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Psammophilous Grasslands and Other Open Sandy Habitats in the Sandomierz Basin as a Refuge for Threatened Orthoptera in Poland

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ABSTRACT

Psammophilous grasslands are declining in Europe due to ecological succession and anthropogenic pressures, yet they group many specialised invertebrates of early successional biotopes. We investigated the occurrence of six threatened species of Orthoptera in 135 patches of psammophilous grasslands and other open sand-related habitats (dry heaths, sandy roads, sand pits) located in the Sandomierz Basin (SE Poland). The aim was to verify whether these habitats, and especially the active military range, serve as a refuge for any of the selected species. Localities of *Podisma pedestris* and *Calliptamus italicus* found in the study area covering 0.7% of Poland's territory represented a significant proportion (50 and 18%, respectively) of UTM grid squares known to be currently occupied by these species in the country. In the regional scale of southern Poland, studied habitats also accumulated a large proportion (ca. 17%) of the current localities of *Oedipoda caerulescens*. However, for *Aiolopus thalassinus*, *Psophus stridulus* and *Sphingonotus caerulans* the importance of the Sandomierz Basin as a country wide refuge was rather minor. Five of the six target species were found on the military range, with two (*P. pedestris*, *P. stridulus*) recorded only there. These results indicate that sand-related habitats are important refuges for some threatened orthopterans in the region and should be actively protected.

Keywords: Acrididae, sandy grasslands, heaths, sand pits, military training ground.

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INTRODUCTION

Grasslands are the most biodiverse habitat type for Orthoptera in Europe, being inhabited by 555 species of these insects, i.e. 51.6% of all those found across the continent (Hochkirch et al, 2016). At the same time, this habitat also groups the highest number of European orthopterans threatened with extinction (more than 100 species; Hochkirch et al, 2016). For these reasons, different types of grasslands are a frequent field of orthopterological research (e.g. Bazyluk & Liana, 1970; Krištín, Kaňuch, & Sárossy, 2004; Fartmann, Krämer, Stelzner, & Poniatowski, 2012; Kenyeres, Szabó, Takács, & Szinetár, 2020). In Poland, among grassland habitats, the fauna of Orthoptera inhabiting xerothermic calcareous grasslands is particularly diverse and well-studied (e.g. Bazyluk & Liana, 1970; Liana, 1976, 1978, 1982, 1990, 1994). In contrast, there is significantly less data on other types of open dry ecosystems – psammophilous grasslands and other inland sand-related habitats (Liana, 1990, 1994; Warchałowska-Śliwa, Maryańska-Nadachowska, & Kostia, 1992; Kuřavová, 2014; Krasoń & Wojton, 2021), although they are more widespread and occupy larger areas than xerothermic grasslands (EEA 2021). At the same time, psammophilous grasslands are among the threatened and declining habitats in Europe (Janssen et al, 2016), mostly as a result of vegetation succession or due to being treated as wastelands, which leads to ongoing afforestation or housing development (Liana, 1999, 2002; Krištín et al, 2004; Kujawa-Pawlaczyk, 2010; Trąba & Rogut, 2013). The highly specialised fauna of psammophilous grasslands includes many rare or threatened taxa (Exeler, Kratochwil, & Hochkirch, 2009; Banaszak & Twerd, 2018; Buszko, 2019; Rozwałka, Rutkowski, Sienkiewicz, & Wiśniowski, 2019; Grbić, Hänggi, & Krnjajić, 2021), and this also applies to orthopterans (Krištín et al, 2004). Some species of these insects are associated with the early stages of succession of psammophilous grassland vegetation, so that they can be regarded as bioindicators of the successional changes occurring in these communities (Fartmann et al, 2012). In Poland, species such as *Calliptamus italicus* (L., 1758), *Oedipoda caerulescens* (L., 1758) or *Sphingonotus caerulans* (L., 1767) are among those strongly associated with open sandy habitats (Warchałowska-Śliwa et al, 1992; Liana, 1999, 2002; Bazyluk & Liana, 2000). Taking into account the alarming status of psammophilous grasslands in Europe (Janssen et al, 2016), also the orthopterans of this ecosystem should be of special research interest, as a potentially highly endangered ecological group.

The study was focused on the recognition of the distribution and frequency of occurrence of selected, threatened species of Orthoptera in psammophilous grasslands and other open sand-related habitats (such as dry heaths, sandy roads, sand pits) located in the Sandomierz Basin (south-eastern Poland). The area is known for the occurrence of many rare invertebrates (Krawczyk, Kata, & Nowak, 2011), including orthopterans (Liana, 1999; Krasoń & Wojton, 2021), though generally it has been rather poorly studied in terms of Orthoptera. And the same time it is characterised by the presence of a large area of open sandy biotopes, potentially utilised by highly specialised entomofauna (Nowacki & Pałka, 2015). They are particularly widespread in the central part of the area, where a large military training ground is located (GDOŚ, 2021). On the basis of the above information, we expect that: 1) psammophilous grasslands and other inland sandy habitats in the region studied are inhabited by several rare, specialised species of Orthoptera, 2) this part of the Sandomierz Basin constitutes a refuge of a country-wide importance for threatened orthopterans of dry, sand-related open ecosystems, and 3) the area of the military training ground serves as a regional biodiversity hotspot for this group of insects.

MATERIAL AND METHODS

Study area and sampled habitats

The study was conducted in south-eastern Poland (Fig. 1), covering a fragment of the Sandomierz Basin (specifically, the western and central part of the so-called Sandomierz Forest), located within the boundaries of the Natura 2000 Special Protection Area ‘Puszcza Sandomierska’ PLB180005. This region is bounded to the east and north-east by the San River valley, to the west and north-west by the valleys of the Vistula and Wisłoka rivers, and to the south by the Sub-Carpathian Ice Marginal Valley (Solon et al, 2018). It is characterised by the occurrence of fluvial sands and Pleistocene aeolian formations, forming complex systems of dunes reaching up to 25 m in height, between which there are drainless deflation depressions, often filled with peat and strongly moistened. This creates large environmental contrasts between dry and wet areas located close to each other, which is characteristic of this region. The area is covered by a mosaic of woodlands (mainly pine and pine-oak forests), semi-open and open areas, both farmed and uncultivated (Krawczyk et al, 2011; Kondracki, 2013; GDOŚ, 2021). The area selected for the study comprised a total of 23 UTM (Universal Transverse Mercator) grid squares, covering approximately 2300 km^2 (Fig. 1).

The study covered several types of inland sandy habitats. The vast majority were thermophilic, pioneer, dry sandy (psammophilous) grasslands of the class *Koelerio glaucae-Corynephoretea canescentis*, developed both on dune sands and those not associated with dunes (Kujawa-Pawlaczyk, 2010; Kulpiński & Tyc, 2012). These grasslands were usually created as a result of human activity (deforestration, agricultural management), so they have a secondary character. They are an early stage of succession in vegetation transformations leading to pine forest, usually forming after its cutting or on the edges of forest patches (Kulpiński & Tyc, 2012). Psammophilous grasslands are also commonly formed on post-agricultural areas on sandy soils, as well as accompany the edges of dirt roads or road and railway embankments (Kujawa-Pawlaczyk, 2010; Trąba & Rogut, 2013). Grasslands with various vegetation structure were surveyed, from areas of bare sand with sparse vegetation to late successional stages, with encroaching undergrowth of shrubs and trees (mainly Scots Pine *Pinus sylvestris* L.; Trąba & Rogut, 2013). Moreover, psammophilous grasslands formed in sand pits and on their margins were sampled (Kujawa-Pawlaczyk, 2010; Trąba & Rogut, 2013). In addition, sandy dry heath

Calluno-Ulicetalia communities (Pawlaczyk, 2012) were surveyed, which occurred on an extensive (nearly 2000 ha; GDOŚ, 2021), active military training ground, in a mosaic with psammophilous grasslands, pine forests and woodlots, forest edge and tall-herb thermophilous communities of *Trifolio-Geranietea* and patches of open dune sands (Rapa & Krawczyk, 2020). All these studied habitats belong to nutrient poor, dry, strongly insolated and thermophilic, in this respect ranking among the most extreme habitats found in the Central European lowlands (Kujawa-Pawlaczyk, 2010; Kulpiński & Tyc, 2012).

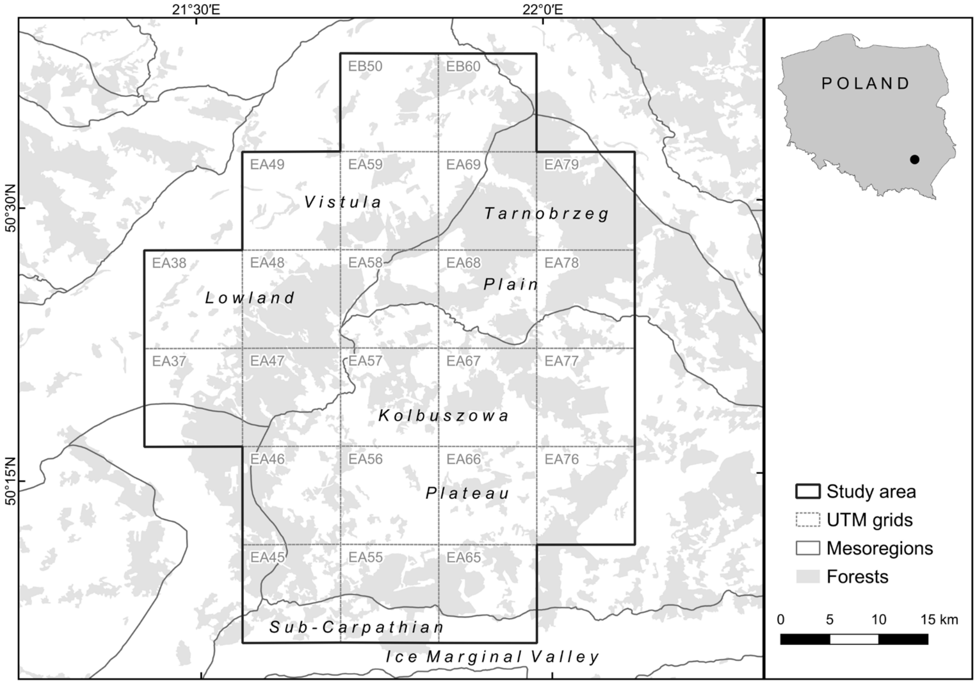

Figure 1. Location of the study area.

Studied species

Sampling was targeted at six selected Orthoptera species belonging to the family Acrididae MacLeay, 1821 (Table 1; taxonomy according to Cigliano, Braun, Eades, & Otte, 2021), found in the open sandy communities described above (Liana, 1990, 1994, 1999; Warchałowska-Śliwa et al, 1992; Bazyluk & Liana, 2000; Kuřavová, 2014). All of these species can be regarded as threatened in Poland, as in the Polish red list of threatened species (Liana, 2002), they were given NT (near threatened) or higher status (Table 1). The occurrence of each of these species has been recorded in the Sandomierz Forest in the past (Bazyluk & Liana, 2000), and some of them also recently (Krasoń & Wojton, 2021).

Table 1. Species of Orthoptera selected for the study. Threat status in Poland is given for each, based on the regional red list of threatened species (Liana, 2002).

No	Species	Threat status
1	*Podisma pedestris* (L., 1758)	VU (vulnerable)
2	*Calliptamus italicus* (L., 1758)	CR (critically endangered)
3	*Aiolopus thalassinus* (Fabr, 1781)	VU (vulnerable)
4	*Psophus stridulus* (L., 1758)	VU (vulnerable)
5	*Oedipoda caerulescens* (L., 1758)	NT (near threatened)
6	*Sphingonotus caerulans* (L., 1767)	NT (near threatened)

Data acquisition and analysis

The study was carried out in 2019 and 2020, with 89% of sites inspected in 2020. Fieldwork was carried out from the last third of June to the second third of August, with the greatest intensity in the last third of July. In each of the 23 UTM grid squares, between 1 and 19 (median=5) patches of sandy habitats were sampled, in which the above-mentioned orthopterans were searched for. Approximately 50% of patches were sampled during the ornithological fieldwork carried out in the area under study. The remaining ones were selected using publicly available satellite and aerial imagery (Google Maps and www.geoportal.gov.pl), as sandy grasslands, due to their unique physiognomy, are usually clearly distinguishable on them. Locations selected in this way were then searched in the field. In 135 sampled habitat patches (localities/sites; Appendix 1), at daytime, adult and larval stages of the studied orthopterans were visually searched for. Insects were identified in the field – with the naked eye, binoculars enabling observation of close objects or from photographs. If necessary, selected individuals were caught and, after species identification, released at the site of capture. Surveys were qualitative (presence/absence) – the abundance of the species in the site was not assessed. Each record was assigned with date, geographical coordinates, UTM grid square, physico-geographical mesoregion and habitat type (psammophilous grassland, dry heath, sand pit, sandy road, railway embankment). This information was collected in a database. The results obtained in the localities selected according to the scheme presented above were used to describe the distribution of the species in the study area and were subjected to quantitative analysis. For each species, the frequency of its occurrence in the studied habitats was calculated as the percentage of sites in which the presence of that species was recorded.

In order to determine the role that the studied region (0.7% of Poland's area) play in the preservation of each threatened species in the country, a comparison of the results of our study was made with the data of the project of mapping distribution of orthopterans in Poland (Żurawlew et al, 2021). We determined the proportion of UTM grid squares occupied by each species in the study area in relation to squares with an up-to-date (= after 1990) occurrence (i) in the country and (ii) in southern Poland (south of the 50°55' parallel). Note, however, that the comparative data (Żurawlew et al, 2021) is incomplete, because the mapping project is ongoing.

RESULTS

In 121 of the 135 sites surveyed (90%; Appendix 1), at least one of the six studied Orthoptera species was recorded. This was most often one (84 sites; 62%) or two species (32 sites; 24%), and much less often three, four or five species (5 sites in total; 4%).

Podisma pedestris. A species with a very clustered distribution. Found in three localities (2%; Fig. 2a, 3), located within one compact area – the military training ground in Nowa Dęba (western part of the Tarnobrzeg Plain). Not found in other parts of the study area. The three occupied UTM grid squares found (Appendix 1) represent 50,0% of the squares with known present occurrence of the species, both in the whole country and in southern Poland.

Calliptamus italicus. The second most frequent species, distributed almost throughout the area, although with uneven frequency. It was found in 39 sites (29%; Fig. 2b, 3). There is a noticeable gradient of frequency, decreasing from north to south. It was most frequent in the northern regions: Tarnobrzeg Plain (52% of sites located within this region) and Vistula Lowland (34%), and less frequent in the Kolbuszowa Plateau (24%), especially in its southern parts (Fig. 3). Not recorded in the Sub-Carpathian Ice Marginal Valley. The 22 occupied UTM grid squares found in the study area (Appendix 1) represent 18,3% of the squares with known present occurrence of the species in the whole country and 43,1% of the squares in southern Poland.

Aiolopus thalassinus. The species was recorded only in one locality (frequency of occurrence <1%; Fig. 3), at the northern edge of the Kolbuszowa Plateau (Fig. 2c). Not found in other regions. The single occupied UTM grid square found in the study area (Appendix 1) represent 0,8% of the squares with known present occurrence of the species in the whole country and 5,6% of the squares in southern Poland.

Psophus stridulus. Similarly to the previous species, it was recorded only in one locality (frequency of occurrence <1%, Fig. 3), in the eastern part of the military training ground near Nowa Dęba (Fig. 2d; western part of the Tarnobrzeg Plain). The single occupied UTM grid square found in the study area (Appendix 1) represent 2,1% of the squares with known present occurrence of the species in the whole country and 3,6% of the squares in southern Poland.

Oedipoda caerulescens. The most frequent of all species, found in 115 sites (85%; Fig. 2e, 3). Distributed quite evenly in the whole area, in many parts noted at every sampled site. It occurs in each of the four mesoregions, although in the Tarnobrzeg Plain it was recorded with relatively lower frequency (71%) than in the remaining ones (85–92%; Fig. 3). The 23 occupied UTM grid squares found in the study area (Appendix 1) represent 17,4% of the squares with known present occurrence of the species in southern Poland. Unfortunately, data for the whole country is not available, but the percentage is certainly much lower than for the southern region and probably insignificant.

Sphingonotus caerulans. It was found in 7 sites (5%; Fig. 2f, 3) concentrated in one area. The distinctive centre of occurrence of this species was the military training ground near Nowa Dęba, where 5 out of 7 localities were found. The other two sites were located nearby – on the northern edge of the Kolbuszowa Plateau and in the south-western part of the Tarnobrzeg Plain. In the latter mesoregion the frequency of occurrence reached 29% of sites (Fig. 3). The two occupied UTM grid squares found in the study area (Appendix 1) represent 1,9% of the squares with known present occurrence of the species in the whole country and 6,1% of the squares in southern Poland.

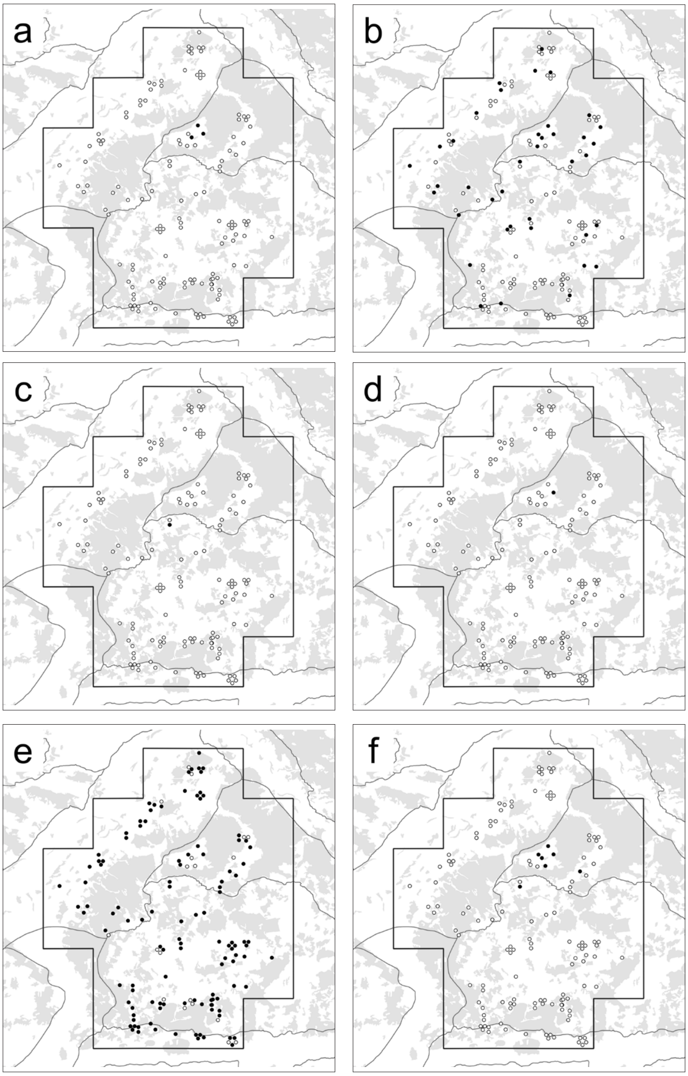

Figure 2. Distribution of each species in the study area – localities where the species was present (solid circles) and those where it was not recorded (empty circles). a) *Podisma pedestris,* b) *Calliptamus italicus,* c) *Aiolopus thalassinus,* d) *Psophus stridulus*, e) *Oedipoda caerulescens,* f) *Sphingonotus caerulans*.

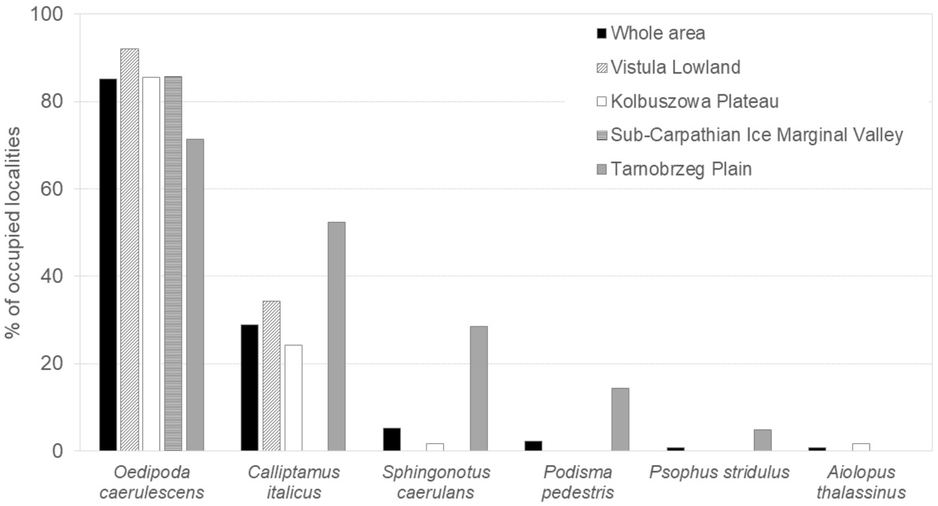

Figure 3. Frequency of occurrence of each species across the study area and in each mesoregion, presented as a percentage of occupied localities.

DISCUSSION

The occurrence of specialised Orthoptera in open sandy habitats, such as psammophilous grasslands and dry heaths, is determined by features such as the large area of exposed, highly insolated soil or sand (suitable for, e.g. egg deposition and development), the presence of low vegetation or the warm and dry microclimate (Maes & Bonte, 2006; Warren & Büttner, 2008; Fartmann et al, 2012; Kenyeres et al, 2020). The presence of all six target threatened Orthoptera species was confirmed in the study area and surveyed types of habitat (cf. hypothesis 1), with *O. caerulescens* being a very widespread species and *C. italicus* being fairly widespread. Both species are distributed quite evenly in the whole studied fragment of the Sandomierz Basin, although the former was generally about three times more frequent than the latter, except for the Tarnobrzeg Plain, where the difference was smaller, only 1.5 times. The remaining four species occurred locally, in small number (*S. caerulans*, *P. pedestris*) or even at single sites (*A. thalassinus*, *P. stridulus*). In the case of *A. thalassinus* this may be due to different larval habitat requirements. This thermophilic and hygrophilic species usually breeds in moist habitats: wet meadows, salt marshes, floodplains of river valleys or near water bodies (Bazyluk & Liana, 2000; Kristín, Kaňuch, & Sárossy, 2007), however, adults also occur in xerophilous and psammophilous grasslands (Bazyluk & Liana, 2000; Krištín et al, 2007), especially when they are located close to the wet habitats (Mielczarek & Grobelny, 2018). That was also the case for the studied locality – the species was encountered in the sand pit. The frequency of occurrence of *A. thalassinus* may be underestimated also due to the fact that the peak of adult abundance occurs in late August and September (Krištín et al, 2007), so it was barely covering with our sampling period. Habitat preferences probably caused also low frequency of occurrence of *P. stridulus,* which was found only at one locality. In lowland Poland it is a species associated mostly with open and ecotone habitats (clearings, heathlands) accompanying pine forests (Liana, 1976; Bazyluk & Liana, 2000), rather than with initial psammophilous grasslands located in an agricultural landscape, where most of the study sites were located. In addition, this species is closely associated with extensive grazing (Rada, Spitzer, Šipoš & Kuras 2017), which is lacking in the research area.

In the case of some species of Acrididae, the studied psammphilous grasslands and other sand-related habitats comprise a significant proportion of currently known localities of these taxa in Poland (*i.e.* UTM grid squares with the occurrence recorded after 1990), so they may be regarded as their refuges (cf. hypothesis 2). Comparison of the results of our research with the data of the project of mapping distribution of orthopterans in Poland (Żurawlew et al, 2021), revealed the remarkable role of the researched region (despite its restricted area) in the preservation of sites of *P. pedestris* and *C. italicus* at the country wide scale. At the regional scale of southern Poland, the sandy habitats of the Sandomierz Basin also proved to be vital as a refuge for *O. caerulescens*. On the other hand, the importance of the region for *A. thalassinus*, *P. stridulus* and *S. caerulans* is lower and does not allow to consider the surveyed area as a refuge for those taxa, especially from a country wide perspective (Żurawlew et al, 2021).

The Tarnobrzeg Plain had the highest species richness among all regions, which was largely due to the location of the military training ground near Nowa Dęba. In its area five of the six target Orthoptera species were found, including two species recorded only here (*P. pedestris*, *P. stridulus*). In addition, the training ground also contained most of the *S. caerulans* sites found during this study. This clearly indicates that the military range is a key refuge for threatened xerophilous orthopterans (cf. hypothesis 3). This may be partly due to its large size (the range is about 30 km^2), as the area and connectivity of sandy habitats positively influences the diversity of threatened invertebrates from different taxonomic groups, including orthopterans (Maes & Bonte, 2006). Some species, such as the extremely xerophilous *S. caerulans* (Bazyluk & Liana, 2000; Krištín et al, 2004), may also be favoured by the specific dry microclimate of the training ground. The natural value of military area is also undoubtedly a consequence of the great variety of sandy habitat types, from pine forests and shrubs, through dry heaths and psammophilous grasslands, to tracts of open sand. Such a mosaic is maintained by military use (e.g. heavy vehicle traffic, explosions; Warren & Büttner, 2008; Gardiner & Benton, 2009; Woodcock & Pywell, 2009), combined with frequent fires (Rapa & Krawczyk, 2020). These inhibit succession, generates local disturbances, and sometimes completely destroy the vegetation cover, which is a necessary condition for the maintenance of early successional biotopes and favourable local vegetation heterogeneity (Maes & Bonte, 2006; Warren & Büttner, 2008). Due to succession-inhibiting land use, the best-developed patches of psammophilous grasslands are often found on active military training grounds (Kulpiński & Tyc, 2012; Janssen et al, 2016). Specific biocoenoses are associated with these regularly disturbed, pioneer habitats of military ranges, including threatened habitat specialists: noctuid moths (Nowacki & Pałka, 2015), orthopterans and beetles (Warren & Büttner, 2008; Gardiner & Benton, 2009) or plants (Rapa & Krawczyk, 2020). It has been suggested that some species (such as *O. caerulescens*) may be dependent on local disturbances destroying vegetation cover and creating a mosaic of vegetation and areas of bare sand (Maes & Bonte, 2006; Warren & Büttner, 2008). Thus, it seems that the continuation of military activities on the training ground near Nowa Dęba is a key condition to maintain the biocoenoses associated with the open habitats of the area.

Psammophilous grasslands are still quite widespread in Poland (Kujawa-Pawlaczyk, 2010; Kulpiński & Tyc, 2012), including the studied region (Trąba & Rogut, 2013). However, they are a subject to many negative pressures (secondary succession, eutrophication, development, afforestation; Liana, 1999, 2002; Exeler et al, 2009; Kujawa-Pawlaczyk, 2010; Janssen et al, 2016; own data), which threaten the conservation status of their fauna, including rare Orthoptera. It is worth emphasizing that vegetation succession occurring in dry grasslands pose a threat especially to orthopterans belonging to the group of habitat specialists (Fartmann et al, 2012), among which endangered species are numerous. And it is known that rapid successional transformations are characteristic for these habitats (Buchholz, 2010; Kulpiński & Tyc, 2012). The most important forms of counteracting negative transformations of these habitats include the use of military training grounds (Janssen et al, 2016) and, in particular, the implementation of active protection measures on the most valuable patches, which inhibit vegetation succession (Buchholz, 2010). The latter include removal of tree and shrub overgrowth, extensive grazing (especially of goats and sheep), hay removal and controlled burning (Maes & Bonte, 2006; Kujawa-Pawlaczyk, 2010; Fartmann et al, 2012; Banaszak & Twerd, 2018; Kenyeres et al, 2020). Proper planning and implementation of such active protection measures, especially creating a complex mosaic of microhabitats and patches of different stages of succession, allows to maintain the high biodiversity of these specific ecosystems (Cremene et al, 2005; Woodcock & Pywell, 2009; Buchholz, 2010). It is also beneficial to restore sandy grasslands that have undergone strong succession as, at least in some cases, this allows for the re-establishment of a species-rich assemblages (Exeler et al, 2009). It should be ensured that an extensive representation of psammophilous grasslands is secured also in the studied fragment of the Sandomierz Basin. Activities aimed at the restoration and maintenance of psammophilous grasslands should be focused primarily in the Tarnobrzeg Plain and Kolbuszowa Plateau, because this is where the greatest number of target Orthoptera species is concentrated. Special care, including entomological and habitat quality monitoring, should be taken over the military training ground near Nowa Dęba, because, as the obtained results show, it plays a key role in preserving the full spectrum of threatened orthopterans of open sandy habitats of the Sandomierz Basin.

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Appendix 1. The list of 135 surveyed sites. For each site the mesoregion, geographical coordinates (X, Y), UTM grid, general habitat type and recorded Orthoptera species (marked ●) are given. Pp - *Podisma pedestris* (L., 1758); Ci - *Calliptamus italicus* (L., 1758); At - *Aiolopus thalassinus* (Fabr., 1781); Ps - *Psophus stridulus* (L., 1758); Oc - *Oedipoda caerulescens* (L., 1758); Sc - S*phingonotus caerulans* (L., 1767).

Mesoregion	Site no.	X (°E)	Y (°N)	UTM grid	Habitat type	Pp	Ci	At	Ps	Oc	Sc
Kolbuszowa Plateau	1	21.66985	50.17301	EA45	psammophilous grassland					●	
	2	21.65929	50.18314	EA45	sand excavation					●	
	3	21.67025	50.15572	EA45	psammophilous grassland					●	
	4	21.67561	50.15560	EA45	psammophilous grassland					●	
	5	21.66844	50.13835	EA45	psammophilous grassland					●	
	6	21.67004	50.13999	EA45	psammophilous grassland		●			●	
	7	21.63478	50.21418	EA46	psammophilous grassland		●			●	
	8	21.66958	50.21013	EA46	sand excavation					●	
	9	21.67272	50.20789	EA46	psammophilous grassland					●	
	10	21.60466	50.30425	EA47	psammophilous grassland		●				
	11	21.72554	50.18314	EA55	psammophilous grassland					●	
	12	21.75526	50.18446	EA55	psammophilous grassland					●	
	13	21.74854	50.17703	EA55	psammophilous grassland					●	
	14	21.74624	50.17551	EA55	psammophilous grassland					●	
	15	21.81644	50.17738	EA55	sand excavation						
	16	21.81568	50.17474	EA55	psammophilous grassland					●	
	17	21.83550	50.18553	EA55	psammophilous grassland						
	18	21.83877	50.18438	EA55	psammophilous grassland					●	
	19	21.83947	50.18064	EA55	psammophilous grassland						
	20	21.72038	50.14439	EA55	psammophilous grassland		●			●	
	21	21.76005	50.18239	EA55	psammophilous grassland						
	22	21.76359	50.22863	EA56	psammophilous grassland					●	
	23	21.75142	50.27536	EA56	psammophilous grassland						
	24	21.74980	50.27791	EA56	psammophilous grassland					●	
	25	21.74696	50.27753	EA56	psammophilous grassland		●			●	
	26	21.74858	50.27797	EA56	sandy road		●				

Mesoregion	Site no.	X (°E)	Y (°N)	UTM grid	Habitat type	Pp	Ci	At	Ps	Oc	Sc
Kolbuszowa Plateau	27	21.80578	50.28294	EA57	psammophilous grassland		●			●	
	28	21.80859	50.28449	EA57	psammophilous grassland					●	
	29	21.72721	50.34588	EA57	psammophilous grassland		●			●	
	30	21.80927	50.32781	EA57	psammophilous grassland					●	
	31	21.80305	50.29602	EA57	psammophilous grassland		●			●	
	32	21.77902	50.39457	EA58	sand excavation			●		●	●
	33	21.77659	50.39489	EA58	psammophilous grassland		●			●	
	34	21.91110	50.16092	EA65	psammophilous grassland		●			●	
	35	21.89117	50.17225	EA65	psammophilous grassland					●	
	36	21.89479	50.18186	EA65	psammophilous grassland					●	
	37	21.86423	50.17830	EA65	psammophilous grassland					●	
	38	21.90793	50.18804	EA65	psammophilous grassland					●	
	39	21.89303	50.17283	EA65	psammophilous grassland						
	40	21.89832	50.18798	EA65	psammophilous grassland					●	
	41	21.91503	50.16285	EA65	psammophilous grassland					●	
	42	21.88708	50.18038	EA65	psammophilous grassland					●	
	43	21.90850	50.14945	EA65	psammophilous grassland						
	44	21.95497	50.21048	EA66	psammophilous grassland		●			●	
	45	21.93122	50.26060	EA66	psammophilous grassland					●	
	46	21.92162	50.24976	EA66	psammophilous grassland					●	
	47	21.95339	50.25472	EA66	sandy road					●	
	48	21.96134	50.26588	EA66	psammophilous grassland		●			●	
	49	21.89189	50.19396	EA66	psammophilous grassland					●	
	50	21.95418	50.28251	EA67	sand excavation					●	
	51	21.95312	50.28135	EA67	psammophilous grassland					●	
	52	21.94667	50.28446	EA67	psammophilous grassland					●	
	53	21.94848	50.28346	EA67	psammophilous grassland					●	
	54	21.91488	50.29049	EA67	psammophilous grassland					●	
	55	21.87381	50.34276	EA67	psammophilous grassland					●	
	56	21.85045	50.33921	EA67	psammophilous grassland					●	
	57	21.98843	50.20866	EA76	psammophilous grassland		●			●	
	58	22.06205	50.26027	EA76	psammophilous grassland					●	
	59	21.98532	50.26302	EA76	psammophilous grassland					●	
	60	21.99189	50.28582	EA77	psammophilous grassland		●			●	
	61	21.98974	50.28765	EA77	psammophilous grassland					●	
	62	21.99192	50.28827	EA77	psammophilous grassland					●	

Mesoregion	Site no.	X (°E)	Y (°N)	UTM grid	Habitat type	Pp	Ci	At	Ps	Oc	Sc
Sub-Carpathian Ice Marginal Valley	63	21.68992	50.13496	EA45	psammophilous grassland					●	
	64	21.68162	50.13320	EA45	psammophilous grassland					●	
	65	21.67004	50.13560	EA45	psammophilous grassland					●	
	66	21.73335	50.13367	EA55	sand excavation					●	
	67	21.78969	50.12521	EA55	psammophilous grassland					●	
	68	21.85377	50.12316	EA65	sand excavation					●	
	69	21.85412	50.12021	EA65	sand excavation					●	
	70	21.84958	50.11994	EA65	psammophilous grassland					●	
	71	21.86840	50.11859	EA65	psammophilous grassland					●	
	72	21.94590	50.10392	EA65	psammophilous grassland					●	
	73	21.94458	50.10403	EA65	sand excavation						
	74	21.94776	50.10275	EA65	psammophilous grassland					●	
	75	21.94731	50.10142	EA65	psammophilous grassland					●	
	76	21.95408	50.10497	EA65	sand excavation						
Tarnobrzeg Plain	77	21.82746	50.42619	EA58	sandy road, dry heath		●				
	78	21.80467	50.43652	EA58	sandy road, dry heath					●	
	79	21.83099	50.44771	EA58	sandy road, dry heath		●			●	●
	80	21.84051	50.44140	EA58	sandy road, dry heath	●	●				●
	81	21.80819	50.42959	EA58	sandy road, dry heath					●	
	82	21.91978	50.38353	EA68	psammophilous grassland					●	
	83	21.91784	50.38437	EA68	psammophilous grassland					●	
	84	21.92444	50.39827	EA68	psammophilous grassland		●			●	
	85	21.94726	50.41652	EA68	sandy railway embankment					●	●
	86	21.96445	50.40896	EA68	psammophilous grassland		●			●	
	87	21.95872	50.44127	EA68	psammophilous grassland		●				
	88	21.85009	50.42719	EA68	sandy road, dry heath						●
	89	21.87333	50.44773	EA68	sandy road, dry heath	●	●		●	●	●
	90	21.97389	50.47736	EA69	psammophilous grassland, dry heath					●	
	91	21.97505	50.47613	EA69	sandy road		●			●	
	92	21.85845	50.46273	EA69	sandy road, dry heath	●	●			●	●
	93	21.98605	50.42978	EA78	psammophilous grassland		●			●	
	94	21.99293	50.47640	EA79	sand excavation					●	
	95	21.99281	50.47580	EA79	sand excavation						
	96	21.99787	50.47449	EA79	psammophilous grassland						
	97	22.00583	50.45939	EA79	psammophilous grassland		●			●	

Mesoregion	Site no.	X (°E)	Y (°N)	UTM grid	Habitat type	Pp	Ci	At	Ps	Oc	Sc
Vistula Lowland	98	21.51967	50.35577	EA37	psammophilous grassland					●	
	99	21.54590	50.35666	EA37	psammophilous grassland		●			●	
	100	21.53568	50.34510	EA37	psammophilous grassland		●			●	
	101	21.55319	50.42764	EA38	psammophilous grassland		●			●	
	102	21.54102	50.39945	EA38	psammophilous grassland					●	
	103	21.46811	50.39340	EA38	psammophilous grassland		●			●	
	104	21.59592	50.31280	EA47	psammophilous grassland					●	
	105	21.65955	50.33003	EA47	psammophilous grassland					●	
	106	21.63254	50.35385	EA47	psammophilous grassland		●			●	
	107	21.61740	50.34323	EA47	sandy road					●	
	108	21.69930	50.33147	EA47	psammophilous grassland		●			●	
	109	21.58681	50.43488	EA48	psammophilous grassland					●	
	110	21.58422	50.43664	EA48	psammophilous grassland		●			●	
	111	21.57884	50.44897	EA48	psammophilous grassland					●	
	112	21.58420	50.43469	EA48	psammophilous grassland					●	
	113	21.70060	50.50656	EA49	psammophilous grassland					●	
	114	21.69296	50.50246	EA49	psammophilous grassland					●	
	115	21.66004	50.48608	EA49	psammophilous grassland					●	
	116	21.65393	50.48024	EA49	psammophilous grassland		●			●	
	117	21.75789	50.53934	EA59	psammophilous grassland					●	
	118	21.75641	50.53906	EA59	psammophilous grassland						
	119	21.73723	50.53777	EA59	psammophilous grassland					●	
	120	21.72289	50.54069	EA59	psammophilous grassland		●			●	
	121	21.72669	50.52824	EA59	psammophilous grassland		●			●	
	122	21.71137	50.50846	EA59	psammophilous grassland					●	
	123	21.84621	50.59420	EB50	psammophilous grassland						
	124	21.84058	50.59944	EB50	psammophilous grassland		●			●	
	125	21.83410	50.60028	EB50	psammophilous grassland					●	
	126	21.82372	50.56232	EB50	psammophilous grassland		●			●	
	127	21.83676	50.60064	EB50	psammophilous grassland						
	128	21.86904	50.55233	EB60	psammophilous grassland					●	
	129	21.86529	50.55248	EB60	psammophilous grassland					●	
	130	21.86582	50.55391	EB60	psammophilous grassland		●			●	
	131	21.86812	50.55511	EB60	psammophilous grassland					●	
	132	21.86662	50.60121	EB60	psammophilous grassland					●	
	133	21.87176	50.60067	EB60	psammophilous grassland					●	
	134	21.87191	50.59944	EB60	psammophilous grassland					●	
	135	21.86508	50.63023	EB60	sand excavation					●	