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► **To cite this version:**

C. Guillermo Bueno, Isabel C. Barrio, Ricardo García-González, Concepción L. Alados, Daniel Gómez-García. Does wild boar rooting affect livestock grazing areas in alpine grasslands?. *European Journal of Wildlife Research*, Springer Verlag, 2010, 56 (5), pp.765-770. 10.1007/s10344-010-0372-2 . hal-00578394

HAL Id: hal-00578394

<https://hal.archives-ouvertes.fr/hal-00578394>

Submitted on 20 Mar 2011

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Does wild boar rooting affect livestock grazing areas in alpine grasslands?

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Received: 23 September 2009 / Revised: 20 January 2010 / Accepted: 24 February 2010 / Published online: 20 March 2010
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Abstract Interactions between traditional livestock management practices and wildlife activities are important in the conservation of many mountain ecosystems including the summer rangelands in the Spanish Central Pyrenees, where rooting by wild boar (*Sus scrofa*) is a large disturbance that can reduce the amount of area available to grazing livestock. This study explored the likely impact of wild boar rooting on Pyrenean grasslands. It quantified the extent of wild boar rooting in livestock grazing areas and determined whether wild boars selected or avoided areas depending on the type of livestock and stocking rates. Wild boar rooting affected 16% of livestock grazing area and occurred in sites that were grazed by cattle, rather than by sheep. In addition, a preference for areas that had intermediate stocking rates was found. The relationship between the increase in the number of wild boars and trends in livestock management suggests that the extent of wild boar rooting will increase especially in cattle grazing areas, and therefore, the area available for cattle grazing in Pyrenean mountain rangelands would decrease significantly.

Keywords Digging · Disturbance · Cattle · Sheep · Stocking rate · *Sus scrofa*

Communicated by C. Gortázar

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Introduction

Mountain grasslands are mostly protected habitats and a major conservation priority in Europe (Council of the European Communities 1992). Those habitats have high socio-economic value because of the traditional livestock management practices, which sustain local economies, preserve cultural values and produce high quality food (Luick 1998; Aldezabal 2001; Fillat et al. 2008). Traditional European livestock management practices provide a balance between grassland production and conservation (Luick 1998; Olf and Ritchie 1998), maintain and enhance the structure and diversity of mountain grasslands (Dullinger 2003; Dennis 2008; Sebastià et al. 2008) and prevent shrub encroachment (Pasche et al. 2004).

In the last century, changes in land use have had a significant impact on the structure and use of mountain ecosystems in Spain. Changes in grazing practices, i.e. a decrease in extensive livestock practices and a trend towards an increase in the number of cattle and a decrease in the number of sheep in extant herds because of the crisis in transhumance systems (Luick 1998; Lasanta-Martínez et al. 2005), have led to the abandonment of grazing activities in some areas mostly used for sheep herding (Vicente-Serrano 2004). On the other hand, rural abandonment and an increase in forested areas (Lasanta-Martínez et al. 2005) have indirectly increased wild boar populations because boars find more abundant and persistent shelters from hunting (Herrero et al. 2008). Wild boar disturbances, i.e. rooting, have severely altered the structure and composition of grasslands in mountain ecosystems (Gallo Orsi et al. 1995; Welander 2000b; Bueno et al. 2009). In digging for food, wild boars turn over the soil, which can impact from a few square centimetres to hundreds of hectares (Gallo Orsi et al. 1995; Massei and Genov 2004). Thus, they can disturb large areas, which can reduce the

amount of area available to livestock (Tisdell 1982). Such a reduction can have an impact on traditional livestock management and local economies (Gortázar et al. 2000). The need to quantify the extent of wild boar rooting in areas used by livestock is especially important in protected areas where livestock grazing is coupled with wildlife management and conservation (Council of the European Communities 1992). Several studies have contributed to the understanding of the main factors involved in the extent and distribution of wild boar rooting in mountain grasslands (Gallo Orsi et al. 1995; Welander 2000a; Bueno et al. 2009), but there is little information about the interactions between wild boar rooting and traditional livestock management practices, especially in mountain environments. Livestock grazing appears to influence the occurrence of wild boar rooting in some areas (Bueno et al. 2009), but most studies have focused on the impact of wild boar disturbances on crops, rather than livestock (Meriggi and Sacchi 1992; Calenge et al. 2004; Wilson 2004; Herrero et al. 2006) and, to a lesser extent, on competition between wild boar and livestock for grazing areas (Kuiters et al. 2005). The aim of this study is to explore the occurrence of wild boar rooting within livestock grazing areas in alpine grasslands, to determine its likely impact on livestock grazing activities. To address this objective, we quantify the extent of wild boar rooting in livestock grazing areas and evaluate the selection of wild boar rooting for areas used by cattle and/or sheep. We also evaluate if wild boar rooting occurs preferably at certain stocking rates, to infer to which extent grazing activities might be affected by wild boar rooting in the near future considering the current trends in livestock management.

Methods

Study area

The study was conducted in Ordesa and Monte Perdido National Park (OMPNP) (42° 36'N, 0° 00') in the Spanish Central Pyrenees. The study area comprised 3,863 ha of natural grasslands between 1,500 and 2,800 m a.s.l., where the average annual temperature is 5°C and average annual precipitation is about 1,720 mm, which is concentrated in spring and autumn (García-González et al. 2007). The topography, lithography, and vegetation of the study area were broadly representative of the Spanish Central Pyrenees. Within the area, livestock management involves large herds of cattle and sheep, which use about 35% of the area during the grazing season (from July to October). In 2004, the numbers of cattle and sheep in the area were 1,350 and 9,580, respectively (data provided by the OMPNP). In the region, wild boars are abundant

(~3.3 boars/km²) despite being heavily hunted (Herrero et al. 2005). They inhabit nearby forests and frequently visit mountain grasslands to search for food, especially when food is scarce in the forests and grassland soils are friable (Welander 2000a; Herrero et al. 2005). Hunting and providing supplementary feeding is not allowed within the National Park.

Wild boar rooting and stocking rate maps

To determine the extent and distribution of wild boar disturbances, the study area was mapped during summer 2005 (June–August). Disturbance patches were drawn on an aerial photograph (scale 1:3,500), georeferenced by more than 1,600 GPS points and incorporated into a GIS, generating a digital disturbance map (scale 1:5,000). The minimum mapping unit was 5 m², and disturbances separated less than 1 m were mapped jointly within the same disturbed patch. The accuracy of the map was 90.6%, obtained by performing a confusion matrix (Congalton and Green 1999). Two hundred forty points were randomly located in the digital disturbance map, stratified between disturbed and undisturbed areas (120 points each) and checked in the field (for more details in this methodology, see Bueno et al. 2009). The map of the stocking rates was generated using a previous map for OMPNP based on an intensive monitoring of livestock movement during a whole grazing season in 1991 (Aldezabal et al. 1992) and updating the numbers of cattle and sheep for 2004 (García-González et al. 2007), which were expressed in standard livestock units (a 500-kg cow or six sheep) per hectare (SLU/ha; for more details see García-González et al. 2007). Shepherds and cowboys did not change from 1991 to 2004 (R. García-González, personal communication), so the same overall grazing areas used by livestock during the grazing season can be safely assumed (García González et al. 1990; García-González et al. 2007; Fillat et al. 2008).

Resource selection analysis

To determine whether wild boar rooting was related to grazing areas, we performed a resource selection analysis comparing the rooted (hectare) to the available (hectare) surface, in which statistical inferences were based on the Chi-squared test. The null hypothesis was that wild boars randomly selected areas used or not by livestock in proportion to availability (Manly et al. 1993). When the observed and expected use of areas differed significantly from that based on availability, we used Bonferroni's confidence intervals to detect significant selection or avoidance of areas by wild boar (Manly et al. 1993; Allredge and Griswold 2006). In addition, within livestock

grazing areas, we distinguished between the areas used by cattle and those used by sheep. Areas used mutually (<18% of the area grazed) were categorised as cattle grazing or sheep grazing areas depending on their relative contributions (>50%) to the overall stocking rate. To extract data from the GIS maps, we used ArcGis 9.2.

Generalised additive models

To describe the relationships between the presence/absence of wild boar rooting and the stocking rates of cattle and sheep, we used univariate binomial Generalized Additive Models (GAM) with a logit link (Hastie and Tibshirani 1990; Nogués-Bravo 2006). To generate the response variable, i.e. occurrence of wild boar rooting, a sample of 1,000 points was stratified into two classes based on the presence or absence of wild boar rooting (500 points inside and 500 points outside disturbed areas). To avoid spatial autocorrelation, points were chosen randomly but were ≥ 50 m apart (Bueno et al. 2009). Predictor variables for each model, i.e. sheep and cattle stocking rates, respectively, were modelled using cubic regression splines, and the optimal amount of smoothing was estimated via cross-validation (Zuur et al. 2009). To improve the fit of the model, stocking rates were log-transformed, which was appropriate because, within the study area, a few areas were used very intensively by livestock and most areas were used rarely or not at all (Aldezabal 2001). All statistical analyses were performed using R 2.7.2 (R Development Core Team 2008) and the *mcgv* package (Hector et al. 1999).

Results

In OMPNP, rooting by wild boars was evident in 16.2% of the area used by livestock (206.6 ha out of 1268.2 ha); 20.8% of the areas used by cattle (103.01 ha out of 495.25 ha) and 13.4% of those used by sheep (103.58 ha out of 772.96 ha) were rooted. According to their availability within the total area studied in OMPNP, areas previously grazed by livestock were selected by wild boar for rooting, and non-grazed areas were avoided (Fig. 1a; Chi-squared = 146.85, $p < 0.001$). Within grazed areas, those holding cattle were significantly selected whereas those used by sheep were avoided by foraging wild boars (Fig. 1b; Chi-squared = 10.29, $p < 0.05$).

Both sheep and cattle stocking densities showed a non-linear pattern on the response. After cross-validation, the effective degrees of freedom were set to 3.272 and 2.198 for sheep and cattle, respectively. Effective degrees of freedom reflect the ruggedness of the smoothing parameter, being values close to one straight line and higher values indicating non-linearities. In both models,

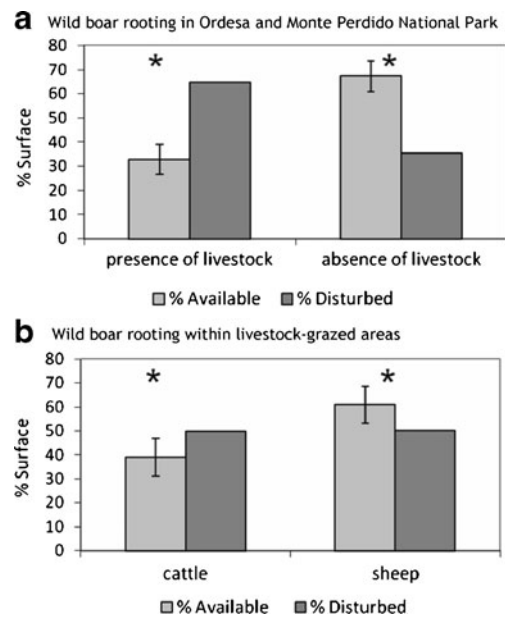


Fig. 1 Wild boar rooting **a** in Ordesa and Monte Perdido National Park and **b** within livestock-grazed areas. Whiskers in the percentages of available surface (light grey bars) represent Bonferroni confidence intervals: non-random selection by wild boar occurred if these intervals are exceeded by the proportion of disturbed area (dark grey bars) while significant avoidance occurs when these intervals are not reached. Asterisks indicate significant cases ($p < 0.05$)

the smoothing term was highly significant (sheep Chi-squared=69.85, $p=0.000$; cattle Chi-squared = 201.9, $p=0.000$). Areas grazed by cattle had a higher occurrence of wild boar rooting among a wider range of stocking rates compared to the areas grazed by sheep (Fig. 2). The presence of wild boar rooting reached its maximum where the sheep stocking rate was 0.03 SLU/ha (Fig. 2a). At higher stocking rates (up to 0.36 SLU/ha), this presence was reduced, and no response was shown further on. Wild boar rooting was largest at cattle stocking rates between 0.04 and 0.26 SLU/ha, and at higher rates, rooting affected a smaller extent (Fig. 2b).

Discussion

In the protected Pyrenean alpine grasslands of the OMPNP, Spain, wild boar rooting affected up to 16% of the area available to grazing livestock, which might represent a serious threat to the already declining livestock grazing activities. In addition, several factors suggest that the trend is worrisome. In recent decades, populations of wild boar have increased in Europe (Geisser and Reyer 2004; Acevedo et al. 2006; Schley et al. 2008). Larger populations might lead to an increase in wild boar disturbances, which has been observed in feral pig populations in other protected mountainous areas (Hone 2002). Furthermore, in the

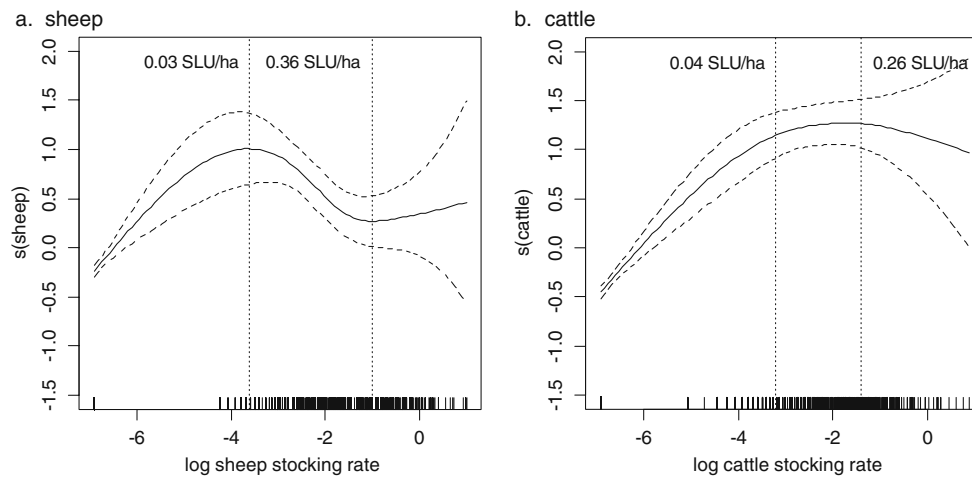


Fig. 2 Estimated smoothing curves (*cubic regression splines*) and point-wise 95% confidence intervals for the Generalized Additive Models containing, respectively, the stocking rates of sheep (**a**) and cattle (**b**) as predictor variables, and the presence/absence of wild boar rooting as the response variable, in Ordesa and Monte Perdido

National Park, Spanish Central Pyrenees. The horizontal axis shows the observed values of stocking rates (*short vertical lines*) and the vertical axis the contribution of the smoother to the fitted values. Critical values of untransformed stocking rates are indicated (*vertical dashed lines*)

OMPNP, disturbances were not randomly distributed among livestock types and stocking rates. For foraging, wild boars appeared to prefer areas that had intermediate stocking rates and those grazed by cattle, and some of the areas grazed by sheep appeared to be avoided. Although the number of livestock in the area has decreased, sheep have been replaced by cattle because the latter are more profitable and less demanding; consequently, the relative number of cattle has increased in mountain ecosystems (Luick 1998; Lasanta-Martínez et al. 2005). Given the relationships between wild boar rooting and the type of livestock and stocking rates, if current livestock management practices continue, wild boar rooting might expand in the near future.

Livestock activities influence the physical properties of soil and nutrient cycles (Bezkorowajnyj et al. 1993; Mikola et al. 2009), which might directly or indirectly influence the foraging behaviour of wild boars. The diet of wild boars in mountain ecosystems is not well studied, but the evidence suggests a clear relationship between rooting activity and the foraging for nutrient-rich foods such as animal proteins and plant storage structures (Baubet et al. 1997; Schley and Roper 2003). Two of the local effects of grazing can explain the differences in wild boar rooting activities among stocking types and rates: faecal droppings differ between sheep and cattle because cattle produce larger scats and sheep disperse smaller pellets widely and in smaller quantities (Aldezabal et al. 1993). Furthermore, cattle dung attracts more insects (Finn and Giller 2002), earthworms (Baubet et al. 1997; Baubet et al. 2003) and voles (Evans et al. 2006) than does sheep dung, and wild boars actively seek these types of foods. In addition, trampling is more

homogeneous and extensive in sheep grazing areas than in cattle grazing areas because sheep have a greater tendency to cluster (Albon et al. 2007). Cattle trampling is heterogeneous and mostly limited to specific pathways, which leaves some patches untouched (Bezkorowajnyj et al. 1993; Albon et al. 2007). Areas that have high stocking rates might be less preferred by wild boar because of the soil compression caused by trampling (Kuiters et al. 2005; Albon et al. 2007), which makes the soil more difficult to dig (Bowman and McDonough 1991; Gallo Orsi et al. 1995; Bueno et al. 2009). Therefore, differences in the use of space by cattle and sheep might explain why cattle grazing areas were more strongly affected by rooting than were the areas grazed by sheep.

Given the current trends in livestock management in Spanish Pyrenees, i.e. an overall decline in the number of livestock and a trend towards cattle, rather than sheep, herding and the increase in wild boar populations, the heterogeneous impact of wild boar rooting might increase in the near future. One result might be a significant reduction in the amount of area suitable for grazing cattle, which might have an adverse effect on the economy in the already depressed extensive livestock management systems in mountain summer rangelands in Spain.

Acknowledgements We thank the staff of OMPNP for the support and data provided. This research was funded by the Spanish Ministry of Science and Innovation and the Spanish Ministry of Environment (MAM 2484/2002-059/2002 and PN-MEC CGL2005-01131/BOS respectively), including a pre-doctoral fellowship to CGB. Earlier versions of the manuscript were considerably improved by S. Palacio, and B. MacWhirter improved the English version.

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