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Effects of free-ranging cattle and landscape complexity on bat foraging: Implications for bat conservation and livestock management

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ABSTRACT

Traditional agropastoralism increases biodiversity by maintaining habitats whose existence depends on human practices as well as by providing wildlife, including bats, with key spatial and trophic resources. Bats in farmland are crucial predators of crop pests, thus offering an economically important ecosystem service. It seems possible that bats may also provide services by feeding on insects associated with livestock. We tested whether bats forage over cattle in a traditionally managed pastoral area of central Italy, i.e. setting the bases for providing pest control services. We found that small bat species (mostly *Pipistrellus* spp.) foraged preferentially over livestock, and that their activity increased, but then reached a plateau or slightly decreased, for progressively larger herds. Landscape complexity also led to an increase in bat activity over livestock. Since insects attracted to cattle at night typically include flies such as mosquitoes (Culicidae) and biting midges (Ceratopogonidae), which are potentially harmful to cattle and may carry serious diseases, and that bats such as *Pipistrellus* spp. are important predators of such flies, we argue that bats may play a valuable pest-suppression role.

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1. Introduction

One of the main consequences of human impact over half of the Earth's land surface (Hooke et al., 2012) is the existence of a complex network of interactions with wildlife, some conspicuous, others subtle, whose comprehensive understanding plays a pivotal role in tailoring effective conservation practices (Caro et al., 2012). Loss of habitat due to replacement of natural land cover with urban and agricultural areas is one of the main drivers of the current biodiversity loss worldwide (Singh, 2002; Turner et al., 2007). While most species succumb, a limited number of adaptable species tolerate or even benefit from large-scale habitat disappearance or alteration (Parker and Nilon, 2012), at the expense of community diversity and the ecosystem services it provides (e.g. Morelli et al., 2016).

Agriculture is one of the most powerful drivers of land use change. An estimated 13% and 26% of the planet's land surface have been converted to cropland and permanent meadows and pastures, respectively (Hooke et al., 2012). Livestock farming is the most widespread human activity, dominating rangeland ecosystems worldwide (Fleischner, 1994; Alkemade et al., 2013). The negative ecological effects of free-range livestock farming comprise biomass removal, vegetation trampling, root destruction, competition with wild ungulates (e.g. Alkemade et al., 2013) and transmission of diseases to wildlife (Smith et al., 2009). However, the type and magnitude of these effects vary according to the extent of habitat grazed, the type of land management applied and whether grazed areas result from conversion of former forest (Alkemade et al., 2013). While intensive farming is responsible for a large-scale decline of biodiversity, low-intensity farming systems, including traditional agricultural and pastoral practices, have rather played a chief role in creating a diverse range of landscapes that sustain rich biological communities including many wildlife species at risk throughout Europe (Moreira et al., 2005). For example, some eastern Mediterranean pastures have actually survived thanks to uninterrupted livestock grazing for over 5000 years (Blondel and Aronson, 1999). Land abandonment – i.e. the cessation of agriculture and pastoralism in previously farmed landscapes driven by major socio-economical changes – is recognised as a major driver of the disappearance of important

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habitats and species whose existence depends on human action (Moreira and Russo, 2007).

Grazing by free-ranging domestic stock has taken over the ecological role of the extinct large herbivores such as aurochs (*Bos primigenius*) and wild horses (*Equus ferus*) that dominated Europe in late Pleistocene and early Holocene in creating and maintaining open landscapes of great value for biodiversity (Hearn, 2015). Besides having direct effects on habitat structure, livestock also represent a direct food source for vertebrates such as large predators (Boitani, 2000) and scavengers (Donázar et al., 2002). Moreover, many coprophagous insects feed on dung (Lumaret and Kirk, 1987), providing prey to insectivorous vertebrates such as birds (Wilson et al., 1999) and bats (Duvergé and Jones, 2003). In some cases, the mere presence or activity of livestock may favour prey availability to insectivores. A familiar example is the cattle egret (*Bubulcus ibis*), often feeding among cattle on insects set in motion by grazing (Heatwole, 1965; Wahungu et al., 2003), so that the presence of livestock has helped this bird to increase its geographical range (Petretti, 2003).

Bats are a biodiverse mammal order providing crucial ecosystem services in both natural and agricultural ecosystems including seed dispersal or pest suppression (Kunz et al., 2011). Given the high sensitivity of bats to human interferences (Jones et al., 2009; Russo and Jones, 2015) many bat populations have shown marked declines in response to land use change and, as for many other taxa, agricultural intensification constitutes a powerful driver of habitat reduction and fragmentation (Heim et al. 2016; Park, 2015). Low-intensity agriculture such as organic farming (Wickramasinghe et al., 2003) or traditionally managed cultivations (Russo et al., 2002, 2005), instead, host higher levels of bat abundance, diversity and foraging activity (Park, 2015). Although the mechanisms generating such patterns are unclear (Park, 2015), several potentially important causal factors may be identified, e.g.: the persistence of high spatio-temporal habitat heterogeneity (Benton et al., 2003); the partial or complete avoidance of pesticides that are widespread in intensive agriculture, where they affect bats through both biomagnification (Jefferies, 1972) and prey depletion (Wickramasinghe et al., 2004); and the presence of small-scale habitats such as hedgerows (Downs and Racey, 2006; Boughey et al., 2011) and water bodies (Korine et al., 2015).

In contrast to intensive farming practices (Park, 2015), moderate livestock grazing may favour bats by maintaining semi-open habitats favoured by many species (Duvergè and Jones, 2003; Lòpez-González et al., 2015), increasing availability of prey (Shiel et al., 1991; Catto et al., 1996; Ransome, 1996) such as dung-dwelling insects (Duvergé and Jones, 2003), and providing artificial drinking sites (Korine et al., 2015; Russo et al., 2016). That several species of bats feed extensively on dung-beetles (Scarabaeidae) and other insects in pastures has been known for a long time (Rydell, 1986) but only recently has it become apparent that bats also feed around the cows themselves (Downs and Sanderson, 2010).

The foraging activity of insectivorous bats may increase crop yields through pest suppression, a vital service in agroecosystems (e.g. Federico et al., 2008; Boyles et al., 2011; McCracken et al., 2012; Maine and Boyles, 2015; Heim et al., 2015; Puig-Montserrat et al., 2015). Although quantitative studies on nocturnal or crepuscular insects parasitizing cattle are missing, it is well known that mosquitoes, biting midges or blackflies have a considerable negative effect on livestock productivity (Davies, 1957; Steelman, 1976; Kazek and Jezierski, 2014): in 1981 an estimated 10% of cattle productivity was lost due to ectoparasites in the US, almost 70% of which was caused by dipterans (Byford et al., 1992). Bats might therefore potentially play an important role in suppressing such pests, acting as mutualists of livestock rather than commensals.

The aim of this study was to investigate if insectivorous bats in a Mediterranean landscape routinely feed over free-ranging cattle, rather than over the dung, as suggested by Downs and Sanderson (2010). We then developed this aspect further by investigating the responses of bat activity and species richness to increasing herd sizes (corresponding to more parasitic insects; Schmidtmann and Valla, 1982) and landscape heterogeneity (whose growth typically has positive effects on bat assemblages; Heim et al., 2015), predicting a positive relationship in both cases.

2. Materials and methods

2.1. Study area

Fieldwork took place in a Site of Community Importance in Castel di Guido, central Italy (41.89 N, 12.31 E, altitude ca 75 m a.s.l.). Part of the area is a bird reserve of the Italian League for Bird Protection ("Oasi Lipu Castel di Guido"). The landscape is characterised by a mosaic of Mediterranean scrublands and oak woodlands (mainly made of *Quercus pubescens* and *Q. suber* standings) interspersed with organic agricultural crops (cereals, alfalfa) and pastures. A few isolated buildings and one small village occur in the area. Water habitats are represented by a few seasonal pools, one anti-fire basin and several cattle troughs. At the site, five free-ranging herds of "Maremmana" cattle are kept in 6.0–9.1 km^2 fenced areas covered with both pastures and natural vegetation, while four "Friesian" and "Chevrolet" cattle herds use 0.5–3.1 km^2 fenced areas dominated by pasture. Livestock were not treated with avermectin or other anti-helmintics in the study area, where farm management is strictly organic.

2.2. Sampling design

To achieve sufficient temporal coverage of data collection, our study was done in two years (2015 and 2016) from June to September, comprising crucial phases of bat life cycle such as pregnancy, lactation, juvenile emancipation and mating.

The study area was over 1300 ha, allowing us to include sufficient spatial variation in data collection. Within this area, we selected 13 sampling plots as far apart as possible from each other. Plots had a radius of 530 ± 235 m (mean $\pm$ standard deviation) and inter-plot distance ranged between 280 and 1900 m. For each plot we recorded bat activity at three different points $\geq$100 m apart (one night per point), each of which corresponding to one of the following treatments: (1) cows present (in such cases recordings were made $<$10 m from livestock); (2) dung present – cows absent (fresh dung was present, but no cows were present within a radius $\geq$70 m around the recording point) and (3) control, i.e. pastures with neither cattle nor dung within $\geq$70 m. When sampling in the "cows present" condition, we assessed herd size by visually counting the numbers of head present at the sampling site. On each night two sampling points were taken at random, and recordings were made continuously for 4 h since sunset.

We used D1000X real-time bat detectors (Pettersson Elektronik AB, Uppsala, Sweden) kept in the heterodyne mode and manually tuned continuously between 30 and 100 kHz to cover call frequencies of all species present in the area. When a bat was heard, calls were recorded in real time at 380 kHz sampling rate until 5 s had elapsed since the last detected call.

2.3. Sound analysis

Recordings were analysed with BatSound 4.12 (Pettersson Elektronik AB) and identification was carried out by applying the quadratic discriminant functions developed by Russo and Jones (2002). Because that approach requires manual selection and

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