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Contrasting responses of insect communities to grazing intensity in lowland heathlands

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ABSTRACT

Grazing at low stocking rates is often recommended for the preservation of the characteristic biodiversity of open landscapes. However, the fine-tuning of grazing management still lacks a good evidence base. This is particularly true for insect communities, as available evidence indicates that these are more vulnerable to grazing than plant communities. The outcome, however, may be expected to differ between insect species. Here, we analysed the impact of different grazing intensities on insect communities from lowland heathlands in the Netherlands. Firstly, we use detailed data on butterfly distribution and abundances to analyse population responses of 10 butterfly species to heathland grazing management. Secondly, we investigated species responses to grazing intensity on 16 field locations across a range of insect groups (butterflies, day-active moths, grasshoppers, and ants). We hypothesized that species from early successional stages would benefit from grazing whereas late-successional species would suffer from grazing. Moreover, we expected summer grazing to have less beneficial effects than year-round grazing. Both hypotheses were largely supported by our results. Species responses to grazing contrasted between early and late successional species. Variation in species responses were strongly linked to grazing intensity and soil moisture, reflecting species-specific niches in relation to vegetation structure and microclimate. We conclude that low-intensity year-round cattle grazing or herded sheep grazing may promote insect biodiversity in large, heterogeneous heathlands, whereas targeted or rotational grazing may be advisable in smaller areas.

1. Introduction

The significance of grasslands and shrublands for the preservation of global biodiversity is often underestimated (Veldman et al., 2015). In Europe, this value has been recognized in defining so-called High Nature Value (HNV) grasslands (Veen et al., 2009). European grasslands and heathlands have a long history of human influence. Hence, they are typically regarded as semi-natural communities, although there is debate to what extent the present-day grasslands and heathlands resemble the natural communities from which they have evolved (WallisDeVries et al., 1998; Vera et al., 2006). There is no question, however, that grazing ungulates, whether wild or domestic, have played a major role in shaping these communities (Olff and Ritchie, 1998).

At present, HNV communities are under threat of both land abandonment and agricultural intensification. With a decreasing significance for agricultural production, their importance for maintaining biodiversity is increasingly appreciated (Veen et al., 2009). This calls for new types of grazing management that give priority to these biodiversity targets. Unfortunately, the evidence base to choose between different grazing regimes is still weak (Newton et al., 2009). Moreover, in investigating the impacts of grazing, there still is a predominant focus on plant communities, whereas arthropod communities have only recently received full attention (Morris, 2000; Bell et al., 2001; WallisDeVries et al., 2002; Littlewood et al., 2012). The urgency to elucidate grazing impacts on arthropods is all the greater, because a recent meta-analysis revealed that, on average, the response of arthropods to an increase in grazing intensity is negative, whereas it is neutral for plants (Van Klink et al., 2015).

The main impacts of grazing ungulates on arthropods can be summarised as threefold (Van Klink et al., 2015): (i) disturbance and unintentional predation, (ii) reduction of resource availability

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for herbivorous arthropods and (iii) changes in habitat quality through alterations of plant diversity, vegetation structure and abiotic conditions. The first two impacts are detrimental, but the third may be either detrimental or beneficial. Beneficial impacts should occur when grazing (a) increases resource availability by suppressing competitors of hostplants or by enhancing regrowth or (b) improves microclimatic conditions by affecting vegetation structure. While Van Klink et al. (2015) have focussed on arthropod diversity, the next challenge is to unravel which species groups and which underlying species traits are vulnerable to grazing and which ones benefit from or tolerate grazing.

With adequate trait data still lacking for many insect species, we argue here that this distinction may be pragmatically elaborated in the context of plant successional dynamics (e.g. Olff et al., 1999; Bokdam, 2001) by characterising species habitats as early or late successional, or, in the context of grazed ecosystems, as associated with short or tall vegetation (e.g. McNaughton, 1984; Van Klink et al., 2013). Thus, late successional arthropods should be sensitive to grazing because they depend on late successional plant species, architectural complexity of high plant canopies or moist and cool microclimates (e.g., Luff, 1966; Gibson et al., 1992; Dennis et al., 1994; Kruess and Tscharntke, 2002). In contrast, early successional arthropods should benefit from grazing because their host plants grow in open vegetation, with heterogeneity from horizontal patchiness and dry and warm microclimates (see Joern and Lawlor, 1981; Thomas, 1993; Thomas et al., 1986; Cherrill and Brown, 1992; Bourn and Thomas, 2002; Roy and Thomas, 2003).

Here, we investigated the impact of grazing on insect communities in lowland heathlands of the Netherlands. These heathlands have a long history of grazing by domestic livestock besides a variety of other land use practices, such as wood cutting, sod-cutting of heather and burning (Siepel et al., 2013). With the demise of traditional grazing practices in the course of the 20th century, remaining heathlands were abandoned or afforested, but since the 1970s, grazing was reinstated as a management tool in nature conservation (WallisDeVries et al., 1998; Siepel et al., 2013). This is all the more necessary as the encroachment of tall grasses, favoured by anthropogenic nitrogen deposition and drainage, threatens heathland diversity (Bakker and Berendse, 1999; Bokdam, 2001). We used a combination of long-term data at a regional scale and a short field study in selected heathlands to determine the occurrence and abundance of insect species in relation to grazing management. We expected insects associated with early successional heathland stages to benefit from grazing and late successional species to suffer from grazing in comparison with ungrazed heathland. Furthermore, we tested whether seasonal grazing would be less beneficial for early successional species than year-round grazing, whereas it might be more detrimental to late successional species, because of the concentration of impacts during the season of main activity (Farruggia et al., 2012; Tadey, 2015).

2. Materials and methods

2.1. Regional analysis

2.1.1. Study areas

Our analysis focused on heathlands in the Netherlands, in particular in the province Noord-Brabant (51°15′–51°45′N, 4°20′–5°55′E), which harbours a variety of larger dry and wet heathlands located on Pleistocene, periglacial sandy soils. For this regional analysis, we included all heathlands from kilometre squares with more than 15 ha of heathland (Fig. A1). For 43 of these areas, we obtained information on management practices (Table A1) from questionnaires sent to the managers.

2.1.2. Data selection and treatment

When considering invertebrates, the data on butterflies are most abundant and suited for analyses of regional variation in occurrence and abundance. We selected ten butterfly species that are common and/or restricted to heathland areas in the Netherlands and with a sufficient availability of records from different areas over a long time period. Five of these species are associated with early successional and five with late successional heathland stages (based on characteristics of larval microhabitats, as documented in WallisDeVries and Raemakers, 2001; Bos et al., 2006; WallisDeVries and Ens, 2010). Although count data based on systematic monitoring in fixed locations provide a reliable, unbiased and sensitive basis for trend analyses (Pollard and Yates, 1993), the lack of records from sufficient locations often prevents their application to evaluate, for example, the impacts of management. Fortunately, the large volume of data from citizen science observers also provides fruitful opportunities for research (Isaac et al., 2014). Recent advances in statistical analysis have enabled the use of this vast source of opportunistic (i.e. non-systematically collected) records for trend analysis (e.g. Van Strien et al., 2013). This analysis focuses on the estimation of occupancy probabilities corrected for variation in recording effort by correcting for detection probability (Van Strien et al., 2011 and 2013 for application to butterfly trend analyses). Unfortunately, population trends based on such presence-absence data are much less sensitive to change than abundance data, although this sensitivity increases when data can be analysed at smaller spatial scales (Cowley et al., 2001). Hence, we adopted a threefold approach in our analysis. Monitoring data were used when sufficiently available and opportunistic data were analysed in two different ways: as presence-absence data in occupancy analyses and as abundance data in an attempt to obtain a greater sensitivity to change.

Records for regional analyses were obtained from two sources: the National Database on Flora and Fauna (www.ndff.nl) for incidental observation records over the period 1980–2010 and the Dutch Butterfly Monitoring Scheme for systematic transect monitoring data over the period 1990–2011 (see Pollard and Yates, 1993 for monitoring methodology and Van Swaay et al., 2002 for data treatment); for *Phengaris alcon*, the monitoring is based on egg counts on its hostplant *Gentiana pneumonanthe* in permanent plots at the end of the flight season of the butterfly. Only monitoring data from within the selected heathlands were used.

Monitoring data were sufficiently abundant for three species only, *Ochlodes sylvanus*, *Plebejus argus* and *Phengaris alcon*. Opportunistic data were available for all species and were treated at 1 × 1 km resolution, using the Dutch national grid system. Occupancy probabilities were estimated on the basis of records for the regional soil district encompassing the selected heathlands, following methods elaborated by Van Strien et al. (2011). Only kilometre squares that could be reliably assigned to one of the 43 selected heathland areas were retained for further statistical analysis. Contiguous kilometre squares with the same management regime were treated as a single area. Records from outside these heathlands can be assumed to have little influence on the analysis, because land use in adjacent areas (forest, agriculture or urban areas) is typically incompatible with the occurrence of the selected butterfly species. Annual abundances were estimated in each km-square as the maximum number of butterflies observed on a single day by an individual observer. For areas covering multiple km-squares, occupancy probabilities were averaged and abundances were summed between km-squares. Zero abundance values have been inferred in a minority of cases (54 out of 8804 records) when species were no longer observed in an area, whereas records of other species indicated a sufficient recording intensity. Abundance data were $\log_{10}$-transformed prior to analysis.

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