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ORIGINAL ARTICLE

Effects of uncut hay meadow strips on spiders

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Abstract
Standard management of Czech hay meadows consists of machine mowing twice a year, with the first mowing in or before mid-June and the second mowing 40–60 days later. Here, we aimed to analyse the effects of the first year of implementation of the agri-environment scheme (AES), which consisted of allowing 3–10% of permanent grasslands within each land block to remain unmown until at least August 15, on the abundance and diversity of spiders. We conducted the study at 40 paired sampling sites in three meadow types in northern Czechia. Spiders were sampled using pitfall traps and sweeping, and the plant cover and vascular plant species composition were analysed. Nearly all study sites were associated with 100% vegetation cover, and hosted 209 vascular plant species, of which 12 were threatened. The number of vascular plant species exhibited only modest differences between the study sites under standard and AES-prescribed management. We captured a total of 3889 individuals of 103 spider species. The abundance of spiders was three-times higher at sites subjected to AES management. The number of species was similar irrespective of the management applied, but the species composition differed in response to the management (Sørensen index 0.562–0.736). The AES management was associated with higher abundance of common vegetation-dwelling farmland spiders, but epigeic spiders decreased there or were insensitive to AES management. It remains to be investigated whether threatened vegetation-dwelling spiders may benefit from similar AESs at sites of their occurrence, such as in fen meadows or steppes.

Keywords Agricultural biodiversity · Agri-environmental schemes · Biodiversity conservation · Common species · Conservation management · Cultural landscape

Introduction

Recent decades have seen increased awareness of the gradual deterioration of agriculturally exploited grasslands and the detrimental effects of large-scale mowing on arthropod density and diversity in grassland ecosystems. Mowing causes the destruction of refugia and suitable habitats for overwintering, increases exposure to predators and harsh weather conditions and causes the direct killing and removal of arthropods with the litter (Schmidt et al. 2008). Spiders are one of the taxa severely affected by mowing (McLachlan 2000; reviewed by Bell et al. 2001). Wetland spiders are particularly sensitive to mowing (Decleer 1990; Cattin et al. 2003; Schmidt et al. 2005), which is likely caused by their requirement for shelters in the form of cavities in dead vegetation (Pühringer 1979; Neumann and Krüger 1991; Bogusch et al. 2016). The decrease in spider abundance in response to grass cutting may reach up to 86%, as shown for linyphiid spiders by Thomas and Jepson (1997). The effects of late and/or less frequent mowing are milder than those of mowing in June or early July (Bell et al. 2001; Albrecht et al. 2010; Lafage and Pétillon 2016), but postponing the date of first mowing only beyond mid-June does not have beneficial effects for spiders (Knop et al. 2006). The decline in populations of spiders that are associated with meadows is of interest to nature

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conservationists due to the decrease or local extinction of threatened species. Importantly, the decline is important also from an economical point of view, as among the evidence-based contributions of common spider species is, for example, the suppression of aphid population growth by 58% by linyphiid spider species (Mansour and Heimbach 1993).

Strip management has been suggested as a solution to the massive losses of biodiversity during hay cutting. In strip management, narrow strips are left unmown and are shifted at the next mowing or retained for several subsequent seasons. First analyses of the influence of this form of management on spiders were performed in alfalfa fields, where the unmown strips contained more abundant and more diverse populations of spiders, which, however, did not expand to the mown parts of the same alfalfa plots (Samu 2003). Rotational fallows consisting of three 10 m wide and 35–50 m long strips were examined in fen meadows by Schmidt et al. (2008). One of these strips was left unmown in an alternating manner each year so that each strip was mown for two out of the three years. Only Araneidae, Clubionidae and Gnaphosidae increased their abundance in the fallows, whereas other spider families did not change their abundance in response to mowing; the overall species richness and abundance was similar between the cut and uncut sites (Schmidt et al. 2008). The mowing of alternating 5–10 m and 50 m wide strips (half mown in June, the other half mown in August) was analysed by Cizek et al. (2012). The cut strips contained more generalists, whereas the uncut strips were preferred by the more hygrophilous species, which likely benefited from more stable and humid microclimatic conditions. All the observed effects were attributed to differences in vegetation height and diversity but not to the timing of mowing (which was in contrast to the beetles and butterflies) (Cizek et al. 2012). Mowing in a small-scale checkerboard pattern was recently examined by Pech et al. (2015). The 15 examined plots of just 4 m^2 each were mown or not once or twice annually for eight consecutive years prior to the study onset. They did not find any difference in spider species richness or species composition, but the spiders were more abundant in the mown plots (Pech et al. 2015).

To translate the above management suggestions into agricultural praxis, agri-environment schemes (AESs) were established in the early 1990s throughout Europe (Kleijn and Sutherland 2003; Humbert et al. 2012; Scheper et al. 2013). However, it was found that many of these well-meant AESs have negligible effects on overall biodiversity or some specific groups of farmland-associated organisms (Kleijn et al. 2006). Thus, a thorough examination of the effects of the application of each AES is needed to evaluate their effects on biodiversity, including that of spiders. In this study, we aimed to analyse the effects of uncut hay meadow strips formed at a field scale as a part of the implementation of the AESs on the abundance and diversity of spiders.

Materials and methods

We conducted the study at 40 sampling sites (Online Resource 1: Table S1) distributed across northern Czechia in the Central Bohemian uplands and Ralsko uplands (50°36′-50°45’N, 14°03′-14°37′E). The sampling sites were selected in pairs. One site in each pair served as a control and was managed conventionally, which means that it was subject to machine mowing twice a year, with the first mowing in or before mid-June and the second mowing 40–60 days later. At all conventionally managed sampling sites, the second mowing was performed before the start of the sampling period of the present study. The other site in each pair was subjected to AES-prescribed management. The AES-prescribed management (specified under the Czech law §18 NV 75/2015 Sb.) consisted of allowing from 3% to 10% of the permanent grasslands within each land block to remain unmown until at least August 15. Only land blocks that were 12 to 16 ha in size were allowed to be subjected to this AES. As control sites, we selected the nearest available meadows, which were approved to be funded through the same AES (thus of the similar size). The distance between treated and control meadows in each pair did not exceed 5 km. Sites within each pair were close to one another, experienced similar abiotic conditions, including soil type, water table, exposition, inclination and landscape structure, and were surrounded by the same habitat. When the treated meadow was at the forest edge, the relevant control meadow was also selected to contain a forest edge, the length of which ranged from 50% to 200% of that near the treated meadow. Among the 20 pairs of examined meadows, ten pairs represented the AES for standard meadows (eutrophicated, intensively cultivated Arrhenatherion hay meadows), five pairs represented the AES for wet meadows, and five pairs represented the AES for xerophilous meadows. At two sites that were aimed to be subject to standard management, the farmers allowed the presence of unmown grass even when not instructed to do so, thus these two sites were treated in the analyses as if they were under the AES management. The data retrieved and analysed over the course of this study represent the pilot evaluation of the effects of the AES specified under §18 NV 75/2015 Sb.

At each sampling site, we installed three pitfall traps, which were deployed from July 25–29, 2016, to August 10–14, 2016. The traps were placed in line transects at a distance of 50 m or more from each other within the transect; the position of each container was marked by a rod with a red ribbon. The traps consisted of two 400 ml polypropylene containers with an upper diameter of 80 mm, which were retracted therein. The inner container was filled up to two-thirds with 50% propylene glycol supplemented with a mixture of ionic and anionic detergents. The traps were not roofed. Instead, the excessive water from precipitation was allowed to flow out through the inner drain hole, which was made at two-thirds of the height of the inner container, and through the outer drain hole, which was made in the bottom of the outer container. Data from 14 out of the total 120 traps were unavailable for the analyses, as these traps were removed, broken or filled with soil or hay; it was reflected when calculating the numbers of spiders expected to be trapped. The transects were situated in the unmown refugial strips or in the mown parts of the control meadows.

During July 25–29, 2016, and August 10–14, 2016, we performed sweeping at all the study sites. At each site, we performed 100 sweeps of the dry vegetation in the unmown refugial strips or in the mown parts of the control meadows. The swept area was of fixed extent irrespectively of the vegetation height. The transects obviously differed in vegetation height – the maximum vegetation height of uncut strips was 50–100 cm, whereas the maximum vegetation height of cut sites was 5–30 cm. We stored the spider individuals obtained by trapping and sweeping in 96% ethanol until they were processed. We identified the spider individuals according to Nentwig et al. (2017), with the nomenclature used according to the World Spider Catalog (2017). We classified the threatened species according to the most recent version of the Czech Red List (Řezáč et al. 2015). The species included in the Red List of spiders are termed "threatened" throughout the text of this study, and this term includes all species known as critically endangered (CR), endangered (EN), vulnerable (VU) or least concern (LC; we follow the terminology suggested by Řezáč et al. (2015), although the latter category should rather be called near-threatened). Representative specimens of the threatened species were deposited in the Eastern Bohemia Museum in Pardubice (curated by Jan Dolanský).

During July 25–29, 2016, we characterized plant cover and vascular plant species composition by performing phytocenologic relevés of the vegetation surrounding each of the transects. We performed the phytocenologic relevés in 150 m^2 areas (5 × 30 m) located along the transects. We quantified the vegetation cover using standardized ranks (Braun-Blanquet 1932; Podani 2006). We used botanical nomenclature according to Kubát (2002). We classified threatened species according to the most recent version of the Czech Red List (Grulich 2012). Vascular plant species included in the Czech Red List were termed as "threatened" and consisted of the following categories of species: critically endangered (C1), endangered (C2), vulnerable (C3), near-threatened (C4a) and data-deficient species (C4b), according to Grulich (2012). The C1 and C2 species were further divided according to the formal reasons leading to their inclusion in the Red List based on rarity and population decline (C1b, C2b), population decline (C1t, C2t), or rarity (C1r, C2r) (Grulich 2012).

We estimated the species richness using the Chao-1 estimator, corrected for unseen species. We compared the species richness of the analysed datasets using the Sørensen similarity index. We also calculated rarefaction curves and basic diversity indices for each of the datasets as described in Heneberg and Řezáč (2014). These consisted of the total number of species found, the total number of individuals found, dominance (1 – Simpson's index), Brillouin's index (useful particularly for species with specific behavioural habits), Margalef's species richness index (sensitive to sample size), equitability (reflecting entropy and the number of taxa), Fisher's alpha (diversity measure), and the Berger-Parker dominance index (number of individuals of the dominant species relative to the total number of individuals). To compare the diversities, we used Shannon *t*-tests with a bias correction term. We used the χ^2 test to assess the species-specific differences in abundance across the groups of study sites, with an equal distribution used to define the expected values. We employed unpaired two-sample *t*-tests to compare the number of vascular plant species per relevé. We performed the calculations in EstimateS 9.1.0 and PAST v. 2.14. Data are shown as the mean ± SD unless stated otherwise.

Results

General patterns

We captured a total of 3889 individuals of 103 species of spiders. Of these, we captured 3104 individuals from 60 species by sweeping and 785 individuals from 58 species by trapping. The rarefaction of both datasets (Fig. 1a) revealed that the dataset obtained by sweeping was nearly complete, while the species diversity of the dataset from pitfall traps was somewhat underestimated. The Chao-1-estimated species richness reached 70.1 ± 7.2 species in the swept dataset and 100.8 ± 23.9 species in the trapped dataset. The individuals obtained by these two methods were further analysed together.

The three meadow types (standard, wet and xerophilous) were associated with different species diversities and species compositions of the spider assemblages. In all three meadow types, the AES-prescribed management was associated with a higher abundance of spiders (χ^2 test $p < 0.001$ each). In contrast, the number of species present in any meadow type did not respond significantly to the AES-prescribed management (χ^2 test $p > 0.05$ each). Together, these results correspond to differences in the numbers of unique site/species records, which significantly increased in standard meadows and wet meadows (χ^2 test $p < 0.001$ each) but not in xerophilous meadows (χ^2 test $p > 0.05$). This change corresponded with significant increases in dominance and equitability in the standard and xerophilous meadows ($p = 0.001$ each, by bootstrapping) but not in wet meadows ($p > 0.05$ by bootstrapping). Correspondingly, the differences in the diversities of spider assemblages in the standard and xerophilous meadows were significant when tested by Shannon *t*-test. However, the Margalef index and Fisher's alpha did not

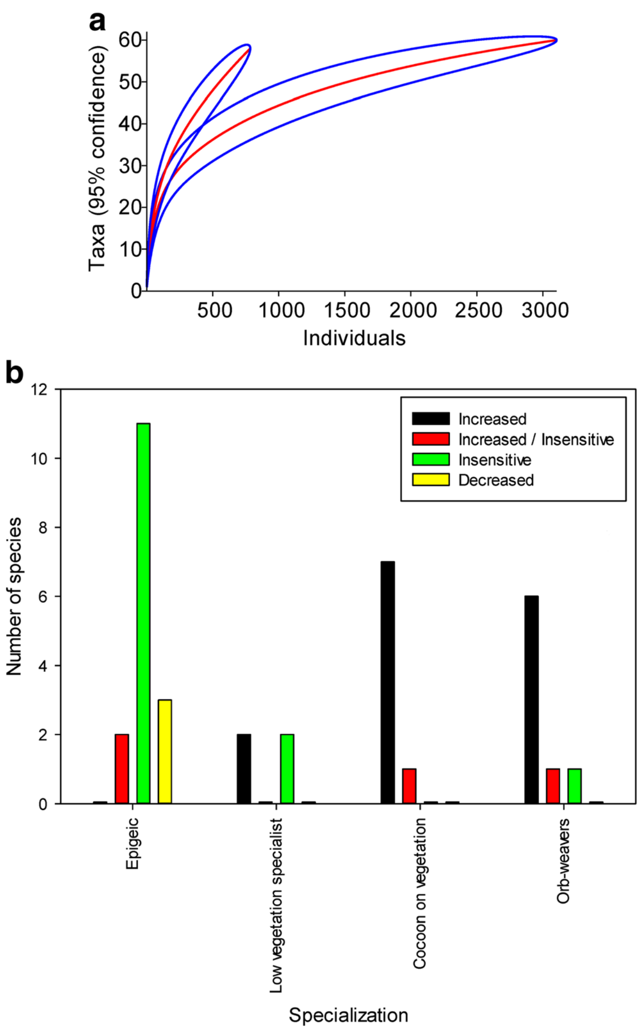

Fig. 1 Analysis of the spider assemblages associated with meadows subject to standard or AES-prescribed management. (**a**) Expected cumulative number of spiders collected by pitfall trapping (left curve) and sweeping (right curve) in the analysed meadows as defined by the rarefaction curves. (**b**) Differences in abundance (sites with implementation of AES compared to the completely cut sites) of spider species of which we captured ≥10 individuals in least one type of meadow when stratified according to their hunting strategy and microhabitat preferences

change significantly in response to the differences in management in any of the three meadow types. The Berger-Parker dominance index was significantly higher for sites under AES-prescribed management in all three meadow types (Table 1), which was caused by increased abundances of *Tetragnatha pinicola* across wet meadows and *Xysticus cristatus* at sampling sites located in standard and xerophilous meadows (Online Resource 1: Table S2). Although the number of spider species was not higher in meadows subject to AES-prescribed management, the Sørensen similarity indices ranged from 0.562 to 0.736 when comparing the meadows with standard and AES-prescribed management (Table 1), which suggests the presence of species-specific responses to AES-prescribed management.

Species-specific responses

The majority (17/32, 53%) of species, of which we captured ≥10 individuals in standard meadows, increased in abundance at sites with uncut strips. Of these, two species (*Evarcha arcuata* and *Xysticus ulmi*) were completely absent at sites subject to standard management, and 35 and 28 individuals were captured, respectively, at sites subject to AES-prescribed management. At these sites, we also found strong increases in the abundance of *Philodromus cespitum* (22 vs 1 individual), *Mangora acalypha* (138 vs 8), *Araneus quadratus* (48 vs 3), *Pisaura mirabilis* (187 vs 25), *Argiope bruennichi* (37 vs 5), *Cheiracanthium erraticum* (13 vs 2), *Agalenatea redii* (38 vs 7) and *Tibellus oblongus* (45 vs 10; χ^2 test $p < 0.001$ each). Generally, all dominant species increased in abundance or were insensitive to the AES-prescribed management. This also applies to the most abundant species of standard meadows, *Xysticus cristatus*, the abundance of which was over three times higher at sites subject to the AES-prescribed management (750 vs 206; χ^2 test $p < 0.001$). The most abundant species that was insensitive to the AES-prescribed management was *Pardosa pullata* (57 vs 57). Only a few species exhibited lower abundance at sites subject to AES-prescribed management; these included *Trochosa terricola*, *Xerolycosa nemoralis*, *Xerolycosa miniata* and *Xysticus bifasciatus*. The dominant species in standard meadows under any management did not include any threatened species. The threatened species were found at low abundance only and included only three LC species present at sites subject to standard management and two threatened species (vulnerable *Styloctetor compar* and one LC species) present at sites subject to the AES-prescribed management (Online Resource 1: Table S2).

The majority (10/12, 83%) of species, of which we captured ≥10 individuals in wet meadows, increased in their abundance. Of these, three species (*Clubiona lutescens*, *Xysticus bifasciatus* and *Xysticus ulmi*) were completely absent at sites subject to standard management, and 20, 43 and 29 individuals of these species were captured, respectively, at sites subject to AES-prescribed management. *Clubiona lutescens* was completely absent in standard meadows, whereas *X. ulmi* displayed the same trend in standard meadows. The following species were found to be more abundant in wet meadows subject to AES-prescribed management when compared to those under standard management: *Mangora acalypha* (24 vs 1), *Tetragnatha pinicola* (125 vs 9), *Pisaura mirabilis* (34 vs 4; χ^2 test $p < 0.001$ each), *Aculepeira ceropegia* (30 vs 10; χ^2 test $p = 0.002$), *Phylloneta impressa* (16 vs 6; χ^2 test $p = 0.033$) and *Xysticus cristatus* (38 vs 18; χ^2 test $p = 0.008$). *Pardosa palustris*, *Pardosa pullata* and *Pachygnatha degeeri* were insensitive to the AES-prescribed management. No species were less abundant in wet meadows subject to AES-prescribed management. The dominant species in wet meadows under any management did not include any

Table 1 Assessment of the diversity of spiders captured in three types of meadows affected or not by AES-prescribed management (Unmown strip) or by standard management with grass cutting performed twice a year (Standard management). Diversity indices are shown. The similarity of examined assemblages was tested using the Sørensen similarity index, Shannon diversity *t*-tests and bootstrapping of the particular diversity indices

AES meadow type	Standard meadows		Wet meadows		Xerophilous meadows	
Treatment Descriptive statistics	Unmown strip	Standard management	Unmown strip	Standard management	Unmown strip	Standard management
Number of sites examined	9	11	5	5	6	4
Number of individuals	1953	665	464	133	488	186
Number of species	72	53	36	27	42	34
Number of unique site/species records	249	143	77	58	110	61
Chao-1 ± SD	89.3 ± 10.2	68.6 ± 11.6	51.0 ± 12.8	40.9 ± 9.6	50.2 ± 6.4	53.4 ± 14.7
Dominance	0.173 ***	0.122	0.111 n/s	0.094	0.171 ***	0.087
Brillouin	2.57	2.78	2.60	2.43	2.41	2.66
Margalef	9.37 n/s	8.00	5.70 n/s	5.32	6.62 n/s	6.32
Equitability	0.61 ***	0.73	0.76 n/s	0.82	0.68 ***	0.83
Fisher's alpha	14.7 n/s	13.5	9.12 n/s	10.23	11.01 n/s	12.19
Berger-Parker dominance index	0.38 **	0.31	0.27 *	0.18	0.38 ***	0.22
Comparison of treatments:						
Shannon *t*-test (t; d_f; p)	−3.86; 1278.9; <0.001		0.62; 241.2; 0.53		−3.16; 451.4; 0.002	
Sørensen similarity index	0.656		0.562		0.736	

Results obtained by bootstrapping: n/s $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p \leq 0.001$

threatened species. The threatened species were found at low abundance only and included only two species of least concern present at sites subject to standard management and two threatened species (vulnerable *Araneus alsine* and one species of least concern) present at sites subject to the AES-prescribed management (Online Resource 1: Table S2).

The responses of spiders were less prominent in xerophilous meadows. In this habitat, only 7/15 (47%) of species, of which we captured ≥10 individuals, increased in their abundance. The seven species were represented by *Araneus quadratus* (17 vs 1), *Pisaura mirabilis* (47 vs 4), *Mangora acalypha* (23 vs 3), *Xysticus cristatus* (184 vs 41; χ^2 test p < 0.001 each), *Tetragnatha pinicola* (26 vs 8; χ^2 test p = 0.002), *Pachygnatha degeeri* (19 vs 8; χ^2 test p = 0.03) and *Aculepeira ceropegia* (35 vs 16; χ^2 test p = 0.008). No species were less abundant in xerophilous meadows subject to AES-prescribed management. In xerophilous meadows under any management, we captured only a single individual of a threatened (least concern) spider species (Online Resource 1: Table S2).

Epigeic spiders did not respond positively to AES-prescribed management

Of the species of which we captured ≥10 individuals in at least one meadow type (Table 2; Fig. 1b), all of those that decreased in abundance (3 species) were epigeic species (scarce xerophilous *Xerolycosa miniata*, and common ubiquitous *Trochosa terricola* and *Xerolycosa nemoralis*). In contrast, those that increased in abundance did not include any epigeic species and were represented by web-weavers (6 species), species that attach their cocoons to vegetation (7 species) and, surprisingly, specialists for low vegetation, represented by *Xysticus cristatus* and *Xysticus ulmi* (Fig. 1b). Among the species that did not display any significant difference in abundance when comparing sites under standard and AES-prescribed management were predominantly epigeic spiders (11 species), a single web-weaving species (*Singa hamata*) and a single specialist for low vegetation (*Xysticus kochi*). Only five species exhibited mixed responses. In four of these species, we recorded both neutral and positive responses, and we recorded a positive response in one type of meadow only in one case; the remaining species (*Xysticus bifasciatus*) was captured only at two sampling sites, albeit at very high abundance, and thus was removed from the analyses.

Vegetation

Nearly all study sites were associated with 100% vegetation cover; the few exceptions were two sites under standard management (60% and 90% cover, respectively) and at one site under AES-prescribed management (80% cover). In total, we found 209 plant species, of which 12 were threatened. The mean number of species per transect exhibited only modest differences between the study sites under standard and AES-prescribed management. Only in the standard meadows, the number of vascular plant species per relevé was slightly

Table 2 Assessment of differences in the abundance of spiders of which we captured ≥10 individuals in three types of meadows affected or not by AES-prescribed management. The difference was calculated by dividing the number of individuals captured at sites under AES-prescribed management by the number of individuals captured at sites under standard management. In cases, in which there were no spiders of the respective species captured at sites under standard management, the difference was assigned an arbitrary value of 100. The differences were tested by χ^2 tests; the expected abundances were equal for both management types

	Meadow type:	Standard		Wet		Xerophilous	
Group	Species	Difference	p (χ^2 test)	Difference	p (χ^2 test)	Difference	p (χ^2 test)
Cocoon on vegetation	*Clubiona lutescens*	3.33	0.05	100.00	0.00		
Cocoon on vegetation	*Ebrechtella tricuspidata*	2.50	0.02				
Cocoon on vegetation	*Cheiracanthium erraticum*	6.50	0.00				
Cocoon on vegetation	*Misumena vatia*	2.42	0.01			1.00	1.00
Cocoon on vegetation	*Philodromus cespitum*	22.00	0.00				
Cocoon on vegetation	*Pisaura mirabilis*	7.48	0.00	8.50	0.00	11.75	0.00
Cocoon on vegetation	*Tibellus oblongus*	4.50	0.00				
Cocoon on vegetation	*Xysticus cristatus*	3.64	0.00	2.11	0.01	4.49	0.00
Epigeic	*Alopecosa pulverulenta*	0.91	0.83			1.17	0.78
Epigeic	*Drassyllus pusillus*	1.00	1.00				
Epigeic	*Erigone dentipalpis*	0.56	0.29	0.11	0.01		
Epigeic	*Heliophanus flavipes*	3.00	0.08				
Epigeic	*Pachygnatha degeeri*	2.50	0.11	0.44	0.06	2.38	0.03
Epigeic	*Pardosa lugubris*	0.65	0.26				
Epigeic	*Pardosa palustris*	1.69	0.01	1.33	0.45	0.67	0.53
Epigeic	*Pardosa prativaga*					0.67	0.53
Epigeic	*Pardosa pullata*	1.00	1.00	0.58	0.10	1.45	0.17
Epigeic	*Piratula latitans*					0.44	0.17
Epigeic	*Trochosa ruricola*	0.71	0.56				
Epigeic	*Trochosa terricola*	0.00	0.00				
Epigeic	*Xerolycosa miniata*	0.09	0.00				
Epigeic	*Xerolycosa nemoralis*	0.00	0.00				
Low vegetation	*Evarcha arcuata*	100.00	0.00				
Low vegetation	*Xysticus bifasciatus*	0.09	0.00	100.00	0.00		
Low vegetation	*Xysticus kochi*	1.62	0.08				
Low vegetation	*Xysticus ulmi*	100.00	0.00	100.00	0.00		
Web-weaver	*Aculepeira ceropegia*	2.19	0.00	3.00	0.00	2.19	0.01
Web-weaver	*Agalenatea redii*	5.43	0.00				
Web-weaver	*Araneus quadratus*	16.00	0.00			17.00	0.00
Web-weaver	*Argiope bruennichi*	7.40	0.00			1.14	0.80
Web-weaver	*Mangora acalypha*	17.25	0.00	24.00	0.00	7.67	0.00
Web-weaver	*Phylloneta impressa*	2.50	0.00	2.67	0.03		
Web-weaver	*Singa hamata*	0.63	0.24				
Web-weaver	*Tetragnatha pinicola*	2.47	0.00	13.89	0.00	3.25	0.00

higher at sites under AES-prescribed management (37.2 ± 6.6 species) compared to sites under standard management (29.7 ± 6.9 species; t-test $p = 0.02$). The number of species per relevé was insensitive to the management type in wet meadows (32.2 ± 8.3 species and 29.6 ± 5.6 species, respectively; t-test $p > 0.05$) and in xerophilous meadows (34.0 ± 14.0 species and 33.5 ± 5.1 species, respectively; t-test $p > 0.05$). The threatened vascular plant species were limited to standard and xerophilous meadows. They included an endangered and declining (C2t) species, *Trifolium spadiceum*, at one of the sites under AES-prescribed management, the vulnerable (C3) species *Pseudolysimachion maritimum* and *Crepis tectorum*, which were present at multiple sites both under standard and AES-prescribed management, the C3 species *Filago minima*, which was present in a single standard meadow without AES-prescribed management, the C3 species

Aphanes arvensis, which was present at a single standard meadow under AES-prescribed management, and multiple near-threatened (C4a: *Centaurium erythraea*, *Galium boreale*, *Inula salicina*, *Potentilla anglica*, *Primula veris* and *Veronica teucrium*) and data-deficient (C4b: *Galium mollugo*) species (Online Resource 1: Table S3).

Discussion

The obsession with farmland conservation practices experienced in Western Europe in recent decades (Stoate et al. 2009) only recently started to affect the post-communistic bloc. The spectrum of measures applied in the post-communistic bloc is limited, and there is great potential to analyze the impact of the newly implemented schemes on the landscape affected by land consolidation in the 1950s and then subject to decades of machine mowing twice a year in the manner of the standard management regime described here. The study region represents a characteristic European landscape, where there is little natural vegetation over large areas, and areas are kept open not by natural disturbance and indigenous herbivores but by farming and farm animals.

Despite the role of AESs having shifted from the protection of threatened habitats or landscapes to the prevention of species loss, they still rely only on a handful of targets attractive to the public, which are easy to promote and monitor. Particularly common are AESs that focus on flagship species, for example farmland birds, and those which address the improvement and maintenance of ecosystem services, such as pollination and biocontrol (Ekroos et al. 2014; Batáry et al. 2015). However, the applied measures are associated with a high degree of uncertainty even for target flagship species with well-known biology and ecology (van Egmond and de Koeijer 2006). Data on most groups of invertebrates, except of pollinators and butterflies, are largely insufficient.

For the selection of AESs` targets, the paradigm shifted from the schemes prescribed in order to protect rare species to the schemes aiming to protect common farmland species, for example the bird species that, until the 1990s, were considered common and not threatened by any means. In contrast to common farmland birds, common farmland invertebrates are still lacking similar clearly defined targets concerning the improvement in their abundance or diversity. Instead, the measures are either crop production oriented or focus on measures that are too simplistic, such as set-asides, the upkeep of abandoned farmland and woodland, maintenance and public access improvement. All these represent well-intentioned measures with a clear focus on some key problems associated with European cultural landscapes. However, biodiversity conservation is usually addressed only indirectly through the maintenance of the countryside and the landscape schemes (Kleijn and Sutherland 2003), and little has changed in this regard during the last two decades. The responses of spiders to particular AESs are incompletely understood. Individual spider species clearly differ in their response to AESs. However, previously available evidence did not allow to provide simple prediction on the response of individual spider species to the application of AESs. Schmidt et al. (2008) found a positive influence of fallows on spider diversity except that of the epigeic dwarf spider *Erigone dentipalpis*. They found that *Evarcha arcuata* and species of Araneidae, Clubionidae and Gnaphosidae increased in the fallows. The same spider taxa are sensitive to mowing in wetlands (Cattin et al. 2003; Schmidt et al. 2005), which is likely due to the disruption of the vegetation structure used by web-weavers and climbing spiders (Schmidt et al. 2008). Araneidae and Clubionidae in particular overwinter on or in herbaceous vegetation (Schaefer 1976). Some authors have suggested that epigeic spiders should also be affected by mowing, particularly by means of the reduction of the litter layer (Bell et al. 2001; Schmidt et al. 2008).

The AES-prescribed management analysed in the present study consisted of allowing from 3% to 10% of permanent grasslands within each land block to remain unmown until at least August 15. Overall, we noticed an increase in spider abundance. At the species-specific level, despite many species exhibited much higher abundance at sites subject to the AES-prescribed management, many others were insensitive to it. We found that while AES-prescribed management was not associated with an increase in the diversity or abundance of threatened species, it was associated with dramatic increases in many common farmland species. The key, which allowed the stratification of species into those that responded positively to the management and those that were insensitive to it or responded only negatively, stemmed from habitat specializations and hunting strategies of the affected species. The web-weavers and species that attach their cocoons to the vegetation multiplied in abundance in the unmown grass strips. In contrast, the epigeic species were either insensitive to such AES-prescribed management or, less frequently, even exhibited a negative response to it. The only web-weaver that showed a neutral response to the implementation of unmown grass strips was *Singa hamata*. Although this web-weaver can be found on tall vascular plants, it weaves its webs close to the soil surface, which likely explains its neutral response to the implementation of unmown grass strips. We noticed a similarly neutral response in the case of *Xysticus kochi*, which prefers open and sparsely vegetated habitats and is usually present in, although not limited to, low vegetation.

In the present study, we focused on the very first effects of the implementation of the unmown strips to large meadows, which were previously subject to hay cutting twice a year for decades. We have shown that the spiders responded quickly, but differently at a species-specific level. While we analysed the short-term effects of the implementation of unmown strips, the present study has a limitation in the absence of information on the recovery of assemblages in the following years, would the same AES be applied to the same set of meadows for several consecutive years. We also did not test for the effects on species that are not active in late summer. Importantly, the short-term effects were not associated with any major changes in a composition of vegetation, which may not necessarily be true during the longer application of the AES. Particularly problematic could be the tendency of farmers to retain the unmown strips in the same positions through the next years and the absence of their mowing even after the summer period required by the relevant current AES scheme. Combining these circumstances allows a formation of some form of a hedge instead of an uncut meadow strip. The problems with the overgrowth of shrubs and trees, which we experience at the steppe remnants and disused pastures and meadows throughout the temperate region (Didier 2001; Morgan et al. 2007; Pornaro et al. 2013), may play a role here as well and need to be addressed by changing the positions of unmown strips.

Conclusions

Spiders, considered a group with limited mobility, were previously suggested to be negatively associated with mown areas (Cattin et al. 2003; Schmidt et al. 2005, 2008; Mazalová et al. 2015). In agreement with these studies, we provided here conclusive evidence showing that AES-prescribed management, which consisted of allowing from 3% to 10% of permanent grasslands within each land block to remain unmown until at least August 15, was associated with the increased abundance of the vast majority of common vegetation-dwelling farmland spiders. However, in contrast, no common epigeic spiders responded positively to the same management. In most cases, their abundance was neutral in response to the prescribed management, or, in three species, it even decreased below the values observed in meadows under standard management, which are mown twice a year, usually before June 15 and in July/August. The differences in mowing schemes were not associated with any major changes in species composition of vascular plant assemblages in mown and unmown areas. As the unmown strips seem to be beneficial to common vegetation-dwelling farmland spiders, it remains to be tested whether threatened vegetation-dwelling spiders benefit from similar AESs at sites of their occurrence, such as in fen meadows or steppes.

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