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ORIGINAL ARTICLE

Hunters serving the ecosystem: the contribution of recreational hunting to wild boar population control

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Abstract The extractive nature of recreational hunting may provide a service to both the ecosystem and society, namely the control of problem species. We reviewed the annual wild boar hunting bag data from hunting sites in Asturias (Spain) from 2000/01 to 2013/14, paying particular attention to the evolution on hunting estates after ban periods. We hypothesized that the annual hunting bag after a hunting ban would be larger than that of the pre-ban period, and that this difference could provide an indication of hunters' relative contribution to wild boar population regulation. The total hunting bag grew during the study period, from 3723 wild boar (0.39ind/km^2) in the 2000/01 hunting year to 7593 in that of 2013/14 (0.79ind/km^2)—a mean annual increase of 5.63%. Low hunting quotas cannot be blamed for these growing trends, since no more than 50% of the authorized animals are hunted. The growth of the mean annual pre-ban hunting bag on the estates on which hunting bans took place was 8.46%. The hunting bag grew by 40.33% immediately after the hunting ban ended—a growth rate seven times higher than that of the background hunting bag. This constitutes a proxy of the regulatory effect of hunters on wild boar population growth. Following the remarkable increase after the ban, the wild boar hunting bag attained values that were slightly lower than those of the pre-ban period, which indicates that hunters are able to reduce wild boar abundance. Hunting, therefore, provides an important service to both the ecosystem and society by contributing to regulating the growth of problem species such as the wild boar.

Keywords Ecosystem service · Hunting · Population dynamics · *Sus scrofa* · Wild ungulates

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Introduction

Wild ungulates have recently undergone a notable growth in most of the northern hemisphere in terms of both population density and distribution range (Apollonio et al. 2010). There are many reasons for this expansion, although those most frequently quoted are changes in land use (Acevedo et al. 2011) and in hunting regulations (Putman et al. 2011). The increasing abundance of these species may lead to conflicts with several sectors owing to traffic accidents (Sáenz-de-Santa-María and Tellería 2015), agriculture damage (Herrero et al. 2006), conservation problems (Bueno et al. 2010), and health risks (Gortázar et al. 2016). Effective management actions are, therefore, required if the undesirable situations caused by extremely high abundances of wild ungulates are to be avoided.

The management of game species is a complex process driven by the interactions between the dynamics of the natural system and stakeholders' decision-making and behavior (Bunnefeld et al. 2011; Keuling et al. 2016). Each of these components is able to independently modulate the population trends, signifying that neither can be omitted when planning management actions in order to control population abundance. Adaptive management, during which a constant population monitoring allows managers to update their management system and to gradually adjust their actions, with subsequent changes to the extraction in an iterative process (Walters

1997), has been widely used for hunting regulation, and has made the recovery of iconic species, such as the Iberian wild goat *Capra pyrenaica*, possible (Shackleton 1997). However, the population trends observed for most wild ungulates in Europe provide evidence that adaptive management is currently not efficient with regard to controlling expanding populations. For instance, Massei et al. (2015) reviewed the wild boar (*Sus scrofa*) population trends in Europe and obtained a mean annual growth rate (number of wild boar hunted per year divided by the number of animals hunted the previous year) of approximately 20%; that is, the wild boar population in Europe increases by 20% each year.

Why does current game management not respond to the population trends? Hunting, and particularly recreational hunting, is increasingly perceived by the ever-growing urban population as an unsustainable and debauched extractive activity (Fischer et al. 2013). This perception contributes toward promoting the stabilization of or even a decline in the number of hunters and a low recruitment of new hunters (e.g., Riley et al. 2003). Hunters may now, therefore, be unable to achieve the extraction rates needed to control the remarkable growth that many wild ungulate populations are undergoing (Massei et al. 2015). Fisher et al. (2009) proposed that ecosystem services be defined as "the aspects of ecosystems utilized (actively or passively) to produce human well-being." In this respect, recreational hunting is an ecosystem service appertaining to the group of cultural ecosystem services (Martín-López et al. 2012). However, in this paper, we argue that it is rather the other way round: hunters' extractive activities may provide a key service to both the ecosystem and society.

We reviewed the annual wild boar hunting bag data from non-commercial hunting sites (game reserves and hunting estates), and checked them for situations in which hunting was temporarily banned for at least one full hunting year. We hypothesized that the annual wild boar hunting bag after a hunting ban would be larger than that of the pre-ban period, and that this difference might provide an indication of hunters' relative contributions to wild boar population regulation.

Materials and methods

This study was conducted throughout Asturias, a province located in northwestern Spain (43° 20′ 00 ″ N 6° 00′ 00 ″ O), where hunting is essentially non-commercial and still traditional among rural inhabitants. Asturias, as a part of the Euro-Siberian climatic dominion is characterized by its Atlantic climate. The influence of the Cantabrian Sea signifies that there is only a moderate fluctuation in seasonal (winter-summer) and daily temperatures and that no droughts occur. Food, water, and shelter are not limiting factors for wild boar in any season in Asturias.

This region is divided into game reserves (n = 17; mean size 12,446 ha ± SD 8489 ha, range 2884–29,870 ha) and estates (n = 60; mean size 12,744 ha ± SD 10,125 ha, range 3270–53,895 ha) used for hunting purposes. The former are managed by the regional authorities and the latter by local hunting clubs under the supervision of the regional authorities. The game reserves occupy 19.8% of Asturias and the hunting estates occupy 71.2%, while hunting is prohibited in the remaining territories (9.0%). Hunting years typically start in September and last until the February of the following year, with most hunting events taking place on Thursdays, Saturdays, and Sundays. Wild boar hunting occurs mostly in the form of small hunting battues or driven hunts in which 12–15 hunters participate (see Segura et al. 2014).

The government records the number of wild boar shot on the hunting sites each year, although roadkills and other mortalities are not recorded. Hunting bag statistics can be used as reliable indices of the relative abundance of wild boar (e.g., Boitani et al. 1995). These indices have been used for, among other purposes, population monitoring over long periods of time (e.g., Sáez-Royuela and Tellería 1986; Imperio et al. 2010), on large spatial scales (e.g., Acevedo et al. 2014; Alexander et al. 2016), and also to monitor populations under contrasting hunting management strategies in Spain (Acevedo et al. 2007). Finally, indices based on harvest data were used as a surrogate for population growth rate (Mysterud et al. 2007). In this study, we describe the temporal variation in the number of wild boar hunted annually from 2000/01 to 2013/14. We paid particular attention to the effect of temporal hunting bans on the wild boar hunted immediately after ban periods (the hunting year after the ban was lifted) and to the evolution of the wild boar hunting bag prior to and after the ban. The hunting bans were carried out on six hunting estates (mean size 14,473 ha ± SD 7154 ha, range 5406–23,530 ha) and lasted between one and three hunting years. We estimated mean pre-ban and post-ban growth rates by considering the three hunting years before and after the ban, respectively. The ban periods are principally established on the basis of purely administrative non-ecological issues. Data for hunting estates were unavailable for 2002/03. For a given time period (n hunting years) and on the basis of the hunting bags for the first (N_1) and the last hunting year (N_n), annual growth rate (GR) was modeled using the following expression: $\mathrm{GR} = \frac{1}{n}\sum_{t=1}^{n}\frac{N_{t+1}-N_t}{N_t}x100$. The effect of the hunting ban was assessed by estimating GRs: annual GRs for the hunting years before and after the ban period, along with the GR that represents the hunting bag of the hunting year immediately after the hunting ban ended in relation to the mean hunting bag for a 3-year period before the ban.

Results and discussion

The total wild boar hunting bag increased in Asturias during our study period, from the 3723 wild boar (0.39 ind/km^2) shot in the 2000/01 hunting year to the 7593 in that of 2013/14 (0.79 ind/km^2). These are relatively low harvest rates per km^2 in the context of other European populations (range 0.01–10 ind/km^2; Melis et al. 2006) and are low to medium for the Iberian Peninsula (range 0–2.5 ind/km^2; Acevedo et al. 2014). This 14-year period witnessed a duplication of the wild boar hunting bag, representing a mean annual increase of 5.63%. This implies a lower growth rate in relation to the previous 5-year period (for Asturias; from the 1994/95 [1744 wild boar shot; Nores et al. 2008] to the 2000/01 hunting years), amounting to 13.47%. These results are compatible with a scenario in which the wild boar population—even if still expanding—could be reaching its ecological carrying capacity (e.g., Bowyer et al. 2014). Even though the current annual wild boar population growth in Asturias is already a cause for concern as regards, for instance, the maintenance of animal tuberculosis (e.g., Muñoz-Mendoza et al. 2013), it is within the lower range of wild boar growth rates reported for European countries (Massei et al. 2015). The values obtained for Asturias correspond to rates estimated for intermediate-quality environments (Bieber and Ruf 2005). It is, in fact, more than four times lower than the mean annual wild boar population growth calculated for Spain (24% annual growth from 1980 to 2010, according to the Spanish Hunters' Federation).

But what of the role of hunting regulation in the hunters' capacity to control wild boar populations? In Asturias, the hunting quota for wild boar per hunting event (3–6 animals) would appear low. However, the hunting bag data show that no more than 50% of the authorized animals are hunted in each battue (Fig. 1). This proves that inadequate (too small) quotas cannot be held responsible for the growing trend in wild boar populations. The hunters' inability to control wild boar numbers could, in contrast, be explained by an insufficient hunting effort, as the total mortality rates are less than the net reproduction (see also Keuling et al. 2013, 2016; Frauendorf et al. 2016). Hunters' efficiency is dependent on the landscape structure and is positively related to the hunting effort, namely the number of hunters, hunting days, etc. (Acevedo et al. 2009). Our results coincide with those of Geisser and Reyer (2004), and we therefore suggest that local teams should place more emphasis on the development of new hunting models in order to reduce the growth of wild boar populations. Since the number of hunters and their recruitment is generally decreasing in Europe (Massei et al. 2015), models with which to maximize the hunting efficacy with a reduced number of hunters (for instance longer hunting years, more hunting days, and longer time spent hunting wild boar rather than small game species) should be explored as a means to effectively reduce wild boar population growth.

On the six hunting estates where hunting bans took place, the mean annual pre-ban growth rate was 8.46% (SD 3.22%). The general trend in all cases in which hunting bans (1–3 years long) occurred during the study period was a growth in the wild boar hunting bag, but some notable increases in this number were observed immediately after the hunting bans (Fig. 2). In these six cases, the hunting bag grew, on average, by 40.33% (SD 20.43%; range 6.5–70.5%) immediately after the hunting ban ended. The growth rate was seven times higher than the background hunting bag growth of 5.63%, and four times higher than the mean annual pre-ban growth rate on these six sites (see Fig. 3). The differences between growth rates both before and after the ban in relation to those immediately after the ban ended were significant (Wilcoxon matched-pairs test; $z = 2.201$, $p < 0.05$, and $z = 2.202$, $p < 0.05$, respectively), as were the differences between growth rates before and after the ban ($z = 1.992$, $p = 0.046$). The rate immediately after the hunting ban ended can be considered as a proxy of the regulatory effect of hunting on wild boar population growth in the study region.

After the increase immediately after the ban ended, the annual wild boar hunting bag remained more stable with similar values to those of the pre-ban period, although with some variability among sites (Fig. 2). The generally stable, and locally even negative, wild boar hunting bag trends after the hunting bans indicate that hunters are indeed able to reduce wild boar abundance, at least in this study area. This result is likely related to the social carrying capacity (Wagar 1964) which, in this species, could be modulated by assumable wild boar damage (e.g., Schley et al. 2008). In Asturias, damage caused by wild boar is compensated by the local hunting clubs, and is the most significant annual cost for hunters (615,725.00€ annually during the study period; F. Quirós-Fernández, unpublished data). Our results show that even with a scarce number of hunters and a limited number of hunting days, hunters can increase the hunting bag and are, in some circumstances, able to control the wild boar population. We suggest that this switch towards a larger hunting bag is possibly driven by the increasing amount of damage that must be compensated by the local hunting clubs during the ban. The challenge for hunters, therefore, involves finding a balance between wild boar abundance and the amount of damage caused. Another way to control the wild boar populations would thus be to raise hunters' awareness of the economic and—mainly—ecological advantages of attempting to attain higher wild boar hunting bags. Hunters would thus be able to provide a key service to both the ecosystem and to society. In this context, it is important to note that we advocate preventing wild boar population growth and eventually balancing high densities, while we do not propose the

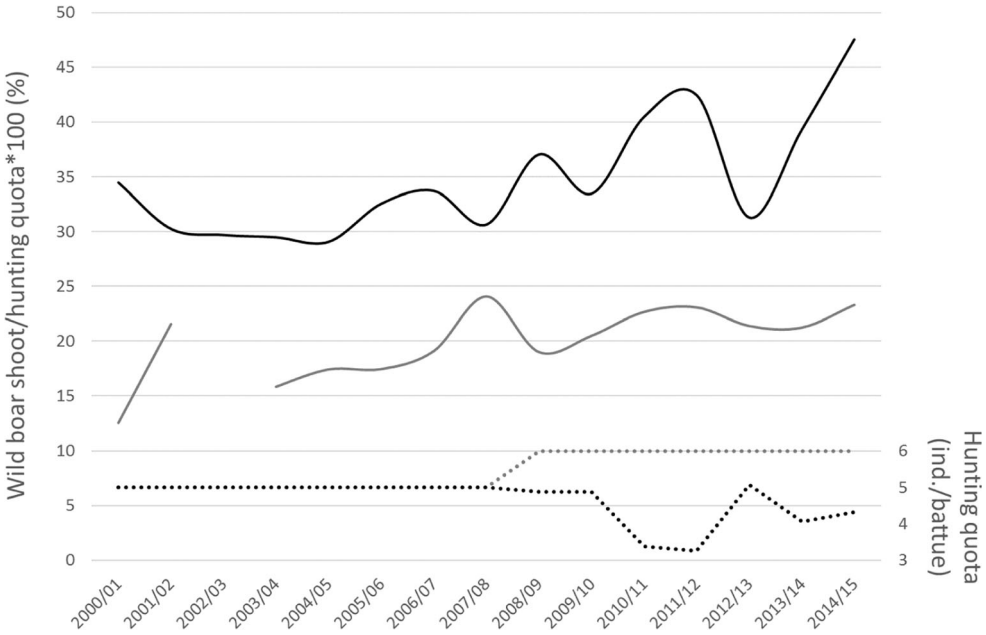

Fig. 1 Mean percentage of wild boar shot in relation to the hunting quota per battue (*solid lines*) in game reserves (*black*) and on hunting estates (*gray*) in Asturias (Spain) between 2000/01 and 2014/15. The *dotted lines* represent the annual established hunting quotas (wild boar shot/battue) for game reserves and hunting estates (same color codes). The hunting bag in Asturias (Spain) from 2000/01 until 2014/15 for the game reserves and the hunting estates lies below 50% of the hunting quota

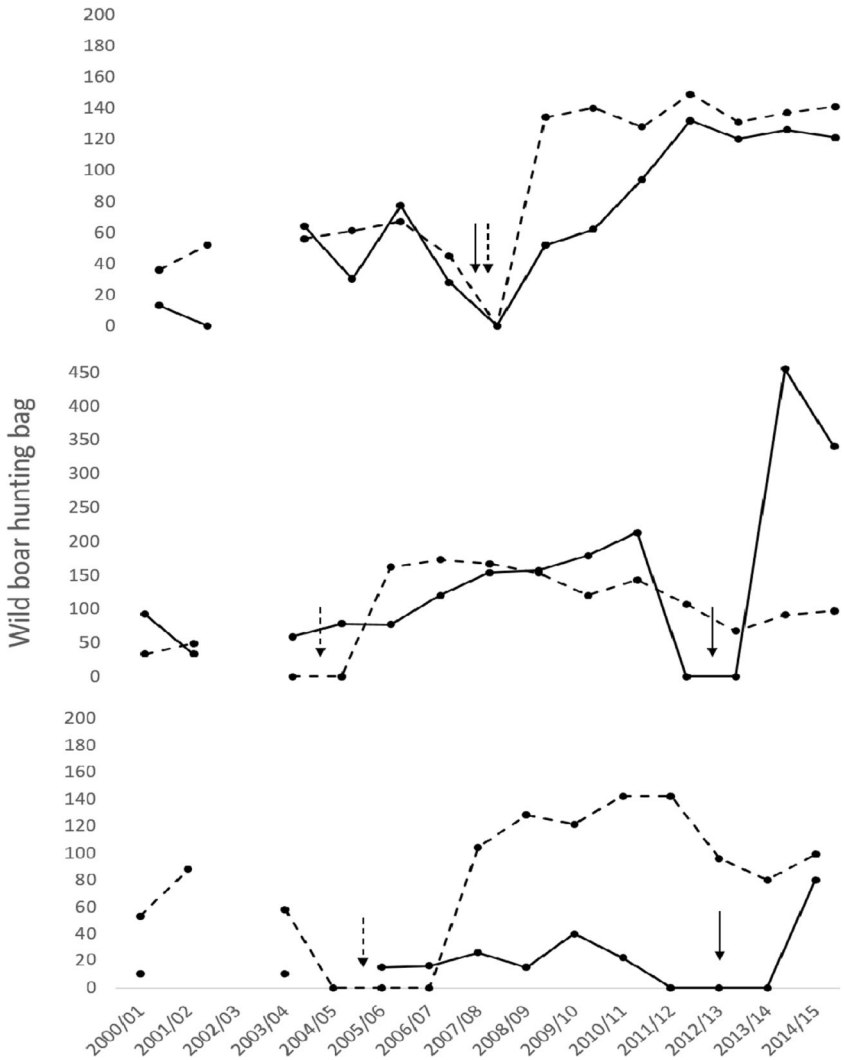

Fig. 2 Total wild boar hunting bags (per hunting year, from 2000/01 to 2014/15) on six hunting estates in Asturias (Spain) where hunting was temporally banned (*arrows*) for one (*upper graph*; two hunting estates), two (*middle*; two hunting estates), and three (*lower*; two hunting estates) hunting years. Remarkable increases in the hunting bags were recorded immediately after hunting restarted on all hunting estates, without exception

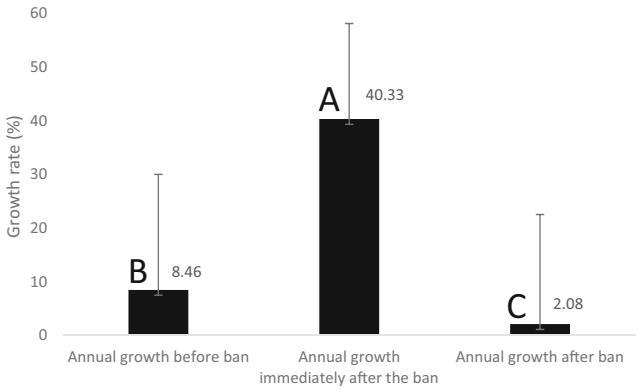

Fig. 3 Relative growth rate of the annual wild boar hunting bag before, immediately after the ban ended, and after a hunting ban of 1 to 3 years for the six hunting estates in Asturias, Spain. Growth rates shown with the same capital letter did not differ significantly, according to the Wilcoxon matched-pairs test ($p > 0.05$); growth rate significantly increased immediately after the ban but the rate years after was similar to that observed before the ban period

suppression of an ecologically important native species (see Mori et al. 2017).

If no hunting had taken place for two hunting years in Asturias, an exponential growth of wild boar population would have been expected (Fig. 4). This projection on wild boar population growth is obviously fictitious, since an asymptote would appear as densities approach the carrying capacity. However, the figure suggests that the role of hunters in wild boar population regulation is a significant one. We conclude that hunters (recreational hunting) provide an important service to the ecosystem and to society, by contributing toward regulating the population growth of problem species such as the wild boar. However, this regulatory effect of hunters is currently incomplete, since there is still a mean annual increase in the wild boar hunting bag of 5.63%. Moreover, other factors such as diseases or predation might also contribute to wild boar population control. Future research should, therefore, focus on two important aspects,

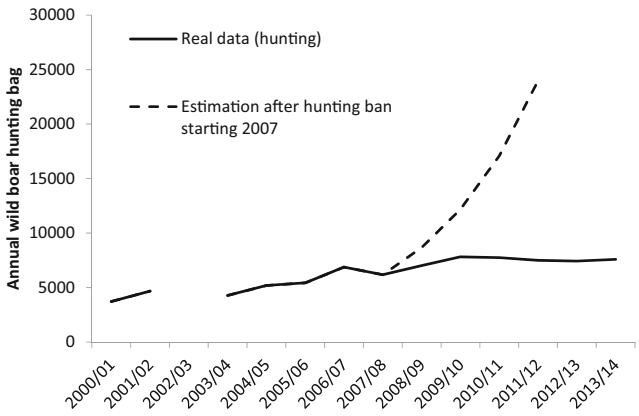

Fig. 4 Mean annual wild boar hunting bag in Asturias (Spain) between 2000/01 and 2013/14 (*solid line*), plotted together with the expected growth of the hunting bag if hunting had ceased completely starting 2007/08 (not considering the carrying capacity)

namely (1) the options to maintain and increase the effect of recreational hunting on the wild boar population, and (2) the relative role played by hunting, diseases and predation in wild boar population dynamics. This is of particular relevance as regards the declining numbers and aging of hunters throughout Europe (Massei et al. 2015).

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