredation
Lynx
Wolf
Brown bear
Sheep

ABSTRACT

Livestock depredation by large carnivores entails economic damage to farmers in many parts of the world. The aim of this paper is to analyse and compare the costs of livestock depredation by carnivores in Sweden across different carnivore species and counties. To this end, we estimate the government's compensation cost function using Swedish data on the county level over the period of 2001 to 2013. Compensation costs due to depredation by three large carnivores are considered: the brown bear (*Ursus arctos*), the wolf (*Canis lupus*) and the lynx (*Lynx lynx*). The results show that a 1% increase in the density of the carnivores leads to a 0.3–0.4% increase in compensation costs, whereas a 1% increase in the density of sheep results in a 0.8 and 1.1% increase in the compensation costs for brown bears and wolves, respectively. A larger share of unfenced pastures is associated with higher compensation costs for brown bear. The marginal cost of an additional carnivore individual varies considerably between counties, ranging between 1 and 82 EUR for lynxes, 0 and 266 EUR for brown bears, and 52 and 1067 EUR for wolves.

1. Introduction

Livestock depredation by large carnivores entails economic damage to farmers in different parts of the world (Asheim and Mysterud, 2004; Baker et al., 2008; Howery and DeLiberto, 2004; Häggmark et al., 2015; Ramler et al., 2014; Sommers et al., 2010). Increased legal protection of large carnivores leads to larger carnivore populations in areas with high human and livestock densities (Linnell et al., 2001) and therefore higher risk, increasing depredation costs. This may add to the conflicts between conservation interests and livestock owners (Dickman, 2010; Dickman et al., 2011; Johansson et al., 2012; Karlsson and Sjöström, 2011; Naughton-Treves et al., 2003; Redpath et al., 2013; Treves and Bruskotter, 2014; Young et al., 2010). Frequently, policies are instituted to support conservation laws, aiming to reduce the economic risk to individual livestock holders, increase the tolerance towards carnivores, and reduce the incentives for illegal hunting (Nyhus et al., 2005). Policy instruments include wildlife damage compensation; subsidies for prevention measures; zoning regulations that restrict, e.g., land use or carnivore hunting; revenue-sharing schemes; and conservation payments (Dickman et al., 2011; Treves and Karanth, 2003; Zabel et al., 2011, 2014).

Carnivore conservation policies have been under intensive debate in Sweden over the last decades. Large carnivores such as brown bears, lynxes, wolves and wolverines are protected by law (EPA, 2006). This has led to a re-establishment of wolves and brown bears from levels close to extinction in the beginning of last century (Linnell et al., 2001; Skonhoft, 2006). Currently, wolves, brown bears and lynxes all reach governmental targets for the minimum population levels required for favourable conservation status, and wolverines are close to the target (Government, 2013). Wolves, brown bears and wolverines are mainly found in central and north Sweden where human and livestock population densities are low, while the lynx is more evenly distributed over the country. The current spatial distribution of the species implies that the negative effects in terms of predation on livestock and game species are lower than would be the case under a more even allocation (Boman et al., 2003). However, the national management plans for wolves and brown bears state that a more even distribution of the species over the country is desirable (EPA, 2014a, 2014b), which can imply further establishment of the species in the more densely inhabited areas in the southern parts of the country. This raises the question of whether changes in carnivore populations affect livestock depredation costs differently in different parts of the country.

Sheep are the most commonly attacked species in Sweden: approximately 500 sheep are killed or injured each year (Elofsson et al., 2015). Other livestock are seldom attacked; cattle, goats and poultry together account for only 1 to 4% of the annual total number of killed or injured livestock. Damage on livestock caused by protected large carnivores is eligible for compensation. The compensation is determined on a case-by-case basis by county administrations (Cinque, 2011; Elofsson et al., 2015). Recommendations on compensation per sheep and per work

* Corresponding author.
E-mail address: Katarina.Elofsson@slu.se (K. Elofsson).
[1] Present address: National Institute of Economic Research, Box 3116, SE-103 62 Stockholm, Sweden.

http://dx.doi.org/10.1016/j.ecolecon.2017.07.008

hour are issued by the Wildlife Damage Centre but are not binding for the county administrations' decisions. Compensation can account for, e.g., higher market values for organic livestock or livestock in gestation, veterinary expenses, additional labour hours, and lost environmental subsidies for natural grazing lands when predation impedes grazing. In practice, county administrators tend to interpret compensation rules generously because they believe decisions should seek to increase acceptance of the predator policy (Cinque, 2011). Funds for compensation are allocated on an annual basis by the Environmental Protection Agency, EPA, to the county administrations based on their claimed needs for this purpose: in 2013, the total compensation amounted to 0.25 million EUR. The compensation rules are the same for ordinary farms,[2] where the livestock are kept within fences, and summer pasture farms, where free-range grazing is applied. To be classified as a summer pasture farm by the Board of Agriculture, there must be a fully functional building in place that has historically been used for summer pasture farming and that is not used as a permanent residence. Moreover, the livestock should be at the summer farm only between May and October, while spending the rest of the year at a home farm, located at a distance from the summer pasture farm. Because summer pasture farms do not use fences, livestock is more exposed to attacks. Evidence from Norway seems to support this: there, almost all sheep graze unattended on unfenced land in the summer, and the share of killed sheep is at least twice as high as in Sweden (Odden et al., 2002; Ross et al., 2016; Skonhoft, 2016). The average compensation for an attack at a summer pasture farm was approximately 1600 EUR for the period of 2003–2013, which can be compared to 950 EUR per attack for all farms (Elofsson et al., 2015). The higher compensation for summer farms can be due to, e.g., increased labour required after an attack, larger profits losses for on-farm processed food products, or more animals being killed or injured in one attack. It is argued in the debate that increasing carnivore populations may constitute a threat to the high natural and cultural benefits these summer pasture farms provide (Hedén, 2014).

The provision of wildlife compensation payments can reduce the incentives for livestock holders to undertake proactive measures (Bulte and Rondeau, 2005; Rollins and Briggs, 1996; Zabel et al., 2011). To counteract such effects, the Swedish policy includes subsidies for the installation of so-called 'carnivore electric fences', designed to keep carnivores out; in 2013, approximately 1.5 million EUR was paid to farmers for such preventive measures.

Few studies compare wildlife depredation costs between predators and across space. Boman (1995) investigates livestock depredation costs for different predator species using data on a national level and calculates the costs of meeting politically targeted increases in predator populations. Bostedt and Grahn (2008) follow a similar approach, while accounting for the potentially moderating effect of alternative wild prey species. A few studies make comparisons of depredation costs across space: Boman et al. (2003) analyse the optimal spatial distribution of wolves in Sweden assuming that the cost of an additional wolf is determined by the relative share of moose and reindeer in the wolf diet in different regions. Jones (2004) compares depredation costs across ten USDA farm production regions using input-output analysis, thereby accounting for both the direct impact on the sheep industry and the indirect impact on the rest of the economy.

The ecological literature shows that livestock depredation depends on predators' preferences for, and the availability of, alternative wild prey (Barja, 2009; Gula, 2008; Khorozyan et al., 2015; Müller, 2006; Sidorovich et al., 2003; Stahl et al., 2001), the exposure of livestock to carnivore attacks (Ghoddousi et al., 2016; Otstavel et al., 2009), and predator control (Wielgus and Peebles, 2014). Moreover, studies on the social dimension of human-carnivore conflicts show that livestock predation is only one of the causes of such conflicts. Other reasons include fear of carnivores (Johansson et al., 2012), predation on hunted species and killing of hunting dogs (Swenson and Andrén, 2005), insufficient information, unfair conservation planning processes or processes that encourage strategic behaviour by stakeholders (Redpath et al., 2013; von Essen and Hansen, 2015) and urban-rural tensions (Skonhoft, 2016).

The aim of this paper is to investigate how the wildlife damage compensation cost for additional carnivores varies across different carnivore species and counties in Sweden. We analyse how the EPA's costs for wildlife damage compensation, administered by the different counties, are affected by the population sizes of three different carnivore species, domesticated livestock, and alternative wild and semi-domesticated prey, recognizing that livestock exposure affects depredation and hence compensation costs. We account for livestock exposure through consideration of the share of unfenced pasture and the use of carnivore electrical fences. Compensation practices can change over time or be applied differently in different counties. In addition, variations in weather between years and in landscape conditions in different counties can affect depredation rates. To capture such variations in time and space, we include time fixed effects and use best linear unbiased predictors (BLUPs) to estimate random effects for each county.

The study uses Swedish data on the county level over the years 2001–2013. Compensation costs due to depredation on domesticated livestock by brown bears (*Ursus arctos*), wolves (*Canis lupus*) and lynxes (*Lynx lynx*) are analysed. Depredation by wolverines is excluded because very few attacks on domesticated livestock have been reported. Costs for depredation on the semi-domesticated reindeer are also excluded because as the compensation scheme for reindeer is fundamentally different from that for domesticated livestock (see Zabel et al., 2011, 2014). The exclusion of costs for depredation on reindeer is a limitation that must be borne in mind when interpreting the results. We use a mixed model approach with panel data to estimate a constant elasticity cost function, implying proportional changes in costs when the explanatory variables are changed. The use of county-level data is advantageous because it implies a larger number of observations compared to earlier studies on wildlife damage compensation costs in Sweden (Boman, 1995; Bostedt and Grahn, 2008) and permits the analysis of differences in compensation costs across counties. The major contributions of the study are the investigation of how livestock exposure and the availability of alternative prey affect the compensation cost and the calculation of the marginal costs of an additional individual of the three predator species, as well as sheep, in different counties.

2. Methods

Our aim is to investigate the EPA's costs for wildlife damage compensation. These costs are determined by the number of killed livestock, the subsequent costs to farmers, and compensation practices. Predator-prey models typically assume that the number of killed prey is a function of the kill rate, i.e., the number of killed prey per predator, and the size of the predator population (see, e.g., Clark, 2010; Vucetich et al., 2011). The kill rate can be a function of prey and, sometimes, predator numbers. There are relatively few sheep in Sweden, and wild prey is abundant (Sand et al., 2014), implying that sheep are only an occasional prey for the studied carnivores. Therefore, the likelihood of carnivore and sheep encounters will matter for the kill rate, suggesting that the effect of additional sheep on the total number of killed sheep should depend on the number of carnivores, and vice versa. Following Boman (1995) and Bostedt and Grahn (2008), we assume that the amounts of predators, P, and livestock, S, affect the number of livestock killed, K, and that the effect of P on K depends on the size of S, and vice versa. Following Boman (1995), Bostedt and Grahn (2008), Zabel et al. (2014) and Skonhoft (2006), we assume that depredation has no feedback effects on the size of the predator populations, i.e., we assume there is no numerical response. Livestock are not an important food source for the studied predators, which mainly feed on wild prey. The brown bear is omnivorous and consumes meat from ungulates, with reindeer being a relatively important food source (Persson et al., 2001; Karlsson

[2] Ordinary farms here include all farms that are not summer pasture farms.