Biological Conservation 187 (2015) 112–119

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Relative importance of pasture size and grazing continuity for the long-term conservation of European dung beetles

Jörn Buse [a,*], Martin Šlachta [b], Frantisek X.J. Sladecek [c,d], Markus Pung [e], Thomas Wagner [e], Martin H. Entling [a]

[a] University Koblenz-Landau, Institute for Environmental Sciences, Ecosystem Analysis, Fortstr. 7, 76829 Landau, Germany
[b] University of South Bohemia, Faculty of Agriculture, Department of Agroecosystems, Studentská 1668, 37005 Ceske Budejovice, Czech Republic
[c] University of South Bohemia, Faculty of Science, Department of Zoology, Branisovska 31, 37005 Ceske Budejovice, Czech Republic
[d] Institute of Entomology of the Czech Academy of Sciences, Biological Centrum, Branisovska 31, 37005 Ceske Budejovice, Czech Republic
[e] University Koblenz-Landau, Institute for Integrated Natural Sciences, Dep. Biology, Universitätsstrasse 1, 56070 Koblenz, Germany

A R T I C L E I N F O

Article history:
Received 13 January 2015
Received in revised form 5 April 2015
Accepted 15 April 2015

Keywords:
Habitat area
Habitat continuity
Geotrupidae
Management
Scarabaeidae
Species richness

A B S T R A C T

Habitat area and continuity are both key issues in conservation biology, for example in the choice and design of areas used as nature reserves. We analyzed how grazing continuity and pasture area affect species richness, functional groups and red-listed species of dung beetles, functionally important but often highly threatened organisms found in pasture areas. We used literature and our own field data to study a chronosequence of 22 pastures ranging from recently established sites up to 1000 years of grazing history in five European countries. Our results show a strong positive effect of grazing continuity on total species richness, especially within the first hundred years of permanent grazing. Species richness showed a stronger increase with grazing continuity in habitat specialists than in habitat generalists. However, the number of red-listed dung beetle species increased strongly with the size of a pasture, leading to higher proportions of red-listed species on large than on small pastures. Due to the length of time needed for specialist species to become established, priority should be given to the conservation of existing pasture areas, and new areas should ideally be connected to these habitats to facilitate colonization. Relatively large pastures (>130 ha) or a coherent network of small pastures are required to ensure long-term survival of red-listed dung beetles.

1. Introduction

Habitat continuity is a key issue in biological conservation (Fritz et al., 2008; Goldberg et al., 2007; Norden et al., 2014; Sverdrup-Thygeson et al., 2014). Forest organisms, such as dead-wood associated species are particularly dependent on old habitats and rarely colonize younger forests even after suitable microhabitats become available (Assmann, 1999; Brunet et al., 2011; Buse, 2012; Hermy et al., 1999). The influence of historical management measures is, however, still apparent in grassland vegetation even after long periods of time (Husakova and Munzbergova, 2014; Purschke et al., 2014, 2012). Therefore, it is to be expected that invertebrates in open habitats are also affected by habitat continuity (Heiniger et al., 2014); this would have important implications for conservation strategies.

The decline in extensively used pastures and meadows throughout Europe is considered a major threat to birds, plants, and many invertebrates (Garcia-Tejero et al., 2013; Hodgson et al., 2005; Wenzel et al., 2006; Wesche et al., 2012). Species with a strong preference for open habitats in combination with other kinds of specialization (e.g. in insects: mono-/oligophagy, short activity period, obligate interaction with other species) have particularly suffered from the abandonment of traditional grassland management (Nilsson et al., 2008). Specialist species of open and semi-open habitats also used to occur in wood pastures, but were negatively affected by the strong decrease in wood pasture area from the 19th century onwards. Consequently, different approaches have been developed and applied to restore species-rich grassland for conservation purposes. One of the frequently proposed management options is low-intensity grazing: This has been discussed and implemented for mesic grasslands, subalpine grasslands, inland sand ecosystems, heathlands and floodplains (Bullock and Pakeman, 1997; Critchley et al., 2003; Fischer and Wipf, 2002; Pykälä, 2003; Schaich et al., 2010). Although positive effects on animal species richness were observed for most sites with low-intensity grazing, only little is known about the general conditions which determine restoration success in the case of

* Corresponding author. Tel.: +49 (0)6341 280 31539.
E-mail address: joernbuse@gmx.de (J. Buse).

http://dx.doi.org/10.1016/j.biocon.2015.04.011
0006-3207/© 2015 Elsevier Ltd. All rights reserved.

red-listed invertebrates (Kruess and Tscharntke, 2002; Lehmann et al., 2004; Zahn et al., 2007). There is considerable uncertainty regarding the extent to which the intended biodiversity benefits of restoration projects develop over extended time periods, e.g. an increasing number of habitat specialists.

As has been shown for plants, when colonizing recently established pastures species appear sequentially according to their habitat preference and dispersal ability (Willems and Bik, 1998). Some plant species probably colonize pastures only after decades of continuous grazing; others remain exclusively in pastures with a long grazing history, possibly because of dispersal limitation (Pykälä, 2003). Furthermore, the colonization of managed sites by different groups of organisms is influenced by the regional species pool, distance to source populations in the region, and habitat age (Audino et al., 2014; Grimbacher and Catterall, 2007; Kirmer et al., 2008). Thus, distinct trait-profiles may be associated with species which depend on habitat continuity (Kimberley et al., 2013).

Dung beetles represent a functionally important ecological group in grazed ecosystems (Nichols et al., 2008). They are of high conservation concern in Central Europe, where around 45% (e.g. Germany and Czech Republic) of the dung beetle species are endangered or extinct according to national Red lists (Farkac et al., 2005; Schmidl and Büche, in press). The intensification of pasture management, on the one hand, and the decline of pasture area, on the other hand, have likely contributed to the decline and regional extinction of dung beetle species (Carpaneto et al., 2007; Hutton and Giller, 2003). The treatment of cattle and other livestock with anthelmintic substances presents an additional threat for dung beetles (Lumaret et al., 2012). Extensively used pastures represent important habitat for dung beetles in today's European landscapes where human pressure on semi-natural land is high (Jay-Robert et al., 2008; Lobo, 2001; Wassmer, 1995a).

Grazing continuity (=number of years with continuous grazing by large herbivores) has a strong positive effect on both overall species richness and species richness of specialist dung beetles (Audino et al., 2014; Imura et al., 2014). However, investigations to date have only considered a relatively short gradient of grazing continuity of up to 20 or 60 years respectively the latter two studies. The linear relationships found in these studies demonstrated that species accumulation was not yet saturated. In addition to grazing continuity, the size of the pastures could be limiting dung beetle establishment and persistence. Area-sensitive species with a low population density could probably only survive in relatively large pastures because they experience a higher extinction risk in smaller areas. In contrast, vegetation structure is probably of minor importance for dung beetle species richness and community composition, compared to other taxonomic groups (Söderström et al., 2001).

The aim of the present study was to investigate possible effects of grazing continuity and pasture area on dung beetle communities in Central Europe. We used presence/absence data of species in 22 different pastures from five Central European countries. We hypothesized that (I) the number of dung beetle species increases with grazing continuity and pasture area; (II) the number of specialist species shows a steeper increase with grazing continuity than the number of generalist species; (III) the conservation value (=mean Red List status of the dung beetle assemblage) of pastures increase with grazing continuity and pasture area.

2. Material and methods

2.1. Study group

Beetles inhabiting dung represent a phylogenetically heterogeneous group of species with different degrees of association with the dung habitat (Hanski and Cambefort, 1991). Typical dung feeding (=coprophagous) species (known as dung beetles) belong to the beetle families Scarabaeidae and Geotrupidae. These dung beetles co-occur in dung pats with a number of predatory and omnivorous species from the families Staphylinidae, Hydrophilidae and Histeridae (Koskela and Hanski, 1977). We focused here solely on the dung beetles which occur in Central Europe. The majority of study sites are in Germany. Ninety-three species of coprophagous Scarabaeidae and Geotrupidae are known from Germany, of which eleven have gone extinct in the past 60 years. One third of the German coprophagous dung beetle species (31 species) are threatened according to the national Red List (Schmidl and Büche, in press). Both threatened and extinct dung beetle species represent a comparatively high level of red-listed species (classes: extinct, critically endangered, endangered, vulnerable species = 45%) compared to other groups of conservation concern such as saproxylic beetles, breeding birds, and grasshoppers (28%, 32%, and 35% threatened in Germany, respectively) (Binot-Hafke et al., 2011; Haupt et al., 2009; Schmidl and Büche, in press). We classified species into habitat generalists and specialists based on the habitats they colonize in Central Europe (Rössner, 2012; Wassmer, 1995b). To test differential effects for dung beetle functional groups we classified species according to their reproduction mode (Table 1) into (a) tunneller (=paracoprid), (b) dweller (=endocoprid), and (c) roller (=telecoprid) species (Hanski and Cambefort, 1991; Rössner, 2012; Skidmore, 1991).

2.2. Data collection

We used dung beetle surveys of 22 extensively grazed pastures representing a gradient from newly established grazed sites to sites with a long grazing history over hundreds of years. All study sites were located in Central to Western Europe (Austria, Belgium, Czech Republic, Germany, Poland) and met the following criteria: (a) sampled between 1970 and 2013, (b) focused on Scarabaeoidea (Geotrupidae and Scarabaeidae), (c) study site grazed by the wisent (European bison), domestic cattle, horses, sheep or a combination of these, (d) history of grazing is documented or can be estimated from other sources (Table A1). The dung beetle list for Bialowieza Primeval forest was included as a representative of an exceptionally long history of grazing by large herbivores (European bison). Bialowieza dung beetle fauna serves as a reference for grazing continuity without interruption (because domestic cattle were present between 1919 and 1952 when European bison were extinct in the wild) (Daleszczyk and Bunevich, 2009). Presence/absence of dung beetle species was extracted from the literature and listed separately for each study site. Abundance data were not available for some study sites and if they were available, then comparability was limited due to differences in sampling methods. In addition, we included three unpublished species lists (Tables A1, A2). Only species whose larvae and/or imagines feed on dung were included in the analysis (Rössner, 2012; Skidmore, 1991). Species lists often contained synonyms which were standardized according to the systematic designation used by Rössner (2012). The 22 pastures studied here are inhabited by a total of 67 coprophagous dung beetle species (Table 1) which represent 72% of the dung beetle species known, for example, from Germany.

For all study sites, we gathered information on grazing continuity in terms of years, study area in ha, main type of grazer/browser, elevation in meters, present pasture management (summer or permanent pasture), and the dung beetle collection method (Table A1). Solar radiation in terms of temperature can be an important factor for dung beetles (Hanski and Cambefort, 1991); however, we did not include this in the analyses, because the differences between our study sites were minor.