

# Rabbit (*Oryctolagus cuniculus*) abundance and protected areas in central-southern Spain: why they do not match?

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**Abstract** European rabbits (*Oryctolagus cuniculus*), a keystone species in the Iberian Mediterranean ecosystem, are the staple prey of the Iberian lynx (*Lynx pardinus*) and the Spanish imperial eagle (*Aquila adalberti*). These predators require medium to high rabbit densities and a low degree of human disturbance. We compared rabbit abundances in areas of central-southern Spain under three levels of protection and management: protected areas, intensively managed (nonprotected) hunting estates, and other nonprotected areas. We used pellet abundance indices to estimate rabbit density in 118 surveys conducted during the summers of 2002 and 2003. We observed greater rabbit abundance in intensively managed hunting estates compared to protected areas and other nonprotected areas, perhaps because policy makers did not consider rabbit numbers when selecting priority areas. Alternatively, differences in game management practices (e.g., predator control or habitat management) may explain the higher rabbit densities observed in managed hunting estates. Our results suggest that the best feeding conditions for the Iberian lynx and the Spanish imperial eagle occur in intensively managed hunting areas, where such predators are frequently persecuted. The conservation of these endangered predators

may require efforts to increase rabbit densities in protected areas.

**Keywords** *Aquila adalberti* · Conservation policy · Hunting · *Lynx pardinus* · Predator persecution

## Introduction

Increased awareness of environmental degradation in Spain has led to a significant increase in the protection of natural areas (>20-fold increase; Morillo and Gómez-Campo 2000) designed to create landscape-scale improvements in biodiversity. While the specific aims of protected areas do not always include the enhancement of target species, associated conservation strategies often assume that protected areas enhance environmental conditions and thereby improve the conservation of target species.

The European rabbit (*Oryctolagus cuniculus*), an endemic species of the Iberian Peninsula, is a keystone species in the Iberian Mediterranean ecosystem (Delibes-Mateos et al. 2007). In recent years, rabbit populations have declined on the Iberian Peninsula, leaving the region vulnerable to ecological and economic consequences (Delibes-Mateos et al. 2008). Therefore, rabbit recovery is an important conservation challenge within this region.

Rabbits are prey for more than 40 predator species in this region including the Spanish imperial eagle (*Aquila adalberti*) and the Iberian lynx (*Lynx pardinus*), which feed almost entirely on rabbits (Delibes-Mateos et al. 2008). Rabbit densities of at least 1 and 4.6 rabbits/ha during the autumn and spring, respectively, are necessary to sustain territorial breeding lynx (Palomares et al. 2001). Declines in the Iberian lynx and the Spanish imperial eagle appear to be at least partially due to reductions in rabbit abundance.

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Thus, management measures to increase rabbit numbers have been carried out in protected areas over the past couple of decades (e.g., Moreno and Villafuerte 1995). In Doñana National Park, approximately 19,000 rabbits were released between 1993 and 2005 as part of the recovery plan aimed at the Iberian lynx and the Spanish imperial eagle (Cabezas and Moreno 2007).

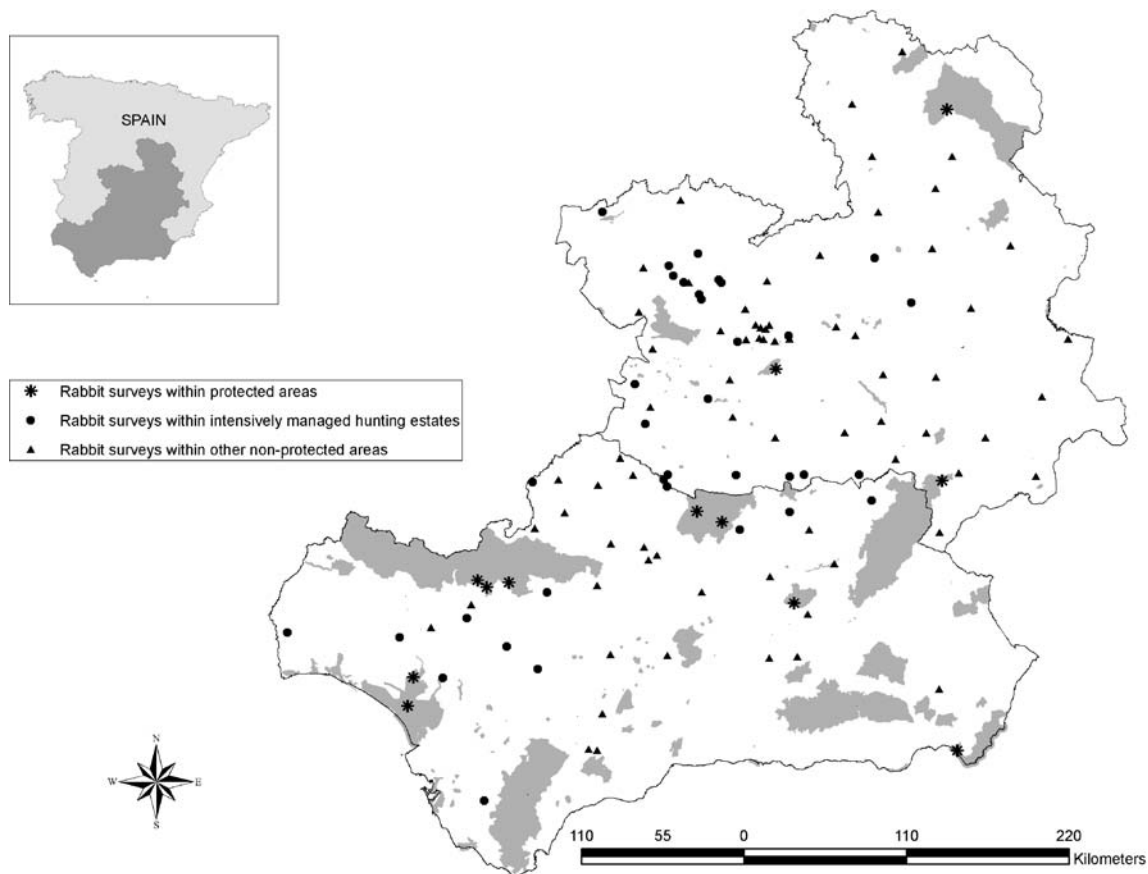
Another concern for the conservation of endangered predators in Spain is the threat of human persecution, especially on hunting estates (Villafuerte et al. 1998; Virgós and Travaini 2005). Illegal trapping was an important cause of mortality of the Iberian lynx until the 1980s, before their populations were mainly restricted to protected areas (Rodríguez and Delibes 2004). In the Doñana area, most deaths occur outside the protected area (Ferrerías et al. 1992). Similar results have been reported for avian predators in the same area (Sergio et al. 2005). Therefore, a significant proportion of the lynx and imperial eagle populations are currently found within natural reserves (Rodríguez and Delibes 2004). Almost 80% of the 10×10-km Universal Transverse Mercator grid cells inhabited by the Iberian lynx are at least partially within protected areas (Palomo and Gisbert 2002).

To our knowledge, only Villafuerte et al. (1998) have studied rabbit abundance in relation to conservation and management measures applied. We compare rabbit abundances among protected areas, intensively managed hunting estates, and other nonprotected areas (e.g., hunting estates where management is not intensive, such as public hunting estates and nonhunting estates) in central-southern Spain.

## Materials and methods

Our study area included the regions of Andalucía and Castilla-La Mancha (central-southern Spain), which contain the highest rabbit abundances in the Iberian peninsula (Villafuerte et al. 1998), and include more than 150 natural protected areas covering about 10% of the total study area (Fig. 1).

Rabbit abundance indices were calculated from 118 transects surveyed during the summers of 2002 and 2003 (Fig. 1). Survey sites were selected according to previous studies (see Delibes-Mateos et al. 2007), and rabbit abundance was estimated using pellet counts (Palomares



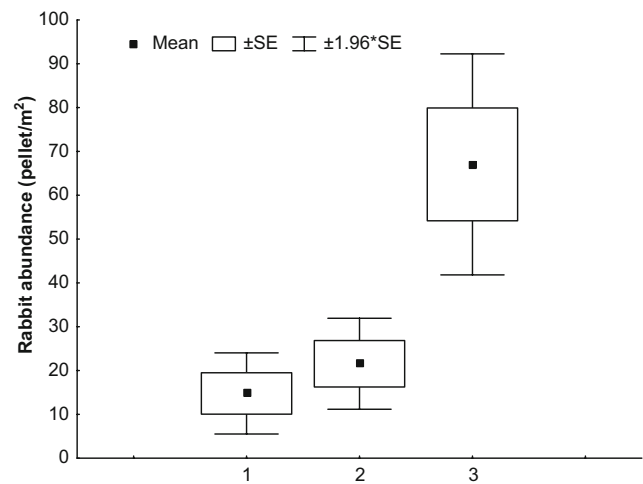
**Fig. 1** Localities in which rabbit abundance was surveyed. Grey areas represent protected areas

2001; Delibes-Mateos et al. 2007). The number of pellets was recorded within a 0.47-m<sup>2</sup> circular plot at each 100-m segment along a 4-km transect (Delibes-Mateos et al. 2007, 2008a). Counting on or near a latrine was avoided. Pellets counts from the 40 plots sampled along each transect were used to calculate a pellet abundance index (PAI; pellets/m<sup>2</sup>) for each transect (Delibes-Mateos et al. 2007).

Transects were categorized with respect to their protection status and intensity of management practiced. Game populations in central-southern Spain have been increasingly managed by wire fencing, predator control, supplementary feeding, and restocking (Virgós and Travaini 2005; Gortázar et al. 2006; Delibes-Mateos et al. 2008a). Because rabbits reach highest numbers in restricted areas with intensive hunting management (Villafuerte et al. 1998), we distinguished between nonprotected transects subject to intensive versus nonintensive management practices. We defined fenced nonprotected areas as intensively managed hunting estates, whereas open areas were defined as “other nonprotected areas”. These other areas included nonhunting estates and hunting estates where management was not intensive. The presence of fencing as an index of the degree of management has been previously employed in investigations in central-southern Spain (Villafuerte et al. 1998). Interviews with managers, hunters, and/or gamekeepers in approximately 60% of the study plots (see for details Delibes-Mateos et al. 2008a) revealed that predator control was more frequent in fenced areas compared to unfenced areas (Mann–Whitney *U* test:  $n=72$ ,  $z=2.18$ ,  $p=0.02$ ). Protected areas included both national and natural parks that have been created to preserve valuable ecosystems and protect endemic and endangered species (e.g., Morillo and Gómez-Campo 2000). We performed 36 rabbit surveys inside intensively managed hunting estates, 70 inside other nonprotected areas, and 12 inside protected areas (Fig. 1). We used a Kruskal–Wallis test to compare rabbit abundances between the three types of study sites.

## Results

The average PAI over all study areas was 34.7 pellets/m<sup>2</sup> (SE=5.4; range=0–302.9). Indices of rabbit abundance in intensively managed hunting estates were greater than those in other nonprotected areas and in protected areas (Kruskal–Wallis test:  $n=118$ ,  $H=20.97$ ,  $p<0.0001$ ; Fig. 2). The average PAI in intensively managed hunting estates was more than four times the average in protected areas (Fig. 2). In addition, 15 of the 36 transects on intensively managed estates had higher PAIs than the maximum observed among protected areas (maximum PAI within protected areas=53 pellets/m<sup>2</sup>), and ten of them had PAIs that were more than twice the maximum recorded in any protected area.



**Fig. 2** Rabbit abundance, given as the PAI (=pellet/m<sup>2</sup>), in areas with three different levels of protection and management: (1) protected areas; (2) nonprotected areas with nonintensive management, such as public hunting estates and nonhunting estates; and (3) intensively managed hunting estates

## Discussion

The highest indices of rabbit abundance occurred in intensively managed hunting estates suggesting that high rabbit numbers, and therefore optimal feeding conditions for predators such as Iberian lynx and imperial eagle, occur in these areas (Villafuerte et al. 1998). Delibes-Mateos et al. (2007) reported that the average PAI among survey sites inhabited by imperial eagle was 101.3 pellets/m<sup>2</sup> compared to the 14.8 pellets/m<sup>2</sup> in protected areas we surveyed. Intensively managed estates typically are favorable for rabbits but may be risky for predators because of illegal persecution (Virgós and Travaini 2005) or human disturbance. Surveillance against illegal persecution of predators outside protected areas is difficult because of the large areas involved (Virgós and Travaini 2005). Although illegal persecution could be reduced through educational programs in the long term, in the short term, it may be necessary to increase rabbit populations within protected areas.

The scarcity of rabbits in protected areas may be because policy makers in Spain are unlikely to account for rabbit numbers when selecting these areas. Although Davic (2003) has suggested the importance of keystone species when choosing priority areas, these species are not considered in Spain, where areas have been traditionally protected to preserve mature ecosystems (Morillo and Gómez-Campo 2000). These environments are usually the final stage of the natural succession and include dense woodlands and/or scrublands. Rabbits reach higher numbers in mixed areas of natural vegetation and crops (and/or pastures), whereas they avoid mature Mediterranean scrubland (Moreno and Villafuerte 1995). Therefore, remote

environments that are traditionally preserved in the Iberian peninsula apparently do not confer optimum habitat conditions for rabbits. Moreover, rabbit populations in such places would be more impacted by rabbit hemorrhagic disease (RHD), as has been predicted because of a higher mean age of rabbit infection (Calvete 2006).

The current low rabbit abundance observed in some protected areas where rabbits were traditionally abundant (e.g., Doñana National Park; Moreno et al. 2007) likely are associated with differences in management practices between hunting estates and protected areas. We previously reported that after a population crash due to RHD, rabbits reached the highest densities on hunting estates that engaged in habitat management and predator control to improve rabbit numbers (Delibes-Mateos et al. 2008a). Predator control is common on hunting estates, and likely explains greater predator densities in protected areas (Travaini et al. 1997; Virgós and Travaini 2005). Thus, higher predator densities could inhibit post-RHD rabbit recovery in these areas (Moreno et al. 2007; Delibes-Mateos et al. 2008b). Similar findings were observed on a reserve in southern Spain where reduced predator control led to a fall in passerine populations that had been targeted for protection (Suarez et al. 1993).

Habitat management, including scrub clearance, establishment of crops, and supplementary feeding, is common in small-game hunting estates (Delibes-Mateos et al. 2008a). Villafuerte et al. (1997) found that rabbit numbers depend largely on the availability of high quality food. Conversely, the abandonment of the traditional management of scrubland in some protected areas has been responsible for the decrease of rabbit numbers in these areas (Moreno and Villafuerte 1995). In addition, the increase in densities of wild boar (*Sus scrofa*) and/or red deer (*Cervus elaphus*) could also limit rabbit populations in some protected areas due to competition for available food (Lozano et al. 2007).

Further study using experimental approaches will be required to fully understand management impacts on rabbit densities and to improve strategies for increasing rabbit populations in protected areas. Effective protection of endangered predators also should be enforced, especially in small-game estates where rabbits reach high numbers.

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