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Grain sowing aimed at wild rabbit *Oryctolagus cuniculus* L. enhancement in Mediterranean environments

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ABSTRACT

Although habitat management practices focussed on the enhancement of hunting and protection of threatened species are common, the scientific validation of such practices is scarce. The wild European rabbit *Oryctolagus cuniculus* L., a hunted and threatened species in its native range, is at the same time a key species for the preservation of threatened Mediterranean predators. Cereal sowing is one of the most common practices to augment the food supply of rabbits, and it is used not only by hunters but also by conservationists. At present, limited scientific information is available regarding the effectiveness of cereal sowing. To evaluate its effectiveness, we analysed data on sowing trials conducted in 125 plots, located in 14 private estates throughout central Spain, most of them with low density populations. Brush was cleared from 44 of these plots prior to sowing. Our results indicated that rabbits preferentially selected sown areas over control (unsown) areas. This selection increased in plots that represented suitable habitats for rabbits, such as pasturelands, as well as when thicket islands and natural or artificial shelters were available within the sown plots. Local enhancement of rabbit populations was also observed. These positive results were also obtained regardless of the initial habitat conditions, not only in the treatment plots but also in the surrounding area. Our recommendations can be broadly applied for managing rabbit-dependent threatened species.

Introduction

The wild rabbit (*Oryctolagus cuniculus* L.) is a Near Threatened mammal (Smith & Boyer 2008). In its native range it is considered as Vulnerable in Spain (Villafuerte & Delibes-Mateos 2007) and as Near Threatened in Portugal (Cabral et al., 2006). And it is also the main small game species in Spain (MAGRAMA, 2014). But it is also one key species in Mediterranean ecosystems (Delibes-Mateos et al., 2007), and several endangered species depend on it. Among these species are Bonelli's eagle (*Aquila fasciata* Vieillot; Moleón et al., 2009), the Spanish imperial eagle (*Aquila adalberti* Brehm), and the Iberian lynx (*Lynx pardinus* Temminck; Ferrer & Negro, 2004). For the preservation of threatened species that depend on wild rabbits, and considering only projects financed by the EU LIFE programme, current funding has reached 100 M€ for rabbit-dependent species (Life Programme 2011).

The severe decline in wild rabbit populations observed in Spain during the last half of the 20th century is due primarily to the outbreak of two viral diseases, myxomatosis and rabbit haemorrhagical disease (Cooke 2002; Virgós et al., 2007), although the decline cannot be attributed only to diseases. It may also have been caused by changes in rural environmental management, such as intensification in pasturelands and agricultural areas or cessation of production in mountain and forest areas (Delibes-Mateos et al., 2010), both linked to a high loss of structural environmental diversity (Pineda 2001). Changes in hunting management practices during recent decades have also had an influence, including an increase in game hunting, especially red deer and wild boar (Cabezas-Díaz et al., 2010; Herruzo and Martínez-Jauregui, 2013), an intensification in game management (Beja et al., 2009), and, in many areas, absence of predator control (Banks 2000; Delibes-Mateos et al., 2008; Fernández de Simón, 2013).

Food quality and abundance controls wild rabbits' reproduction (De Blas, 1989; Gonçalves et al., 2002). Breeding season starts

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when rabbits consume more than a certain value of protein in their diet (De Blas, 1989). This high value of protein is found on certain food, such as green grasses or legumes (San Miguel, 2006). Therefore increasing availability of quality food may enhance rabbit reproduction index, thus aiding in population recovery (San Miguel, 2006).

To solve problems associated with reduced rabbit populations, many measures have been taken, in the framework of different conservation projects and strategies (Moreno et al., 2004; García 2005; San Miguel 2006) and hunting management strategies (Delibes-Mateos et al., 2008). One of the basic results obtained from programmes implemented to date is that, in order to enhance rabbit populations, environmental management is a crucial tool (San Miguel 2006; Delibes-Mateos et al., 2008; Godinho et al., 2013). Populations are favoured by different practices applied to their habitat (Ferreira et al., 2013), including firebreaks with sowing (Ferreira & Alves, 2009), burning of scrubland in order to promote pastures (Moreno & Villafuerte, 1995), provision of shelter with enclosures (Catalán et al., 2008), or shelter construction (Fernández-Olalla et al., 2010). One of the most frequently used measures to enhance populations of small game is sowing of food crops (Delibes-Mateos et al., 2008; Casas & Viñuela, 2010), which has seldom been considered as a management tool for the threatened predators (but see Guerrero-Casado et al., 2013). Previous studies have assessed how habitat selection by rabbits is affected by different types of crops in small experimental areas (Muñoz 2005). However, information on the use of dryland farming is still lacking.

The objective of this study was to evaluate the efficacy of cereal sowing for increasing density of wild rabbit populations. Our initial hypothesis was that this measure could be considered effective if rabbits preferred the sown areas. Thus, we first assessed whether rabbits select sown over control (unsown) areas. We then aimed to determine the characteristics of sowing that influenced a positive selection by rabbits. After the treatments were implemented, we evaluated whether differences in the evolution of the relative abundance of rabbits between treatment and control plots were evident.

Material and methods

Study area

The study was carried out in 14 private estates that are part of the Natura 2000 network in central Spain (Albacete, Cáceres, Ciudad Real, Jaén, and Toledo Provinces; Fig. 1). More precisely, the study plots were located in the following Sites of Scientific Interest (SCIs): *Rumblar, Guadalén y Guadalmena* basins (four estates), *Sierra Morena* (three estates), *Sierra del Relumbrar y las Estribaciones de Alcaraz* (five estates), *Montes de Toledo* (one estate), and *Sierra de San Pedro* (one estate). Some of these areas are also considered Special Protection Areas (SPAs).

From a biogeographical point of view, all sites are located in the western Iberian Mediterranean Province (Rivas-Martínez et al., 2004) and are characterized by acid lithology and nutrient-poor soils. The area has a meso-Mediterranean climate, with ombroclimate from dry to sub-moist, continental, with important year-to-year fluctuations, high summer droughts, and year to year rainfall variations (MMA 2002). As a result, most of the study area is covered by a mosaic of forest (mainly oak thickets in initial successional states, with rockrose *Cistus ladanifer* L. and *Cistus monspeliensis* L. dominated brush, therophitic herbaceous grasses, rocky areas, and thick bushes, viz. the so-called Mediterranean *mancha*).

The estates' main use is big game rearing, although most of them also secondarily raise livestock (González & San Miguel, 2005). In most of the study area, rabbits have low or very low population numbers (Guzmán et al., 2004), similar to other protected areas (Delibes-Mateos et al., 2009).

Essay: Cereal sowing

In total, we sowed 125 plots, hereafter referred to as 'treatment plots'. In 44 plots, prior brush clearing was achieved by several cross-passes with a deep plough. Here, cereal sowing acts to reduce recolonization by thickets (Muslera & Ratera, 1993) and increases the availability of high-quality food (fodder during winter and spring, and grain in summer) for rabbits, big game, and livestock.

Cereals (barley and oat seed) were sown (150 kg ha^{-1}), no fertilizer was used, and only one estate was permanently closed to grazing. For sowing, we used a spinning compost machine and covering. Per estate, the number of treatment plots varied between 3 and 19 (mean ± SD = 8.93 ± 6.04), and plot surface area varied from 0.04 to 43.07 ha (mean ± SD = 2.55 ± 5.54 ha). As a rule, plots were smaller than those generally used for livestock or big game (San Miguel 2006). When plot size exceeded 0.5 ha (67 plots), small thickets inside the sown plot tended to be left as rabbit shelters (at least 10 m^2 and representing at least 5% of the plot surface; these were provided in 53% of total plots and in the 60% of plots >0.5 ha). For sowing, we avoided slopes exceeding 10%, and the shapes of the sown plots were adapted to the local topography. We preferred elongated forms in order to obtain a high perimeter/surface relationship. Sown plots were established in eight estates (n = 46 plots) during summer 2004, six estates (n = 34) in 2005, and six estates (n = 45) in 2006.

Field data: Rabbit and treatment survey

To determine positive selection of treatment plots over control areas, we established transects to detect signs in both treated and control areas with similar ecological characteristics. Signs included the presence of latrines (Mykytowycz, 1968), defined as an accumulation of at least 20 excrements (Virgós et al., 2003), which are widely used in studies of habitat use (Palma et al., 1999; Virgós et al., 2003; Guzmán et al., 2004; Guerrero-Casado et al., 2013; but see Fernández de Simón et al., 2011). All latrines observed during transect surveys were counted. The distance covered along each transect was recorded to standardize effort. To maximize the probability of finding latrines, transects were established along the border of treatment areas (Moreno & Villafuerte, 1995). Transect length was adapted to the treatment area perimeter (mean ± SD = 0.39 ± 0.35 km). Therefore, transect length increased with increasing treatment area perimeter, and we attempted to cover entire perimeters. Transects were also established in the control areas and covered a similar distance. Control transects were designed mainly through paths, as rabbits tend to mark on them (Monclús & De Miguel, 2003), and surveyed the most similar ecological conditions as its equivalent treatment transect. Treatment and control transects were designed to be spatially close, but with a separation between treatment and control with at least 200 m. We chose this distance because it is considered the longest distance traversed by rabbits on one day (Lombardi et al., 2003). Monitoring was done during late spring, when rabbit abundance and use of sowing are generally highest (Beltrán, 1991; Cacho et al., 2002).

In parallel with the treatment survey, wild rabbit abundance was surveyed at each estate, as this may influence the use of habitat and feed (Lombardi et al., 2003; Muñoz, 2005). For monitoring, we basically followed the method proposed by Palomares (2001). In each estate a net comprising several linear transects was established. The number of transects was not homogeneous between estates (2–15). The season chosen for the survey was late spring