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Original Investigation

Motorway verges: Paradise for prey species? A case study with the European rabbit

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ABSTRACT

Roads have many effects on the mammal populations of their surroundings. Prey species are thought to establish dense populations in road verges due to a predation release effect, which arise as a side-effect of roadside avoidance by predators and/or predator roadkill. A species that has been suggested to benefit from predation release and attain high densities near roads is the European rabbit, a keystone species in Mediterranean ecosystems. We monitored rabbit relative abundance at three distances from a motorway (50, 450 and 850 m) during a 6 month period, as well as hunting and predator pressures, in a suitable area for rabbits. The lowest rabbit abundance was found next to the motorway (6.76 ± 8.87 pellets/m^2 per month) and the highest abundance at an intermediate distance (17.65 ± 23.11 pellets/m^2 per month). Hunting and carnivore pressures were highest at the sampling transect located farthest from the infrastructure. Thus, variability in rabbit abundance did not match the predation release effect found close to the motorway, and some sort of road avoidance or other process must underlie the observed abundance pattern. We advocate for a formal measurement of prey populations response to roads prior to any generalization as, in the case of rabbit, the response to roads and the potential cascading effects on other species may depend on landscape characteristics.

Introduction

Roads transform the environment, giving rise to multiple effects on the mammal populations of their surroundings (Trombulak and Frissell, 2000; Fahrig and Rytwinski, 2009). In most cases they have pernicious effects on mammals through fragmentation or mortality (Forman et al., 2003; Jaeger et al., 2005; Coffin, 2007), but in some occasions they may have positive effects on species that make use of road verges as corridors or habitats. This seems to be the case of several small mammal species, which establish themselves in vegetated verges and can become abundant near roads (Bellamy et al., 2000; Brock and Kelt, 2004; Sabino-Marques and Mira, 2011). For example, Rytwinski and Fahrig (2007) found higher abundances of white-footed mouse (*Peromyscus leucopus*) in zones with higher road density, and another study carried out in USA found that juveniles of two lagomorph species (*Sylvilagus audubonii* and *Lepus californicus*) were only in areas adjacent to roads (Bissonette and Rosa, 2009). Typical life history traits of small mammals, e.g. high reproductive rates, allow them to establish near roads, replacing very quickly the individuals lost to the population by traffic mortality (Rytwinski and Fahrig, 2012). The presence of a steady and relatively abundant supply of prey alongside roads may attract predators and increase their likelihood of being run-over (Little et al., 2002; Ramp and Ben-Ami, 2006) with two main consequences. From a biological perspective, the increased mortality of predators could benefit the populations of small mammals in areas of high road density due to the predation release effect (Rytwinski and Fahrig, 2012). From the conservation and management viewpoints, it could be an issue of concern given that mammal predators usually have low population densities, low fecundity, and large home ranges, and all these characteristics make their populations particularly vulnerable to increased mortality provoked by traffic (Spellerberg, 1998; Trombulak and Frissell, 2000; Forman et al., 2003).

Predation release has been proposed as a cause for the apparent high densities of wild European rabbits (*Oryctolagus cuniculus*) observed close to roads, together with the effects of lower hunting pressure and the presence of suitable soil to build warrens (Bautista et al., 2004; Barrientos and Bolonio, 2009). However, very few studies have examined species abundance as a function of distance from roads, especially in lagomorphs, and results are somehow contradictory (see a review in Benítez-López et al., 2010). A North American study by Bissonette and Rosa (2009) found a greater abundance of two lagomorph species (*Sylvilagus audubonii* and *Lepus californicus*) alongside roads. However, a study focused in the European hare (*Lepus europaeus*), found greatest abundance at

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a distance of 400–500 m from motorways (Roedenbeck and Voser, 2008).

The European rabbit is a key prey species in Mediterranean ecosystems (Delibes-Mateos et al., 2007), and the rabbit itself is currently of serious conservation concern since its populations in its natural range have declined by 70% in 30 years (Virgós et al., 2007). The rabbit also has a major impact on the ecosystem structure, influencing the floristic composition and giving rise to the heterogeneity on which many other organisms depend (Delibes-Mateos et al., 2008; Gálvez-Bravo et al., 2009). In addition to this, the species is important from a social perspective, producing significant economic benefits as a game species (Fa et al., 1999) but also causing agricultural losses by feeding on crops (Martinez et al., 2003; Barrio et al., 2010).

Although some studies have related the presence of European rabbits with an increased road mortality of predators (Barrientos and Bolonio, 2009; Barrientos and de Dios Miranda, 2012), no study has compared wild rabbit abundance near roads with that in the surrounding matrix. This information will help us evaluate rabbit response to roads, which can have important implications, as predator road mortality could be a by-product of high prey abundance. In that case, it should be a factor to consider when designing measures to minimize road impact on wildlife since several species of conservation concern, such as the Spanish imperial eagle (*Aquila adalberti*) and the Iberian lynx (*Lynx pardinus*) are among rabbit predators. In fact, both species are affected by roads and/or roadkills (Ferreras et al., 1992; Bautista et al., 2004).

The aim of this study is to estimate the variability in rabbit abundance related to distance from a motorway, as well as variations in hunting pressure and carnivore abundance at that scale as a measure of predation risk. This information will determine both whether there is an area of predation release near the motorway, and whether rabbit abundance responds to it. We predict that rabbits will be more abundant closer to the motorway, where hunting and carnivore pressures will be lower.

Material and methods

Study area

The study was conducted in central Spain, adjacent to A-3 motorway, in Madrid province (40°12′N, 3°19′W). The climate is continental Mediterranean, with a mean annual precipitation of 438 mm and a mean annual temperature of 13.8 °C. The substrate was similar throughout the area, comprised by a mixture of marls, clays and gypsum which are very suitable to warren building. Three main natural vegetation formations could be distinguished throughout the area: steppe dominated by *Stipa tenacissima* on sunny slopes (*Stipa* formations), grassland dominated by gypsophilous plants on clay outcrops (Grasslands), and thyme (*Thymus* spp.) scrub elsewhere (*Thymus* formations). In addition, there were some small field crops, most of these being fallow during the study year, except for some olive and almond groves (Orchard crops). This mosaic landscape is typical from this part of Spain and is one of the most suitable for rabbits in Mediterranean ecosystems (Fa et al., 1999), being one of the areas with highest rabbit density in Spain (Villafuerte, 2007). The four-lane A3 motorway was opened to traffic in 1995 and had a mean traffic volume of 31,462 vehicles per day in 2008 (Ministerio de Fomento Gobierno de España, 2010). At 5–10 m from the road there was a perimetral fence 1.5 m tall and made of wire mesh of 30.5×15 cm built according to 1990s road building regulations to prevent human and large animals to enter the motorway. Since it was neither reinforced nor pinned to the ground and the mesh spaces were large, it meant no obstacle to the movement of rabbits and carnivores.

Sampling design and data collection

In order to investigate changes in rabbit abundance, three strips (A, B and C) were marked out in the study area at increasing distances from the motorway, and they were surveyed for 6 months. Strip A began along the line of the motorway boundary fence and the other two strips ran parallel to it. Each strip was 2000 m long and 100 m wide, with an inter-strip separation of 300 m, being the mean distance between each strip and motorway of 50, 450 and 850 m, respectively. The separation between strips was chosen in relation to the average home range size of a rabbit (circa 1 ha or smaller, Lombardi et al., 2007; Devillard et al., 2008), so that one home range would not extend over two strips. Moreover, the strip length allowed it to cross the home ranges of several independent rabbit groups.

We randomly selected 20 points inside each strip ('HawthsTools' extension, ArcGis 9.2, ESRI, 2009). We estimated an index of rabbit abundance by pellet counts in pellet clearance permanent plots (Palomares, 2001). This method has been validated recently as more reliable in relation to rabbit abundance than other abundance indeces for the Iberian Peninsula, such as the number of burrows or latrine counts (Fernandez-de-Simon et al., 2011). The fieldwork took place from March to September 2009 and each plot was surveyed monthly. In March, one permanent plot of 0.6 m of radius (1.13 m^2) was placed at each point, and all the rabbit pellets were cleared. Plots were placed avoiding unsuitable areas, such as orchard crops, steep slopes and rabbit latrines, in which the accumulation of pellets could not reflect the abundance of rabbits. From the first visit on, once a month we counted the accumulated pellets inside each circular plot and cleared them for the next visit.

Since pellet persistence can differ between sites (Iborra and Lumaret, 1997; Fernandez-de-Simon et al., 2011), we estimated a rate of pellet decay in each strip. Four control plots were evenly spaced along each strip, protected by a wire mesh that excluded rabbits, but not rain or coprophagous beetles. We placed 30–40 fresh pellets in each plot every visit and counted those remaining in the next month, before clearing and replacing them for new fresh pellets. Accordingly to other studies that found that one month time is short enough for disintegration rates not to affect the study results (Moreno and Villafuerte, 1995), we found very high permanence rates (93.5 ± 1.34% pellets) and similar along the whole study area. Therefore, we did not use decay rates to correct the values of the abundance index.

Parallel to the rabbit abundance measures, we also estimated indices of carnivore pressure and hunting pressure within the strips. One transect of 2 km long and 2 m wide was walked in each strip once a month by the same observer. The count of carnivore scats in the transect was used as an index of carnivore strip-use intensity, and thus of relative potential predation pressure in it. Assuming that carnivores mark more frequently those parts of the study area more visited, the number of scats in a strip should be related to the time that a carnivore spends there and with an increased risk of predation for rabbits. We cleared the transect lines of carnivore scats in March and collected data from April to September, clearing all the scats found in each visit. All the material we found were originated from mid-sized carnivores: cats (*Felis* sp.), foxes (*Vulpes vulpes*) and mustelids (*Meles meles* and *Martes foina*), all of which feed on rabbits in Mediterranean ecosystems (Delibes-Mateos et al., 2008), so we opted to analyze all the data together as "carnivores". The index of hunting pressure was defined as the number of spent cartridges found in each transect. The hunting season ends in February and does not recommence until September, so we walked slightly different transects every month and those cartridges found in March were also included in the analysis. The cartridges were removed in each visit to avoid possible double counting where transects overlapped.