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Conservation value of dry grasslands in Westphalia (Northwest Germany) based on pitfall trap data of Orthoptera

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Abstract

As part of a detailed survey of diversity and ecology of spider assemblages, nearly all dry grassland habitats of northern Westphalia were investigated by pitfall trapping from 2006 to 2008. Although pitfall trapping is a rather uncommon sampling technique for grasshoppers, it is known to be an appropriate collecting method in sparsely vegetated habitats, such as dry grasslands. All in all, 24 study sites (Genisto-Callunetum, Spergulo-Corynephoretum) in 9 investigation areas were sampled continuously from August 2006 to July 2008. A total of 2,975 grasshopper specimens from 13 species were captured, with *Myrmeleotettix maculatus* as the most abundant species by far. Further frequent species were *Chorthippus mollis*, *Stenobothrus lineatus* and *Gryllus campestris*. Ordination (DCA) showed species groupings at the site level and Poisson generalised linear models (GLM) revealed significant responses of several grasshopper species to site and landscape parameters. The very frequent occurrence of the locally threatened *Chorthippus mollis* and of the xerothermic *Myrmeleotettix maculatus* suggested that the studied dry grassland sites may have at least some limited value for xerothermic species. Especially, the largest and less isolated sites have high value for conservation, as shown by ecological preferences of the target species *Gryllus campestris* and the threatened *Stenobothrus lineatus*. It appears to be quite worthwhile to consider and analyse results from pitfall trapping studies conducted in sparsely vegetated habitat types.

Zusammenfassung

Im Rahmen einer Untersuchung zur Diversität und Ökologie von Spinnengemeinschaften erfolgten in den Jahren 2006 bis 2008 Bodenfallenerfassungen in nahezu allen Sandlebensräumen der Westfälischen Bucht. Obwohl Bodenfallen zumeist nicht für die Erfassung von Heuschrecken eingesetzt werden, können die Fangergebnisse gerade in offenen Habitattypen wertvolle Ergebnisse liefern. Insgesamt wurden in neun Gebieten 24 Untersuchungsflächen (Genisto-Callunetum, Spergulo-Corynephoretum) befangen. Es konnten dabei 2.975 Individuen aus 13 Arten erfasst werden. Die häufigste Art war mit Abstand *Myrmeleotettix maculatus*, ebenfalls häufig kamen *Chorthippus mollis*, *Stenobothrus lineatus* und *Gryllus campestris* vor. Die Ordination (DCA) zeigte eine deutliche Gruppierung der Arten und die Ergebnisse der Poisson GLM (generalisierte lineare Modelle) belegten einen signifikanten Einfluss bestimmter Habitat- und Landschaftsparameter auf das Vorkommen zahlreicher Arten. Das häufige Vorkommen xerophiler und gefährdeter Arten zeigt den hohen naturschutzfachlichen

Wert der untersuchten Gebiete, wobei vor allem große und wenig isolierte Flächen aufgrund ihrer Bedeutung für die Zielart *Gryllus campestris* sowie für die gefährdete Art *Stenobothrus lineatus* besonders hervorzuheben sind. Grundsätzlich belegt die Studie, dass eine Auswertung von Bodenfallenfängen aus offenen Habitattypen sehr aufschlussreiche naturschutzfachliche Ergebnisse liefern kann.

Introduction

Nutrient-poor sandy grasslands and heathlands are among the most endangered ecosystems in Germany (RIECKEN et al. 2006). During the past 50 years, the area of open sand habitats has considerably decreased due to lack of disturbance (drifting sand, grazing, and fire) and intensive cultivation and afforestation (BERGER-LANDEFELDT & SUKOPP 1965, JECKEL 1984, JENTSCH et al. 2002, KRATOCHWIL 2004). In north western Germany, sand habitats exhibit a large number of specialised and rare species (BELLMANN 1997, WIESBAUER & MAZZUCCO 1997, STEVEN 2004). These habitats take up only small areas (VERBÜCHELN & JÖBGES 2000, PARDEY 2004) and many biotopes, as e.g., dry grasslands, heathlands, and inland dunes, are in danger of disappearing in North Rhine-Westphalia (VERBÜCHELN et al. 1999) and Lower Saxony (DRACHENFELS 1996). Therefore, many stenotopic species of these habitats are endangered by habitat loss and fragmentation (MAAS et al. 2002).

Orthoptera occur in a wide variety of open terrestrial habitats. In particular, they are very abundant in grassland and heathland and often the main invertebrate consumers (CURRY 1994). In addition, Orthoptera play an important role as food source for many predator groups, such as birds and spiders (JOERN 1986, CHERILL & BEGON 1989, SAMWAYS 1997). Orthoptera are highly sensitive to environmental changes, for example due to grazing, mowing, abandonment, succession or invasive plant species (KÖHLER & KOPETZ 1993, BÁLDI & KISBENEDEK 1997, FARTMANN & MATTES 1997, SAMWAYS 1997, SCHIRMEL 2010) and are therefore a suitable indicator group within all kinds of diversity and conservation studies (PONIATOWSKI & FARTMANN 2008).

Within a detailed investigation of diversity and ecology of spider assemblages, nearly all dry grassland habitats of northern Westphalia were investigated by pitfall trapping from 2006 to 2008 (BUCHHOLZ 2010). During such ecological field studies, which often include an intensive trapping program, high numbers of by-catch organisms, such as grasshoppers, are caught. According to PUTMAN (1995) and NEW (1999), field workers should take this data into account. Recently, BUCHHOLZ et al. (2010) pointed out that analyses of by-caught animals might provide useful ecological information and faunistic data.

In general, sweep netting, transect counts and box-quadrat sampling are common methods to assess diversity and abundance of Orthoptera, whereas pitfall trapping has been rarely used (GARDINER et al. 2005). Pitfall trapping is a destructive sampling method and should therefore be applied with care, for example when other methods cannot be used (e.g. in military areas, cf. BIERINGER & ZULKA 2003). However, according to REMMERT (1978) and INGRISCH & KÖHLER (1998), the analysis of by-caught Orthoptera from pitfall trap studies could pro-

vide suitable results. WALLASCHEK (1995) and lately SCHIRMEL et al. (2010a) stated that pitfall trapping is a reasonable sampling method in sparsely vegetated habitats, such as dry grasslands, which comprise high numbers of geobiont species. This could have been shown e.g. in the studies of SCHNITTER et al. (2003) and KLATT (2006).

To this date, several studies have analysed diversity and ecology of Orthoptera in open and dry grassland ecosystems (e.g. SCHIEMENZ 1969, OSCHMANN 1969, INGRISCH 1987, KÖHLER & KOPETZ 1993, PERNER 1997, ZEHM 1997) but Northwest Germany in particular has so far been rarely investigated – only studies by SALZBRUNN (1996), KÜBLER (2000) and PERSIGEHL & ASSMANN (2004) and autecological studies of HOCHKIRCH (1996) and HOCHKIRCH et al. (2006) deal with this topic in Northwest Germany. The aim of the present study is to increase the current knowledge by **(i)** presenting an extensive data set of dry grassland Orthoptera in northern Westphalia, **(ii)** providing information to characterise the ecological status of the investigated habitat types and **(iii)** describing special needs of certain dry grassland indicator species.

Methods

Study area

The investigation areas lied scattered in the Westphalian Bay, which takes up the northwestern part of the federal state of North Rhine-Westphalia in NW Germany (elevation; 40-130 m.a.s.l.) (Fig. 1). Maximum distances between the areas were about 125 km (W-E) and 75 km (N-S). The predominantly level to slightly undulating landscape is glacially formed and the ice-age top layers are fluvial and aeolic sands with dry soil conditions (MEYNEN & SCHMITHÜSEN 1959; DINTER 1999). The climate is Sub-Atlantic with a mean annual temperature of 9.5 to 10 °C and an annual precipitation between 700 and 750 mm. The distinct Sub-Atlantic character of the climate in the West weakens towards the East (MURL NRW 1989). According to BURRICHTER (1973), the potential natural vegetation consists of beech and oak forests (Fago-Quercetum typicum). The lowlands are used mainly by agriculture. Large extensions of the sand regions are covered by grasslands. The percentage of forest is mostly small (DINTER 1999).

Sampling design

Overall, 24 study sites in 9 investigation areas were sampled continuously from August 2006 to July 2008 (Fig. 1, Tab. 1). The whole range of habitat types representing the dry sand ecosystems of the study area, such as Genisto-Callunetum and Spergulo-Corynephoretum, was considered. Four pitfall traps were installed at each study site. The traps were 500 ml plastic cups with a 90 mm diameter that were one-quarter filled with a 4% formalin-detergent solution. The position of each trap was determined randomly but traps had a minimum distance of 5 m to each other. Emptying was carried out every four weeks. Afterwards, Orthoptera were sorted and transferred to 75% ethanol and, subsequently, adults were identified using keys of SYCHEV (1979), INGRISCH (1995), and BELLMANN (2006).

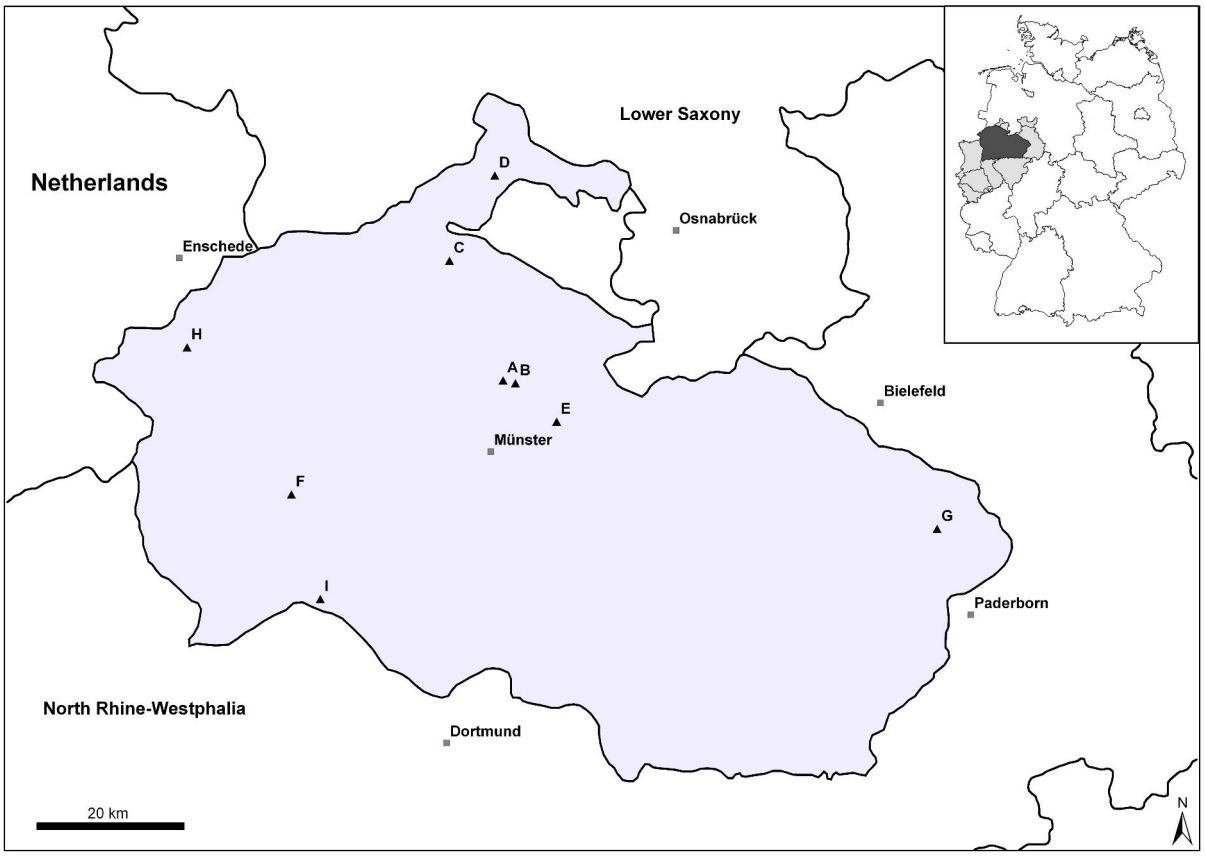

Fig. 1: Map of study area. A = Bockholter Berge, B = Boltenmoor, C = Elter Sand, D = Heiliges Meer, E = Klatenberge, F = Letter Wacholderheide, G = Moosheide, H = Wacholderheide Hörsteloe, I = Westruper Heide (see Tab. 1 for further information).

Tab. 1: Study area characteristics (size = size of nature reserve [ha], isol. = isolation of nature reserve, sand. = total size of dry grassland patches [ha]).

ID	area name	MTB-Q	N	E	size	isol.	sand.
A	Bockholter Berge	3912-1	52°03'30.21"	07°39'39.05"	60.8	4.4	0.8
B	Boltenmoor	3912-1	52°01'18.58"	07°41'10.12"	33.9	3.7	1.6
C	Elter Sand	3711-3	52°13'27.45"	07°32'02.04"	26.7	7.1	4.0
D	Heiliges Meer	3611-2	52°21'12.11"	07°38'02.91"	73.5	12.1	11.4
E	Klatenberge	3912-4	52°00'16.73"	07°47'02.70"	5.0	2.0	2.9
F	Letter Wacholderheide	4109-1	51°53'12.09"	07°10'05.81"	4.4	9.9	0.3
G	Moosheide	4118-1/3	51°51'18.71"	08°40'58.69"	443.3	3.3	38.0
H	Wacholderheide Hörsteloe	3907-1	52°05'45.50"	06°54'43.20"	87.8	28.8	1.5
I	Westruper Heide	4209-3	51°44'07.03"	07°14'16.47"	76.7	6.4	8.6

Three parameters were recorded both for the habitat and the landscape. Vegetation structure was determined in an area of 1 m^2 around each pitfall trap (four measurements per site, subsequently averaged) by estimating the coverage [%], height [cm] and density [% at a height of 0–20 cm] of the herbal layer (cf. SUNDERMEIER 1998a, b). As a landscape parameter, isolation was calculated as geometric mean of the distance to the next three dry grassland areas. Furthermore, the size of both the nature reserve and the open dry grassland patches were assessed using GIS.

Data analysis

Analyses were based on adult Orthoptera data, because a part of the nymphs was undeterminable (especially of the *Chorthippus biguttulus*-group). All the subsequent statistical analyses were performed using the software environment R 2.11.1 (R DEVELOPMENT CORE TEAM 2009) including the packages VEGAN (OKSANEN ET AL. 2008) and MASS (VENABLES & RIPLEY 2010) for multivariate statistics. In order to find groupings of species among the study sites, a Detrended Correspondence Analysis (DCA) was performed. Prior to the ordination analysis, rare species present with less than 3 individuals per site were omitted, in order to reduce the statistical noise in the data set without losing much information (MCCUNE & GRACE 2002; LEYER & WESCHE 2007). Afterwards, species data were square-root transformed.

Responses of species to habitat and landscape parameters (predictors: coverage, height and density of herbal layer, size of nature reserve, isolation of study area, size of open dry grassland patches) were tested using Poisson generalised linear models (GLM). We chose a quasi-GLM model to compensate for the detected overdispersion (CRAWLEY 2007; ZUUR et al. 2009). Since Akaike's information criterion (AKAIKE 1973) is not defined for quasi-Poisson models, the most appropriate models were determined by analysis of deviance (ZUUR et al. 2009). The residual deviance was used as a goodness-of-fit measure by calculating the pseudo-R^2 (DOBSON 2002).

Information about the conservation status of Orthoptera for North-Rhine Westphalia and Germany ("Red List", "RL" in the following) is based on MAAS et al. (2002).

Results

A total of 2,975 grasshopper specimens were captured (Tab. 2). 2,614 (88%) of them could be assigned to 13 species, whereas 361 individuals (12%) were (partly undeterminable) nymphs. By far the most abundant species was *Myrmeleotettix maculatus* (n = 1,709) comprising 57% of the total catch. Further frequent species were *Chorthippus mollis* (n = 390, 13%), *Stenobothrus lineatus* (n = 150, 5%) and *Gryllus campestris* (n = 123, 4%). *Meconema thalassinum* and *Omocestes viridulus* were recorded as singletons.

M. maculatus and *C. mollis* were widely distributed across all studied dry grassland areas in northern Westphalia but most species were restricted to certain areas (Tab. 2): *G. campestris* only occurred in two study areas (G and I), as did *Stenobothrus stigmaticus* (mostly in D and less in H). *S. lineatus* was exclusively

recorded in G and *Metrioptera roeseli* was exclusively found in D. Consequently, species showed groupings at the site level since *G. campestris* and *S. lineatus* were clearly separated from *Chorthippus parallelus*, *M. roeseli*, *Nemobius sylvestris*, *S. stigmaticus* and *Tetrix undulata* in the ordination plot (Fig. 2).

GLM results revealed significant responses of several grasshopper species to site and landscape parameters, whereas activity densities of particular species were affected in significantly different ways (Tab. 3). Abundances of *G. campestris* and *N. sylvestris* were clearly determined by landscape parameters. Individual numbers of the former increase with increasing size of nature reserve and open dry grassland patches and decrease with increasing isolation. The same applies to *N. sylvestris* in the case of size but, in contrast, abundances decrease significantly with higher proportion of dry grassland patches. *Chorthippus biguttulus*, *M. maculatus* and *T. undulata* responded at a site level. Last, abundances of *S. lineatus* were affected by coverage and density of herbal layer, as well as by the size of the nature reserve.

Tab 2: Species list. Explanation of study area ID: A = Bockholter Berge, B = Boltenmoor C = Elter Sand, D = Heiliges Meer, E = Klatenberge, F = Letter Wacholderheide, G = Moosheide, H = Wacholderheide Hörsteloe, I = Westruper Heide (see Fig. 1 and Tab. 1 for further information). Status = Red List-status for North-Rhine Westphalia and Germany (Maas et al. 2002).

study area	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**total**	**status**	
no. of sites	**2**	**2**	**1**	**4**	**1**	**1**	**5**	**2**	**6**		NRW	D
species												
Chorthippus biguttulus	.	.	.	13	1	.	.	5	5	**24**	*	*
Chorthippus brunneus	1	2	.	1	1	.	1	.	1	**7**	*	*
Chorthippus mollis	.	136	12	157	8	.	51	1	25	**390**	**3**	*
Chorthippus parallelus	.	2	.	84	.	.	2	.	.	**88**	*	*
Gryllus campestris	.	.	.	.	.	.	102	.	21	**123**	**2**	**3**
Meconema thalassinum	1	.	.	.	.	.	.	.	.	**1**	*	*
Metrioptera roeselii	.	.	.	16	.	.	.	.	.	**16**	*	*
Myrmeleotettix maculatus	110	612	182	134	119	10	181	95	266	**1709**	*	*
Nemobius sylvestris	4	.	.	.	.	2	.	.	.	**6**	*	*
Omocestus viridulus	.	.	.	1	.	.	.	.	.	**1**	*	*
Stenobothrus lineatus	.	.	.	.	.	.	150	.	.	**150**	**3**	*
Stenobothrus stigmaticus	.	.	.	48	.	.	.	3	.	**51**	**2**	**3**
Tetrix undulata	.	7	1	39	.	.	.	.	1	**48**	*	*
total	**116**	**759**	**195**	**493**	**129**	**12**	**487**	**104**	**319**	**2614**		

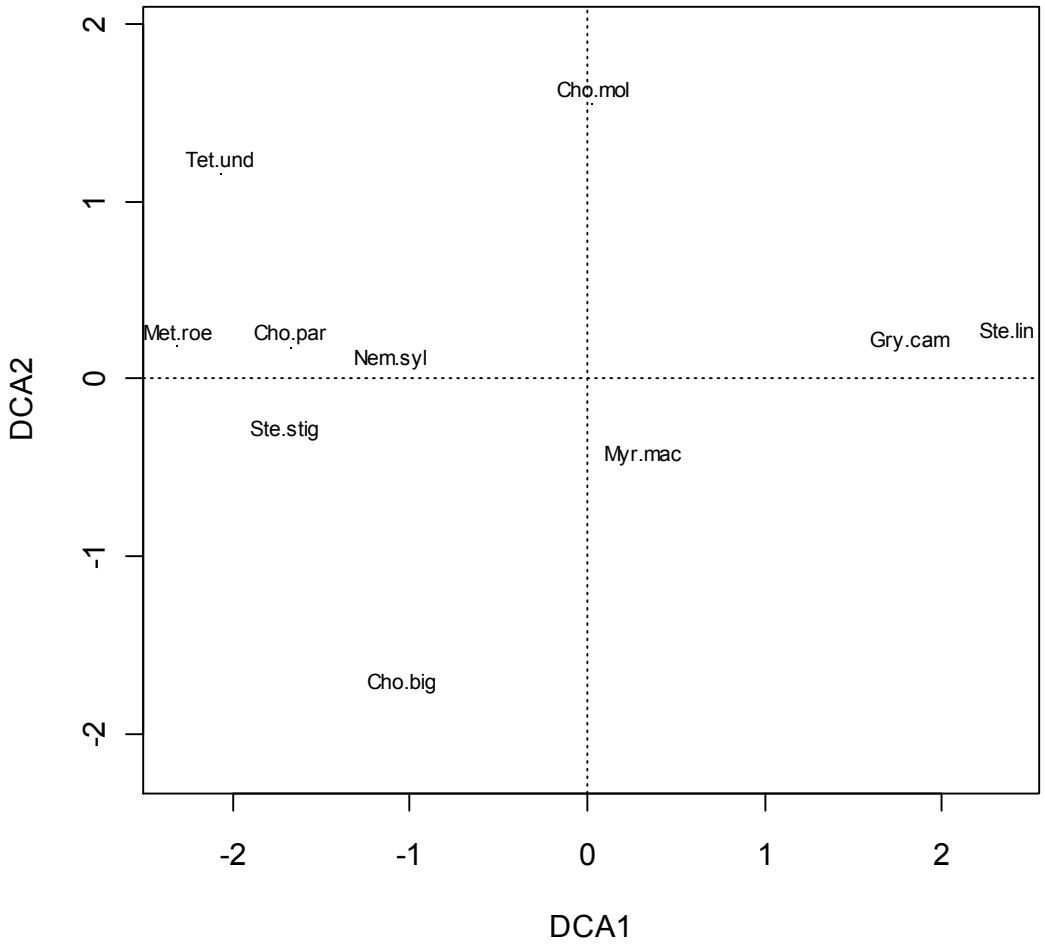

Fig. 2: DCA ordination of grasshopper species. Cho.big = *Chorthippus biguttulus*, Cho.mol = *Chorthippus mollis*, Cho.par = *Chorthippus parallelus*, Gry.cam = *Gryllus campestris*, Met.roe = *Metrioptera roeselii*, Myr.mac = *Myrmeleotettix maculatus*, Nem.syl = *Nemobius sylvestris*, Ste.lin = *Stenobothrus lineatus*, Ste.sti = *Stenobothrus stigmaticus*, Tet.und = *Tetrix undulata*.

Discussion

The species inventory of the investigated sand ecosystem sites is clearly dominated by dry grassland species. The predominant species was the xerothermic *Myrmeleotettix maculatus*, which is a typical and widespread element of dry and open habitats (DETZEL 1998, PERSIGEHL & ASSMANN 2004, SCHIRMEL et al. 2010b), occurring in very high abundances in all habitat types throughout the study area. Apart from weak negative responses to increasing density of herbal layer, this species showed only low habitat preferences within the studied areas. The same applied to the locally threatened *Chorthippus mollis* (RL NRW 3), which showed similar habitat preferences as *Myrmeleotettix maculatus* (HEMPEL & SCHIEMENZ 1963, DETZEL 1998, KÖHLER 2001). On the other hand, most of the investigated sites are small-sized and contain at least numerous densely vegetated patches that explain the occurrence of several typical (mesophilous) grassland species such as *Metrioptera roeseli*, *Chorthippus biguttulus* and *C. parallelus* (DETZEL 1998). A comparison of our data with available data concerning the local Orthoptera fauna of single study areas shows that they are quite similar, in

particular data regarding the species inventory and the abundances (e.g. "Moosheide" (="Senne"): RETZLAFF & ROBRECHT 1991, ORTMANN 1996; "Heiliges Meer": BUßMANN 2004).

Tab. 3: Responses of grasshoppers to environmental and landscape parameters were analysed using general linear models (GLM). Significance levels are indicated as ***($p < 0.001$), **($p < 0.01$) or *($p < 0.05$). Whether or not the parameter had a positive or negative effect on species density is indicated as "-" for decreasing and "+" for increasing. Abbreviations: site parameters: c.hl = coverage of herbal layer, h.hl = height of herbal layer, d.hl = density of herbal layer in 0–20 cm height; landscape parameters: size = size of nature reserve, isol. = isolation, sand = size of open dry grasslands.

species	site parameters				landscape parameters			
	c.hl	h.hl	d.hl	R^2	size	isol.	sand.	R^2
Chorthippus biguttulus	.	**+** **	**-**	72.6	.	.	.	.
Chorthippus mollis	.	.	.	.	.	.	.	.
Chorthippus parallelus	.	.	.	.	.	.	.	.
Gryllus campestris	.	.	.	.	**+** ***	**-***	**+** ***	99.9
Metrioptera roeselii	.	.	.	.	.	.	.	.
Myrmeleotettix maculatus	.	.	**-** *	29.1	.	.	.	.
Nemobius sylvestris	.	.	.	.	**+*****	.	**-*****	99.9
Stenobothrus lineatus	**+** **	.	**+**	55.5	**+*****	.	.	33.6
Stenobothrus stigmaticus	.	.	.	.	.	.	.	.
Tetrix undulata	.	**-**	**+** *	8.2	.	.	.	.

The records of the three threatened and protected species *Gryllus campestris* (RL NRW 2) *Stenobothrus lineatus* (RL NRW 3) and *S. stigmaticus* (RL NRW 2) indicate a good state of preservation of certain sites, which are therefore of interest for conservation. *Stenobothrus lineatus* as well as *Stenobothrus stigmaticus* are xerophilous species with strong habitat bindings to dry and open grasslands. According to RÖBER (1951), KÖHLER (1988) and BEHRENS & FARTMANN (2004), the latter is much more specialized to dry habitat conditions with lower vegetation density and height. These findings were also supported by our GLM analysis, where *Stenobothrus lineatus* showed a positive relation with the cover and height of the vegetation. In Germany, *Stenobothrus stigmaticus* is only locally and sparsely distributed, mainly in sandy regions. In Westphalia the species is very rare (VOLPERS 1998): In our study the species could be recorded only in two *Calluna*-heathland areas. In contrast to *Stenobothrus lineatus*, the size of the area did not have an impact on the occurrence of *S. stigmaticus*. *Stenobothrus lineatus*, which reaches its north-western distribution limit in Westphalia (MAAS et al. 2002), only occurred in the largest study areas. This is in conformity with the findings of BEHRENS & FARTMANN (2004), who pointed out that habitats of *Stenobothrus lineatus* were larger than those of *Stenobothrus stigmaticus*. The field cricket (*Gryllus campestris*) is one of the most important target species within the

framework of dry grassland and heathland conservation in Northwest Germany (HOCHKIRCH 1996, HOCHKIRCH et al. 2006). The species inhabits mainly dry grasslands, heathlands and oligotrophic grasslands, where it lives in burrows (KLEUKERS et al. 1997, DETZEL 1998). In Westphalia, *Gryllus campestris* reaches the northern edge of its range (KLEUKERS et al. 1997, MAAS et al. 2002). Within the study, it has been recorded only in two areas, namely Westruper Heide and Moosheide. As shown by the GLM results, the occurrence of the field cricket is exclusively constrained by landscape parameters, while site variables play only a minor role. Consequently, *Gryllus campestris*, as well as *Stenobothrus lineatus*, need large areas, such as Moosheide, that are ideally connected in a nature reserve network (Westruper Heide) to ensure little isolation and therefore high connectivity between dry sand ecosystems (cf. MAAS et al. 2002). Connectivity might be especially important, since both species feature only low dispersal power (MAAS et al. 2002). Last, a high proportion of typical dry and open grassland is essential, whereas dry and sandy soils are presumably much more important than certain vegetation structure features (as indicated by missing responses to vegetation structure within the GLM analyses).

As mentioned above, most of the investigated sites are small-sized, which might cause edge effects. This also explains the combined occurrence of the xerothermic *Stenobothrus stigmaticus* with the eurytopic and mesophilous *Metrioptera roeselli* and *Chorthippus parallelus* (shown in the DCA). The records of *Nemobius sylvestris* revealed an effect of adjacent forests, for example due to higher input of litter. According to BAUER et al. (1997), BREINL et al. (1997) and WEIPERT & WEIGEL (1998), thick layers of oak and scotch pine litter create particularly suitable habitat conditions for *Nemobius sylvestris*, which is known as typical inhabitant of wooded but dry grassland with abundant litter (PERNER 1997, KÖHLER 1998).

To summarize, the study comprised a species inventory of 13 species and therefore provides a valuable data set for nearly all dry grassland habitats in northern Westphalia. It was possible to point out certain ecological needs at a site and landscape level. Thus, we were able to supply useful information concerning species of special conservation interest. The very frequent occurrence of the locally threatened *Chorthippus mollis* and of the xerothermic *Myrmeleotettix maculatus* suggested that the studied dry grassland sites had at least some value for xerothermic species. Similar results could be shown for spiders, where the dry grassland sites exhibited several rare and threatened species (BUCHHOLZ 2010). In particular the largest (or connected) sites have high value for conservation, as the occurrence of the target species *Gryllus campestris* and also of the threatened *Stenobothrus lineatus* depends on size. It seems to be very worthwhile to consider and analyse results from pitfall trapping studies conducted in sparsely vegetated habitat types. This can be of importance when monitoring dry sand ecosystems, since a large extent of these areas is located on military training areas (MELBER et al. 1996, PARDEY 2004, VOITHENBERG 2004), where common sampling methods (e.g. transect counts and sweep netting) are not feasible.

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