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Grazing abandonment and dung beetle assemblage composition: Reproductive behaviour has something to say

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ABSTRACT

Grazed pastures are important habitats that support high biodiversity. However, in recent decades pasture management practices have experienced drastic changes. To identify better management practices that permit the coupling of productivity and biodiversity conservation, attention must be given to the intensity of grazing management. By using a recognized bio-indicator group such as dung beetles, we analysed the impact of grazing intensity on assemblage composition in a gradient from abandoned grazing to low and moderate grazing levels. Moreover, we studied whether or not assemblage composition shifts are related to species-specific responses or to more generalized effects by categorizing dung beetles into functional groups. We found differential effects on dung beetle communities depending on their feeding and reproductive behaviour; "no-nest building" species were the functional group most affected because of their inability to relocate food. Moreover, the decreased level of herbivory in abandoned areas led to shrub and tree encroachments. We demonstrated that dung beetles from abandoned areas were sensitive to this incipient habitat change due to the presence of indicator species associated with shrub and woodland habitats. Therefore, community composition varies depending on both species-specific and generalized responses due to the sensitivity of "no-nest building" species. From a management standpoint, we suggest maintaining a low to moderate level of grazing intensity to conserve a well-structured functional assemblage of dung beetles.

1. Introduction

Grazing by large domestic herbivores is one of the most important drivers of grassland insect biodiversity (Joern and Laws, 2013). The impact of grazing on insect diversity may be positive (Joern, 2005), negative (Kruess and Tscharntke, 2002; van Klink et al., 2015) or neutral (Bestelmeyer and Wiens, 2001; Rambo and Faeth, 1999) depending on the study group (Sjödin et al., 2008), biogeographical region (Barragán et al., 2014), and grazing intensity (van Klink et al., 2015). Hence, understanding what level of grazing intensity is the best for conservation purposes must be a priority, especially in areas with ancient grazing histories such as the Mediterranean basin (Perevolotsky and Seligman, 1998).

Understanding the relationship between grazing management and insect biodiversity has become increasingly important in the face of ongoing changes in the management of domestic grazing animals. Several areas with a history of animal production for human purposes face sudden changes that alter traditional management practices with high environmental values (Bernués et al., 2011; Cocca et al., 2012; MacDonald et al., 2000). In the context of the Mediterranean basin, pasture management shows problems of intensification (Caraveli, 2000; Riedel et al., 2007) and on-going extensification (Caraveli, 2000) that have led to total abandonment (Cramer et al., 2008). These processes show spatial distributions dependent on the profitability of the area, with intensification in more productive areas and abandonment in the marginal ones (Caraveli, 2000; MacDonald et al., 2000).

Dung beetles are among the most important taxa of grasslands and are mainly linked to the faeces of herbivorous mammals for feeding and nesting (Halffter and Matthews, 1966). Dung beetles are responsible for dung burial and the decomposition of dung, soil bioturbation, and the enrichment of soils, all of which translates into higher plant productivity (Bornemissza, 1960; Nervo et al., 2017; Nichols et al., 2008; Wu et al., 2011). Furthermore, this insect group is sensitive to changes in vegetation structure caused by different levels of grazing activity (Verdú et al., 2007) making them a good bio-indicator group for evaluating the ecological status of an environment (Halffter and Favila,

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1993; Spector, 2006). Due to strong competition for ephemeral resources such as dung (Finn and Gittings, 2003; Halffter and Matthews, 1966; Hanski and Cambefort, 1991), diverse behavioural strategies have evolved in dung beetles to exploit this trophic resource, especially while building nest. They can directly use this resource without any manipulation or relocation (no-nest building functional group), or they can manipulate or relocate the dung in different ways. The manipulation or relocation of dung defines the different functional groups: relocation of the dung into tunnels dugs below the dung pat (paracoprid functional group); horizontal relocation of the dung before burying it (telecoprid functional group); and manipulation of the dung within the dung pat without relocation (endocoprid functional group). These different behaviours have important biological and conservation implications as decreases in dung beetle populations appear to have a differential impact depending on the functional group (Carpaneto et al., 2007; Lobo, 2001).

Dung beetle diversity is known to be locally affected by grazing intensity (Lobo et al., 2006), overgrazing (Negro et al., 2011b), grazing abandonment (Carpaneto et al., 2005; Jay-Robert et al., 2008; Kadiri et al., 1997; Tonelli et al., 2018) and grazing extensification (Tonelli et al., 2017), which may have negative effects on dung beetle richness, abundance and community structure. However, less is known about the effects of grazing intensity on dung beetle composition. The few studies that have been undertaken almost always highlighted the species-specific response of dung beetles towards this factor, without investigating any general consequences on the dung beetles themselves, for example, on the functional groups (but see Numa et al., 2012).

Hence, the aim of the present work included studying the effects of grazing intensity on dung beetle assemblage composition and to investigate whether or not these impacts had species-specific responses, or if generalizations could be made by analysing the effects on different functional groups. Specifically, we attempted to answer the following questions: a) Were there differential effects on dung beetle functional groups dependent on grazing intensity? b) Were there indicator species for a particular grazing intensity treatment? c) Were these differences reflected in the entire community composition?

2. Materials and methods

2.1. Study area

The study was carried in the Pesaro-Urbino province in the Marche Region of Central Italy. The landscape of the area consists of a mosaic of open and wooded patches, the structure of which is typical of the Roman organization known as Sylva-Saltus-Ager (= woods-pastures-fields). The study areas are pastures belonging to *Brizo mediae-Brometum erecti* and *Asperula purpureae-Brometum erecti* phyto-associations. All the study sites have the same altitudinal zonation (submountainous) in order to avoid bias related to altitude (Ubaldi, 1993), and vary between 500 m a.s.l. and 900 m a.s.l. The climate of the study area is temperate, and the soil is calcareous (see Tonelli et al., 2018 for further details about the study area).

To evaluate the effect of grazing intensity, we compared areas with a range of grazing activity, from abandoned to moderate:

a) 'Abandoned' (Calamello-Paravento pastures; 43°30′43,00″N; 12°40′58,68″E; altitudinal range 550–750 m a.s.l.): These pastures, once used by cows and sheep, were abandoned about fifteen years ago and today are only used by wildlife species such as roe deer (*Capreolus capreolus* L., 1758), wild boar (*Sus scrofa* L., 1758) and fallow deer (*Dama dama* L., 1758). Reduced herbivory has led to shrub and tree encroachment, principally by *Quercus ilex* L., *Spartium junceum* L. and *Rosa canina* L., which covers, heterogeneously, approximately 15% of the pasture area (Tonelli M., personal observation, 2013).
b) 'Low Grazing Intensity' (Pietralata pastures; 43°39′33,64″N; 12°42′27,65″E; altitudinal range 750–900 m a.s.l.): These secondary grasslands are used by approximately forty horses, which have reverted to a wild state. The livestock density in this pasture is approximately 0.7 Livestock Units/ha. Additionally, wildlife fauna, such as roe deer (*Capreolus capreolus* L., 1758), wild boar (*Sus scrofa* L., 1758) and fallow deer (*Dama dama* L., 1758), are present in the area.
c) 'Moderate Grazing Intensity' (Montebello pastures; 43°43′13.83″N; 12°45′19.98″E; altitudinal range 500–600 m a.s.l.). Cows bred according to organic farming guidelines use these pastures, and the livestock density is approximately 1.5 Livestock Units/ha. Additionally, wildlife fauna, such as roe deer (*Capreolus capreolus* L., 1758), wild boar (*Sus scrofa* L., 1758) and fallow deer (*Dama dama* L., 1758), are present in the area.

2.2. Sampling design and dung beetle trapping

To collect dung beetles, standardized pitfall traps (Lobo et al., 1988) baited with cow and horse ivermectin-free dung were used (Errouissi and Lumaret, 2010). Two bait types were used to increase trap attractiveness (Dormont et al., 2007) and, with the purpose of preserving the insects, the pitfall traps were filled with propylene glycol (50%).

At each sampling area, 3 replicates were selected, each separated by a minimum distance of 500 m, which was greater than the distance needed to maintain spatial independence (Larsen and Forsyth, 2005; Silva and Hernández, 2015). Within each replicate, 4 traps were placed, separated by at least 50 m, for a total of 12 traps for each sampling area and 36 traps for all 3 study areas. Due to the scarcity of dung in the abandoned area, approximately 10 dung pats were randomly placed on the surface around the traps. This procedure is recommended to prevent biasing the results caused by excessive attractiveness of traps in areas without the interference of natural dung pats (Lobo et al., 1998; Treitler et al., 2017).

During each sampling period, the traps were left active for 48 h, and samples were collected approximately every 15 days from June 2013 to November 2013 and in May and June 2014.

Dung beetles were identified at the species level according to monographic (Baraud, 1992; Dellacasa and Dellacasa, 2006) and specific works (Martín-Piera and Zunino, 1986; Miraldo et al., 2014; Rössner et al., 2010; Rössner and Fery, 2014).

2.3. Data analysis

2.3.1. Sampling completeness

Inventory completeness was evaluated using a sample coverage analysis that allowed for the comparison of different communities of equally complete sample coverage (Chao and Jost, 2012), thus avoiding biases related to standardized sample size methods (e.g., rarefaction). iNext software v.1.0 was used for this analysis (Hsieh et al., 2013).

2.3.2. Functional group analysis

Dung beetles can be categorized into different functional groups based on their differential use of trophic resources that occur mainly when nesting (Bornemissza, 1976; Halffter and Matthews, 1966).

First, we can distinguish two main strategies: a) direct and immediate use of trophic resources without nest construction, and b) relocation—or at least manipulation—behaviour with nest construction. In the first strategy, eggs are laid directly in the excrement, where in general, the entire developmental process takes place (functional group: no-nest building). The second strategy involves some nesting behaviour, and larvae develop within brood masses or brood balls. Within it we can discern three main classes of tactics (Bornemissza, 1969, 1971; Halffter and Edmonds, 1982; Halffter and Matthews, 1966; Zunino, 1991; Zunino and Palestrini, 1986): a) endocoprid, involving manipulation of the trophic resource, without its relocation. Eggs are laid in brood balls that remain within the food source; b) paracoprid: eggs are