



Spatial and temporal interactions between livestock and wildlife in South Central Spain assessed by camera traps



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ABSTRACT

The diversification of livestock farms into hunting estates in South Central Spain (SCS) may impede the success of *Mycobacterium bovis* eradication programmes by facilitating transmission between wildlife and livestock. In this observational study we aimed to provide information of relevance about the nature and frequency of interactions (observed visits to study points) between livestock (cattle and domestic pigs) and wildlife (wild boar and red deer). The study was conducted in an extensive cattle farm in SCS where the land is also used for game hunting. During a period of one year, camera traps ($n = 16$) were placed at a priori risk points for interspecies interactions: water (natural and artificial troughs), food placed on the ground for baiting wildlife, and pasture. To define indirect interspecies interactions, a critical time window for *M. bovis* to survive in the environment was selected based on the literature. Results suggest that wildlife frequented food and pasture points more often than water points, and that the number of visits increased through the dry season, peaking during the acorn season (October–January) and the deer breeding season (June–July). Direct interactions were rare ($n = 10$), as opposed to indirect interactions ($n = 8992$). Wildlife-followed-by-livestock interactions ($n = 7714$) occurred much more often than livestock-followed-by-wildlife ($n = 1278$) and were frequent at water points (66% water points, 17% food, 17% pasture). Results also suggest that water points are a hotspot for indirect interactions and might therefore be a source of infection at the wildlife–livestock interface in the territory covered, particularly for *M. bovis*, as it is around water where the bacteria seem to survive the longest. Preventing aggregation and therefore reducing contact rates between domestic and wild animals especially at water points may be valuable for disease control in South Central Spain.

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1. Introduction

Pathogens shared by livestock and wildlife are considered an increasing problem worldwide (Daszak, 2000; Cleaveland et al., 2001; Gortazar et al., 2007). There are implications in areas such as public health (Michel et al., 2010), economic loss (WorldBank, 2012), conservation of endangered species (Gortazar et al., 2008) and animal

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welfare (Sainsbury et al., 1995). Understanding infection dynamics and disease transmission is key to establishing multi-host pathogen control measures.

Mycobacterium tuberculosis complex (MTC) bacterial pathogens (including *M. bovis* and *M. caprae*) cause tuberculosis (TB) and are important because they are transmitted within and between livestock and wildlife populations through direct and indirect routes of infection (Morris et al., 1994; Palmer et al., 2001, 2004; Hermoso de Mendoza et al., 2006). *M. bovis* causes chronic TB in cattle and is able to affect a wide range of hosts, including humans (Morris et al., 1994; O'Reilly and Daborn, 1995; Delahay et al., 2001). It is considered a public health and economic concern both in developing and developed countries (Cosivi et al., 1998; Diez et al., 2002; Zinsstag et al., 2006; EFSA, 2011). Eradication of TB in cattle has been attempted by test and slaughter campaigns in several countries. However, it is thought that the existence of wildlife reservoirs (see Haydon et al., 2002) compromises the success of this strategy (Corner, 2006; Gortazar et al., 2008).

In Spain, cattle TB prevalence has reduced since the introduction of a compulsory National eradication programme in 1987. However, in some areas herd prevalence is as high as 7.22%, although a negative trend in time in prevalence has been observed overall (RASVE, 2013). TB in South Central Spain (SCS), where hunting is part of popular tradition, is highly prevalent not only in cattle (2011 herd prevalence: 5.35% (RASVE, 2013)), but also in wild boar *Sus scrofa* (mean prevalence on SCS hunting estates: 44.5–52.4%) and red deer *Cervus elaphus* (13.7–18.5%) (Vicente et al., 2007b; Gortazar et al., 2008; Garcia-Bocanegra et al., 2012). Wild boar are a known TB reservoir for cattle in Spain (Naranjo et al., 2008) and a maintenance host in Portugal (Santos et al., 2009), whilst red deer are highly suspected of being also a true reservoir (Vicente et al., 2007b). Prevalence data for domestic pigs is lacking and therefore their potential contribution to the maintenance of TB, as shown by Di Marco et al. (2012) in Sicily, is unknown (Parra et al., 2005). In SCS, there has been a tendency for private livestock farms to diversify into hunting estates during recent decades, thereby encouraging shared space use between wild and domestic species. Furthermore, translocations of trophy species, fencing of wildlife populations and supplementary feeding have increased aggregation and shared space use between domestic and wild animals (Gortazar et al., 2006; Vicente et al., 2007a), which could lead to indirect transmission of disease at the interface (Palmer et al., 2004) if the necessary conditions occur (Corner, 2006). Survival times of *M. bovis* in the environment, although highly variable, may be as much as several months, e.g. Fine et al. (2011), giving rise to the possibility of indirect transmission through shared space use. Disease control at the wildlife–livestock interface requires mitigation of contact between wildlife and cattle, through adequate biosecurity, husbandry measures and pasture management (Judge et al., 2011). Therefore, the description of the spatial and temporal patterns of interactions at the interface is a necessary first step.

This study aims to provide information of relevance about the nature and frequency of interactions between livestock (cattle and domestic pig) and wildlife (wild boar

and red deer) in an extensive beef cattle farm in Ciudad Real province, SCS. It refers exclusively to interspecies interactions and therefore should not be taken as a transmission model. We tested the hypothesis that water and food points in dry Mediterranean conditions are more appealing than pasture points and therefore are a hotspot for livestock and wildlife interactions. We also evaluated the aggregation potential on wildlife of food baiting on the ground, a practice commonly performed on large game hunting estates in SCS.

2. Materials and methods

2.1. Literature review

The study included a literature review (see Supplementary data I) to identify estimations of survival times in the environment for *M. bovis* in different areas of the world.

2.2. Study area

The study was conducted at an extensive beef cattle farm called “Aguila y Timones” (38°32'51.49" N; 4°9'23.73" W, UTM Grid zone 30S), in Ciudad Real province, Castilla La Mancha region, SCS (Fig. 1a). The farm territory covered 300 ha and contained an average of ninety cows and five domestic pigs. Livestock extensive farming in south-western Iberian Peninsula is practiced in typical agroforestry systems called “dehesas” (savannah-like habitats) characterised by the presence of wooded pasture (predominantly oak trees *Quercus* spp. (Diaz et al., 1997)). Farm sizes can be highly variable depending on the suitability of the land for livestock rearing. Large game hunting is a secondary use of this land and has become the predominant source of income, resulting in a heterogeneous distribution of land uses. Territories adjacent to the study farm consist of hunting estates (separated by wire fencing), a water reservoir and, partially, by a river which seasonally becomes dry. Telemetry data shows that wildlife and pigs go through the wire fence and can move between and across fenced territories (Vicente et al., 2010). Food baiting has been in place at the farm for several years as part of the popular tradition of game hunting, typical in SCS where game and extensive farming practices physically overlap and/or border. Wild boar, red and roe deer (*Capreolus capreolus*) on the farm occur in moderate densities compared to the rest of the region (no more than 15–20 red deer, 10 roe deer and 10 wild boar (Vicente, personal communication)). On our study farm, government test-and-slaughter activities during 2008–2011 (based on skin test, confirmed by culture after sampling at the slaughterhouse) shown mean cattle herd prevalence to be 8.65%. Regarding wildlife, animals shot on the farm and in the neighbouring hunting estates during the hunting season 2010–2011 shown a 83.9% and a 29.7% TB prevalence (based on the criteria following by Vicente et al., 2006) in wild boar and red deer respectively (Vicente, personal communication). This farm is considered representative of others in the area based on similar management practices, environmental conditions, similar mean prevalence of tuberculosis-like lesions (Vicente et al., 2006) and MTC (Boadella et al., 2011; Garcia-Bocanegra

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