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One year of conservation management is not sufficient for increasing the conservation value of abandoned fen meadows

Ein Jahr Naturschutzmanagement reicht nicht aus, um den ökologischen Wert brachgefallener Niedermoorwiesen zu erhöhen

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Abstract

In Central Europe many grasslands are threatened by the abandonment of traditional land use, leading to litter accumulation and encroachment of competitive grasses, woody and invasive species, ultimately causing the loss of biodiversity in the long run. Resumption of traditional management practices might reverse the negative effects of abandonment, but can be challenging in the current socio-economic context, especially in habitats providing poor-quality forage, such as fen meadows. Given the limited resources of nature conservation agencies, it is crucial to find proper alternative management options to tackle the complex conservation problems these habitats are facing.

We studied three sampling sites in an abandoned fen meadow in West Hungary that are subjected to litter accumulation and the encroachment of competitive grasses, shrubs and the invasive giant goldenrod (*Solidago gigantea*). In a baseline survey in 2019, we evaluated the relationship between the above-mentioned threat factors and conservation value indicators (i.e. Shannon diversity, herbaceous species richness, cover of forbs, number of flowering shoots of forbs, naturalness score and forage quality). In a field experiment we used the BACI (Before-After-Control-Impact) design to study the effects of a traditional (mowing) and two alternative (mowing without hay removal, burning) conservation measures and no management (control) on the threat factors and conservation value indicators. We tested the short-term effects of these management types on all dependent variables measured in 2020 by using generalised linear mixed-effect models.

In our study system the purple moor-grass (*Molinia arundinacea*) as dominant species had the most significant negative impact, affecting four out of the six conservation value indicators studied. Litter accumulation had significant negative effects on three indicators. We found that the single application of the tested treatments was not successful in reaching the conservation targets, neither in terms of mitigating the threat factors nor in increasing the conservation value indicators. Mowing and burning treatments both reduced the amount of litter, but the cover of *Molinia* (the strongest predictor of the conservation value indicators) was unaffected by all treatment types. As a consequence, we did not

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detect any effects of the treatments on the indicators of conservation value one year after the treatments. It is likely that repeated treatments are necessary to achieve positive changes in conservation value. Another possible explanation is that the applied treatments did not target the most influential threat factor, i.e. the encroachment of *Molinia*. Therefore, we recommend determining the most influential threat factors first before applying resource-consuming conservation management treatments in grasslands facing multiple threat factors.

Keywords: abandonment, controlled burning, litter accumulation, *Molinia*, mowing, mulching, *Solidago*, shrub encroachment, traditional management, wet meadow

Erweiterte deutsche Zusammenfassung am Ende des Artikels

1. Introduction

Natural and semi-natural grasslands play an important role in preserving high levels of biodiversity (VALKÓ et al. 2016a). They provide important ecosystem services, and they have a great economic and social importance and substantial landscaping values (DENGLER et al. 2014). Therefore, the conservation of these habitats is not only of ecological importance, but also of economical and societal relevance. However, grassland biodiversity and functioning are threatened by both intensification and abandonment of traditional management practices (CSERGŐ et al. 2013, KUHN et al. 2021). On the one hand, ploughing, the invasion of aggressively spreading alien plant species and eutrophication caused by intensive use of fertilisers in neighbouring areas are major threat factors for species-rich grasslands (DENGLER & TISCHEW 2018). On the other hand, many grasslands are threatened by the abandonment of traditional land use due to a decline in low-intensity animal husbandry systems (ISSELSTEIN et al. 2005), which leads to plant litter accumulation and the encroachment of shrubs and trees (PÁPAY et al. 2020) and ultimately causes the loss of biodiversity in the long run (VALKÓ et al. 2012, KÖHLER et al. 2020). The decline of traditional land use practices such as scything is a typical consequence of the abandonment of low-intensity smallholder livestock farming.

Several studies have shown that grassland degradation can be countered by the resumption of traditional management practices as grassland species and communities have evolved under these types of disturbances over the centuries (VALKÓ et al. 2018, JANIŠOVÁ et al. 2020). Mowing with subsequent biomass removal is a widespread practice in managing grasslands for conservation purposes. The effect of mowing on the vegetation depends on its timing and frequency, the size of uncut refuges and the stubble height (HUMBERT et al. 2012, NAKAHAMA et al. 2016, TÄLLE et al. 2018). The most common practice in nutrient-poor and/or dry grasslands is yearly mowing in late spring or early summer, which may be followed by aftermath grazing at the end of the vegetation period (TÄLLE et al. 2018). In regions where traditional mowing practices are not sustainable under the current socio-economic conditions, alternative options for the conservation management of grasslands have to be found. Mulching and prescribed burning can be such alternative options (VALKÓ et al. 2018, HAMŘÍK & KOŠULIČ 2021, PAVLŮ et al. 2021).

Unlike mowing, mulching does not imply the removal of plant litter as the cuttings are shredded and spread on site. It has the advantage of being suitable to control shrubs and even smaller trees, so it is often used to suppress woody species. It is also cheaper than mowing as it saves the costs for transport (and, if necessary, disposal) of the cut material (LIIRA et al. 2009). However, mulching is no option if biomass removal is the goal.

Prescribed burning has traditionally been used as a conservation measure in many parts of the world, especially in the fire-prone ecosystems of North America, Africa and Australia (VALKÓ & DEÁK 2021). In Europe the traditional ecological knowledge on fire as a grassland management tool has been considerably eroded, and today prescribed fire in grasslands usually occurs in experimental setups (VALKÓ et al. 2014). Burning is faster, more cost-effective and less labour-intensive than mowing or grazing (LIIRA et al. 2009). It can be suitable for removing accumulated plant litter and preventing shrub encroachment (VALKÓ et al. 2014). The effect of controlled burning depends on its timing and frequency and on the intensity of the fire (VALKÓ et al. 2014).

The objective of our study was to evaluate early vegetation changes after the application of three different grassland management measures aiming to tackle conservation problems that affect many grasslands throughout Europe. The systems studied were fen meadows in West Hungary that have been abandoned for four decades. The studied meadows are subjected to litter accumulation and the encroachment of competitive grasses, shrubs and the invasive giant goldenrod (*Solidago gigantea*). The management of such fen meadows poses a great challenge for conservation management in this region because the cessation of low-intensity smallholder livestock farming is common here. Given the limited financial sources available for nature conservation, it is crucial to find proper and cost-effective alternative management options to tackle the complex conservation problems these habitats are facing. Also, it is important to evaluate whether a single management action can reverse the degradation process to some extent and increase the conservation value of fen meadows, or if the measure has to be repeated. To address these problems, we first evaluated the relationship between the major threat factors in the studied grasslands (i.e. litter accumulation, competitive grasses, invasive species and woody species) and several indicators of grassland conservation value. Thereafter we compared the effects of a traditional (mowing) and two alternative (mowing without hay removal, burning) conservation measures with the effect of abandonment on the threat factors and the conservation value indicators.

2. Materials and methods

2.1 Study area

The study area is situated in Nyirád (West Hungary), at the edge of the Bakony Mountains, in the nature reserve 'Nyirádi Sár-álló' (meaning 'Muddy place at Nyirád') established in 2005. It belongs to the Natura 2000 site ''Felső-Nyirádi erdő és Meggyes-erdő (HUBF20011)' and is managed by the Balaton-felvidéki National Park. The nature reserve covers 360 ha. The larger part of the area is covered by lowland pedunculate oak-hornbeam woodlands, and only approximately 100 ha are grassland. The area used to be drained by ditches. The most drastic intervention happened in the 1990s, when a deep channel cut the fen into two parts and the groundwater level dropped by several metres, causing the wet habitats to dry out rapidly. To reverse the damaging process, the Balaton-felvidéki National Park placed a waterproof geotextile vertically in the ground in 2004, which resulted in the subsequent rise of the groundwater level in the fen meadows.

The forests, grasslands and wetlands composed a species-rich habitat complex, with threatened plant species such as *Asphodelus albus*, *Gladiolus palustris*, *Hypericum barbatum*, *Sparganium natans* etc. The grasslands were used as a pasture until the 1980s (exact date of abandonment unknown). Since then there has been no regular management, and natural reforestation has begun throughout the area. The Balaton-felvidéki National Park cuts pines and juniper trees in the dry parts of the meadows and occasionally mulches the *Molinia* meadows. The *Molinia* meadows, in which our sampling areas are situated, cover the largest part of the grassland area (ca 50 ha). The studied *Molinia* meadows harbour several protected plant species such as *Carex fritschii*, *Dianthus deltoides*, *Potentilla rupestris*, *Polygala amarella*, *Allium carinatum*, *Iris sibirica*, *Sesleria uliginosa*, *Stipa pennata*, *Carex hartmannii* and *Platanthera bifolia*.

For characterising the productivity of the studied meadows, we collected a total of 36 aboveground biomass samples from sampling plots of 20 cm × 20 cm size in 2019. The biomass samples were air-dried and then sorted into living plant biomass and (dead) plant litter. After sorting the samples the weight of the two fractions was measured.

We selected three study sites (site coordinates in WGS84: Site 1: 46.9935° N, 17.42092° E; Site 2: 46.99581° N, 17.41742° E; Site 3: 46.99448° N, 17.41444° E; Fig. 1), which were all dominated by purple moor-grass (*Molinia arundinacea*) and affected by the same conservational problems, namely encroachment of shrubs and perennials grasses, litter accumulation and presence of the invasive alien giant goldenrod (*Solidago gigantea*).

2.2 Treatments

In each of the three study sites we selected four 10 m × 10 m (100-m^2) plots, one per treatment type. We left a buffer zone of 5 m between and around the single plots. We used the BACI (Before-After-Control-Impact) design to study the effect of mowing with hay removal (named 'mowing' hereafter), mowing without hay removal, burning and no management (control) on the fen meadow vegetation. The treatments mowing and mowing without hay removal were applied after the baseline survey (see section 2.3 'Sampling') using brushcutters and brush knives. We removed the cut material by raking from the 'mowing' plots and left it spread out on the ones selected for 'mowing without hay

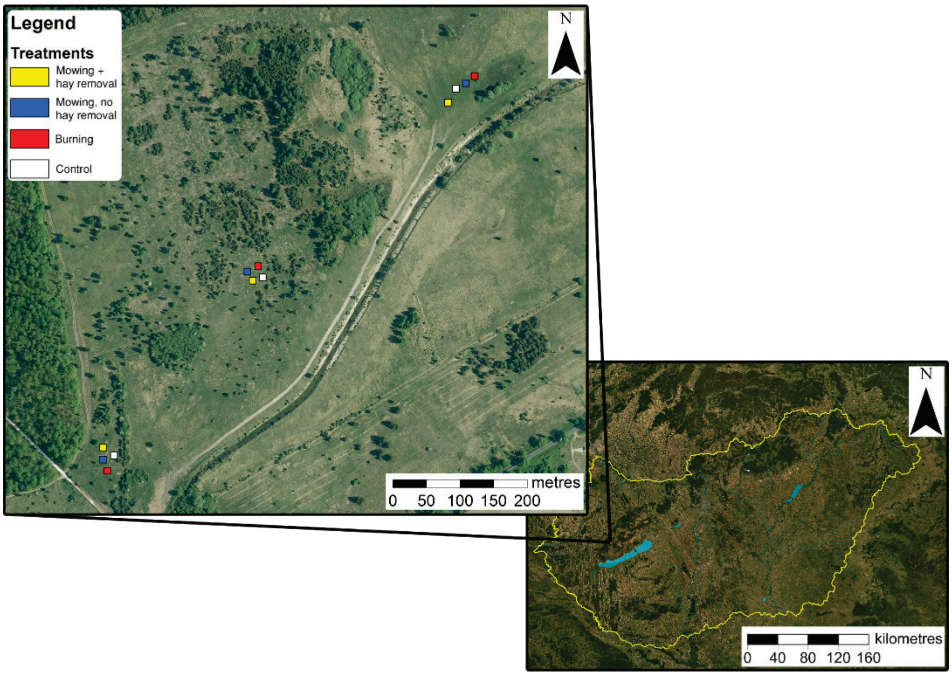

Fig. 1. Location of the three study sites in Nyirád, West Hungary, and arrangement of the treatment plots within the fen meadows.

Abb. 1. Lage der drei Untersuchungsflächen in den Moorwiesen in Nyirád, Westungarn, und der Flächen mit den unterschiedlichen Behandlungsweisen.

Fig. 2. Plots after application of the four different treatments in the fen meadows in Nyirád, West Hungary. The photos of the two mowing treatments and the control were taken in July 2020, the photo of the burning treatment after its application in January 2020 (Photos: B. Pacsai).

Abb. 2. Die Flächen in den Moorwiesen in Nyirád, Westungarn, nach Durchführung der vier Behandlungen. Die Bilder der zwei Typen von Mahd (oben links: Mahd mit Entfernung des Schnittguts; oben rechts: das Schnittgut verbleibt nach der Mahd auf der Fläche) und das Bild der Kontrolle wurden im Juli 2020 aufgenommen, während das Bild der gebrannten Fläche im Januar 2020, nach Durchführung des Brennens, entstanden ist (Fotos: B. Pacsai).

removal'. Mowing without hay removal resembles mulching insofar as the cut biomass is left on the site, but in contrast to mulching, the material is not shredded. The stubble height varied between 10 and 25 cm depending on field conditions. The controlled burning was carried out in winter (10 January 2020) to minimise negative side effects on wildlife (Fig. 2).

2.3 Sampling

In every plot we designated three 2 m × 2 m (4-m^2) permanent quadrats where we recorded the percentage cover of all vascular plant species in 2019 (as baseline survey before the treatments) and 2020 (one year after the first treatments). In total we sampled 36 quadrats each year (3 sites × 4 treatments × 3 replicates). In addition to the percentage cover of each vascular plant species, we also recorded the number of flowering shoots of the forbs and estimated the area covered by plant litter and the cover of shrubs. The baseline survey was performed between 29 May and 7 June 2019, and the survey one year after the treatments was conducted between 4 and 11 June 2020. We followed the nomenclature of Király (2009) for plant taxa.

2.4 Data analysis

For expressing the naturalness of the vegetation, we classified the recorded plant species into Social Behaviour Types (SBT) as defined by BORHIDI (1995). The SBT system assigns a naturalness value to each SBT category, ranging from to -3 (AC – adventive competitors) to +10 (Su – unique specialist species). Furthermore, species were classified according to their forage quality based on the classification of BALÁZS (1949). Forage quality scores ranged from -3 (toxic species) to +8 (highly valuable forage species). We calculated cover-weighted naturalness and forage quality scores for all plots.

In the first step we analysed the effects of potential threat factors on the indicators of the nature conservation value of the grasslands. The analysed threat factors (predictors) were cover of litter, cover of highly competitive native grasses (*Molinia arundinacea*, *Calamagrostis epigeios*), cover of the invasive giant goldenrod (*Solidago gigantea*) and cover of shrubs. Indicators of the nature conservation value of grasslands (dependent variables) were Shannon diversity, herbaceous species richness, cover of forbs, number of flowering shoots of forbs, naturalness score and forage quality score. We also ran regression models on the data of the baseline survey (1st year) to reveal the relationships between the threat factors and all indicator values. We used separate General Linear Mixed Models (GLMM) for each of the threat factors. In these models the threat factors were included as continuous predictors, indicators of conservation value as dependent variables and site identity as random factor.

In a second step we analysed the effects of the treatments (mowing, mowing without hay removal, burning and control) on the vegetation characteristics (threat factors and indicators of conservation value) by using a before-after-control-impact (BACI) approach. We performed GLMMs where treatment and year were set as categorical predictors, the vegetation characteristics (i.e. litter cover, *Molinia* cover, *Calamagrostis* cover, *Solidago* cover, cover of shrubs, Shannon diversity, number of herbaceous species, forb cover, number of flowering shoots of forbs, naturalness score and forage quality) as dependent variables and site identity as random factor. We were also interested in the interaction term of treatment and year as this interaction indicates if the direction or the magnitude of the temporal change is different among the treatments. We performed Fisher LSD post-hoc tests to reveal differences between the treatments in both years. All analyses were calculated in Statistica 10.0 (StatSoft Inc., Tulsa, OK, USA).

3. Results

A total of 154 plant species were recorded in the phytosociological relevés. During the baseline survey the average amount of litter was 1074 g/m^2, the average amount of living biomass was 270 g/m^2.

3.1 Baseline survey: Effects of threat factors on conservation value

Litter cover negatively affected Shannon diversity, number of herbaceous species and number of flowering shoots of forbs in the surveyed grasslands (Table 1, Fig. 3). In the case of the other dependent variables (forb cover, naturalness score and forage quality), there was no significant litter effect (Table 1). *Molinia* cover negatively affected Shannon diversity, number of herbaceous species, forb cover and number of flowering shoots of forbs (Table 1, Fig. 3). In the case of the naturalness score and forage quality, we did not detect any significant effect of *Molinia* (Table 1). There was no effect of *Calamagrostis* cover on any indicator of conservation value. *Solidago* cover negatively affected the naturalness score and forage quality (Table 1, Fig. 3). No effect of *Solidago* cover was detected in the case of the other variables. We did not detect any effect of shrub cover on the indicators of conservation value (Table 1).

Table 1. Effects of different threat factors on six indicators of conservation value. Downward arrows indicate negative relationships between variable combinations, and asterisks denote the level of significance for the threat factor effect (* $p < 0.05$; *** $p < 0.001$; n.s. – non-significant).

Tabelle 1. Die Effekte unterschiedlicher Gefährdungsfaktoren auf sechs Indikatoren für den Naturschutzwert der Flächen. Ein nach unten gerichteter Pfeil zeigt den negativen Effekt eines Faktors auf einen Indikator an. Signifikanzniveaus: * $p < 0,05$; *** $p < 0,001$; n.s. – nicht signifikant.

Threat factors	Indicators of conservation value					
	Shannon diversity	No. of herbaceous species	Cover of forbs	No. of flowering shoots of forbs	Naturalness score	Forage quality
Litter cover	↓ *	↓ *	n.s.	↓ *	n.s.	n.s.
Molinia cover	↓ ***	↓ ***	↓ ***	↓ *	n.s.	n.s.
Calamagrostis cover	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Solidago cover	n.s.	n.s.	n.s.	n.s.	↓ ***	↓ ***
Shrub cover	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

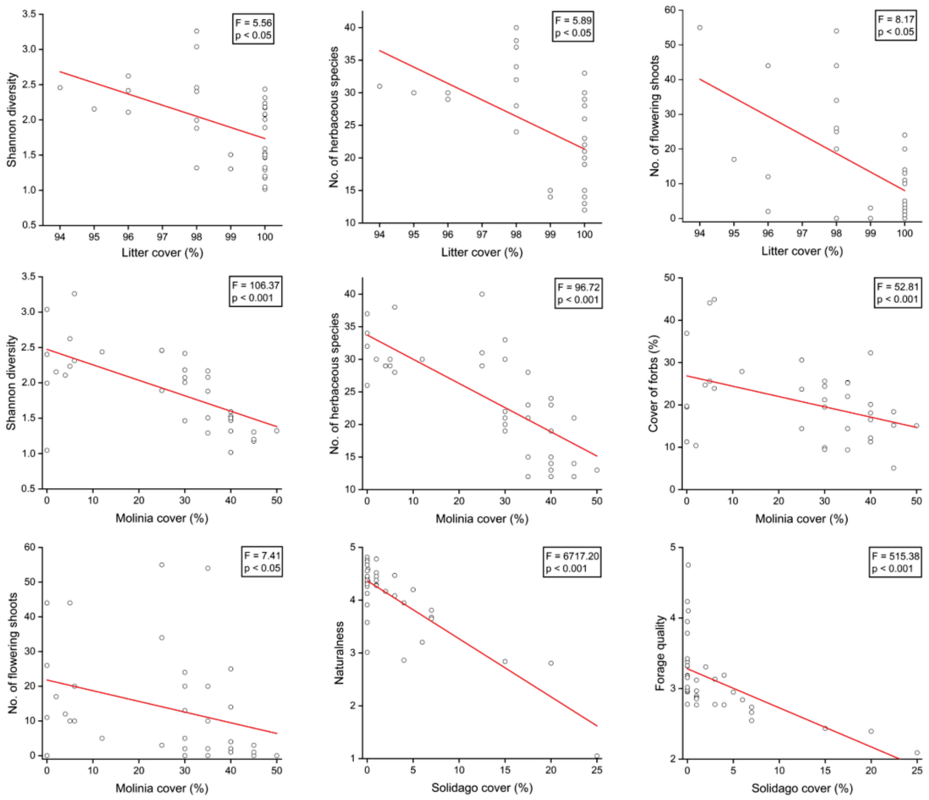

Fig. 3. Effects of several threat factors on the conservation value indicators. Only significant threat factors are displayed on the panels, together with the *F*- and *p*-values of the General Linear Mixed Models.

Abb. 3. Die Effekte unterschiedlicher Gefährdungsfaktoren auf die Indikatoren des Naturschutzwerts der Moorwiesen. Nur signifikante Faktoren sind dargestellt, mit *F*- und *p*-Werten aus linearen gemischten Modellen.

3.2 Effects of treatments on threat factors and conservation value

Litter cover was the only variable that was impacted by the management (there was a significant treatment × year interaction; GLMM; intercept: $F = 7529.08$, $p < 0.001$; Year × Management: $F = 224.58$, $p < 0.001$; Fig. 4). We did not detect differences in litter cover during the baseline survey (first year), but in the second year litter cover was lower in the mown and in the burned plots compared with the control and the 'mown without hay removal' plots. The effect of burning (-83%) on the cover of litter was stronger than the effect of mowing (-30%).

4. Discussion

In the grasslands we investigated, the cover of *Molinia arundinacea* as the dominant species had the most significant negative impact on the conservation value, affecting four out of the six studied indicators (i.e. Shannon diversity, number of herbaceous species, forb cover and number of flowering shoots of forbs). In a previous study, LEPŠ (2014) also found that the dominance of *Molinia* can be a major driver and decrease plant species richness in abandoned fen meadows. In such cases, when the dominant grass species is a strong competitor, the primary task for nature conservation is to control the abundance and biomass of this species (CSERGŐ et al. 2013). Litter cover also had an adverse effect on three indicators of conservation value (i.e. Shannon diversity, number of herbaceous species and number of flowering shoots of forbs), but its significance was smaller than the effect of *Molinia* in all cases. Based on these findings, the priority conservation objectives should be to reduce

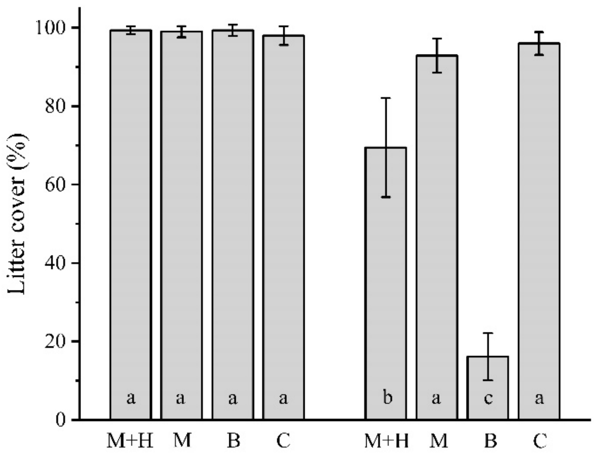

Fig. 4. Litter cover in the baseline survey (left) and one year after the experimental treatments (right). Bars denote mean values, whiskers the standard deviation. Significant differences between treatments are indicated by different lower-case letters according to the Fisher LSD post-hoc tests. Abbreviations: M+H: mowing with hay removal; M: mowing without hay removal, B: burning, C: control.

Abb. 4. Streudeckung während der Ausgangserhebung (links) und ein Jahr nach den experimentellen Behandlungen (rechts). Die Balken geben Mittelwerte an, die Whisker die Standardabweichung. Signifikante Unterschiede zwischen den Behandlungen sind durch unterschiedliche Kleinbuchstaben gemäß dem Fisher-LSD-Post-hoc-Test gekennzeichnet. Abkürzungen: M+H: Mahd mit Abfuhr des Schnittguts; M: Mahd ohne Abfuhr des Schnittguts, B: Brennen, C: Kontrolle.

the cover of *Molinia* in areas where its dominance is apparent and to decrease litter accumulation in order to increase the conservation value of the fen meadows. In the studied meadows the cover of *Calamagrostis epigeios* and the shrub cover were rather moderate so that these factors did not have a direct effect on the conservation value. However, preventive measures and continuous monitoring are needed to prevent these threat factors from becoming a real problem in the future. *Calamagrostis* is a highly competitive grass and rapidly expanding in various habitat types in Central Europe, favoured by various forms of disturbance, including wild boar rooting and burning (REBELE & LEHMANN 2001, DEÁK et al. 2014). Therefore, its abundance should be regularly monitored, even in managed meadows. Although the cover of the invasive giant goldenrod (*Solidago gigantea*) was also moderate at the study sites (its cover in Year 1 was 3.3±5.7% (mean±SD)), it had a significant negative effect on the conservation value and on forage quality due to its saponin content (WEBER & JAKOBS 2005). This result suggests that a targeted control of *Solidago* by regular twice-a-year mowing (ŚWIERSZCZ et al. 2017) might be necessary in the future.

We found that the single application of the three treatments was not successful in reaching the conservation targets. Mowing and burning both reduced the amount of litter (see also VALKÓ et al. 2012, 2018), which is favourable as the reduction of the litter layer might improve the germination conditions for specialist forb species (FACELLI & PICKETT 1991, MIGLÉCZ et al. 2013). We found that in the case of mowing without hay removal, litter accumulation remained at a level similar to the control. However, shredding the cut material might be a promising strategy to accelerate litter decomposition processes (PAVLŮ et al. 2016) and can increase the effectiveness of the mowing without hay removal. Burning reduces the amount of accumulated litter immediately (MILES 1971), but temporarily puts air quality at risk (HAIKERWAL et al. 2015) and causes collateral damage e.g. in overwintering insects. Mowing with hay removal has in the long term a similar effect as burning (HEJCMAN et al. 2009, TÖRÖK et al. 2009). When mowing is not combined with hay removal within a few weeks, excess nutrients remain on the site (SHAFFERS et al. 1998), which can support the encroachment of *Molinia* in the long run (TOMASSEN et al. 2003).

In our study we did not detect any significant effects of the treatments on five out of six conservation value indicators after one year of singly applied treatments. One possible reason is that the applied treatments did not target the most influential threat factor, i.e. the dominance of *Molinia*. We found no difference in the abundance of *Molinia* under the different treatments, which might be the reason for the lack of more positive conservation outcomes. *Molinia* can relocate nutrients very efficiently to its roots and rhizomes so that this species can rely on nutrient stores after mowing (TAYLOR et al. 2001). Another possible explanation is that the treatments have to be applied repeatedly in multiple consecutive years for detectable positive changes in conservation value (KLIMEŠ et al. 2013, LEPŠ 2014), which highlights the necessity of long-term studies for the proper evaluation of grassland conservation and restoration measures (RESCH et al. 2021). Finally, we assume that both mechanisms might act in concert.

Our results suggest that in grasslands facing multiple threat factors, it is highly recommended to determine the most influential one(s) before conservation management treatments are applied. Based on earlier results (see also KELEMEN et al. 2014, VALKÓ et al. 2014), both burning and mowing with hay removal might be good solutions on sites where litter accumulation is the major problem. On sites where the encroachment of competitive grasses is most problematic, the management should be targeted at their reduction or suppression, e.g. by mechanical removal (LEPŠ 2014) or by sowing of hemiparasitic plants (TĚŠITEL et al. 2017, 2018). Several studies showed that hemiparasites can reduce growth and competitive ability of dominant (grass) species and thus facilitate the regeneration of specialist species from seeds by opening gaps for seedling establishment (HEER et al. 2018, 2021, TĚŠITEL et al. 2017, 2018). For example, it was found that *Rhinanthus major* (TĚŠITEL et al. 2018) and *R. alectorolophus* (TĚŠITEL et al. 2017) can be highly effective in the control of *Calamagrostis epigeios.* Concerning the suppression of *Molinia* by hemiparasites, we did not find any published studies. However, DEMEY (2013) hypothesised that clonal grasses, such as *Molinia* can be vulnerable to hemiparasites, as when a ramet is parasitised, the parasite can access the whole clonal structure. Therefore, the applicability and effectiveness of this method should be tested in the near future. As several hemiparasitic taxa, such as *Rhinanthus* spp. or *Melampyrum* spp., are native elements of the species pool of fen meadows in Hungary, high-density sowing of their seeds might be a promising nature-based solution to break grass dominance and provide establishment gaps for rare fen meadow specialist species.

Erweiterte deutsche Zusammenfassung

Einleitung – In Mitteleuropa sind viele Grasländer durch die Aufgabe der traditionellen Nutzung bedroht, was oft zur Akkumulation von Streu und zur Dominanz von konkurrenzkräftigen Gräsern, Gehölzen und/oder invasiven Arten führt. Dies bewirkt langfristig einen Verlust der biologischen Vielfalt (VALKÓ et al. 2018). Die Wiederaufnahme der traditionellen Bewirtschaftung könnte die negativen Auswirkungen der Nutzungsaufgabe umkehren, ist jedoch unter den derzeitigen sozioökonomischen Bedingungen und insbesondere in Lebensräumen mit schlechter Futterqualität, wie in Moorwiesen, eine Herausforderung. Angesichts begrenzter finanzieller Ressourcen für den Naturschutz ist es von entscheidender Bedeutung, geeignete alternative Managementoptionen zu finden, um die komplexen Erhaltungsprobleme dieser Lebensräume anzugehen (TÄLLE et al. 2016). Um dies zu erreichen, haben wir zunächst die Beziehungen zwischen den wichtigsten Gefährdungsfaktoren (Streuakkumulation, Deckung konkurrenzstarker Gräser, Deckung von invasiven Arten und Deckung von Gehölzen) und verschiedenen Indikatoren für den Naturschutzwert von Moorwiesen untersucht. Anschließend verglichen wir die Auswirkungen der traditionellen einmaligen Mahd und von zwei weiteren alternativen Methoden (Mahd ohne Abfuhr des Schnittguts und Brennen) auf die Gefährdungsfaktoren und die Indikatoren für den Naturschutzwert mit den Auswirkungen der Nutzungsaufgabe (Kontrolle).

Materialien und Methoden – Wir untersuchten drei Niedermoorwiesen in Westungarn (Abb. 1), deren Nutzung eingestellt wurde und die nun von Streuakkumulation und der Ausbreitung von konkurrenzstarken Gräsern (*Calamagrostis epigeios* und *Molinia arundinacea*), Gehölzen und der invasiven Riesen-Goldrute (*Solidago gigantea*) betroffen sind. An jedem der drei Standorte wählten wir vier 10 m × 10 m große Flächen aus, für die jeweils eine der experimentellen Behandlungsweisen festgelegt wurde. In jeder dieser Flächen legten wir drei 2 m × 2 m große Quadrate an, in denen wir in den Jahren 2019 und 2020 die prozentuale Deckung aller Gefäßpflanzenarten erfassten. In einer Grundlagenerhebung im Jahr 2019 untersuchten wir zudem die Beziehung zwischen den oben genannten Gefährdungsfaktoren und den Indikatoren für den Naturschutzwert (Shannon-Diversität, Artenreichtum und Deckung krautiger Pflanzen, Anzahl der blühenden Triebe krautiger Pflanzen, Indikatorwerte für Natürlichkeitsgrad und für Futterqualität). Im Feldexperiment untersuchten wir dann die Auswirkungen der traditionellen Mahd mit Schnittgutabfuhr, der Mahd ohne Abfuhr des Schnittguts und des Brennens (Abb. 2) auf die Gefährdungsfaktoren und den Naturschutzwert, und verglichen diese mit der Kontrollfläche. Hierbei testeten wir die kurzfristigen Auswirkungen dieser Bewirtschaftungsarten auf alle im Jahr 2020 gemessenen abhängigen Variablen mit linearen gemischten Modellen.

Ergebnisse – Es zeigte sich, dass das dominante Rohr-Pfeifengras (*Molinia arundinacea*) die signifikantesten negativen Auswirkungen auf die Indikatoren des Naturschutzwerts hatte, da sie vier (Shannon-Diversität, Artenreichtum und Deckung krautiger Pflanzen, Anzahl der blühenden Triebe krautiger Pflanzen; Tab. 1, Abb. 3) der sechs untersuchten Indikatoren beeinträchtigte. Die Akkumulation von Streu hatte ebenfalls signifikant negative Auswirkungen auf drei Indikatoren (Shannon-Diversität, Artenreichtum krautiger Pflanzen, Anzahl der blühenden Triebe krautiger Pflanzen). Die Deckung von *Solidago gigantea* wirkte sich zudem negativ auf den Natürlichkeitsgrad und die Futterqualität aus. Gehölze und die Deckung von *Calamagrostis epigeios* hatten keinen signifikanten Einfluss auf die untersuchten Indikatoren (Tab. 1, Abb. 3). Die Streuauflage war die einzige abhängige Variable, die von den Behandlungsweisen beeinflusst wurde. Allerdings nur von zwei der drei Methoden: Brennen reduzierte die Streuauflage um 83 %, während Mahd mit Schnittgutabfuhr diese um 30 % reduzierte (Abb. 4). Keine der untersuchten Behandlungsweisen hatte jedoch signifikante Auswirkungen auf einen der anderen Indikatoren für den Naturschutzwert.

Diskussion – Wir haben festgestellt, dass die einmalige Anwendung der getesteten Behandlungsweisen nicht erfolgreich war, um die Erhaltungsziele zu erreichen. Dies sowohl im Hinblick auf die Minderung der Gefährdungsfaktoren als auch auf die Erhöhung des Naturschutzwerts. Sowohl Mahd mit Schnittgutabfuhr als auch Brennen verringerten die Streubedeckung. Die Dominanz von *Molinia arundinacea*, dem stärksten Prädiktor für den Naturschutzwert, wurde jedoch durch keine der Behandlungsweisen beeinflusst. Folglich konnten wir ein Jahr nach Beginn des Experiments keine Auswirkungen der Managementoptionen auf den Naturschutzwert feststellen. Es ist daher sehr wahrscheinlich, dass wiederholtes (kontinuierliches) Management notwendig ist, um nachweisbare positive Veränderungen des Naturschutzwerts beobachten zu können (siehe auch KLIMEŠ et al. 2013, LEPŠ 2014). Eine weitere mögliche Erklärung für das Fehlen kurzfristiger Effekte auf den Naturschutzwert ist, dass die durchgeführten Managementoptionen nicht auf den wichtigsten Gefährdungsfaktor, die Dominanz von *Molinia arundinacea*, abzielten. Eine vielversprechende Option könnte hierfür sein, die Dominanz der Gräser durch die Aussaat von Hemiparasiten zu reduzieren (HEER et al. 2018, 2021, TĚŠITEL et al. 2017, 2018). Wir empfehlen daher, zunächst die wichtigsten Gefährdungsfaktoren zu ermitteln, bevor ein ressourcenintensives Management in Grasländern mit unterschiedlichen potenziellen Gefährdungsfaktoren durchgeführt wird.

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Author contributions

JB, AK and AM conceived and designed the research; JB, BF, VL, AM, BP and PS collected the data and performed the treatments; OV and AK analysed the data, JB, BF, OV and AK wrote and edited the manuscript. All authors gave their final approval for publication.

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