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Sustained parasiticide use in cattle farming affects dung beetle functional assemblages

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ABSTRACT

In pastoral agricultural landscapes, dung beetles provide important ecosystem functions including the removal of standing livestock dung, increasing pasture fertility and reducing parasite transmission. Faecal residues of the macrocyclic lactones (MLs) and synthetic pyrethroids (SPs) commonly used to treat livestock against endo- or ectoparasites (parasiticides), can have negative impacts on invertebrates such as dung inhabiting beetles. However, the extent of any functional ecological impact from their sustained use is unclear. The current work aimed to quantify the landscape-level effects on dung inhabiting beetle species assemblages associated with sustained parasiticide use within different farming systems. Cow dung-baited pitfall trapping was undertaken on 24 beef cattle farms in SW England, which either used MLs (n = 8), SPs (n = 7) or no parasiticides (n = 9). There were no differences in overall beetle abundance between farm types, however species richness, diversity, and functional diversity were higher on farms with a history of using no parasiticides compared to farms that used parasiticides. Species of endocoprid (dung dwelling) beetle dominated the community on farms that used parasiticides, particularly MLs, while paracoprid (dung burying) beetles were rare, possibly due to differential impacts depending on life history traits of the functional groups. The results are of concern because the long-term loss of dung beetle diversity and changes in functional assemblages have the potential to impair ecosystem function in agricultural landscapes.

1. Introduction

Livestock farming in the United Kingdom (UK) commonly uses a range of systemic macrocyclic lactone (ML) compounds to treat cattle against endoparasites (worms and fluke) while topical insecticides, such as synthetic pyrethroids (SPs), are more commonly used against ectoparasites (ticks and lice) and biting flies (AHDB, 2017). Macrocyclic lactones activate invertebrate-specific glutamate-gated chloride channels resulting in paralysis and death (Bloomquist, 1996). Pyrethroids are also neurotoxic to insects and prevent the closure of axonal sodium channels (Casida et al., 1983). However, residues of these compounds are known to be excreted largely unmetabolized in cattle faeces for approximately 1–4 weeks after treatment, where they continue to have insecticidal effects via the mechanisms described above (Herd et al., 1996; Sommer et al., 1992; Vale et al., 2004; Wardhaugh et al., 1998). The negative impacts that these residues have on invertebrates, for example dung colonizing beetles, is well documented, for both MLs (e.g. Beynon et al., 2012a,b; Strong et al., 1996; Wall and Strong, 1987) and SPs (Bang et al., 2007; Vale et al., 2004; Wardhaugh et al., 1998).

Dung colonizing beetles provide important ecosystem functions in agricultural landscapes including the removal of standing dung from pastures (Beynon et al., 2012b; Holter, 1979), bioturbation (Mittal, 1993), nutrient cycling (Doube, 2008), and parasite control (Sands and Wall, 2016). Dung breakdown and incorporation into the earth is essential in nutrient cycling and the return of nutrient rich organic matter back into the soil (Yoshitake et al., 2014). Work in Australia has shown that cattle dung burial by the paracoprid beetle *Bubas bison* (Linnaeus 1767) resulted in elevated levels of nitrate, ammonia, phosphate, sulphur and carbon in soil, as well as increased soil organic matter and increased pH, for at least two years after the burial event (Doube, 2008). Beetle activity in faeces may make the environment unfavourable for the survival and development of the free-living stages of gastrointestinal parasites of livestock, which develop in dung pats (Sands and Wall, 2016). Studies have demonstrated a reduction in parasite larval recovery from pasture herbage when dung was colonised by dung beetles compared to uncolonized dung (English, 1979; Sands and Wall, 2016). Current estimates place the economic value of dung beetles to the UK cattle industry at £367 million per year, largely due to the cost of parasite control (Beynon et al., 2015). Any reduction in the abundance or diversity of dung beetles, due to sustained effects of treatment

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with parasiticides (endo- and/or ecto- parasiticidal veterinary treatments) (Hutton and Giller, 2003), may therefore result in reduced ecosystem function and production losses in agricultural systems (Manning et al., 2016; Tixier et al., 2015).

Pasture-level experimental studies have suggested decreased species richness and diversity for a number of dung inhabiting taxa after treatment with ivermectin (MK-0933, 22, 23-dihydroavermectin B1; a macrocyclic lactone antiparasiticide derived from the bacterium *Streptomyces avermitilis* (Chhaiya et al., 2012)) (Jochmann and Blanckenhorn, 2016; Krüger and Scholtz, 1998a). There were significant reductions in the abundance of 12 out of 32 hymenopteran and dipteran taxa collected from ivermectin-treated dung compared to control dung (Jochmann and Blanckenhorn, 2016). Species specific effects of ivermectin residues on dung inhabiting beetles have also been reported, with significantly reduced adult survival and offspring emergence in two and four out of nine dung beetle species respectively (Beynon et al., 2012b). Studies comparing different farming systems found higher dung insect abundance and diversity on organic farms, where veterinary parasiticides are not used intensively, compared to rough grazing or intensive farms (Hutton and Giller, 2003), and on nature conservation areas and organic farms than conventionally managed farms (Geiger et al., 2010).

The extent of any sustained ecological impact on dung beetle assemblage structure resulting from the toxic effects of veterinary parasiticides reported in experimental studies remains unclear (Wall and Beynon, 2012). Recent experimental work has suggested no evidence of any persistent impact of anthelmintic exposure on ecosystem multifunctionality (Manning et al., 2017a). However, landscape level studies that consider entire dung beetle communities are lacking. The aim of the current work was therefore to quantify the sustained effects of chemical residues in cattle dung on dung colonizing beetle communities as a result of long-term parasiticide use within farming systems, via a landscape-level study examining species abundance, richness, diversity and functional diversity. Dung beetles, *sensu stricto*, are represented by the families Scarabaeidae and Geotrupidae, and include species of *Geotrupes, Onthophagus* and *Aphodius* in temperate climates (Skidmore, 1991). However, other beetles, including those in the families Histeridae, Hydrophilidae and Staphylinidae also live and feed in dung, for example the coprophagous hydrophilid *Sphaeridium lunatum* (Fabricius 1792) has been shown to have similar morphological adaptations of its mouthparts for dung feeding as coprophagous Scarabaeidae species (Holter, 2004). Little is known about the contribution of these latter beetle families to the dung invertebrate community or the process of dung decomposition, but due to their high abundance in temperate cattle dung pats their role may merit further study. As a result, this study refers to two subsets of beetles, the 'dung beetles proper' (Scarabaeidae and Geotrupidae), and 'all dung inhabiting Coleoptera' (also including Hydrophilidae, Histeridae and Staphylinidae).

2. Methods

2.1. Study sites

Twenty-four beef farms located across SW England were chosen as study sites, 12 were registered organic and 12 were conventionally managed. Within these two broad categories, farms represented a range of different parasiticide use practices, size and terrain (hill, upland and lowland). Based on their history of parasiticide use the farms fell into three categories: farms that used no SPs or MLs (n = 8), farms that used SPs only (n = 7) and farms that used MLs only (n = 9). None of the organic farms treated with MLs, however six used SPs. Nine of the farms that were not registered as organic used MLs, while one used SPs and two used no parasiticides. To qualify for inclusion in this study, farms must have been operating under the same management practices for at least the previous 3 years. Complete information regarding key farm variables can be found in Table. 1.

2.2. Pitfall trapping

Pitfall trapping was carried out in 2016 during early summer (13th June – 26th July) on all 24 farms, and late summer (15th August – 8th September) on 16 of the farms. Each organic farm was paired with its most proximate conventional farm and trapping was performed on the two paired farms simultaneously to control for any climatic variation between trapping days. At each farm, 10 cow-dung baited pitfall traps were set up between 09:00 and 12:00 h, 5 m apart, along a straight transect within 50 m of grazing beef cattle but separated from the herd by a fence to prevent trampling. One organic farm was removed from the study at an early stage because its cattle were allowed to roam across moorland so it could not be guaranteed that pitfall traps were within 50 m of the herd. Pitfall traps consisted of plastic buckets (18 cm diameter × 16 cm depth) that were buried flush with the ground, half filled with water to which 1 ml of detergent was added, and covered with wire mesh with a 2 × 2 cm grid. Freshly voided cattle dung collected from the organic farm in each pair was homogenised and used for both farms of the pair, to prevent differences in attractiveness due to variation in dung chemical parameters. Dung was placed on the wire mesh using a 20 cm diameter pat former that held 800 g faeces, and a rain guard was positioned at a height of 20 cm to prevent flooding. Beetles attracted to the dung entered the pat and fell through the wire mesh into the bucket below. The traps were left for 24 h before beetles were collected and stored in ethanol. All Coleoptera trapped were counted, and identified using Jessop (1986) and Skidmore (1991).

2.3. Data analysis

For the purpose of this study, analysis was applied to two groups; the dung beetles proper (families Scarabaeidae and Geotrupidae), and all dung inhabiting Coleoptera, which also included beetles in the families Hydrophilidae, Histeridae and Staphylinidae. To compare species assemblages between the three farm types (farms that used no parasiticides, SPs-only, or MLs-only), rank/abundance distributions were plotted based on the number of dung inhabiting coleopteran species and their relative abundances. A detrended correspondence analysis (DCA) was performed on proportional species abundance between farms, to compare dung beetle assemblage similarity. DCA is a community ordination technique, which can be used to analyse community composition data, look at similarities between sites and identify characteristic species in each community (Magurran, 1988). It produces a graph whereby similar objects are ordinated near each other (Janžekovič and Novak, 2012), and was included in this study in order to examine similarities in dung beetle assemblage structure across the three farm types.

Communities were described by total abundance, number of taxa (richness), and two measures of biodiversity: the Shannon diversity index H' and the Simpson dominance index D (Magurran, 1988; Shannon, 1948; Simpson, 1949). These biodiversity measures were chosen because they can provide important information about community composition. For example, the Shannon diversity index H' is based on the proportional abundances of species, taking evenness and species richness into account, and represents the uncertainty about the identity of an unknown individual (Morris et al., 2014; Magurran, 1988). The Simpson dominance index D is less sensitive to species richness but is weighted towards the abundances of the commonest species, providing information on the degree to which single species dominate the community. It represents the probability that two randomly chosen individuals belong to different species (Morris et al., 2014; Magurran, 1988). They are calculated from the equations: $H' = -\Sigma (n_i/N \ln (n_i/N))$ and $D = \Sigma (n_i(n_i - 1)/N(N - 1))$ respectively, where n_i is the number of individuals found in the ith species and N is the total number of individuals. It must be noted that these indices are representative of a sample therefore fail to include all species from the community (Magurran, 1988). Analysis of these measures was applied