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Do dry ledges reduce the barrier effect of roads?

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ABSTRACT

Wildlife crossing structures combined with fencing seek to improve permeability and habitat connectivity across roads and reduce wildlife-vehicle collisions. However, the presence of water inside culverts can seriously limit their effectiveness. The implementation of dry ledges can be a good measure to allow crossing when flooded. So far, there is a lack of knowledge on the effectiveness of dry ledges combined with fencing for a wide diversity of vertebrates. The main goal of this study is to evaluate how the presence of dry ledge affect culvert use for Mediterranean mesocarnivores (red fox *Vulpes vulpes*, stone marten *Martes foina*, European badger *Meles meles*, European otter *Lutra lutra* and common genet *Genetta genetta*). Between January and March 2008, wooden dry ledges were placed in 15 of 32 surveyed culverts. Additionally 100 meters of small mesh size and buried fences were installed along each side of all culverts. During one year we used video surveillance and track-plates to detect crossing events over seven consecutive nights per season in each monitored culvert. We evaluate the relative importance of dry ledges on culvert use and compare the number of road-kills within a 100 m buffer radius around the culverts before and after fence installation and culverts that were never fenced (control culverts). Although different species responded to culvert features differently, the presence of dry ledges was the most relevant feature explaining crossing events, in particular, for stone martens and genets. The fencing used did not reduce mammals road-kill prevalence. Our results imply that in order to improve culvert use, road managers should take into account the placement of ledges on culverts that remain flooded most of the year (more than 3 cm of water-depth). We also suggest exploring the role of ledge size and construction materials to increase the likelihood of being used by foxes and badgers.

1. Introduction

The negative effects of high traffic roads on animal populations have been intensively described in the last decades (Cain et al., 2003; Clevenger et al., 2003; Farhig and Rytwinski, 2009; Forman and Alexander, 1998; Klar et al., 2009). For many species roads create barriers to migration, dispersal and genetic exchange through the inhibition of crossing movements and the additional mortality due to collisions with vehicles (e.g. McGregor et al., 2008; Rondinini and Doncaster, 2002; Shepard et al., 2008; Strasburg, 2006; Rytwinski and Fahrig, 2012). Nowadays, there is a growing interest to mitigate these impacts by means of a wide variety of measures (Corlatti et al., 2008; Glista et al., 2009). Examples are the construction of underpasses and overpasses to maintain landscape connectivity (Clevenger and Waltho, 2000; Foster and Humphrey, 1995) and the use of fences, one-way gates, reflectors and/or warning signs (Aresco, 2005; D'Angelo et al., 2006; Klar et al., 2009; Reed et al., 1974; Sullivan et al., 2004; Ujvári et al., 1998) to reduce mortality.

Special attention has been paid to the use of drainage culverts as potential underpasses, due to the large number present along roads, their relative low cost (Mata et al., 2008), and to their well-documented use by many terrestrial vertebrates (Clevenger et al., 2001; Grilo et al., 2008; Ng et al., 2004; Rodriguez et al., 1996; Yanes et al., 1995). Nevertheless, the presence of water inside many culverts may limit their use as passages (Serronha et al., 2012). The installation of dry ledges can be a good management measure to allow crossing when flooded (e.g. Meaney et al., 2007). In spite of this, for many vertebrates such as carnivores, the information on the effectiveness of dry ledges in terms of increased permeability is still scarce. Equally, there is few information on the effectiveness of fencing road sections for carnivores and small mammals. Jaeger and Fahrig (2004) suggested that fencing may not be worth due to high costs and the limitation of animal movements which may be

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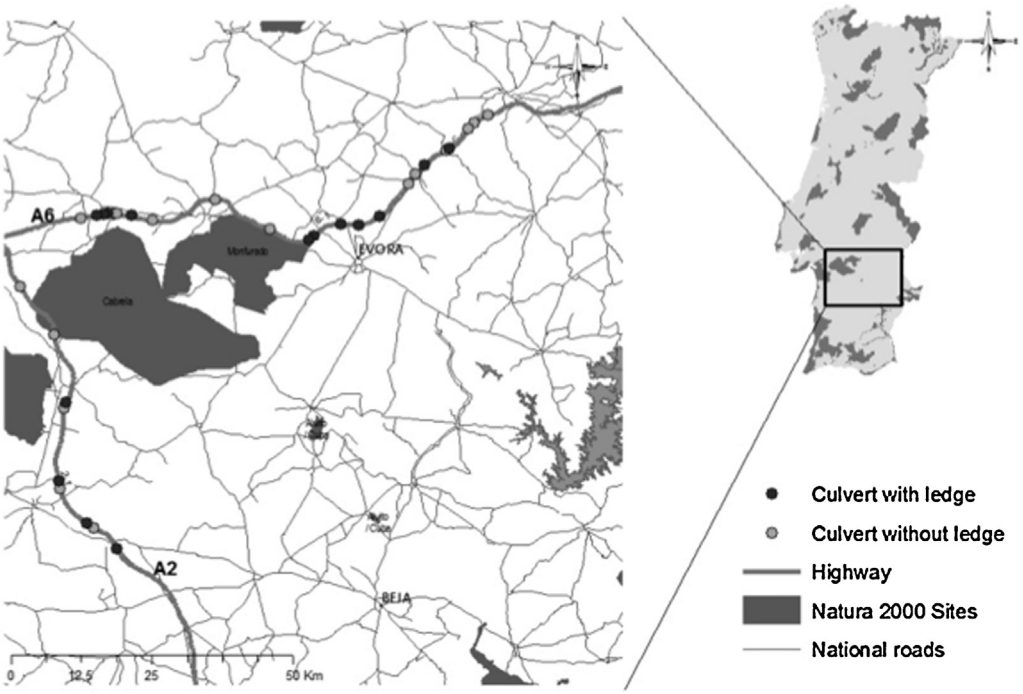

Figure 1. Study area and location of the monitored passages along the A2 and A6 highways in Portugal.

even more harmful than mortality. One interesting solution is fencing just the road sections with high incidence of road-kills (e.g. Klar et al., 2009) but when road-kills data is limited, we argue that the complementary use of fences combined with crossing structures, as suggested by several authors (e.g. Boarman et al., 1997; Dodd et al., 2004), may be also effective in reducing the road mortality.

The main goal of this study is to evaluate the effectiveness of dry ledges combined with fencing for mesocarnivores in culverts flooded part of the year by addressing the following questions: 1) what is the relative importance of ledges combined with fencing on culverts use? 2) which water-related descriptors influence the use of ledges? and 3) does complementary fencing reduce mammals mortality? We expect the effectiveness to be different according to species life history traits. A priori, we expect dry ledges to be more effective for smaller and water-reluctant species. Knowledge on these topics will provide support for a better understanding on the effectiveness of dry ledges, and therefore, reduce the overall impact of the road network in a cost-effective way.

2. Methods

2.1. Study area

The study was carried out in Alentejo province of southern Portugal along A2 (95 km) and A6 (150 km) highways sections (the intersection of both highways is located at 38° 36′ N and 8° 38′ W, Fig. 1). These highways under a private concession (BRISA Auto-Estradas de Portugal, S.A.) were built between 1996 and 2001 and have an annual average daily traffic of 13,949 vehicles and annual average night time (6pm to 6am) traffic of 5536 vehicles. On average, there are two crossing structures per kilometer of which more than 70% are drainage culverts. Both highways have livestock exclusion fencing (unburied, 150 cm height with 12 cm mesh size) which is generally ineffective in preventing crossing for almost all mammals (Grilo et al., 2009).

Land cover in the vicinity of the highway is representative of the typical Mediterranean landscape dominated by cork oak woodlands (*Quercus suber)* and holm oak (*Q. ilex)* that alternate with cereal crops. Excluding the two largest cities in the region, which have a population density of 1980 inhabitants/km^2, the population density in the study area is 21 inhabitants/km^2. The studied highways border four Rede Natura 2000 sites (Sado, Cabrela, Monfurado and Caia) each of which host a high carnivore richness (Santos-Reis and Petrucci-Fonseca, 1999).

2.2. Data collection

We surveyed 32 culverts along segments of these two highways: 13 circular culverts (1 and 1.5 m of diameter) and 19 squared culverts (ranging from 2×2 to 4×4 m). Between January and March 2008, wooden dry ledges of 50 cm width were placed 30 cm from the ground in 15 culverts: three circular culverts (1 and 1.5 m of diameter) and 12 squared culverts (ranging from 2×2 to 4×4 m). Ledges were installed in those culverts with a higher probability of being flooded during the rainy seasons (average water depth 5 ± 4 cm and average water cover $54 \pm 30\%$). In April 2008 and in addition to the livestock exclusion fences, 100 meters of small mesh size fences (2.5 cm wide) were installed (50 cm of height and buried 50 cm to avoid under-passing) along each side of 32 culverts surveyed, totalizing 12.8 km of fence, and 32 other similar culverts (with the same shapes and sizes as described above) were randomly selected in order to better control the role of fencing.

We used video surveillance and track-pads to detect the use of culverts by mesocarnivores. Two cameras with movement and heat sensors were oriented towards one entrance of each culvert and a fine layer of marble dust, with 120 cm of length, was placed covering the entire culvert width. Monitoring was conducted over seven consecutive nights per season in each culvert for one year after ledge installation. Every day video batteries were replaced and track pads were checked. Culverts were described in terms of spatial and temporal features over the monitoring period (Table 1). Spatial features include culvert features (presence of dry ledge, vegetation at the entrance, distance from culvert entrance to highway and openness), and the surrounding landscape within a buffer of