



# Mediterranean mesocarnivores in spatially structured managed landscapes: community organisation in time and space



Gonçalo Curveira-Santos<sup>a,b,\*</sup>, Tiago A. Marques<sup>c,d</sup>, Mats Björklund<sup>a</sup>, Margarida Santos-Reis<sup>b</sup>

<sup>a</sup> Department of Animal Ecology, Evolutionary Biology Centre, Uppsala University, Norbyvägen 18-D, SE-752 36, Uppsala, Sweden

<sup>b</sup> cE3c – Centre for Ecology, Evolution and Environmental Changes, Faculdade de Ciências da Universidade de Lisboa, Ed. C2, Campo Grande, 1749-016 Lisboa, Portugal

<sup>c</sup> Centre for Research into Environmental and Ecological Modelling, University of St Andrews, The Observatory, Buchanan Gardens, St Andrews, KY16 9LZ, UK

<sup>d</sup> Centro de Estatística e Aplicações da Universidade de Lisboa, Faculdade de Ciências da Universidade de Lisboa, Ed. C6, Piso 4, Campo Grande, 1749-016 Lisboa, Portugal

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## ABSTRACT

In the multi-functional and biodiverse cork oak landscapes of Iberia (Montado), agro-silvo-pastoral practices promote landscape heterogeneity and create intricate habitat and resource availability patterns. We used camera-traps to investigate the temporal and spatial organisation of a mesocarnivore community in a Montado landscape in central Portugal. The target carnivore assemblage was largely dominated by three generalist species – the red fox *Vulpes vulpes*, the European badger *Meles meles* and the Egyptian mongoose *Herpestes ichneumon* – while remaining community members – the common genet *Genetta genetta* and the feral cat *Felis silvestris* spp. – exhibited restricted distributions. Interspecific differences in activity rhythms and habitat use were particularly marked among widespread species. Low temporal overlap was reported between the diurnal mongoose and predominantly nocturnal red fox and badger. For the latter two species, contrasting differences in habitat use were associated with anthropogenic-induced environmental heterogeneity. Whereas the red fox used more intensively Montado areas preserving dense shrubby understory and avoided semi-disturbed mosaics of sparse shrubs, the badgers displayed the opposite pattern. Our findings add to previous evidence suggesting that the spatial structure created in highly managed landscapes, particularly the diversity of resulting understory structures, promotes the abundance and spread of generalist mesocarnivore species. These may benefit from the surplus of resource amount (e.g. prey) and the creation of different human-made habitats conditions that provide particular combinations of ecological resources favourable to each species requirements. We concur the common view that maintaining understory heterogeneity in Montado landscapes, menaced by current intensification and extensification trends, is important where carnivore persistence is a relevant conservation goal, but alert for potential effects on carnivore assemblages structuring and impacts for specialist species less tolerant to disturbance.

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## 1. Introduction

Multifunctional landscapes across the Mediterranean basin harbour a great proportion of this region's biodiversity (Cox and Underwood, 2011). Such biodiversity value is largely associated

with the environmental heterogeneity preserved in centuries-old traditional agro-environmental systems, now menaced by intense and rapid environmental, economic and social changes (Pinto-Correia and Mascarenhas, 1999; Aranzabal et al., 2008). Intensification schemes in most productive regions led to the loss of semi-natural habitats while the abandonment of marginal farming areas promoted scrub encroachment and afforestation. These pervasive trends prompted population declines of several species, thus generating a need for management prescriptions most favourable to biodiversity conservation within managed landscapes (Benton et al., 2003; Henle et al., 2008; Wade et al., 2008). However, the implementation of successful agri-environmental schemes is

\* Corresponding author at: cE3c – Centre for Ecology, Evolution and Environmental Changes, Faculdade de Ciências da Universidade de Lisboa, Ed. C2, Campo Grande, 1749-016 Lisboa, Portugal.

E-mail addresses: [goncalo-cs@hotmail.com](mailto:goncalo-cs@hotmail.com) (G. Curveira-Santos), [tam2@st-andrews.ac.uk](mailto:tam2@st-andrews.ac.uk) (T.A. Marques), [mats.bjorklund@ebc.uu.se](mailto:mats.bjorklund@ebc.uu.se) (M. Björklund), [mmreis@fc.ul.pt](mailto:mmreis@fc.ul.pt) (M. Santos-Reis).

conditional on our ability to foresee how alternative management choices affect the structure and functioning of the system and key functional groups (Benton et al., 2003).

Studies assessing wildlife responses to management options in human-dominated environments (e.g. agricultural landscapes *sensu lato*) often target species richness (e.g. Silva et al., 2008; Godinho et al., 2011; Gonçalves et al., 2011; Leal et al., 2011), or single threatened species (e.g. Lozano et al., 2003; Pita et al., 2006), overlooking guild-level approaches focused on species-specific responses and community organisation. Such knowledge is particularly important for groups of functional importance, such as mammalian carnivores, directly and indirectly associated with biodiversity patterns (Ray et al., 2005; Sergio et al. 2008; Prugh et al., 2009; Roemer et al., 2009; Ripple et al., 2014). Iberian carnivore guilds have been the focus of extended research on community structuring processes across space, time, and food resources, in natural or semi-natural habitats (e.g. Fedriani et al., 1999; Carvalho and Gomes, 2004; Monterroso et al., 2014). However, less attention was given to carnivore communities exposed to anthropogenic pressures (but see Pereira et al., 2012; Barrull et al., 2013; Cruz et al., 2015), particularly within a context of highly managed landscapes, such as those deriving from agricultural and/or pastoral practices. Anthropogenic-induced environmental heterogeneity may create surplus of resource variety and availability, providing adequate ecological conditions for a wide range of carnivore species (Rosalino et al., 2009; Verdade et al., 2011). Nevertheless, local carnivore populations may vary in their ability to exploit the existing resources or cope with the associated disturbance (De Angelo et al., 2011). Therefore, augmented environmental heterogeneity may induce differential selective behaviours among sympatric species within the same trophic level, thus altering community organisation patterns (Rosenzweig, 1987).

Unique to the Mediterranean region, the Iberian cork oak (*Quercus suber*) and/or holm oak (*Quercus rotundifolia*) woodland – or “Montado” (“Dehesa” in Spanish) – is the last major wood-pasture system in Europe (Blondel and Aronson, 1999), representing a sustainable multi-use system well-adapted to the local edapho-climatic constraints. Centuries of agro-silvo-pastoral practices have transformed the native Mediterranean scrubland into spatially complex agroecosystems, where extensive and heterogeneous cork/holm oak woodlands, shaped by different management options (e.g. grazed and non-grazed areas), are interspersed with other production lands and remnant semi-natural vegetation (Pinto-Correia and Mascarenhas, 1999). Management actions within oak woodlands prevent shrub encroachment, either by grazing or mechanical means of varied intensity, while dense vegetation is preserved in less accessible areas or those set aside for wildlife conservation; thus creating highly heterogeneous and spatially structured landscapes mainly in regard to differences in understory structure and density. This variety of cover types (compositional heterogeneity) and their intricate spatial patterning (configurational heterogeneity) promotes complex habitat mosaics and resource availability patterns (Fahrig et al., 2011), the maintenance of which depends on continuous management at the farmstead level (Gonçalves et al., 2011). Due to its structural complexity, the Montado agroecosystem holds high species richness and maintains a balance between human activity and biodiversity preservation, being recognized as a high nature value farmland (Pinto-Correia and Vos, 2004).

In spite of carnivores being reported as sensitive to human disturbance (Gittleman et al., 2011) all ten mesocarnivore species with resident populations in southern Portugal persist in the intensively managed Montado landscapes (Santos-Reis et al., 1999). Nonetheless, most studies aimed to understand how human-induced environmental heterogeneity relate to carnivore

diversity patterns (Pita et al., 2009; Rosalino et al., 2009; Gonçalves et al., 2011), while anthropogenic influence as a community-structuring force within carnivore assemblages remains unclear. Here, we investigated the spatio-temporal structure of a meso-carnivore assemblage in a Montado farmstead in central Portugal. We assessed interspecific differences among coexisting species in circadian activity and habitat use to reveal how community organisation patterns relate, directly or indirectly, to features of a landscape shaped by management actions. Specifically, we hypothesized: i) activity and temporal overlap patterns to be similar to reports for other Iberian natural and semi-natural areas (Monterroso et al., 2013, 2014), in accordance with our target species behavioural habits and low levels of direct disturbance in the study area; and ii) the existence of interspecific differences in habitat use patterns, reflecting each species ecological requirements, i.e. a community exhibiting a spatial structure supported by human-induced environmental heterogeneity.

## 2. Materials and methods

### 2.1. Study area and target community

This study was conducted in the forested area (“Charneca” – 100 km<sup>2</sup>) of the largest agro-forestry farmstead in Portugal – Companhia das Lezírias S.A. (180 km<sup>2</sup>). The study area is representative of the agro-silvo-pastoral cork-oak systems with a vast geographic extension across the Mediterranean basin (Aronson et al., 2009). The farmstead has been intensively managed since its foundation in 1836, in the Charneca primarily for silviculture and pastoral practices, and varied management options gave rise to a complex and heterogeneous landscape (Fig. 1). The cork oak Montado woodland (~61 km<sup>2</sup>) is the dominant land-cover, occurring in pure or mixed patches with maritime pine (*Pinus pinaster*), and with variable composition and density of understory structures (dense, sparse and absent; Fig SA1). This mosaic is complemented by interspersed maritime pine stands (~14 km<sup>2</sup>), and scattered patches of eucalyptus (*Eucalyptus globulus*) and scrublands. Croplands (rice fields and irrigated plots) cover the remaining area (Gonçalves et al., 2011). More than 35 km of watercourses cross the study area, of which ca. 11 km are permanent and associated with fully developed arboreal and shrubby strata of riparian vegetation (Ferreira and Aguiar, 2006). The majority of the forested area (~55 km<sup>2</sup>) is used for biological cattle raising. From late September until late February/March, around 1500 cows roam within the “Charneca”, organized into 50–300 head herds that rotate among grazing plots of up to 4 km<sup>2</sup> (Gonçalves et al., 2011); in Spring cattle are guided to the farmstead’s marshy areas (called “Lezíria”, c.a. 20 km North-east), with richer soils and pastures, where they reside until late Summer.

The study area supports a diverse mesocarnivore community, including eight out of the ten mesocarnivore species occurring in the Portuguese Montado (Santos-Reis et al., 1999; Gonçalves et al., 2011). Our target community comprised the five most abundant species found locally (Gonçalves et al., 2011): two native species (red fox *Vulpes vulpes* and European badger *Meles meles*), two exotic, naturalized, species (common genet *Genetta genetta* and Egyptian mongoose *Herpestes ichneumon*), originating from Africa (Gaubert, 2016), and the feral cat (*Felis silvestris* spp.). The designation “feral cat” arises from uncertain species identification in a population of wild-phenotype cats roaming free across the landscape, independently of human settlements, and includes genetically confirmed first generation hybrids of European wildcat (*Felis silvestris silvestris*) and its domestic counterpart (*Felis silvestris catus*) (Gonçalves et al., 2011).

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