Title
Spatial patterns of road kills: a case study in Southern Portugal

Permalink
https://escholarship.org/uc/item/8r07z6nf

Authors
Ascensão, Fernando
Mira, António

Publication Date
2005-08-29
**Spatial Patterns of Road Kills: A Case Study in Southern Portugal**

Fernando Ascensão (E-mail: fernandoascensao@yahoo.com) and António Mira (E-mail: amira@uevora.pt), Unidade de Biologia da Conservação, Departamento de Biologia, Universidade de Évora, Núcleo da Mitra, Apartado 94, 7002-554, Évora, Portugal

**Abstract:** Roads promote high levels of animal-vehicle collisions and have one of the most visible man-made impacts on wildlife. In Portugal, SW Europe, very few ecological studies have focused on the impacts from roads on vertebrates. Knowledge of the main factors driving the emergence of hotspots of vertebrate mortality is still scarce.

A segment of a main road 26-km long was sampled by car at an average speed of 20 km/h every two weeks for two years (54 surveys) between 1995 and 1997. All road-killed specimens found were collected and identified to species level. Results suggested that some road sections should receive particular mitigation actions given that mortality hotspots may arise, particularly sections where montado is the dominant habitat and where stream and other water courses run nearby and parallel to the road.

**Introduction**

One major human agent of habitat fragmentation is the ever-increasing and expanding road network worldwide (Forman et al. 2002) that can be harmful to various faunal groups such as invertebrates (e.g., Haskell 2001), amphibians (e.g., Carr and Fahrig 2001), reptiles (e.g., Gibbs and Shriver 2002), birds (e.g., Kuittunen et al. 1998) or mammals (e.g., Philcox et al. 1999). Roads and traffic can act as barriers which may make animal movements difficult and reduce population connectivity. By diminishing the gene flow and disrupting sink-source population dynamics, roads may increase inbreeding and loss of genetic diversity (Ferreras 2001). Resultant isolation might lead to higher local population extinction risks due to stochastic effects (van der Zande et al. 1980; Saunders et al. 1991; Fahrig and Merriam 1994; Cooper and Walters 2002).

Roads also promote high levels of animal-vehicle collisions, which is particularly significant for larger species with wider home ranges as carnivores. These collisions are one of the most visible road impacts on wildlife (e.g.: Hodson 1960; Oxley et al. 1974; Fahrig et al. 1995; Philcox et al. 1999; Gibbs and Shriver 2002; Taylor and Goldingay 2004).

In Portugal, SW Europe, very few ecological studies have focused on the impacts of roads on vertebrate populations. Knowledge of the main factors driving to the emergence of hotspots of vertebrate mortality is still scarce. This study refers to a two-year roadkill survey on a main road (IP2) located in southern Portugal (figure 1).

**Study Area**

The study was conducted in Portalegre District, between the cities of Portalegre and Monforte cities near the Natural Park of S.Mamede (NPSM) (figure 1). This region is in the center of the Iberian Peninsula, generally dominated by smooth areas, except on the natural park where mountain topography reaching 1024 meters a.s.l. The climate is mediterranean, although the NPSM is considered to be an Atlantic Biogeographic island in the middle of a mediterranean region. This biogeographic crossroad enables the coexistence within the same area of several species from both biogeographic regions.

Road vicinity is dominated by characteristic mediterranean agro-forestry areas; cork and holm oak tree stands (Quercus suber and Q. rotundifolia), hereafter referred as “montado;” open land as pastures, meadows, or extensive agriculture (cereal, fodder); and olive groves (figure 2). This IP2 section has a moderate traffic intensity of about 5000 vehicles day -1.

**Methods**

**Sampling**

A segment of the IP2 road (26-km long) was sampled by car at an average speed of 20 km/h every two weeks for two years (54 surveys) between 1995 and 1997. All vertebrates found killed on the pavement were collected and identified to species level *in loco*, whenever possible, or by analysis of skin, scales, feather or hairs, depending on the taxonomic group, in the laboratory.

It should be emphasized that the number of casualties found was most probably biased due to several constraints, namely carrion foraging from other animals, climatic conditions, and physical characteristics of roads, which can mislead correct counting and detection of corpses on roads (see Erritzoe et al. 2003, pers. observ.). Thus, records should be regarded as an underestimation of real carnage occurring on the road. Furthermore, non-daily surveys prevent the detection of all small-bodied animals like amphibians, passerines, or small mammals, since their corpses often remain between one and three days on the traffic lane (António Mira, unpublished data).
Explanatory variables
For each 0.5-km road section, we created a 500-meter-radius buffer, with its center on the section’s middle point. Land cover was assessed for these buffers through orthofoto map analysis, with corrections from field work observations. Five classes of land cover were considered: montado (MNT), open areas (OPEN), olive groves (OLIVE), fruit tree groves and horticultures (FRUIT), and urban areas (URBAN) (figure 2).

On each buffer, we also considered the length of streams present inside each buffer (STREAM_L) and the distance of the middle point section to nearest stream (STREAM_D). The number of culverts (CULVERT) and houses (HOUSE) present on each 0.5 km road section were as well considered. All the information was processed with ArcView 3.2 (ESRI, Redlands, California).

We considered that a section was a potential vertebrate-mortality hotspot when its probability summation exceeded the 90 percent threshold, that is Σp(x)>90%.

Data analysis
Differences of explanatory variables between hotspots and low-mortality sections were evaluated with the Mann-Whitney U-test (Zar 1999). This analysis was performed for all observations, for anurans and caudata orders (amphibians), and for the vertebrate classes reptiles, birds, and mammals (domestic cat and dog were excluded from analyses).

For multivariate analysis, we used canonical ordination techniques. A direct gradient analysis (Canonical Correspondence Analysis (CCA)) was executed with the mortality rates of the most 24 killed species (species with above 15 casualties, table 1) and the explanatory variables considered, with downweight of rare species and detrending by segments options (Jongman et al. 1995), using CANOCO for Windows version 4.5 (ter Braak and Šmilauer 2002).

We selected the variables MNT, OLIVE, OPEN, FRUIT, CULVERT, STREAM_L, and STREAM_D. This option was chosen in order to achieve a compromise between obtaining the maximum percentage of variance explained and the significance of both eigenvalues and correlations of species-explanatory variables with the axis. The significance of species-environment correlation was tested by the Monte Carlo test (499 permutations). Ordination axes were interpreted using the intraset correlations that allow inference on the relative importance of each variable for predicting community composition (ter Braak 1986).

Results
A total of 2421 vertebrate road-killed specimens were collected, which corresponded to about 46 specimens per 0.5 km per year. At the species level, 2128 individuals were identified. Eighty non-domestic species were recorded (table 1).

Casualties among vertebrate classes were significantly different (chi-test, $X^2 = 1630$, df = 3; $p<0.001$), being higher for amphibians ($n = 1362$), followed by birds ($n = 681$), mammals ($n = 225$), and reptiles ($n = 153$).

Several sections were defined as vertebrate-mortality hotspots (VMH), both for all observations and for each vertebrate class (figure 3). VMH clusters seemed to be mainly aggregated at the first half of the studied road segment.

Regarding amphibians, hotspots of anuran mortality occurred mainly in the proximity of streams ($U = 203.5$, $n1 = 35$, $n2 = 18$; $p<0.05$), and in sections with a lower number of culverts ($U = 159.0$, $n1 = 35$, $n2 = 18$; $p<0.01$). For caudata, a high number of killed specimens were detected in sections with a low number of houses near the road ($U = 214.0$, $n1 = 37$, $n2 = 16$; $p<0.05$).

Concerning reptiles, road sections with high mortality also had a lower number of culverts ($U = 192.5$, $n1 = 37$, $n2 = 16$; $p<0.05$). Stream proximity was also significant, because the hotspots of mortality were closer to stream lines than to other sections ($U = 203.5$, $n1 = 37$, $n2 = 16$; $p = 0.073$). Higher bird mortality occurred in road sections near watercourses ($U = 145.0$, $n1 = 39$, $n2 = 14$; $p<0.01$), with houses in close proximity of the road ($U = 153.5$, $n1 = 39$, $n2 = 14$; $p<0.01$), and with a lower cover of montado ($U = 153.0$, $n1 = 39$, $n2 = 14$; $p<0.05$).

Concerning environmental variables, there were no significant differences between road sections with high and low mortality of mammals.

The direct-gradient analysis (CCA) results are shown in figure 4. The eigenvalues were 0.153 in the first axis and 0.063 in the second. The Monte Carlo test was significant for both the first canonical axis ($F = 6.099$, $P<0.001$) and all canonical axes ($F = 1.933$, $P<0.001$). The first two axes explained 74.2% of data variability. First axis reflects mainly the effects of fruit-tree groves and horticulture (FRUIT), which are related to anthropogenic presence, and the montado cover density (MNT). The second axis reflects the proximity and length of watercourses near the road (STREAM_P and STREAM_L).
On the CCA plot, we observed that most species are positioned on the left side, suggesting that higher mortality rates occurred in sections dominated by montado. Exceptions to this are the cases of *Passer domesticus* (PD) or *Sylvia atricapilla* (SyA), species that are related to anthropogenic environments and are shown close to the FRUIT variable. Fruit-tree groves and small horticulture are typically located near small urban areas in Mediterranean landscapes (as is the case near Portalegre). Anuran mortality seemed to have occurred on sections close to watercourses. Also noteworthy is that the position of several small species (such as the amphibians *Bufo bufo* (BB), *Bufo calamita* (BC), the reptile *Natrix maura* (NM), and the small mammal *Apodemus sylvaticus* (AS) suggests that higher mortality levels occurred on sections with a lower number of culverts.

**Discussion**

Mortality rates on the Portuguese road presented in this study support the ideas that further road expansion should consider impacts on animal populations and that mitigation measures must be taken account on the existing road network. Furthermore, considering that the Iberian Peninsula is included in a global-biodiversity hotspot, namely the Mediterranean Basin (Myers et al. 2000), and that most species are in one way or another threatened by anthropogenic actions such as road expansion (de Vries et al. 2002), high-priority actions should be implemented so that on Iberian roads can provide a more permeable road system to animal movement. This is more relevant for the studied road given its location, which is near the border of an important Portuguese protected area, Serra de S. Mamede Natural Park (figure 1). This area is located in a biogeographic crossroad combining Mediterranean and Atlantic climatic characteristics, which provides multiple habitat patches allowing high species diversity and richness. Probably this is reflected in the highest number of road-killed species and specimens being found on the first kilometers. As suggested by Spector (2002), biogeographic crossroads appear to be areas of high conservation priority and opportunity in both the short and long term and require increased attention in the process of setting conservation priorities.

Results suggest that some road sections should receive particular mitigation actions given that mortality hotspots may arise. This is particularly true in sections where montado is the dominant habitat and where stream and other watercourses run nearby and parallel to the road. Also, the presence of culverts may diminish the collision risk, providing alternative paths for road crossings. This way, as previous authors described (e.g., Yanes et al. 1995; Rodríguez et al. 1996; Cain et al. 2003; Mata et al. 2005), the implementation of several of these or other similar structures, with different sizes and configurations, should be of primary concern.

Presently, an ongoing project using the same methodology is taking place on the same segment of road with the purpose of evaluating and comparing the vertebrate mortality rates and their spatial patterns 10 years after.

![Figure 1. Location of studied IP2 road section (A) and map of study area (B).](image-url)
Figure 2. Land cover (main classes) within each 500-meter-radius buffer (near 79 ha) along the studied road.

Figure 3. Road mortality along 0.5-km road sections. The dashed line sets the threshold for the definition of vertebrate mortality hotspots (Malo et al. 2004): 46 individuals for all observations, 24 for anurans, eight for caudata, five for reptiles, 17 for birds, and five for mammals.

Figure 4. CCA ordination plots of the 24 most killed species (squares are amphibians, circles are reptiles, stars are birds, and diamonds are mammals), with explanatory variables. See text for variables' names. Longer vector lines represent stronger "intraset correlations" (ter Braak 1986). See text for variables' names and methods.
Species: Amphibians - BB, Bufo bufob; BC, Bufo calamita; DG, Discoglossus galganoi; PeC, Pelobates cultripes; PW, Pleurodeles waltl; SaS, Salamandra salamandra; Reptiles - ES, Elaphe scalaris; LL, Lacerta lepida; MM, Malpolon monspessulanus; NM, Natrix maora; Birds - ER, Erithacus rubecula; MC, Miliaria calandra; PC, Parus caeruleus; PD, Passer domesticus; PhC, Phylloscopus collybita; SeS, Serinus serinus; SM, Sylvia melanoccephala; StA, Strix aluco; SU, Sylvia undata; SyA, Sylvia atricapilla; TA, Tyto alba; Mammals - AS, Apodemus sylvaticus; EE, Erinaceus europaeus.

Table 1. Species identified during field work (54 surveys on a 26 kilometer road section); Portuguese red book status (RBS); and number of specimens (N). Species are sorted, within each class, by decreasing number of casualties.
Acknowledgment: This work was partially supported by EP-Estradas de Portugal, E.P.E. (Portuguese Roads Institution).

References


