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ORIGINAL PAPER

Rapid response of Orthoptera to restoration of montane heathland

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Abstract Understanding how to restore threatened ecosystems is of special relevance for nature conservation. The aim of this study was to use Orthoptera as ecological indicators for the effects of montane heathland restoration in Central Europe. We analysed the three following treatments: (i) montane heathlands (MONHEATH) ($N = 7$), (ii) restoration sites (RESSITE) ($N = 3$) and (iii) clear-cuts of spruce forests as unprocessed and ungrazed control sites (CONTROL) ($N = 3$). Vegetation structure and microclimate differed considerably between MONHEATH on the one hand and RESSITE and CONTROL on the other hand. Orthoptera species richness and density did so too. MONHEATH was characterised by a high-growing dense dwarf-shrub and moss layer having a cool microclimate and high soil moisture. In contrast, RESSITE and CONTROL had sparse vegetation and a warm microclimate; Orthoptera species richness and density was highest on these sites. Our study clearly showed that heathland Orthoptera responded rapidly to restoration measures, while Ericaceae dwarf shrubs slowly established. The vast majority of Orthoptera species found on the restoration sites are early and mid-successional species. The colonization of the sites by late-successional Orthoptera species in the future will depend on the further development of the heathland vegetation; that is, if Ericaceae will expand to the sites. We conclude that the realised restoration measures are suitable to promote heathland Orthoptera of early and mid-successional stages. However, the current management of montane heathlands is insufficient and needs to be intensified in order to provide structurally diverse habitats with their characteristic orthopteran assemblages.

Keywords Conservation management · Montane heathland restoration · Grasshopper · Microclimate · Succession · Vegetation structure

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Introduction

Heathlands are important ecosystems for the conservation of biodiversity (Usher 1992; Thompson and MacDonald 1995; Sundseth 2005) and, thus, protected under the EU Habitats Directive (Thompson and MacDonald 1995; Ssymank et al. 1998). They encompass a range of rare plant and animal species; some of them are even exclusively found in heathland habitats (Symes and Day 2003). Apart from its specialized wildlife, heathlands are important semi-natural landscapes known for their beauty and high cultural value (Haaland 2003).

However, land-use change, the most important driver of biodiversity loss worldwide (Sala et al. 2000; Wessel et al. 2004), has negatively affected heathland biota (Thompson and MacDonald 1995). The huge decline of heathlands started in the middle of the 19th century and was triggered by technological improvements and the development of fertilizer (Symes and Day 2003; Keienburg and Prüter 2004). Lowland heathlands have been converted to permanent agricultural fields, while montane heathlands have become degraded by afforestation (Symes and Day 2003; Walker et al. 2004) and cessation of traditional management practices like sheep grazing, sod cutting and burning (Hahn 2007). This has led to a massive destruction of heathlands resulting in a severe biodiversity loss (Berdowski 1993). Recently, atmospheric nitrogen deposition has become a further threat to heathlands. It reduces regeneration of heather and favours the encroachment of grasses and mosses (Lindemann 1993; Bobbink et al. 1998; Wessel et al. 2004).

Montane heathlands are restricted to areas with a cold and wet mountain climate (Britton et al. 2005) and the flora and fauna is exceptionally rich in arctic-alpine and boreal-montane species (Thompson and MacDonald 1995). Besides *Calluna vulgaris* are two other Ericaceae, *Vaccinium myrtillus* and *Vaccinium vitis-idea* the dominant plant species of these heathlands (Geringhoff and Daniëls 2003). Within Central Europe the 'Rothaargebirge' (Fig. 1) is one of the last mountain ranges where larger montane heathlands have remained (Geringhoff and Daniëls 2003) and that could serve as a potential reference area for this ecosystem (Breder and Schubert 1998).

While many aspects of lowland heathland ecosystems have been studied in detail (e.g., Gimmingham 1992; Michael 1993; Bullock and Pakeman 1996; Symes and Day 2003; Keienburg and Prüter 2004) montane heathlands did not attract much scientific attention. Management and restoration practices gained from lowland heathlands were applied and transferred to montane heathlands (Hoffmann 1998), irrespective of differences in climatic and edaphic conditions or the community composition (Breder and Schubert 1998). According to Felton and Marsden (1990) there is a need for better understanding of montane heathland management and restoration.

Even though, montane heathland vegetation is generally made up of relatively few plant species (Ratcliffe and Thompson 1988; Usher 1992) due to acidic soil and harsh climatic conditions (Symes and Day 2003) arthropod diversity can be extremely high (Usher 1992; Usher and Thompson 1993). Heathlands are known to harbour a variety of Orthoptera species (Marshall and Haes 1988; Schlumprecht and Waeber 2003; Schirmel et al. 2011). As the main arthropod consumers in open habitats and an important food source for vertebrates like birds or lizards (Belovsky and Slade 1993), Orthoptera are key organisms in heathland ecosystems. Moreover, they require a specific vegetation structure (Gardiner et al. 2002; Poniatowski and Fartmann 2008; Fartmann et al. 2012) and microclimate (Willott and Hassall 1998; Gardiner and Dover 2008) which make them excellent indicators in general (Poniatowski and Fartmann 2008; Bazelet and Samways 2011) and especially for restoration measures (Kiehl and Wagner 2006).

In this study we investigate the response of Orthoptera to restoration of montane heathlands in the Rothaargebirge (NW Germany, Central Europe). We compare existing montane heathlands with restoration and control sites under consideration of biotic (vegetation structure) and abiotic factors (microclimate and soil moisture).

Materials and methods

Study area and study sites

The study was conducted in summer 2011 in the highest parts of the 'Süderbergland' mountain range, the 'Rothaargebirge', at the border of the German Federal States of North Rhine-Westphalia and Hesse (51°28′N, 7°33′E) ranging from 540 to 831 m a.s.l. (mean ± SE = 705 ± 39.8) (Fig. 1). The study area has a montane climate with a mean annual temperature of 5 °C, a mean annual precipitation of 1,454 mm and a prolonged snow cover of 100 d/a (Deutscher Wetterdienst, pers. comm.).

As study sites we selected the seven most representative montane heathlands of the study area. All sites are nature reserves (MUNLV 2012) and the heathlands within the study sites are grazed by sheep or goats (pers. obs.).

Restoration methods

The restoration of montane heathlands was conducted in winter 2007/2008 and 2008/2009, respectively, in the direct vicinity of existing montane heathlands on three of the study sites

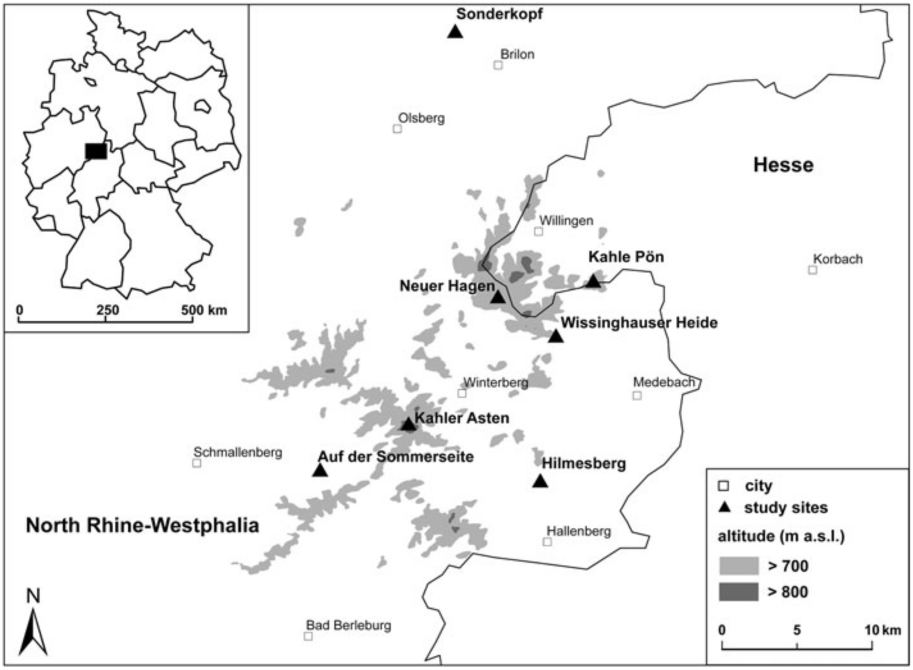


Fig. 1 Study area in Central Germany

('Hilmesberg', 'Kahle Pön', 'Wissinghauser Heide'). All restoration sites were on former spruce forests that were cut and cleared from remaining branches. On each restoration field, seed material from the largest remaining montane heathland in the region ('Neuer Hagen', 73.9 ha) was spread out.

Two different restoration techniques, namely hydroseeding and the spread of chopper material were applied. The hyrdoseeding procedure is particularly known from revegetation of construction sites (Matesanz et al. 2006). Moreover, it is applied on areas lacking access to vehicles, like steep slopes (Montoro et al. 2000) and wetlands. The hydroseeding material is composed of the harvested seed material (threshed montane heathland species) from the donor site, water and erosion control agents. In order to evenly spread the material, the agents are mixed to a homogenous suspension in an all-terrain hydroseeder. The mixture was evenly sprayed on the restoration sites.

The other applied restoration method was the transfer and spread of chopper material. The chopper material was harvested using a specifically designed machine that removes the complete organic layer down to the mineral soil (cf. Keienburg and Prüter 2004). All restoration sites are grazed by cattle, goats or sheep. With respect to vegetation structure, Orthoptera diversity and density the different types of restoration (hydroseeding vs. transfer of chopper material) and grazing regimes did not differ and thus were analysed together.

Experimental design

In total, we established 13 permanent plots with an area size of 500 m^2 (20 × 25 m) each. The three following treatments were analysed: (i) montane heathlands (MONHEATH) dominated by *C. vulgaris*, *V. myrtillus* and *V. vitis-idea*; one plot per study site ($N = 7$). (ii) Restoration sites (RESSITE) processed with the hydroseeding procedure or the application of chopper material; one plot each at three of the study sites ($N = 3$). (iii) Clear-cuts of spruce forests as unprocessed and ungrazed control sites (CONTROL); one plot each at three of the study sites ($N = 3$). Per plot we always sampled three randomly selected subplots (replicates).

Vegetation

Each subplot had a size of 16 m^2 (4 × 4 m). Measurement of environmental parameters took place in an undisturbed part of the subplot from mid-June to mid-July. We recorded the following parameters of the horizontal structure (in 5 % steps): total vegetation cover, cover of herbs/grasses, dwarf shrubs, mosses, lichens, bare soil, litter and deadwood. In cases where cover was above 95 % or below 5, 2.5 % steps were used, according to Behrens and Fartmann (2004). The average height of the aforementioned vegetation layers was ascertained to an accuracy of 2.5 cm.

Microclimate and soil moisture

Microclimate was recorded from mid-August to the end of September 2011 with a Hygrochron Temperature/Humidity Logger (iButton DS1923, Maxim/Dallas, USA). To protect the Hygrochron sensor from direct sunlight and precipitation it was put in a self-constructed radiation shield (cf. Schirmel et al. 2011). Per plot one sensor was installed 10 cm above ground. Air temperature and humidity were measured and recorded hourly.

We measured soil moisture with the Theta Probe ML2. Soil samples were collected during dry weather in August 2011. In order to avoid variations due to different soil densities, composition and small scale variability in transpiration and evaporation losses, we took three samples in a soil depth of 5 cm on each subplot.

Orthoptera

Orthoptera sampling took place from mid-July to mid-August. Densities were recorded using a box quadrat (Ingrisch and Köhler 1998; Gardiner et al. 2005) that is the best method to estimate Orthoptera abundance (Gardiner and Hill 2006). The box quadrat is 0.8 m high and has an area of 2 m^2 (1.41 × 1.41 m). Its sides are covered with white gauze. During sampling, the box quadrat was randomly dropped over vegetation at 10 different points per plot (total area: 20 m^2; cf. Fartmann et al. 2008; Poniatowski and Fartmann 2011b). To avoid edge effects, sampling took place at least 20 m from the next neighbouring treatment (Schirmel et al. 2010). Surveys were conducted under warm and sunny weather conditions between 10:00 and 18:00 h. Orthoptera species were determined using Bellmann (2006). Scientific nomenclature follows Coray and Lehmann (1998).

Statistical analysis

Prior to evaluation the data obtained from the subplots were pooled. Differences between environmental parameters as well as Orthoptera species richness and density (individuals/10 m^2) among treatments were tested using one-way ANOVA followed by Holm–Sidak tests. If data did not meet ANOVA assumptions (normal distribution and variance homogeneity) we performed a Kruskal–Wallis ANOVA on Ranks with Dunn's test as a post hoc test.

In order to analyse the relationship between Orthoptera species and environmental data a Redundancy Analysis (RDA) was conducted, as a prior Detrended Canonical Correspondence Analysis (DCCA) showed a gradient length of <4 (Leyer and Wesche 2007). Intercorrelations of all predictor variables were examined by applying a Pearson's correlation matrix. In cases of high inter-correlation (Pearson correlation coefficient [r] of $>|0.7|$) among variables, one of them was excluded from the analyses (Fielding and Haworth 1995). Only significant variables (Monte Carlo Permutation test with 499 unrestricted permutations at $P < 0.05$) were stepwise included in the model. By applying a Principal Component Analysis (PCA) we created a summarizing factor (cf. Poniatowski and Fartmann 2011a), hereafter called dwarf shrub/moss. The new variable represents an independent principal component with an eigenvalue of 1.87. It accounted for 93 % of total variance in the data set and was positively correlated with dwarf shrub cover ($r = 0.89$ $P < 0.01$) and height ($r = 0.77$, $P < 0.01$) as well as moss cover ($r = 0.79$, $P < 0.001$) and height ($r = 0.79$, $P < 0.001$).

The RDA was done using Canoco 4.5, while all other data were analysed using SigmaPlot 11.0 and SPSS statistics 20.

Results

Environmental parameters

Although the total area size of MONHEATH was greater than that of RESSITE and CONTROL there was no significant difference among the three treatments (Table 1). In contrast, all vegetation-structure parameters differed significantly among the treatments (Table 1). However, for the cover and height of lichens pair-wise comparisons did not reveal any significant differences. Particularly striking were the differences in vegetation structure between montane heathlands (MONHEATH) and the two other treatments (RESSITE, CONTROL). The cover of total vegetation, dwarf shrubs and mosses as well as the height of dwarf shrubs and mosses were significantly higher in MONHEATH than in RESSITE and CONTROL, whereas the cover of herbs/grasses was significantly lower. The height of herbs/grasses was significantly higher in CONTROL than in the two other treatments. There was no significant difference between the cover of litter among the treatments while the cover of deadwood was significantly lower on MONHEATH than on RESSITE and CONTROL. The cover of bare soil was highest in RESSITE significantly differing from MONHEATH.

Although altitude differed significantly among the treatments, pair-wise comparisons did not reveal any significant difference (Table 1). Microclimatic conditions (temperature, humidity) and soil moisture also differed among the treatments (Fig. 2). Temperature was significantly lower in MONHEATH compared to RESSITE and CONTROL. Humidity and soil moisture were lowest in RESSITE significantly differing from MONHEATH but not from CONTROL (Fig. 2).

Table 1 Mean values ± SE of structural and abiotic parameters

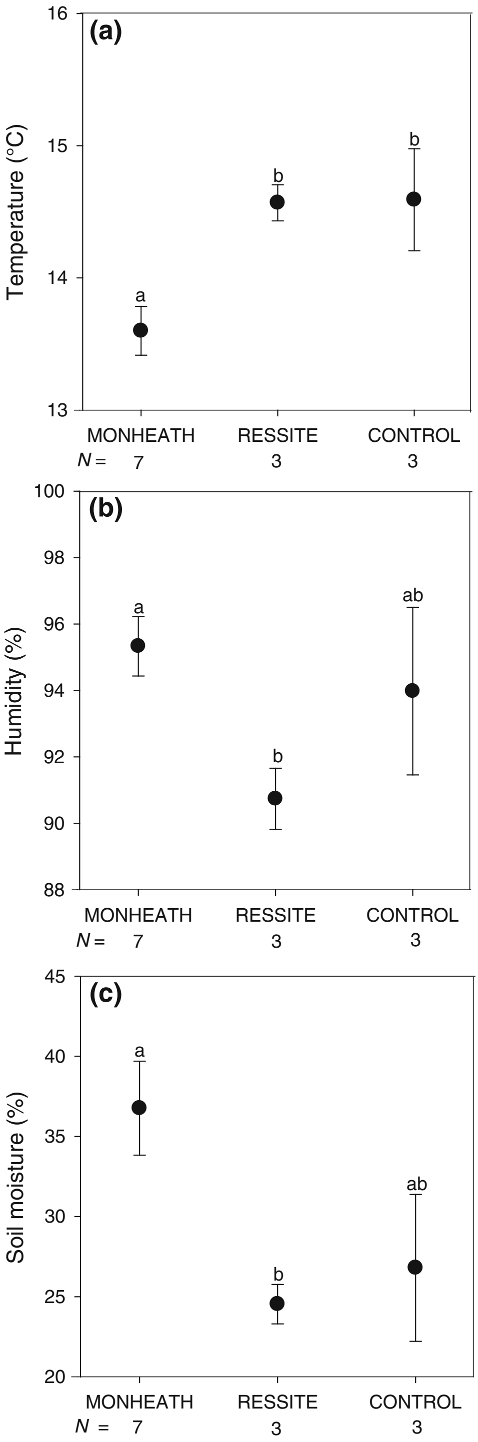
	Treatment			P	Pair-wise comparisons
	MONHEATH	RESSITE	CONTROL		
Cover (%)					
Total vegetation	94.4 ± 2.2	71.3 ± 4.9	74.0 ± 4.1	**	H > R, C
Herbs/grasses	8.1 ± 2.9	59.7 ± 3.4	71.8 ± 4.6	***	H < R, C
Dwarf shrubs	74.5 ± 3.9	11.1 ± 3.1	2.2 ± 1.2	***	H > R, C
Mosses	12.0 ± 1.9	2.2 ± 1.1	1.5 ± 0.6	***	H > R, C
Lichens	1.1 ± 0.4	0.0	0.0	*	n.s.
Bare soil	2.2 ± 2.0	6.4 ± 1.5	3.5 ± 1.6	*	H < R
Litter	4.2 ± 1.5	20.5 ± 6.5	10.5 ± 6.4	n.s.	n.s.
Deadwood	0.13 ± 0.08	3.9 ± 0.7	12.0 ± 2.7	***	H < R, C
Height (cm)					
Herbs/grasses	58.6 ± 2.6	66.2 ± 3.8	99.7 ± 7.9	**	C > R, H
Dwarf shrubs	34.4 ± 3.5	10.9 ± 1.3	5.1 ± 2.5	***	H > R, C
Mosses	3.3 ± 0.2	0.4 ± 0.1	0.3 ± 0.1	***	H > R, C
Lichens	0.6 ± 0.3	0.0	0.0	*	n.s.
Soil moisture (%)	36.85 ± 2.9	24.64 ± 1.3	27.0 ± 4.5	*	H > R
Area size (ha)	16.1 ± 10.1	4.4 ± 2.2	1.1 ± 4.4	n.s.	–
Altitude a.s.l. (m)	745.1 ± 24.0	674.9 ± 16.6	645.4 ± 34.2	*	n.s.

Differences among treatments (MONHEATH = montane heath, RESSITE = restoration sites, CONTROL = control sites) were analysed by Kruskal–Wallis-ANOVA on ranks. The last column indicates which treatments differed significantly from each other ($P < 0.05$, Dunn's method for pair-wise comparisons). Trees and shrubs occurred only sporadically (<0.2 %) with no significant differences between treatments and are thus not shown

n.s. not significant

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$

Fig. 2 Comparison of environmental data (mean values, standard error bars) between montane heath (MONHEATH), restoration sites (RESSITE) and control sites (CONTROL) for **a** field layer temperature (ANOVA, F = 9.095, df = 2, $P < 0.001$) **b** field layer air humidity (ANOVA, F = 5.224, df = 2, $P < 0.05$) **c** soil moisture (Kruskal–Wallis ANOVA on ranks, H = 8.757, df = 2, $P < 0.05$). Significance between groups tested using Holm-Sidak test (**a**, **b**) and Dunn's test as a post hoc test (**c**). Different letters indicate significant differences between treatments at $P < 0.05$



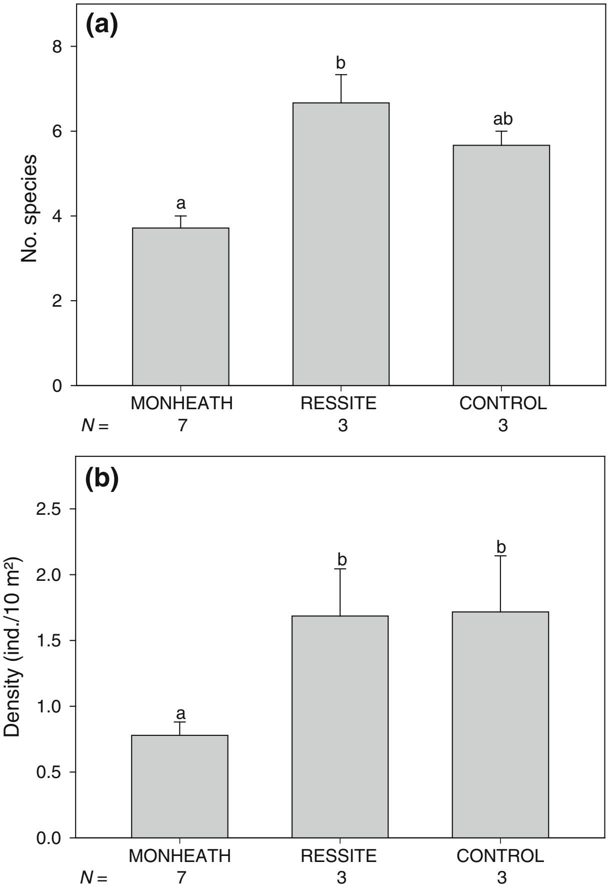


Fig. 3 Mean values (±SE) for montane heath (MONHEATH), restoration sites (RESSITE) and control sites (CONTROL) of **a** Orthoptera species richness (ANOVA, F = 11.154, df = 2, $P < 0.001$, Holm-Sidak post hoc test) and **b** density (Kruskal–Wallis ANOVA on ranks, H = 7.631, df = 2, $P < 0.01$, Dunn's test). Different letters indicate significant differences between treatments at $P < 0.05$

Orthoptera species richness and density

In total, we recorded 10 Orthoptera species comprising 1,170 individuals on 13 plots. The dominating species was *Chorthippus biguttulus* with 432 individuals (37 %), followed by *Ch. parallelus* with 218 individuals (18 %). Species richness was highest on RESSITE, significantly differing from MONHEATH (Fig. 3a). Orthoptera densities showed a similar pattern, thus RESSITE and CONTROL had significantly higher densities than MONHEATH (Fig. 3b)

Orthoptera response to environmental parameters

RDA ordination based on Orthoptera species and environmental data showed a clear separation of species and study sites, in particular between MONHEATH and RESSITE/CONTROL (Fig. 4, Table 2). Five of the environmental variables significantly contributed to our ordination model (Fig. 4). The first axis represents a microclimate/dwarf shrub gradient. Dwarf shrubs/mosses and soil moisture were positively, temperature and bare soil

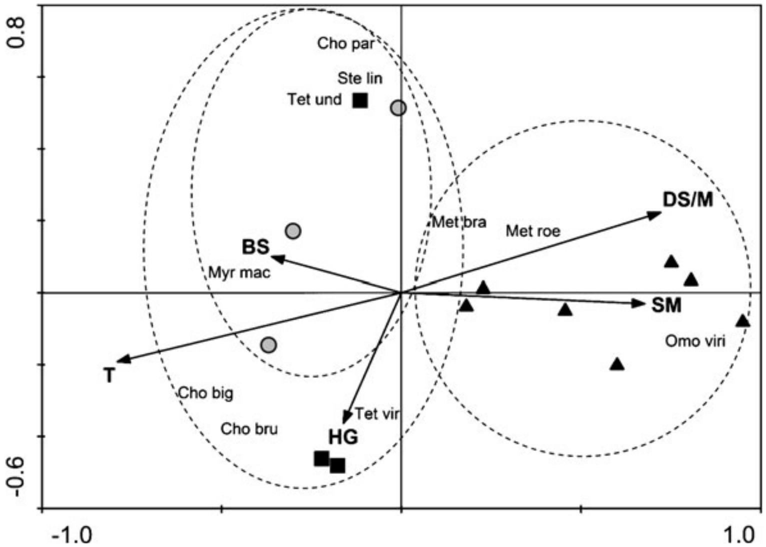


Fig. 4 RDA ordination based on Orthoptera data and environmental parameters. Abbreviations of environmental/structural parameters: *BS* cover of bare soil, *DS/M* cover and height of dwarf shrubs and mosses, *HG* cover of herbs/grasses, *SM* soil moisture, *T* temperature. *Triangles* indicate montane heathlands; *Quadrates* indicate control sites and circles show restoration sites. Abbreviations of species names: Myr mac, *Myrmeleotettix maculatus*; Omo vir, *Omocestus viridulus*; Met roe, *Metrioptera roeselii*; Met bra, *Metrioptera brachyptera*; Ste lin, *Stenobothrus lineatus*; Tet vir, *Tettigonia viridissima*; Cho par, *Chorthippus parallelus*; Cho bru, *Chorthippus brunneus*; Cho big, *Chorthippus biguttulus*; Tet und, *Tetrix undulata*

Table 2 Summary of RDA based on Orthoptera and environmental data (see Statistical analysis)

Axis	1	2
Eigenvalues	0.499	0.158
Species-environment correlations	0.942	0.866
Cumulative variance explained (%)		
Of species data	49.9	65.7
Of species-environment relation	66.4	87.4

negatively correlated with this axis. *Omocestus viridulus*, *Metrioptera roeselii* and *M. brachyptera* were characteristic of MONHEATH and associated with a high-growing and dense dwarf-shrub and moss layer, a lack of bare soil, relatively low temperatures and high soil moisture. *C. biguttulus*, *Ch. brunneus, Ch. parallelus*, *Tetrix undulata* and *Stenobothrus lineatus* were typical of RESSITE and CONTROL and correlated with high temperatures and sparse vegetation. *Myrmeleotettix maculatus* was particularly strongly correlated with bare soil (RESSITE) while *Tettigonia viridissima* occurred on sites with a high share of tall herbs and grasses (CONTROL).

Discussion

Vegetation structure and microclimatic conditions differed considerably between MONHEATH on the one hand and RESSITE and CONTROL on the other hand. Orthoptera species richness and density did so too. MONHEATH was characterised by a high-growing dense dwarf-shrub and moss layer having a cool microclimate and high soil moisture. In contrast, RESSITE and CONTROL had sparse vegetation and a warm microclimate; Orthoptera species richness and density were highest on these sites.

Heathlands are known to harbour many Orthoptera species and all species found in this study are characteristic heathland species (Marshall and Haes 1988; Schlumprecht and Waeber 2003; Schirmel et al. 2011). Surprisingly, Orthoptera species richness and density were generally low at MONHEATH and even lower than at RESSITE and CONTROL. Although all of the MONHEATH sites were subjected to low-intensity grazing, they had a high-growing and dense layer of old dwarf shrubs. Extensive and homogenous stands of dwarf-shrub heath are relatively poor habitats for Orthoptera (Schirmel et al. 2010, 2011; Wünsch et al. 2012). They exhibit adverse microclimatic conditions (cool and moist) for most species and the food supply, in particular for graminivorous Caelifera, is also low. The three species characteristic of MONHEATH, *M. brachyptera*, *M. roeselii* and *O. viridulus*, are known to be confined to late successional stages of heathland or grassland (Poniatowski and Fartmann 2008; Schirmel et al. 2011; Fartmann et al. 2012).

Dwarf shrubs of the family Ericaceae (*C. vulgaris*, *V. myrtillus*, *V. vitis-idea*) slowly established on RESSITE and CONTROL and still had a low coverage. In contrast, Orthoptera responded rapidly to restoration measures and to clear-cutting. Five of the six species (*Ch. biguttulus, Ch. brunneus*, *Ch. parallelus*, *M. maculatus*, *T. undulata* and *S. lineatus*) that we found regularly in RESSITE and CONTROL are characteristic of early and mid-successional stages of heathland or grassland (Poniatowski and Fartmann 2008; Schirmel et al. 2011; Fartmann et al. 2012). The sixth species, *T. viridissma*, was associated with CONTROL plots having a high cover of grasses and herbs and usually occurs in late successional stages of open habitats (Poniatowski and Fartmann 2008; Schirmel et al. 2011; Fartmann et al. 2012). All six species oviposit into or near the ground (Fartmann and Mattes 1997) and, therefore, depend on bare soil. Moreover, the sparse vegetation with patches of bare soil promotes the warming of the sites (cf. Stoutjesdijk and Barkman 1992) and most likely explains the higher temperatures on RESSITE and CONTROL. As cold-blooded organisms most Orthoptera generally require high ambient temperatures for optimal growth and development (Chappell and Whitman 1990; Willott and Hassall 1998). Due to the relatively cool mountain climate, warm microclimatic conditions might generally be of crucial importance for Orthoptera. Even a species like *M. brachyptera*, associated with late successional stages of heathlands, shows under the climatic conditions of the study area a preference for warm microhabitats (Poniatowski and Fartmann 2007). Besides sufficient egg-laying sites and a favourable microclimate RESSITE and CONTROL provide a more heterogeneous structure and, therefore, conditions that promote high species numbers and densities (Schirmel et al. 2011; Fartmann et al. 2012).

In contrast to our expectations, the differences between RESSITE and CONTROL in vegetation structure, microclimate, soil moisture and Orthoptera community composition were very small. Even the cover of dwarf shrubs did not differ among the two treatments; however, it was four times higher on RESSITE than on CONTROL. A possible explanation for the lack of difference might be the short time period of two/three growing seasons since the restoration measurements have been conducted. Ericaceae and heathland plant communities in general are known to need longer time periods to establish successfully (Walker et al. 2007; Diaz et al. 2008; Pywell et al. 2011).

In conclusion this study clearly showed that heathland Orthoptera responded rapidly to restoration measures, while Ericaceae dwarf shrubs slowly established. The vast majority of Orthoptera species found on the restoration sites are early and mid-successional species. The colonization of the sites by late-successional Orthoptera species will strongly depend on the further development of the heathland vegetation; that is, if Ericaceae will expand to the sites.

Implications for conservation

This study clearly shows that the last remaining upland heathlands in the Rothaargebirge only harbour a fraction of the potential heathland Orthoptera species. Species of early and mid-successional stages that are occurring on restoration and control sites are widely missing. Uneven aged stands of dwarf shrubs, resembling all life cycle stages of heather are known to accommodate a high biodiversity of invertebrates (Symes and Day 2003). In many heathland orthopterans the egg, nymphal and adult stages have different requirements (Wünsch et al. 2012), therefore, mosaics of different stages of heathland succession from bare ground-rich sites to dense heath stands are of vital importance for the long-term survival of the whole heathland Orthoptera community (Schirmel et al. 2010, 2011). Current low-intensity grazing and disturbance regimes in the montane heathlands of the study area, together with atmospheric nitrogen deposition (Bobbink et al. 1998; Wessel et al. 2004), favour mostly late-successional species. Similar observations have been made for bird species, like the woodlark (*Lullula arborea*). The woodlark was formerly a widespread breeding bird of the montane heathland in the Rothaargebirge (see review in Legge 2009a). Today the species only occasionally breeds in the heathlands since suitable open habitat structures are probably too rare (own observation). The meadow pipit (*Anthus pratensis*) is a declining species in the montane heathlands that might also be negatively affected by succession (Legge 2009b).

We conclude that the realised restoration measurements are suitable to promote heathland Orthoptera of early and mid-successional stages. However, the current management of the montane heathlands is insufficient and needs to be intensified in order to provide structurally diverse habitats with their characteristic orthopteran assemblages. To achieve this aim, a further enlargement of the existing heathlands and continuous management are necessary. We suggest that typical management practices known from the lowlands like the complete or partial removal of the organic soil layer (Symes and Day 2003; Keienburg and Prüter 2004) should be applied to all montane heathlands and not only for parts of the sites Neuer Hagen and Kahle Pön. Moreover, grazing should be continued and intensified as sheep and goats help to create a mosaic of heather age-classes and transitions zones merging into adjacent habitats.

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