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SHORT COMMUNICATION

Predation of simulated red-legged partridge nests in big game estates from South Central Spain

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Abstract Over the past few decades, the wild boar has been undergoing an expansion in Europe, which may have negatively affected small game populations and particularly red-legged partridges. We aim to evaluate the red-legged partridge nest predation by wild boar at high boar abundances by placing artificial nests in nine big game estates. Predation rates were compared between nests placed in fenced controlled plots with no wild boar access (but accessible to other predators) and open plots in which the wild boar gains access. The proportion of nests and eggs predated was significantly lower in wild boar exclusion areas, recording a predation rate of 50 % for the nests and 38 % for the eggs in these areas, whereas in the presence of wild boar, the predation rate was 80 % for the nests and 58 % for the eggs. Moreover, the wild boar was identified as the main nest predator in unfenced areas, accounting for 36 and 48 % of the predated nests and eggs respectively. This study sheds light on the wild boar predation on nests of the red-legged partridges.

Keywords *Alectoris rufa* · Nest predation · Red-legged partridge · *Sus scrofa* · Wild boar

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Introduction

Wild boar (*Sus scrofa*) has increased its distribution and it is reaching abundances previously unrecorded (Acevedo et al. 2007) which may exert a large and varied number of effects on the environment and sympatric fauna (Barrios-García and Ballari 2012). More specifically, the wild boar may act as a predator of ground-nesting birds, such as the red-legged partridge (*Alectoris rufa*) (García and Vargas 2000). The red-legged partridge is the bird game with the highest economical value in Spain, and it is also an important key prey species. However, as a consequence of habitat loss, over-harvesting and genetic problems associated with the release of farm-reared partridges, the species is currently considered as 'vulnerable' on a worldwide level and SPEC 2 by BirdLife International (Tucker and Heath 1994). Here, we hypothesize that the wild boar could affect nesting success by predation, which can be affected by habitat and management features of the hunting ground.

Work carried out with artificial nests in Spain showed corvids as the main predators in dry and scrubland patches in mixed crop zones (García and Vargas 2000). However, in areas of the Iberian Peninsula where the wild boar reaches high densities due to the big game management, its role as red-legged partridge nest predator remains almost unexplored (but see García and Vargas 2000). Therefore, the aim of this study was to assess the relative role of wild boar as partridge nest predator in relation to other predator species and habitat features in big game estates from South Central Spain characterized by a range of wild boar densities usually high. To do so, artificial nests were placed in different habitats, and predation rates were compared with nests placed in wild boar exclusion plots.

Material and methods

Study area and experimental design

Data was collected from nine different big game estates located in Córdoba province, southern Spain. We placed eggs in ten nests per estate in April and May 2012. The ten nests were placed in pairs at five sampling points on each estate ($N=86$). In each case, one of the coupled nests was located within a 0.5-ha exclusion fence (mesh size of 150 mm×100 mm) to prevent the wild boar from coming into contact with them, although they were accessible to other predators. Four natural eggs of red-legged partridges collected from a game farm and two plaster eggs were placed in each nest ($N=516$) (Yanes et al. 1998). Egg predators were assigned according to the tooth marks on the plaster eggs (Duarte and Vargas 2001). Moreover, automatic cameras were placed in 28 nests to identify predators (14 cameras on nests inside the fence and 14 on nests outside the fence).

Estimating wild boar, carnivore and red-legged partridge abundance

Wild boar abundance was estimated following the methodology employed by Acevedo et al. (2007) based on the frequency of faecal dropping on walked transect. Two transects of 4 km per estate were performed in September and October 2011 in order to record the frequency of dropping into ten sectors of 10 m in length. The carnivores' abundance was estimated through the use of spotlight counts during the months of July and August in order to obtain a kilometric abundance index (KAI). Two routes 20 km long were spotlighted per estate, and any carnivores observed were noted down. We also obtained an index of abundance by counting carnivore scats in the two 4-km-long transects abovementioned. Red-legged partridge abundance was estimated by driven transect sampling (Borralho et al. 1996), performing two transects of 20 km in each hunting state.

Structure of vegetation

The habitat in which each nest had been placed was classified according to the characteristics of the vegetation as (1) *dehesa* (open habitat), (2) scrubland and (3) edge (ecotone between 1 and 2). The maximum height of the vegetation in a 1-m perimeter around the nest was also measured (Taylor and Ford 1998). These variables were selected because the habitat and height of the vegetation affect nest detectability of wild boar (Rands 1988).

Statistical analysis

Since the number of scats per kilometre and the number of carnivores detected by spotlight counts were highly correlated, a carnivore's abundance index was created with a principal component analysis, in which both estimators were included into one single component, which explained 80.8 % of the variance. Chi-squared tests were used to compare the proportion of nests and eggs that were predated between treatment and among predator species. In order to determine the factors that relate to the survival of partridge nests, two sets of generalized linear mixed models were constructed, in which the dependent variables were whether the nest was total or partially predated vs. not predated (model 1) and the number of eggs predated per nest (0 to 6 eggs) (model 2). In these models, the abundances of wild boar, the height of the vegetation, the treatment place in which the nests were located (fenced or unfenced plots), carnivores' PCA index, habitat type (open, scrubland and edge) and the interaction between these two last variables were included as explanatory variables, and 'estate' was considered as random variable. We used a binomial distribution with a logit-link function for model 1 and a Poisson function with a log-link function for model 2.

We performed the full arrangement of models (all possible combinations), and model selection was performed through a best subset approach using the Akaike information criterion corrected for small sample size (AICc; Burnham and Anderson 2002). The generated models were ranked according to AICc values, where the model with the lowest AICc is the best one. We also reported the ΔAICc value in order to compare the difference between each candidate model and the best model. As a rule, a $\Delta i < 2$ suggests substantial evidence for the model (and then for the variables included) (Burnham and Anderson 2002), so we finally selected any model with $\Delta i < 2$ with respect to the model with the lowest AICc. Model averaging procedure based on the sum of Akaike weights was performed in order to calculate the relative importance of predictor variables. Statistical analyses were performed using InfoStat software.

Results

In the study area, red-legged partridge abundances ranged from 0.11 to 0.64 partridges/km, and carnivore abundance ranged from 1.86 to 13.20 scats/km; the PCA index ranged from −1.59 to 2.33, while the wild boar frequency index ranged from 0.04 to 0.47. Thirty out of the 86 nests were not predated, 21 were partially predated and 35 were totally predated (thus, 65 % of nests presented some degree of predation). The average predation per estate was 5.55±2.29

(mean±S.D.) for nest and 28.22±10.29 (mean±S.D.) for eggs. Overall, the proportion of predated eggs (χ^2=6.73; *d.f.* =2; p<0.05) so as the proportion of predated nests (χ^2=5.5; *d.f.* =1; p<0.05) were higher in unfenced placements (80 % of nest and 58 % of eggs) than within the fenced plots (50 % of nests and 38 % of eggs).

In unfenced nests, the most frequent nest and egg predator was significantly the wild boar, accounting for 36 % of the predated nests (wild boar vs. others, χ^2=324; *d.f.* =1; p<0.001) and 47.8 % of the predated eggs (wild boar vs. others, χ^2=435; *d.f.* =2; p<0.001), followed by rodents (Fig. 1). Nests located within the fenced plots were more predated by rodents (40 %) (rodents vs. others, χ^2=404; *d.f.* =1; p<0.001), while carnivores were the main consumer in terms of the overall proportion of predated eggs (48 %) (carnivores vs. others, χ^2=396; *d.f.* =2; p<0.001).

The treatment was included in all the most parsimonious models (model 1 and model 2), being the nests placed in unfenced areas more predated and having a higher number of eggs predated compared with the nest located in fenced plots (mean±S.D.=3.15±2.62 and 2.29±2.63 for unfenced and fenced, respectively) (Table 1). Wild boar abundance, the height of vegetation and the interaction between carnivore index and habitat type were also retained in some of the best candidate models (Table 1).

Table 1 The best candidate models to explain nest predation (model 1) and egg predation (model 2). The number of estimated parameters (k), the Akaike information criteria for small sample size (AICc) and the difference between each model and the best model (ΔAICc) and the Akaike weight (w_i) are given

	k	AICc	ΔAICc	w_i
Candidate model 1				
Treatment + carnivores × habitat	2	108.37	0	0.50
Treatment	1	109.42	1.05	0.29
Treatment + carnivores × habitat + wild boar	3	110.29	1.92	0.19
Candidate model 2				
Treatment + vegetation height	2	263.02	0	0.47
Treatment + vegetation height + carnivores × habitat	3	264.13	1.11	0.27
Treatment	1	264.22	1.2	0.25

Discussion

Most previous studies on red-legged partridge nest predation showed that corvids, feral cats and dogs are the main predators (Duarte and Vargas 2001). In contrast, our results suggest that the wild boar is the principal nest predator in areas devoted to big game exploitation with high density of wild ungulates (0.78–2.22 wild boars/km^2 in this study area,

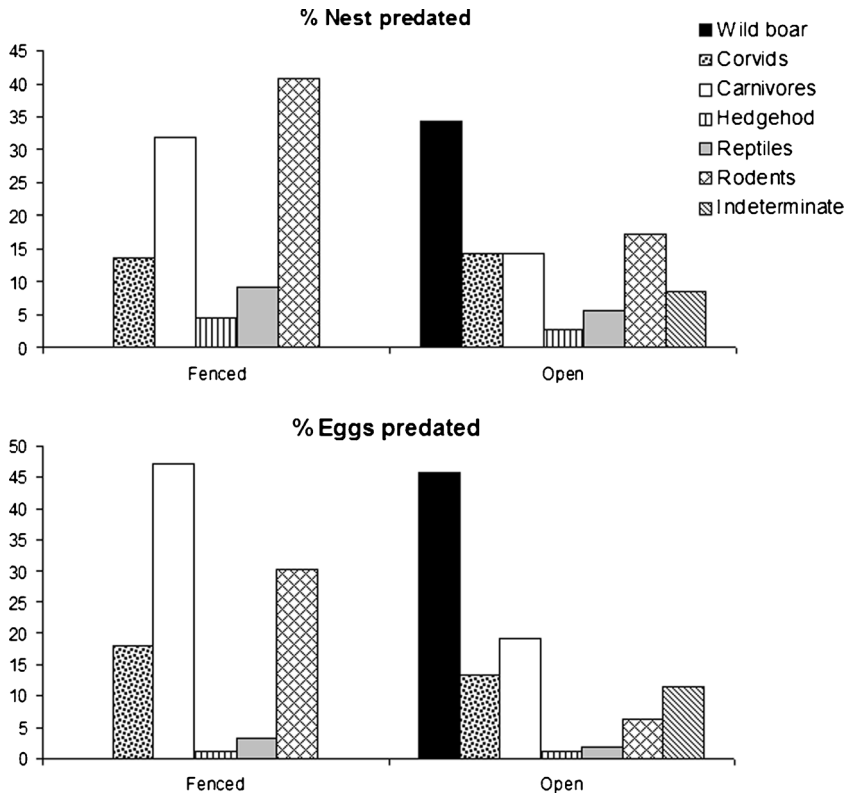

Fig. 1 Percentage of nests and eggs preyed by different species according to treatment (open vs. fenced)

Bosch et al. 2012). This wild boar overabundance could determine that the overall rate of predation that we found in open plots was very high (80 % of nests) compared to other studies such as Rands (1988) (48.3 %) and Yanes et al. (1998) (44 %) and are even much higher than the only precedent reported in a big hunting game estate in the study region (66.7 %, García and Vargas 2000).

Our study design allowed us to quantify the effect of wild boar on nest predation, recording a 45 % extra of predation rate in plots with wild boar presence and an increase of 122 % relative to the baseline nest predation rate in fenced plots. This suggests that the survival of ground-nesting birds could be strongly affected by the presence of high density of wild boars; thus, the wild boar overabundance can be considered an additional harmful factor for the red-legged partridge conservation. Interestingly, we found a slightly direct effect of wild boar abundance on nest predation, which may be due to the high wild boar density in all states included in this study which currently are in the highest abundances recorded in Spain (Acevedo et al. 2007).

Although the wild boar overabundance can produce significant impacts in different ecosystem components (Barrios-García and Ballari 2012), little is known regarding the ecological impact of the current densities in Iberian ecosystem. Our results evidence that the current wild boar densities in the big game estates in Central Spain could affect the ground-nesting birds, and it is therefore advisable to reduce their numbers in order to make compatible the big game exploitation and biodiversity conservation.

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