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Influence of landscape characteristics on carnivore diversity and abundance in Mediterranean farmland

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ABSTRACT

Predation is increasingly pointed out as one of the factors contributing to population declines of ground-nesting farmland birds, though it remains poorly understood how ongoing transformations of agricultural landscapes affect predator assemblages. This study addressed this issue, estimating the contribution of landscape composition and configuration to spatial variation in species richness and abundances of mammalian carnivores across a gradient of agricultural intensification in southern Portugal. The carnivore assemblage was diverse (10 species), but it was largely dominated by just three widespread and abundant species of generalist predators: domestic dog (*Canis familiaris*), red fox (*Vulpes vulpes*) and Egyptian mongoose (*Herpestes ichneumon*). The number of domestic carnivore species and the abundance of cats (*Felis catus*) increased along with farmland occupation by human dwellings, whereas dogs were not responsive to landscape variables. The species richness of wild carnivores was highest in landscapes with a patchwork of arable fields and semi-natural habitats such as forests and shrubland, though it was also high in irrigated landscapes with dense networks of irrigation channels and tree lines bordering agricultural fields. Irrigation was also positively associated with the abundance of otters (*Lutra lutra*) and mongooses. Cats, foxes, badgers (*Meles meles*), and total and wild carnivore abundances, were positively affected by increasing cover by eucalyptus and pine forest plantations. In general, results suggest that the highest diversity and abundance of carnivores in Mediterranean farmland may occur in mosaic landscapes with small agricultural fields, high cover by woody vegetation patches and corridors, and many human dwellings. Preventing scrub encroachment and afforestation may thus be necessary to maintain a low predation risk in open farmland habitats, which are often inhabited by ground-nesting birds of high conservation concern. Conversely, keeping shrubland and forest patches within farmed landscapes may be essential where carnivore persistence is a relevant conservation goal.

1. Introduction

Over the past decades, European agricultural landscapes have gone through a process of significant transformations associated with a period of intense and rapid economic and social changes (Vos and Meekes, 1999; Stoate et al., 2001; Jongman, 2002; Aranzabal et al., 2008). Across most of Europe, there has been a pervasive trend for land-use intensification and the loss of semi-natural habitats in the most productive regions, along with scrub encroachment and afforestation in marginal farming areas (Falcucci et al., 2007; Van Doorn and Bakker, 2007; Aranzabal et al., 2008). These transformations have resulted in major population declines of farmland species over vast geographic areas and across taxonomic groups, prompting a quest for the agricultural practices most favourable to the conservation of biodiversity within farmed landscapes (e.g., Benton et al., 2003; Aschwanden et al., 2007; Henle et al., 2008; Maes et al., 2008; Wade et al., 2008).

Agri-environmental management prescriptions are often targeted at maintaining or restoring critical feeding, reproduction or dispersal habitats of species or assemblages or species, generally assuming a direct link between habitat loss and farmland population declines (Stoate et al., 2001; Beja and Alcazar, 2003; Aschwanden et al., 2007; Henle et al., 2008; Maes et al., 2008; Wade et al., 2008). However, other indirect links may affect populations in changing farmland landscapes. For instance, the

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increasing abundance of invasive and commensal species has very often unknown consequences for the survival of indigenous species, as a result of the potential changes in competition and predation interactions (Shapira et al., 2008). This suggests that altered biotic interactions, particularly predation processes, could rival habitat change as a causal agent in farmland population declines (e.g., Evans, 2004). Different studies have indeed emphasised the relationships between landscape transformations and potential predation effects on farmland biodiversity, involving both the direct killing of individuals and changes in their behaviour and habitat selection patterns to reduce predation risk (Whittingham and Evans, 2004; Eggers et al., 2005; Wallander et al., 2006; Sims et al., 2008). Nevertheless, information on how agricultural change affects predator abundance and predation patterns and, hence, the persistence of many farmland species, is still scarce. Research on this subject is thus needed in order to improve agri-environmental schemes designed to retain farmland biodiversity, particularly in highly managed landscapes.

In Mediterranean Europe, predation has been increasingly invoked to explain patterns of habitat selection and dynamics of declining populations of open farmland birds (Silva et al., 2004; Moreira et al., 2005; Reino et al., 2009), as well as that of other species of conservation importance such as for instance the European rabbit *Oryctolagus cuniculus* (Calvete et al., 2004) and the Cabrera vole *Microtus cabrerae* (Pita et al., 2007). Although limited information is generally available to support these contentions, there is already some evidence indicating that ground-nesting passerines are highly vulnerable to predation in farmland landscapes (Yanes and Suárez, 1995), that changes in predation rates may vary with agricultural land uses (Pescador and Peris, 2001), and that population declines may occur due to increased densities of generalist predators such as foxes (*Vulpes vulpes*) and feral dogs (*Canis familiaris*) (Suárez et al., 1993; Yanes and Suárez, 1996). It remains unresolved, however, whether current trends of agricultural change affect the interactions between predators and protected species, partly due to a poor understanding on the composition and structure of predator assemblages inhabiting Mediterranean farmland, and how these are affected by landscape change (but see Falcucci et al., 2007). For instance, it remains poorly understood how predators respond to changes in agricultural field size or in the amount and spatial configuration of interstitial habitats such as hedges or woodlots, which often vary along with changes in agricultural land uses (e.g., Jongman, 2002). This information is particularly needed in the case of mammalian carnivores, which may be among the most influential predators in farmed landscapes and for which this kind of information is largely lacking (but see Virgós et al., 2002; Mangas et al., 2008). Furthermore, some of the carnivores likely to occur in Mediterranean farmed landscapes are also considered of conservation concern (e.g., Lozano et al., 2003; Mestre et al., 2007), which may generate dilemmas between the conservation of predators and that of their prey.

This study addressed these issues by examining correlates of carnivore assemblage variation across a Mediterranean farmland landscape, in a region where extensive agricultural land uses have been progressively abandoned or replaced by intensive irrigated agriculture, with overall negative consequences for farmland biodiversity (Beja and Alcazar, 2003; Pita et al., 2007). Specifically, the study quantified relationships between landscape patterns and carnivore assemblage attributes, in terms of species richness and abundance of the most widespread species. The study focused on variables reflecting landscape composition and structure, because these have been shown to strongly affect carnivore assemblages (Gehring and Swihart, 2003; Virgós et al., 2002; Mangas et al., 2008). Results were then used to discuss how landscape changes may affect the persistence of Mediterranean farmland carnivores, and how these in turn may affect populations of declining farmland species, particularly ground-nesting birds.

2. Methods

2.1. Study area

The study was conducted in the coastal plateau of southwestern Portugal. The region is included in the thermo-Mediterranean bioclimatic zone (Rivas-Martinez, 1981), with mean temperatures of about 16 °C and mean annual rainfall around 650 mm, of which >80% falls in October to March. This arable landscape is mainly devoted to irrigated agriculture and livestock production. Woody cover within the agricultural landscape is restricted to some woodlots and hedges delimiting fields and protecting crops from maritime winds. Shrubby hedges are most frequent around small fields close to villages, whereas tree lines were planted around larger fields generally devoted to irrigated agriculture. There are also more natural areas surrounding and interspersing the arable landscape, including coastal dunes, open cork oak (*Quercus suber*) woodlands, and Mediterranean woodlands and shrublands covering the slopes of entrenched rivers and streams crossing the coastal plateau. Although the area is included in a Natural Park and within a Site of Community Importance classified under the European Directive 92/43/CEE, agriculture is becoming ever more intensive since the early 1990s. Intensification processes include: (i) increases in cattle stock densities and the replacement of extensive pastureland by improved pastures; (ii) increases in the area occupied by vegetable crops for international markets, often grown in greenhouses; (iii) the loss of semi-natural habitats such as temporary ponds and shrubland; (iv) increases in the size of irrigated fields, which are mainly used for fodder crops such as corn and sorghum; and (v) the development of paved road networks (Beja and Alcazar, 2003; Pita et al., 2007). These changes have shown measurable negative impacts on amphibians (Beja and Alcazar, 2003), birds (Alcazar, 2003), and small mammals (Pita et al., 2007). Despite the overall trend for agricultural intensification, some areas have been abandoned or maintain extensive agricultural land uses, due for instance to the lack of irrigation infrastructures or legal constraints.

2.2. Carnivore surveys

This study is part of a larger research program investigating predation patterns and processes in Mediterranean farmland, involving 60 agricultural fields selected randomly along the coastal plateau of southwestern Portugal, 17 of which were sampled in 2002 and another 43 in 2003. Carnivores were surveyed on three occasions (spring, summer and autumn) between March and October, within circular 1-km radius plots (3.14 km^2) centred on each field (Fig. 1). This spatial extent was considered adequate for surveying carnivores at large spatial scales in the southern Iberian Peninsula (e.g., Barea-Azcón et al., 2006), and it was also expected to reflect the wide range of landscape types across the study area.

Carnivore surveys were based on the detection of indirect field signs of their presence, including both faeces and footprints (e.g., Matos et al., 2009; Beja et al., in press). Faeces of the different species were identified according to shape, size, odour and location, discarding scats showing ambiguous identity to reduce identification errors (Barea-Azcón et al., 2006; Mangas et al., 2008). Footprints were also used because they can generally be identified with more certainty than faeces, though they are also prone to potential errors as their presence or absence may be strongly influenced by substrate type (Barea-Azcón et al., 2006). This potential problem was not considered important in the present study area, because the soil was generally sandy and there were