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Vegetation and climate determine ant-mound occupancy by a declining herbivorous insect in grasslands

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ABSTRACT

There is considerable research on the effects of soil-disturbing ecosystem engineers in semi-natural Central European grasslands in terms of plant species diversity, soil properties and soil microorganisms. However, knowledge on the importance of such ecosystem engineers for animal diversity is still relatively rare. In this study we analyse the role of *Lasius flavus* nest mounds as habitats for larvae of the declining burnet moth species *Zygaena purpuralis* in calcareous grasslands. We assumed that anthills act as preferred larval habitats in dependence on climate or vegetation structure. The analysis considers a macroclimatic gradient by comparing sites with differing elevation and, hence, local climates. Additionally, we analysed the importance of anthills for *Z. purpuralis* along a microclimatic gradient by comparing sites with different vegetation structures. The study clearly shows that anthills are important larval habitats when general microclimatic conditions in the grasslands are unfavourable due to a cool climate at higher elevation or dense vegetation. The likelihood of detecting larvae of the burnet moth species on sites where anthills were occupied was higher on the mounds than within the surrounding vegetation. Anthills were preferred as larval habitats by *Z. purpuralis* as they combine two essential elements for successful larval development: (i) a favourable microclimate thanks to an open vegetation structure and (ii) a sufficient amount of food. The study underlines the importance of *L. flavus* as an ecosystem engineer for maintaining habitat heterogeneity and biodiversity within semi-natural grasslands.

1. Introduction

Research on species relationships is of special scientific concern for the understanding of ecosystem functioning (Laska and Wootton, 1998). Therefore, a great number of theories describe functional relationships between species such as the concept of keystone species or ecosystem engineers (Bond, 1993; Jones et al., 1994). Ecosystem engineers are organisms that alter the availability of resources by modifying the physical state of biotic or abiotic materials and therefore create habitats (Jones et al., 1994). Autogenic ecosystem engineers provide resources and habitats by means of their own physical structures. A typical example are mussel beds of *Mytilus edulis* which function as habitats for a wide variety of marine invertebrate species (e.g. Arribas et al., 2014). Allogenic ecosystem engineers transform other living or non-living materials and thus create habitats indirectly (Jones et al., 1994). Concerning allogenic ecosystem engineers the ecological influence of fossorial or hypogeic species which cause soil disturbance and create microhabitats because of their burrowing or mound-building activities is of special scientific interest (Folgarait, 1998; Davidson et al., 2012). Classic and well-studied examples comprise subterranean herbivores such as pocket gophers or marmots within grasslands (van Staalduinen and Werger, 2006; Reichman, 2007; Yoshihara et al., 2009). Several studies demonstrated that microsites created by these species serve as important habitats for certain taxonomic groups, such as plants or insects (e.g. Davidson and Lightfoot, 2007; Yoshihara et al., 2010).

Within Europe, typical soil-disturbing ecosystem engineers include different species of ants (e.g. the yellow meadow ant, *Lasius flavus*) or rodents (e.g. the European rabbit, *Oryctolagus cuniculus*) and the European mole (*Talpa europaea*) (Dostál, 2005; Seifan et al., 2010; Ferreira, 2012). These ecosystem engineers frequently reside

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within open habitats, especially semi-natural grasslands. In Europe, semi-natural grasslands maintained by traditional, low-intensive land use practices are among the most species-rich habitats (Veen et al., 2009). Within these grasslands the effects of soil-disturbing ecosystem engineers have been extensively studied in terms of plant species diversity, soil properties and soil microorganisms (e.g. Dean et al., 1997; Blomqvist et al., 2000; Lenoir, 2009; Schiffers et al., 2010; Seifan et al., 2010; Boots and Clipson, 2013). Mounds created by ants or moles harbour a reduced plant biomass and favour certain plant species such as annual plants (King, 1977, a, b, c; Dean et al., 1997; Dauber et al., 2006; Lenoir, 2009; Streitberger et al., 2014). Therefore, these mounds increase vegetation heterogeneity in grasslands (Dauber et al., 2006).

However, with regards to Central European grassland ecosystems knowledge on the importance of these microsites for animal diversity is still relatively sparse. Yet, there is evidence that mounds created by soil-disturbing ecosystem engineers play an important role as habitats for insect species dependent on a warm microclimate. For example, the ant species *Formica exsecta* prefers molehills as nesting grounds as these sites are subject to high solar insolation (Bliss et al., 2006; Katzerke et al., 2010). Furthermore, molehills are the preferred perching sites of the butterfly species *Inachis io* and other territorial Nymphalid species thanks to favourable microclimatic conditions (Dennis, 2004; Dennis and Sparks, 2005). In addition to that, the two butterfly species *Pyrgus malvae* and *Lycaena phlaeas* prefer molehills for oviposition as these sites offer suitable microclimatic conditions for larval development (Streitberger and Fartmann, 2013; Streitberger et al., 2014).

In general, a favourable microclimate which is interlinked with vegetation structure (Stoutjesdijk and Barkman, 1992) plays an important role in the larval development of Lepidoptera (García-Barros and Fartmann, 2009). For example, in Central Europe a warm microclimate owed to an open vegetation structure is essential for the development of the immature stages of many thermophilous butterfly species (e.g. Salz and Fartmann, 2009; Krämer et al., 2012; Helbing et al., 2015). However, the microclimatic requirements of Lepidoptera species depend on the macroclimatic conditions. In fact, geographically shifting microhabitats along macroclimatic gradients are evident among a wide variety of Lepidoptera species (Thomas et al., 1998; García-Barros and Fartmann, 2009; Henry and Schultz, 2013).

Because of the open vegetation structure, in contrast to the surrounding matrix vegetation, it is likely that anthills serve as important larval habitats for thermophilous Lepidoptera species within Central European grasslands. However, knowledge on the role of ant mounds in the reproduction of Lepidotera is still lacking.

In this study we analyse the role of *Lasius flavus* ant nest mounds as habitats for larvae of the declining burnet moth species *Zygaena purpuralis* in calcareous grasslands in Central Germany. As larvae of this species depend on a warm microclimate (Fartmann, 2004) we assume that anthills act as preferred larval habitats. Nonetheless, it is conceivable that the importance of anthills as a larval habitat for this species differs according to climate or vegetation structure. We suppose that anthills play an important role as larval habitats for this species within abandoned grasslands with a dense vegetation structure and cool microclimate and within grasslands located in regions with a cooler local climate. Therefore, the analysis takes place along a macroclimatic gradient and compares sites with differing elevation and, hence, local climates. Additionally, we analyse the importance of anthills for *Z. purpuralis* along a microclimatic gradient by comparing sites with different vegetation structures. In the light of the results we derive management strategies for the conservation of the burnet moth species.

2. Materials and methods

2.1. Study species

2.1.1. Lasius flavus

Lasius flavus (Fabricius 1782) (Hymenoptera: Formicidae) has a Palearctic distribution and is one of the most dominant *Lasius* species found within agricultural and urban habitats throughout Europe (Seifert, 2007). In Central Europe, this oligothermic ant species occurs frequently within moist to wet grasslands maintained by low-intensity land use (Seifert, 1993, 2007). *L. flavus* is a hypogeic species which builds above-ground nest mounds in order to create suitable microclimatic conditions for its offspring (Dlussky, 1981). The main food sources of this species are root aphids and their honeydew (Pontin, 1978). Even though *L. flavus* still occurs frequently within grasslands in Central Europe, it is sensitive to eutrophication (Seifert, 1993).

2.1.2. Zygaena purpuralis

The distribution of the transparent burnet *Zygaena purpuralis* (Brünnich 1763) (Lepidoptera: Zygaenidae) ranges from the British Isles to North-Western China (Ebert, 1994). Within our study area, the Diemel Valley, *Z. purpuralis* is on the wing from mid-June until the end of July (Fartmann, 2004). It is a univoltine species and hibernates in the larval stage. The larvae feed monophagously on *Thymus* species (Ebert, 1994; Fartmann, 2004). In Central Europe, the species prefers warm south- or west-facing open habitats, especially thyme-rich, semi-dry or dry grasslands with a high proportion of bare ground (Ebert, 1994; Fartmann, 2004; Wagner, 2006). In Germany *Z. purpuralis* is listed as near-threatened (Reinhardt and Bolz, 2011).

2.2. Study area

The Diemel Valley is located in Central Germany, at the border of North Rhine-Westphalia and Hesse (51°22′N/8°38′E and 51°38′N/9°25′E). Overall, the area is characterized by a suboceanic climate (Müller-Wille, 1981). However, because of a strong elevational gradient climatic conditions differ strongly across the study area (Fartmann, 2004). The Upper Diemel Valley (300–500 m a.s.l.), located around the city of Marsberg, represents the coldest (mean annual temperature 6.5–8 °C) and wettest part (mean annual precipitation of 700–1000 mm). Further east, the middle and lower parts of the Diemel Valley (100–300 m a.s.l.) exhibit milder and drier climatic conditions (mean annual temperatures between 7.5 and 9 °C, mean annual precipitation 600–850 mm). Large parts of the hillsides along the Diemel Valley consist of limestone and have been grazed for centuries. Because of a long tradition of shepherd grazing calcareous grasslands are still frequent within the region. Nowadays, about 55% of these grasslands are still actively managed, mainly by traditional rough sheep grazing (Fartmann, 2004). In the northern half of Germany the Diemel Valley represents the region with the greatest area of calcareous grasslands (Fartmann, 2004).

2.3. Sampling design

Sampling of *Z. purpuralis* larvae took place in the second half of May 2013. Within 22 calcareous grassland patches across the study area with known occurrence of the burnet moth species (own unpublished data) altogether 40 sites measuring 10 × 10 m and a high abundance of *L. flavus* anthills were randomly selected. Within these sites all anthills with a minimum height of 5 cm and the presence of at least one of the host plants (*Thymus praecox* ssp. *praecox* and *T. pulegioides* ssp. *pulegioides*, respectively) underwent further analyses. At each selected anthill we set up a plot measuring