Effects of different mowing regimes on orthopterans of Central-European mesic hay meadows

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Abstract

Method, frequency and date of mowing influence the presence and population size of Orthoptera species, which show strong dependence on the vertical structure of grasslands. Responses of orthopteran assemblages to the effects of various mowing regimes applied to different parts of the same habitat are still not fully understood. In this study, we asked how different mowing regimes (mowing in May; mowing in September; mowing in May and September; abandonment of mowing) influence species richness, Shannon diversity and density of local orthopteran assemblages on a small spatial scale in Central European mesic hay meadows. Furthermore, the study aimed to determine the type of meadow management that is most suitable for preserving local orthopteran assemblages. The date of mowing had no significant overall effect on species richness, density or diversity of grasshoppers. However, grasshopper species richness and Shannon diversity were reduced immediately after mowing (in June sampling of sites mown in May), and rose later in the season. Grasshopper density was low on abandoned sites which were not mowed in the last ten years and there was a negative correlation between orthopteran density and vegetation height. Nymphs, on the other hand, showed elevated density just after mowing which was reduced later in the season. Life forms of the orthopteran assemblages showed dominance of pratinicol species. Silvicol species were found only in abandoned habitats, while arbusticol species were found only on abandoned patches and patches mown in September. Results showed that the long-term preservation of natural orthopteran assemblages in mesic hay meadows would benefit from landuse practices which are diversified spatially and temporally, as practiced in traditional extensive management regimes.

Key words

density, vegetation height, grassland management, Hungary, biodiversity conservation

Introduction

Orthoptera (grasshoppers, crickets and katydids) are considered one of the best taxa for the ecological evaluation of the habitat quality and management of grasslands (Kruess and Tscharntke 2002, Batáry et al. 2007, Fartmann et al. 2012). Due to their utility as bioindicators, special attention is paid to the group in practical nature protection (Noss 1990, Pearson 1994, Déri et al. 2007, Bazelet and Samways 2011). Mowing changes the vertical structure of vegetation, which plays a decisive role in the organization of orthopteran assemblages (Joern 1979, Guido and Chemini 2000). Cutting of the vegetation triggers a marked change in its nutritional value (Smith and Capinera 2005) and microclimatic conditions (Stebaev and Nikitina 1976), affecting the habitat potential for orthopterans. In addition, mowing significantly increases the exposure of individuals to predation (Belovsky and Slade 1993, Braschler et al. 2009). Mowing changes the conditions in a direct way for those species that lay their eggs on the vegetation (Gardiner and Hassall 2009). Indirect effects include microclimatic conditions becoming unfavourable, particularly for those species that lay their eggs in the ground (Stoutjesdijk and Barkman 1992, Wingerden et al. 1992).

It is clear therefore that the method, frequency and date of mowing are all basic factors influencing the presence and the current population size of orthopteran species, as well as the development of the structure of orthopteran assemblages, both in the short and the long-term (Buri et al. 2013). Previous studies found that the mowing operation of grasslands itself has a temporary negative impact on orthopterans as a result of mortality and the loss of plant production (Gardiner and Hill 2006, Gardiner and Hassall 2009, Humbert et al. 2010, Rada et al. 2014). In the medium and the long term, however, species richness, diversity and density of assemblages is highest if regular mowing is applied (Marini et al. 2009), and lowest if the meadow is abandoned (Nagy and Kisfali 2007). Extreme and frequent mowing has a negative effect on both the abundance and the species richness of orthopterans (Marini et al. 2008, Buri et al. 2013).

According to the results by Chambers and Samways (1998), species richness and abundance of orthopterans increases from single mowing per year towards mowing three times per year. In wet and semi-dry grasslands, mowing twice a year usually results in a richer, more structured vegetation of higher-yielding biomass than single mowing, which determines the occurrence of orthopterans (Jutila and Grace 2002). One of the main underlying factors for this relationship lies in the fact that the repeated mowing of the vegetation provides good germination and growth conditions even for less competitive plant species (Parr and Way 1988, Bakker et al. 2002, Bissels et al. 2006). Buri et al. (2013) revealed that small changes in grassland management (e.g. delaying mowing, leaving uncut grass patches) could result in significant positive changes in density and species richness of orthopterans.

Őrség National Park is situated at the western border of Hungary and belongs to IUCN category V of protected areas. Plant species rich mesic hay meadows of the national park developed through centuries of human impact. These grasslands were managed traditionally by mowing twice a year (May-June and August-September). Since 1990, due to economic considerations, once-a-year (May-June) mowing became the typical way of management and abandonment became widespread as well (Babai et al. 2015). Around 2000, mowing once-a-year in August-September was introduced on some valuable grasslands due to the prescriptions of the national park administration to protect butterfly species, such as *Maculinea* species (Kőrösi et al. 2014). To understand the effect of the above listed management regimes on the plant and animal communities of meadows, Őrség National Park Directorate launched an experiment on four of its own meadows in 2007. Patches within the same habitat types were subjected to different mowing regimes: mowing once a year at the end of May, mowing once a year in the beginning of September; mowing twice a year both at the end of May and beginning September; abandoned without any management. Study areas were managed just in the above mentioned way: no other management practices were included (e.g. grazing). The abandoned areas were last mowed before 2007. Trees and scrubs were removed, and at the time of fieldwork, abandoned sites consisted of tall-grass vegetation only. Vegetation results of this experiment were gathered by Szépligeti et al. (2016). In 2014, seven years after establishment of the experiment, results showed that the species richness and diversity of the vegetation were the highest at patches of double mowing each year, while the abandoned areas had the lowest values. Areas receiving once-a-year, i.e. spring or autumn mowing occupied an intermediate position in terms of the above parameters (Szépligeti et al. 2016). A keystone species of nature conservation, *Phengaris teleius* (Bergsträsser) butterfly and its host plant, *Sanguisorba officinalis*, showed the highest density on the patch mown once a year in autumn (Kőrösi et al. 2014).

We aimed to answer the following main question in this paper: how do different mowing regimes influence species richness, diversity and density of orthopteran assemblages of some typical natural Central-European mesic hay meadows? We hypothesised that autumn mowing once a year could result in the highest species richness, diversity and density in local orthopteran assemblages. Furthermore, we make recommendations for mowing strategies to preserve the orthopteran assemblages in these local mesic hay meadows.

Methods

Study sites.— Vegetation of the four study sites were identified as mesophilic hay meadows [Alopecuro-Arrhenatheretum (Mathé and Kovács 1960) Soó 1971]. Site I and II (geographical centres: Site I: N46.768, E16.329 / Site II: N46.766, E16.334) were separated by 200 m from each other, while Site III and IV (geographical centres: Site III: N46.737, E16.374 / Site IV: N46.736, E16.377) were located 5 km further downstream in the valley of Szentgyörgyvölgyi stream and also 200 m from each other (Fig. 1). Sites were situated at 210–230 m above sea level and were characterized by alluvial soils. Groundwater was usually close to the surface. The annual mean temperature was 9.5 °C, the annual mean rainfall was around 800 mm (Dövényi 2010).

Within the four sampling sites (Site I–IV) adjacent quadrats of 20 m × 20 m were designated (16 quadrats in Site I and II, 12 quadrats in Site III and IV, see Fig. 1). Quadrats were assigned to four different treatments, and each treatment was applied consistently each year beginning in 2007: (a) mowing once a year at the end of May (M); (b) mowing once a year at the beginning of September (S); (c) mowing twice a year both at the end of May and the beginning of September (MS); (d) abandoned without management (C). Proportion of the treatments was similar on each site: in sites I and II there were four quadrats of each type of treatment (n = 16 quadrats in total per site); and in sites III and IV there were three quadrats of each treatment (n = 12 quadrats in total per site). Mowing was carried out by a tractor powered RK-165 type drum mower.

Data collection.— Data were collected three times at each study site in 2015 (June, July, August). The collection of orthopterans was carried out by sweep netting, using 300 sweeps within each quadrat in each meadow. Every sampling of 300 sweeps covered in Site I and II four 20 m × 20 m quadrats (altogether 1,600 square metres) and in Site III and IV three 20 m × 20 m quadrats (altogether 1,200 square metres). Specimens collected per treatment type in each meadow were considered as one sample. To the samples collected by sweep netting we added a simple count of the number of adult specimens which were detected by direct observation/ collection. Sweep netted samples were identified to species level (excluding *Chorthippus* nymphs).

Nomenclature of orthopteran species followed the work of Cigliano et al. (2017). Categories of Uvarov (1977) and Ingrisch and Köhler (1998) were used for classification of life forms (arboricol: species found in habitats ruled by tree-sized elements; arbusticol: species found in habitats ruled of shrub-sized items; silvicol: species found in forest habitats with a grass understory; pratinicol: species found in grasslands of tall grass; graminicol: species found in grasslands of short grass).

Characterization of climatic requirements of the species as thermophilic, moderately-thermophilic, mesophilic, moderately-hygrophilic, and hygrophilic were assigned based on works of Varga (1997), Rácz (1998) and Ingrisch and Köhler (1998).

Covariables.— Microclimate and habitat data (average height and cover of the vegetation) were collected at 2-3 pseudo-randomly selected spots in each orthopteran sampling area. Microclimate was measured by TESTO 625 equipment (air temperature and humidity at the surface of the soil, and at 10, 20, 30, and 120 cm height). Height of the vegetation was measured in cm with the use of a 30 cm wide and 100 cm high white card. Total cover of the vegetation was measured in a square metre quadrat occurring around the spot. Related to each orthopteran sampling, percentage cover of each plant species was estimated. Average values of the data measured in the same orthopteran sampling area were used.

Data processing and analyses.— We derived the following variables from field data on orthopterans: (a) species richness; (b) total density of orthopterans (specimens/m^2); (c) total density of nymphs (specimens/ m^2); (d) Shannon diversity; (e) life-form spectra; (f) ecotype spectra. All samples from the same treatment, site and season were clumped.

We determined the relative values of air temperature and humidity data: data measured at the soil surface/10/20/30 cm height minus data measured at 120 cm height. According to our previous results (Bauer and Kenyeres 2006), the impact of weather condi-

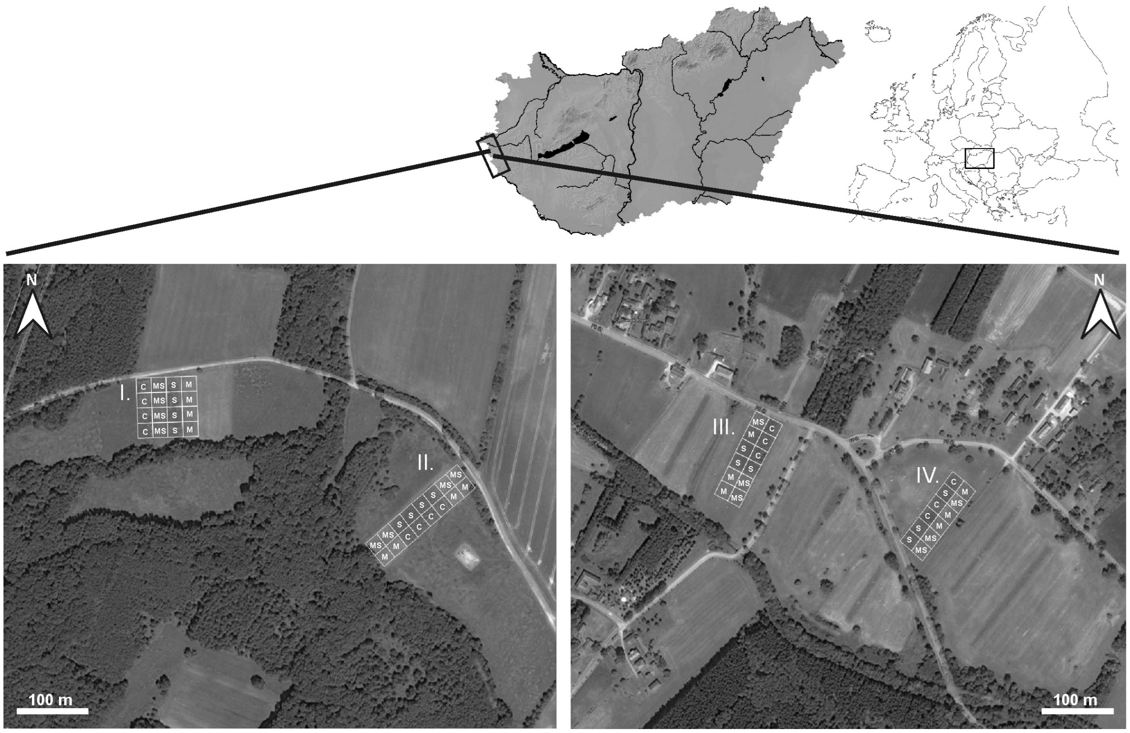


Figure 1. Location of the four study sites in Őrség National Park and the quadrats of different mowing regimes (quadrats are 20 × 20 metres; M: mowing once a year in May; MS: mowing twice a year in May and September; S: mowing once a year in September; C: abandoned).

tions prevailing at the time of the survey on the analyses can be minimized by using relative microclimate values.

For statistical analyses, Mann-Whitney U test was used to evaluate statistical differences among recorded values of vegetation height, and among the derived orthopteran variables. Generalized linear models (Poisson distribution; response variables: species richness, density and Shannon diversity of orthopterans; predictor variables: vegetation height, relative temperature in the grass – at soil surface/10/20/30 cm height and mean) and PCA were performed by using PAST 1.95 (Hammer et al. 2001) software package. Spatial information processing was performed in Quantum GIS (version 1.8).

Results

A total of 1,352 specimens of 24 orthopteran species were collected during the study. The largest number of specimens belonged to species of wet and semi-dry habitats of good habitat quality such as *Mecostethus parapleurus* (Hagenbach), *Pseudochorthippus parallelus* (Zetterstedt), *Roeseliana roeselii* (Hagenbach), *Euthystira brachyptera* (Ocskay), and *Chrysochraon dispar* (Germar).

Sites mown in May or twice a year (M, MS) had significantly shorter vegetation in June than sites mown in September (S) or abandoned ones (C) (Mann-Whitney test: U_{M-S}=0, p=0.03; U_{MS-S}=0, p=0.03; U_{M-C}=1, p=0.002; U_{MS-C}=0, p=0.03; Fig. 2). Abandoned sites had significantly taller vegetation than sites mown in September (S) (U_{S-C}=0, p=0.03). In July and August, just abandoned sites had significantly different (taller) spatial vegetation structure than mown sites (July: U_{M-C}=0, p=0.02; U_{MS-C}=0, p=0.03; U_{S-C}=1, p=0.04; August: U_{M-C}=0, p=0.03; U_{MS-C}=0, p=0.002; U_{S-C}=1, p=0.02).

Species richness and Shannon diversity showed just slight, non-significant, differences between treatment types in a comparative dataset including results of all sampling periods per treatment types – just species richness of abandoned areas appeared lower than that of the other treatment types, but this was not significant. Significantly lower grasshopper densities were recorded on abandoned patches (C) than on patches mown in May (M) (U_{M-C}=29.5, p=0.015) or mown in September (S) (U_{S-C}=21.5, p=0.011) (Fig. 3).

In seasonal comparison (Fig. 4), species richness in June was non-significantly higher on patches mown in May and September (MS) and on the abandoned (C) ones than on patches mown in May (M) and mown in September (S). In July and August species richness increased on patches mown in May (M) and mown in September (S) relative to June's species richness. Species richness on patches mown in May (M) was significantly higher in July than in June ($U_{MJn-MJl}$=1, p=0.045). However, the species richness did not change throughout the season on patches mown in May and September (MS) nor on the abandoned (C) patches. In August the species richness was significantly higher on the patches mown in May (M) than on abandoned (C) ones ($U_{MAg-CAg}$=0, p=0.02).

Orthoptera density in June appeared higher on patches mown in May and September (MS) and mown in September (S) than on patches mown in May (M) or abandoned (C). In July and August orthopteran density was similar on patches mown in May (M), mown in May and September (MS) and mown in September (S). On abandoned (C) patches this parameter in July was significantly lower than on patches mown in May (M) and mown in September (S) ($U_{MJl-CJl}$=0, p=0.03; $U_{SJl-CJl}$=1, p=0.002), and in August was significantly lower than on patches mown in May and September (MS) ($U_{MSAg-CAg}$=0, p=0.027) (Fig. 4).

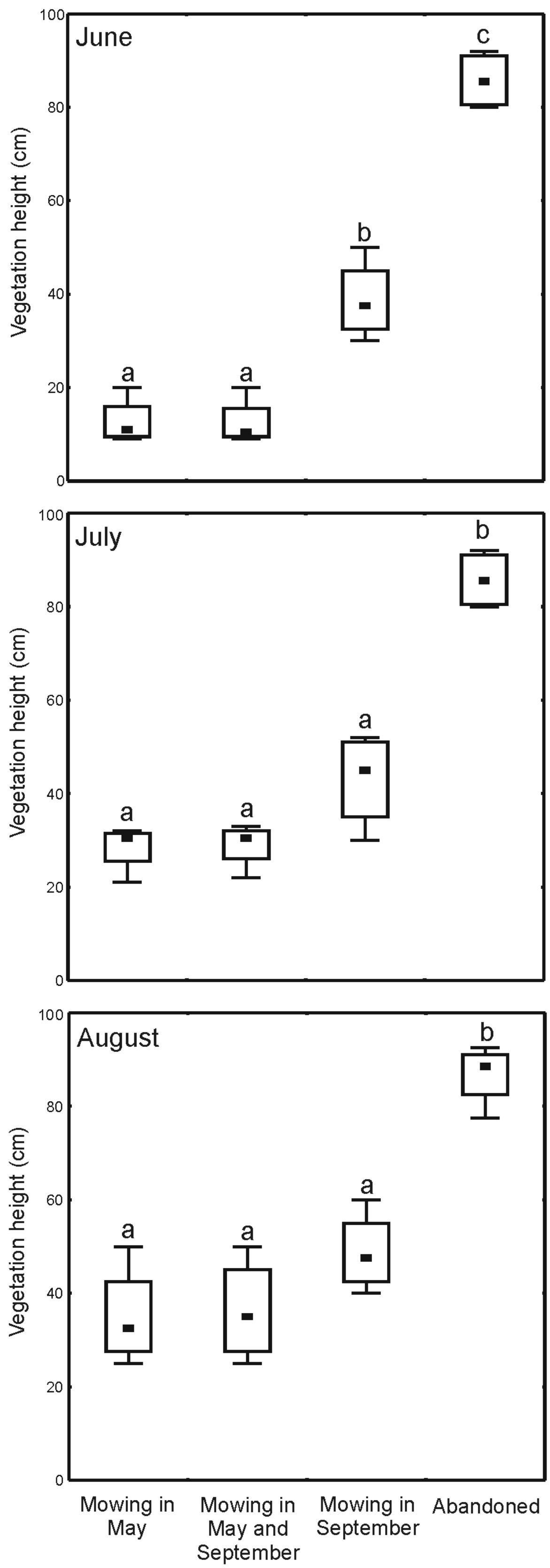


Figure 2. Box-plots (median values with minimum, maximum and ±SE) of vegetation height in four treatment types. Significant ($p<0.05$) differences detected by Mann-Whitney U test are indicated by different letters.

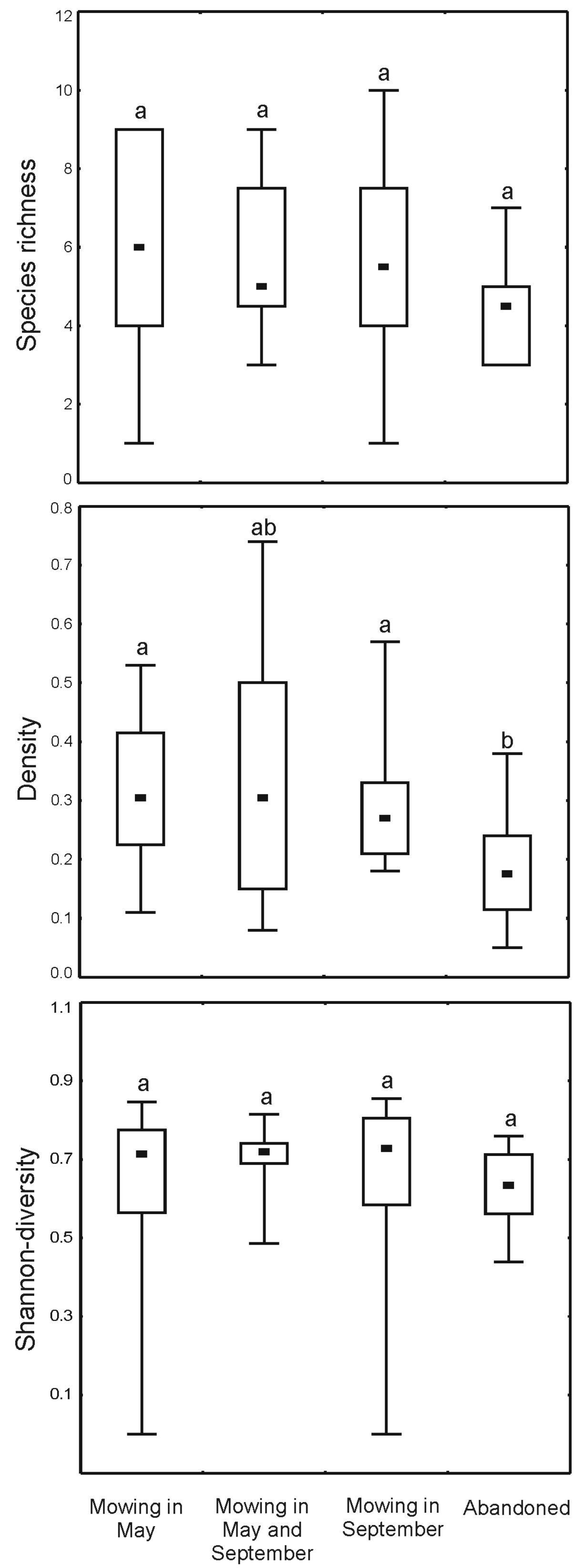


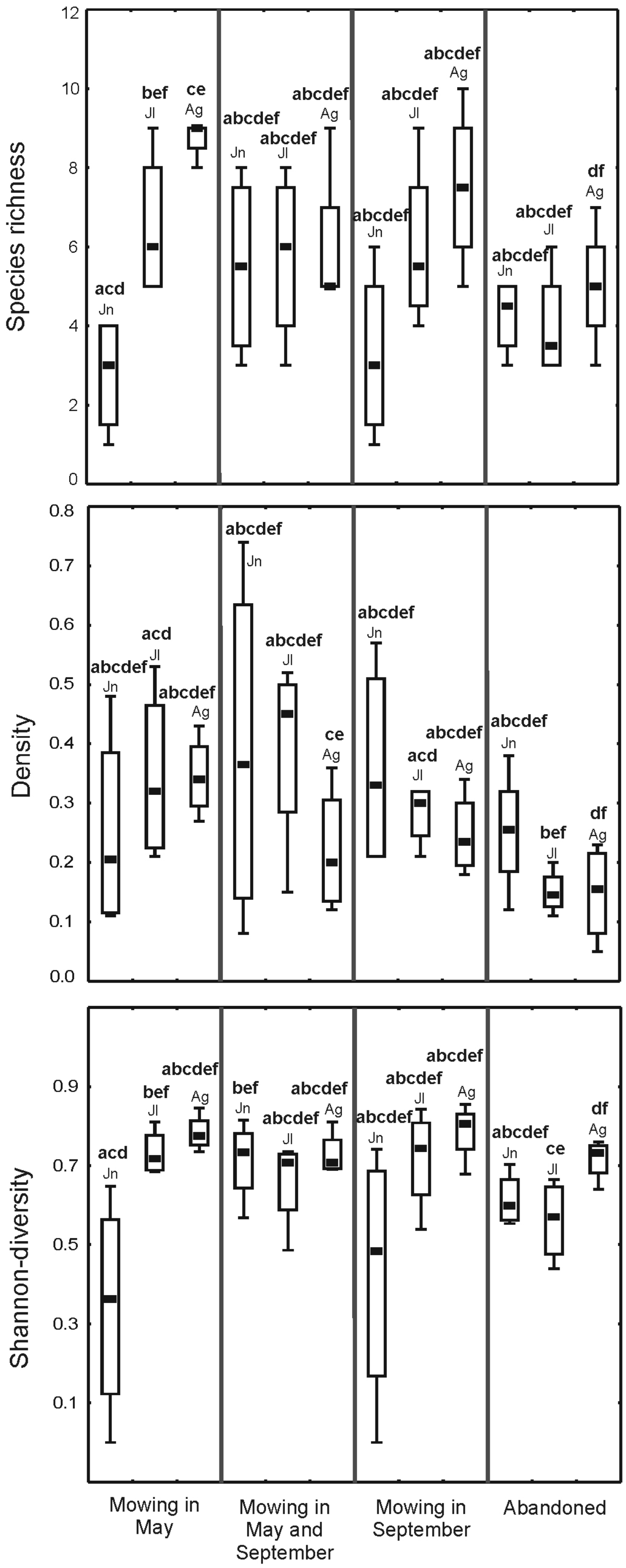
Figure 3. Box-plots (median values with minimum, maximum and ±SE) of species richness, density (specimen/m^2) and Shannon diversity of orthopterans in four treatment types of sites I–IV. Significant ($p<0.05$) differences detected by Mann-Whitney U test are indicated by different letters.

Shannon diversity in June was significantly higher on patches mown in May and September (MS) than on patches mown in May ($U_{MJn-MS-Jn}=1$, $p=0.03$) (Fig. 4). In July Shannon diversity increased significantly on patches mown in May (M) ($U_{MJn-MJl}=0$, $p=0.026$). Shannon diversity in July and August was similar on treated patches, but in July was significantly lower on abandoned patches than on patches mown in May ($U_{MJl-CJl}=1$, $p=0.002$).

Density of nymphs (Fig. 5) in June was significantly higher on patches mown in May (M) than on patches mown in September (S) or abandoned (C) ($U_{MJn-SJn}=0$, $p=0.04$; $U_{MJn-CJn}=1$, $p=0.02$).

Based on the results of PCA carried out on the pooled samples, orthopteran assemblages of different treatment types (M, S, MS, C) could not be clearly distinguished. At community level, only individual assemblage composition of the abandoned area showed a low level of independence (Fig. 6). The latter result was also visible in the life form and ecotype data. Silvicol species were found only on abandoned (C) patches. Arbusticol species were found on abandoned (C) patches and those maintained by September mowing (S). Graminicol species were found in grasslands mown in May (M), and abandoned ones. Pratinicol species dominated all examined patches (see Appendix). On the ecotype spectrum, a high proportion of hygrophilic species was seen in areas mown in May (M) and mown in May and September (MS), while mesophilic species reached high abundances in the patches treated by September mowing (S).

Generalized linear model (with Poisson distribution, including all sites and treatment types) showed significant negative relations between the vegetation height and density of orthopterans (Table 1). In addition, several significant positive correlations were found between the density of orthopterans and ambient temperature values. Significant negative correlations were found



Figrue 4. Box-plots (median values with minimum, maximum and ±SE) of species richness, adult density (specimen/m²) and Shannon diversity of orthopterans in four treatment types (mowing once a year in May; mowing twice a year in May and September; mowing once a year in September; abandoned) in June (Jn), July (Jl) and August (Ag). Significant (p<0.05) differences detected by Mann-Whitney U test are indicated by different letters.

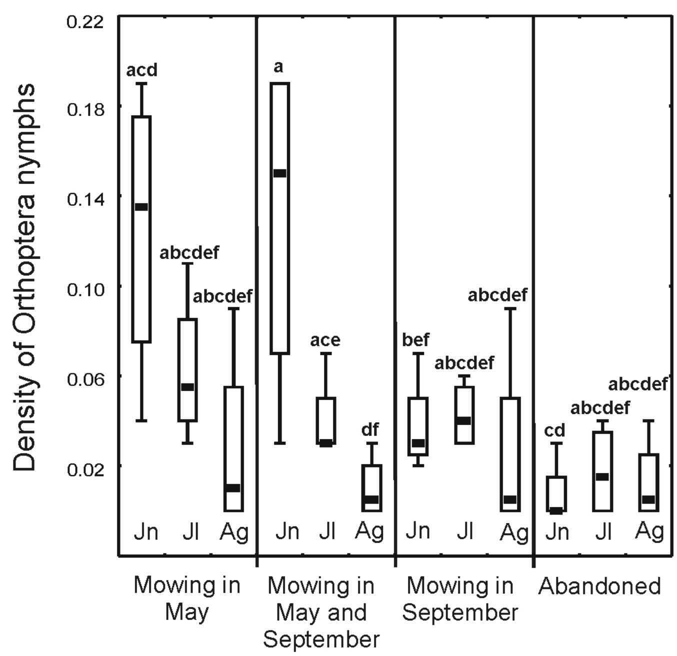


Figure 5. Box-plots (median values with minimum, maximum and ±SE) of nymphal density (specimen/m²) of orthopterans in four treatment types (mowing once a year in May; mowing twice a year in May and September; mowing once a year in September; abandoned) in June (Jn), July (Jl) and August (Ag). Significant (p<0.05) differences detected by Mann-Whitney U test are indicated by different letters.

Table 1. Results of generalized linear model (Poisson distribution) of species richness, density and Shannon diversity of orthopterans in relation to vegetation height, relative temperature in the vegetation (June, July, August)(significant values in bold).

		Vegetation		Orthopterans					
		Vegetation height		Species richness		Density		Shannon diversity	
		Estimate	p	Estimate	p	Estimate	p	Estimate	p
Orthopterans	Species richness	−0.0181	0.191						
	Density	**−0.2178**	**<0.001**	**4.1727**	**<0.001**				
	Shannon diversity	0.0005	0.904	0.0708	0.210	0.0052	0.519		
Relative temperature in the grass	Ground surface	**−6.9572**	**<0.001**	0.2617	0.214	**4.8088**	**<0.001**	0.0025	0.971
	10 cm height	**−5.8852**	**<0.001**	0.1209	0.572	**4.4912**	**<0.001**	−0.0066	0.927
	20 cm height	**−4.6333**	**<0.001**	0.1526	0.501	**4.4454**	**<0.001**	−0.0039	0.960
	30 cm height	0.1302	0.867	0.1317	0.556	**2.0167**	**<0.001**	0.0049	0.950
	Mean	**−5.3531**	**<0.001**	0.1960	0.407	**4.8699**	**<0.001**	−0.0009	0.990

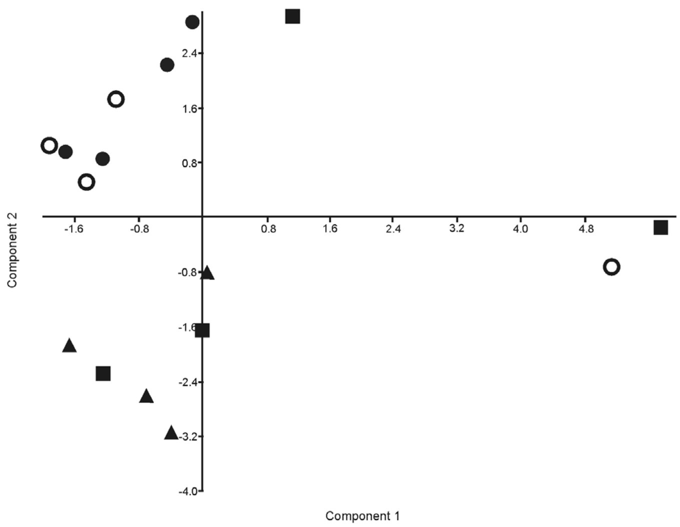


Figure 6. PCA based on the orthopteran samples of four study sites (sites I–IV) (black circle: mowing once a year in May; black square: mowing twice a year in May and September; empty circle: mowing once a year in September; black triangle: abandoned).

between the height of the vegetation and the temperature of soil surface and most of the regions of the sward.

Discussion

Our study showed that adult orthopterans were present with lower density in abandoned areas than in areas which had been mown, regardless of when or how often the mowing took place. However, density of nymphs was highest in areas which had recently been mown. Nymph densities were highest in June on sites which had been mown in May, regardless of whether the site was mowed again in September or not. The nymphs which accounted for these high densities were mostly *Pseudochorthippus* and *Chorthippus* spp.

The negative correlation between density of orthopterans (including both nymphs and adults) and vegetation height may be related to the fact that cutting of vegetation in May resulted in shorter but thicker sward structure (Jutila and Grace 2002) rich in leaves of more favourable plant species [mesophytic plants, with medium (4-6) Water balance-value, see Borhidi 1995]. Further, the short, thick sward structure may offer better conditions for the vulnerable, less mobile nymphs in terms of mobility, and hiding from predators (Braschler et al. 2009).

It is well known that impacts of mowing and removal of the harvest can lead to 70% mortality of orthopterans (Humbert et al. 2009). Our results did not provide support for this phenomenon as high orthopteran densities were detected on patches mowed just a few weeks before Orthoptera sampling. This discrepancy was probably caused by the fact that mown patches were situated close to uncut refuges (Humbert et al. 2012), and cutting height, influencing maintenance of ground-dwelling fauna (Humbert et al. 2009), was higher than 10 cm.

Orthopteran assemblages are linked to vegetation units of higher taxonomical level rather than to plant species (Kemp et al. 1990, Bauer et al. 2004). The scale of the different treatments could have enabled small scale migration of orthopterans to and from the uncut plots (Humbert et al. 2012). This explains why areas mown using different regimes (M, S, MS) did not have different grasshopper assemblages.

Species that were found to be dominant in our study (*Pseudochorthippus parallelus, Roeseliana roeselii*) were also found most characteristic in humid, intensely mown meadows by other authors in nearby regions of Europe (Gardiner et al. 2002, Marini et al. 2008, Poniatowski and Fartmann 2008). Our results confirmed that abundances of orthopteran assemblages are highly influenced by land use (Guido and Chemini 2000, Kruess and Tscharntke 2002, Knop et al. 2006, Kenyeres and Cservenka 2014). This can be deduced clearly from the fact that the choice of habitat by orthopterans is mainly influenced by vegetation structure (O'Neill et al. 2003).

Based on our results, abandonment management had a negative impact on the grasshopper density but did not significantly affect species richness or Shannon diversity of orthopterans of hay meadows. This result is entirely consistent with the findings of the botanical studies of Szépligeti et al. (2016) and orthopterological investigations in other study areas (Nagy and Kisfali 2007). The uncut patches could balance the temporal negative effect of mowing. Therefore providing refuges during each mowing session may be an alternative to subjecting different parts of the meadow to different mowing regimes. Considering conservation of insects with low dispersal ability, a maximum of 30 m distance between two refuges would be optimal (Hossain et al. 2002). It is important to note that the margins (Marshall 2002) and refuges (Humbert et al. 2009) should be located in rotation in different parts of the mown fields (Buri et al. 2013) and should be mown at the next haying event (see results of abandonment, e.g. decreasing of plant diversity, invasions of *Solidago gigantea*) (Szépligeti et al. 2016).

Although our study did not reveal it, mortality caused by mowing could still be assumed (Gardiner and Hill 2006). Therefore, we recommend that grasslands should be maintained by bar mowers, which cause 50% lower mortality than rotary mowers (Humbert et al. 2009). To benefit conservation of orthopteran species that lay their eggs in or near the soil, cutting height should be higher than 10 cm (Gardiner and Hassall 2009, Humbert et al. 2012). Considering yearly differences in mean temperature and rainfall, the mowing regime timing should depend on weather conditions of the given year (Gardiner and Hassall 2009, Buri et al. 2013) in order to provide vegetation structure and microclimate required by orthopterans of mesic hay meadows.

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References

Babai D, Tóth A, Szentirmai I, Biró M, Máté A, Demeter L, Szépligeti M, Varga A, Molnár Á, Kun R, Molnár Zs (2015) Do conservation and agri-environmental regulations effectively support traditional small-scale farming in East-Central European cultural landscapes? Biodiversity and Conservation 24: 3305–3327. https://doi.org/10.1007/s10531-015-0971-z

Bakker JP, Elzinga JA, de Vries Y (2002) Effects of long-term cutting in a grassland system: perspectives for restoration of plant communities on nutrient-poor soils. Applied Vegetation Science 5: 107–120.

Batáry P, Orci KM, Báldi A, Kleijn D, Kisbenedek T, Erdős S (2007) Effects of local and landscape scale and cattle grazing intensity on Orthoptera assemblages of the Hungarian Great Plain. Basic and Applied Ecology 8: 280–290. https://doi.org/10.1016/j.baae.2006.03.012

Bauer N, Kenyeres Z (2006) Data to the microclimate of some characteristic grassland associations of the Transdanubian Mountains. Acta Botanica Hungarica 48: 9–27. https://doi.org/10.1556/ABot.48.2006.1-2.2

Bauer N, Kenyeres Z, Kisbenedek T (2004) A comparison of cluster analysis and diversity-ordering in community classification. Community Ecology 5: 189–196. https://doi.org/10.1556/ComEc.5.2004.2.7

Bazelet C, Samways MJ (2011) Identifying grasshopper bioindicators for habitat quality assessment of ecological networks. Ecological Indicators 11: 1259–1269. https://doi.org/10.1016/j.ecolind.2011.01.005

Belovsky GE, Slade JB (1993) The role of vertebrate and invertebrate predators in a grasshopper community. Oikos 68: 193–201. https://doi.org/10.2307/3544830

Bissels S, Donath TW, Hölzel N, Otte A (2006) Effects of different mowing regimes on seedling recruitment in alluvial grasslands. Basic and Applied Ecology 7: 433–442. https://doi.org/10.1016/j.baae.2005.10.002

Borhidi A (1995) Social behaviour types, the naturalness, and relative ecological indicator values of the higher plants in the Hungarian Flora. Acta Botanica Hungarica 39: 97–181.

Braschler B, Marini L, Thommen GH, Baur B (2009) Effects of small-scale grassland fragmentation and frequent mowing on population density and species diversity of orthopterans: a long-term study. Ecological Entomology 34: 321–329. https://doi.org/10.1111/j.1365-2311.2008.01080.x

Buri P, Arlettaz R, Humbert JY (2013) Delaying mowing and leaving uncut refuges boosts orthopterans in extensively managed meadows: Evidence drawn from field-scale experimentation. Agriculture, Ecosystems and Environment 181: 22–30. https://doi.org/10.1016/j.agee.2013.09.003

Chambers BQ, Samways MJ (1998) Grasshopper response to a 40-year experimental burning and mowing regime, with recommendations for invertebrate conservation management. Biodiversity and Conservation 7: 985–1012. https://doi.org/10.1023/A:1008803513740

Cigliano MM, Braun H, Eades DC, Otte D (2017) Orthoptera Species File. Version 5.0/5.0. http://Orthoptera.SpeciesFile.org

Déri E, Horváth R, Lengyel Sz, Nagy A, Varga Z (2007) Zoológiai kutatások a gépi kaszálás hatásának vizsgálatára hat magyarországi tájegységben. [Zoological studies on the effects of mowing in six regions of Hungary.] Állattani Közlemények 92: 59–70.

Dövényi Z (Ed.) (2010) Magyarország kistájainak katasztere. [Cadastre of the Hungarian Microregions.]. MTA Földrajztudományi Kutatóintézet, Budapest.

Fartmann T, Krämer B, Stelzner F, Poniatowski D (2012) Orthoptera as ecological indicators for succession in steppe grassland. Ecological Indicators 20: 337–344. https://doi.org/10.1016/j.ecolind.2012.03.002

Gardiner T, Pye M, Field R, Hill J (2002) The influence of sward height and vegetation composition in determining the habitat preferences of three *Chorthippus* species (Orthoptera: Acrididae) in Chelmsford, Essex, UK. Journal of Orthoptera Research 11: 207–213. https://doi.org/10.1665/1082-6467(2002)011[0207:TIOSHA]2.0.CO;2

Gardiner T, Hill J (2006) Mortality of Orthoptera caused by mechanised mowing of grassland. British Journal of Entomology and Natural History 19: 38–40.

Gardiner T, Hassall M (2009) Does microclimate affect grasshopper populations after cutting of hay in improved grassland? Journal of Insect Conservation 13: 97–102. https://doi.org/10.1007/s10841-007-9129-y

Guido M, Chemini C (2000) Response of Orthoptera assemblage composition to land-use in the southern Alps of Italy. Mitteilungen der Schweizerischen Entomologischen Gesellschaft 73: 353–367.

Hammer Ø, Harper DAT, Ryan PD (2001) PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4: 1–9.

Hossain Z, Gurr GM, Wratten SD, Raman A (2002) Habitat manipulation in lucerne *Medicago sativa*: arthropod population dynamics in harvested and 'refuge' crop strips. Journal of Applied Ecology 39: 445–454. https://doi.org/10.1046/j.1365-2664.2002.00729.x

Humbert JY, Ghazoul J, Walter T (2009) Meadow harvesting techniques and their impacts on field fauna. Agriculture, Ecosystems and Environment 130: 1–8. https://doi.org/10.1016/j.agee.2008.11.014

Humbert JY, Ghazoul J, Richner N, Walter T (2010) Hay harvesting causes high orthopteran mortality. Agriculture, Ecosystems and Environment 139: 522–527. https://doi.org/10.1016/j.agee.2010.09.012

Humbert JY, Ghazoul J, Richner N, Walter T (2012) Uncut grass refuges mitigate the impact of mechanical meadow harvesting on orthopterans. Biological Conservation 152: 96–101. https://doi.org/10.1016/j.biocon.2012.03.015

Ingrisch S, Köhler G (1998) Die Heuschrecken Mitteleuropas. Die Neue Brehm–Bücherei Bd. 629, Westarp Wissenschaften, Magdeburg.

Joern A (1979) Resource utilization and community structure in assemblages of arid grassland grasshoppers (Orthoptera: Acrididae). Transactions of the American Entomological Society 105: 253–300.

Jutila HM, Grace JB (2002) Effects of disturbance on germination and seedling establishment in a coastal prairie grassland: A test of the competitive release hypothesis. Journal of Ecology 90: 291–302. https://doi.org/10.1046/j.1365-2745.2001.00665.x

Kemp WP, Harvey SJ, O'Neil KM (1990) Pattern of vegetation and grasshopper community composition. Oecologia 83: 299–308. https://doi.org/10.1007/BF00317552

Kenyeres Z, Cservenka J (2014) Effects of climate change and various grassland management practices on grasshopper (Orthoptera) assemblages. Advances in Ecology vol. 2014. https://doi.org/10.1155/2014/601813

Knop E, Kleijn D, Herzog F, Schmid B (2006) Effectiveness of the Swiss agri-environment scheme in promoting biodiversity. Journal of Applied Ecology 43: 120–127. https://doi.org/10.1111/j.1365-2664.2005.01113.x

Kőrösi Á, Szentirmai I, Batáry P, Kövér Sz, Örvössy N, Peregovits L (2014) Effects of timing and frequency of mowing on the threatened scarce large blue butterfly – A fine-scale experiment. Agriculture, Ecosystems and Environment 196: 24–33. https://doi.org/10.1016/j.agee.2014.06.019

Kruess A, Tscharntke T (2002) Grazing intensity and the diversity of Orthoptera, butterflies and trap-nesting bees and wasps. Conservation Biology 16: 1570–1580. https://doi.org/10.1046/j.1523-1739.2002.01334.x

Marini L, Fontana P, Scotton M, Klimek S (2008) Vascular plant and Orthoptera diversity in relation to grassland management and landscape composition in the European Alps. Journal of Applied Ecology 45: 361–370. https://doi.org/10.1111/j.1365-2664.2007.01402.x

Marini L, Fontana P, Battisti A, Gaston KJ (2009) Agricultural management, vegetation traits and landscape drive orthopteran and butterfly diversity in a grassland–forest mosaic: a multi-scale approach. Insect Conservation and Diversity 2: 213–220. https://doi.org/10.1111/j.1752-4598.2009.00053.x

Marshall EJP (2002) Introducing field margin ecology in Europe. Agriculture, Ecosystems and Environment 89: 1–4. https://doi.org/10.1016/S0167-8809(01)00314-0

Nagy A, Kisfali M (2007) Effects of mowing intensity on Orthoptera assemblages of meadows in southwest Hungary. Analele Universităţii din Oradea, Fascicula: Protecţia Mediului 12: 100–105.

Noss RF (1990) Indicators for monitoring biodiversity: A hierarchical approach. Conservation Biology 4: 355–364. https://doi.org/10.1111/j.1523-1739.1990.tb00309.x

O'Neill KM, Olson BE, Rolston MG, Wallander R, Larson DP, Seibert CE (2003) Effects of livestock grazing on rangeland Orthoptera (Orthoptera: Acrididae) abundance. Agriculture, Ecosystems and Environment 97: 51–64. https://doi.org/10.1016/S0167-8809(03)00136-1

Parr TW, Way JM (1988) Management of roadside vegetation: the long-term effects of cutting. Journal of Applied Ecology 25: 1073–1087. https://doi.org/10.2307/2403767

Pearson DL (1994) Selecting indicator taxa for the quantitative assessment of biodiversity. Philosophical Transactions of the Royal Society of London, Ser. B 345: 75–79.

Poniatowski D, Fartmann T (2008) The classification of insect communities: Lessons from orthopteran assemblages of semi-dry calcareous grasslands in central Germany. European Journal of Entomology 105: 659–671. https://doi.org/10.14411/eje.2008.090

Rada S, Mazalová M, Šipoš J, Kuras T (2014) Impacts of mowing, grazing and edge effect on Orthoptera of submontane grasslands: perspectives for biodiversity protection. Polish Journal of Ecology 62: 123–138. https://doi.org/10.3161/104.062.0112

Rácz I (1998) Biogeographical survey of the Orthoptera fauna in Central part of the Carpathian Basin (Hungary): Fauna types and community types. Articulata 13: 53–69.

Smith TR, Capinera JL (2005) Host preferences and habitat associations of some Florida grasshoppers (Orthoptera: Acrididae). Environmental Entomology 34: 210–224. https://doi.org/10.1603/0046-225X-34.1.210

Stebaev IV, Nikitina SI (1976) Behavioural patterns of different life forms of grasshoppers from steppes and semideserts of Tuva 3. Zoologicheskii Zhurnal 55: 715–720.

Stoutjesdijk PH, Barkman JJ (1992) Microclimate, Vegetation and Fauna. Polus Press AB, Knivsta Sweden, 216 pp.

Szépligeti M, Kőrösi Á, Szentirmai I, Házi J, Bartha D, Bartha S (2016) Evaluating alternative mowing regimes for conservation management of Central European mesic hay meadows: A field experiment. Plant Biosystems. https://doi.org/10.1080/11263504.2016.1255268

Uvarov BP (1977) Grasshoppers and Locusts, Vol. II. Centre for Overseas Pest Research, London.

Varga Z (1997) Trockenrasen im pannonischen Raum: Zusammenhang der physiognomischen Struktur und der florischtischen Komposition mit den Insektenzönosen. Phytocoenologia 27: 509–571. https://doi.org/10.1127/phyto/27/1997/509

Wingerden WKRE, Kreveld AR, Bongers W (1992) Analysis of species composition and abundance of grasshoppers (Orth., Acrididae) in natural and fertilized grasslands. Journal of Applied Ecology 113: 138–152. https://doi.org/10.1111/j.1439-0418.1992.tb00647.x

Appendix 1

Species composition and quantity of the pooled samples of different mowing regimes (LF: life form; EF: ecotype form; M: mowing once a year in May; MS: mowing twice a year in May and September; S: mowing once a year in September; C: abandoned without management; arbu: arbusticol; gra: graminicol; pra: pratinicol; sil: silvicol; hyg: hygrophilic; mes: mesophilic; m-hyg: moderately-hygrophilic; m-ther: moderately-thermophilic; ther: thermophilic).

Taxon	LF	EF	M	MS	S	C
Caelifera						
Acridoidea						
Acridomorpha						
Acrididae						
Gomphocerinae						
Chrysochraon dispar (Germar, 1834)	pra	m-hyg	3	37	13	43
Euchorthippus declivus (Brisout de Barneville, 1848)	gra	ther	1		2	
Euthystira brachyptera (Ocskay, 1826)	pra	mes	28	28	29	14
Chorthippus biguttulus (Linnaeus, 1758)	pra	m-ther	4		8	
Chorthippus brunneus (Thunberg, 1815)	pra	m-ther	6	10	8	1
Chorthippus dorsatus (Zetterstedt, 1821)	pra	mes	24	6	16	2
Chorthippus oschei Helversen, 1986	pra	mes	3	3	1	1
Chorthippus sp. (nymphs)			86	37	75	15
Gomphocerippus rufus (Linnaeus, 1758)	sil	mes			1	
Pseudochorthippus parallelus (Zetterstedt, 1821)	pra	mes	48	62	62	34
Omocestus haemorrhoidalis (Charpentier, 1825)	pra	ther		1		
Omocestus viridulus Linnaeus, 1758	pra	mes		1		
Stenobothrus lineatus (Panzer, 1796)	pra	m-ther				2
Melanoplinae						
Odontopodisma schmidtii (Fieber, 1853)	pra	mes		2		1
Oedipodinae						
Mecostethus parapleurus (Hagenbach, 1822)	pra	hyg	122	111	79	39
Stethophyma grossum (Linnaeus, 1758)	pra	hyg	5	5	1	1
Pezotettiginae						
Pezotettix giornae (Rossi, 1794)	gra	ther	3		5	
Tetrigoidea						
Tetrigidae						
Tetriginae						
Tetrix bipunctata (Linnaeus, 1758)	sil	m-ther			1	
Ensifera						
Tettigonioidea						
Tettigoniidae						
Conocephalinae						
Conocephalus discolor Thunberg, 1815	pra	hyg	7	2	3	3
Ruspolia nitidula (Scopoli, 1786)	pra	m-hyg	15	8	7	10
Tettigoniinae						
Decticus verrucivorus (Linnaeus, 1785)	pra	mes	1	6	3	1
Roeseliana roeselii (Hagenbach, 1822)	pra	m-hyg	17	65	28	50
Tettigonia viridissima Linnaeus, 1758	arbu	mes		1		2
Phaneropteridae						
Phaneropterinae						
Leptophyes albovittata (Kollar, 1833)	arbu	ther		4	5	
Phaneroptera falcata (Poda, 1761)	arbu	ther	3	11	9	1