MONITORING OF NATURA 2000 GRASSLAND HABITATS IN SAC ŠUMAVA

ZDENKA KŘENOVÁ[1,2,*], VÍT GRULICH[†], and ALENA VYDROVÁ[3]

[1] Global Change Research Centre AS CR, Bělidla 4a, 60200 Brno, Czech Republic
[2] Institute for Environmental Studies, Faculty of Science, Charles University, Benátská 2, 12900 Prague, Czech Republic
[†] Department of Botany and Zoology, Faculty of Science, Masaryk University, Kotlářská 2, 61137 Brno, Czech Republic
[3] AOPK ČR, Kaplanova 1931/1, 14800 Praha 11 – Chodov, Czech Republic
* Corresponding author: krenova.z@czechglobe.cz

ABSTRACT

The Bohemian Forest grasslands have emerged gradually over centuries, with political turbulence in the second half of the 20th century strongly affecting the region, including its meadows. Today, there are cultural and partly degraded meadows as well as fragments of highly valuable semi-natural mountain meadows, important biodiversity localities in the mostly wooded Bohemian Forest landscape. Their conservation value began to be taken into account in 1991, when the Šumava NP was established, and re-emphasized in 2004, when certain grasslands were recognized as Natura 2000 habitats. Maintaining favorable conditions of meadow habitats is a hard task even in strictly protected areas and the most common difficulties are listed in this paper. More attention has been paid to the management of grasslands in the region during the last decade. The Šumava NP Authority provides the necessary management of the most valued localities and has organized simple monitoring in some managed sites. This paper presents the results of the first five years of monitoring of 16 sites. Results are discussed, along with field experiences, and more effective management strategies are proposed. Appropriate and carefully executed management is recognized as a necessary tool for ensuring proper care of conservationally valuable habitats, including grasslands of European importance protected under the Natura 2000 network. Monitoring is an essential tool to observe management quality. Results of this preliminary study deliver a substantial set of experiences that can be used to improve the management and monitoring of Natura 2000 habitats, as well as other species rich meadows occurring in the Šumava NP.

Keywords: conservation; fens; management; monitoring; national park; *Molinion* meadows; Natura 2000; *Nardus* grasslands

Introduction

In the Central European landscape, grasslands are primarily semi-natural habitats, the products of local ecological conditions and long-term active management (Chytrý and Blažková 2007). The Bohemian Forest grasslands have emerged gradually over centuries, coevally with the region's colonization. For centuries, the Bohemian Forest, where Šumava Special Area of Conservation (SAC Šumava) is located, was for defensive reasons maintained as untouched, deep forest on the south-west border of the Bohemian Kingdom. Deforestation has gradually and slowly altered the region. At the highest elevations, the first gaps in untouched mountain forest were created during the second half of the 18th century or later (Záruba and Koblasa 2000). Therefore, meadows spontaneously arising in deforested areas are relatively young habitats, not more than 300 years old.

Political and social turbulence in the second half of the 20th century strongly affected the Bohemian Forest region, including its grasslands. Most of the German population was displaced after World War II and a large part of the territory was closed by the Iron Curtain. As a result, many settlements have completely disappeared, as has the traditional agricultural use of the landscape. In the "accessible" area of the region in front of the Iron Curtain fences, state farms were established, extensive drainage projects implemented and many meadows were plowed and sown with a mixture of cultivated grasses. Until 1990, so-called substitute reclamation ("improvement" of less productive locations as a substitute for the occupation of agricultural land elsewhere) damaged many fen grasslands and nutrition poor mountain meadows of this region.

Today, the grasslands of the region are heterogeneous. There are cultural and partly degraded meadows as well as fragments of highly valuable semi-natural mountain meadows. Species diversity in Bohemian Forest meadows does not reach the level of species diversity of famous meadows in the White Carpathian Mountains (Hájková et al. 2011) however they are important biodiversity localities in the mostly wooded Bohemian Forest landscape. The conservation value of these meadows began to be taken into account in 1991, when the Šumava National Park (Šumava NP) was established, and emphasized again in 2004, when certain grasslands were designated as Natura 2000 habitats (i.e. habitats listed in the Annex I, the Habitats Directive 92/43/EEC) and selected for protection in SAC Šumava.

Similarly, to other parts of the Czech Republic and many European countries, currently the management of Bohemian Forest meadows is not primarily determined by the need to provide grazing and hay for cattle, a former traditional source of livelihood of the local population. Many localities, especially those species rich, are not managed for economic reasons, but for conservation purposes. Protected areas help us to fulfill our moral commitment and preserve the cultural and natural heritage for future generations. The Šumava NP Authority is the competent body of the state administration for nature

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protection and is obliged to maintain the favorable condition of meadow habitats or, if necessary, to ensure the improvement of their status. This task is not easy to fulfill even in the most strictly protected area, the National Park.

Thirty years of the Šumava NP have demonstrated the most common difficulties in the management of grasslands:

(1) Other priorities in the management of this large protected area. Since the beginning of its existence, the Šumava NP has been primarily battling with the management of forests (bark beetle outbreaks, windstorms, felling, non-intervention management practices, etc.), which also provoke dynamic social and political debates; therefore, the care of grassland habitats has not received similar attention;

(2) Ensuring appropriate management in a large area of the Šumava NP is difficult, both for logistic and economic reasons;

(3) Many grasslands are held in private ownership and the influence of the Šumava NP Authority on their management is limited;

(4) The Šumava NP is an attractive recreational area and many valuable meadows have been already lost due to development activities (new pensions and apartment rental houses, touristic infrastructure, etc.).

Nevertheless, more attention has been paid to the management of grasslands in the region during the last decade. The Šumava NP Authority provides the necessary management of the most valued localities. Some sites are managed under the framework of long-term cooperation with land tenants, some are repeatedly outsourced to external contractors, and other sites are managed directly by employees of the Šumava NP Authority.

Monitoring of managed meadows is an essential tool for clearer understanding of applied measures and long-term changes of grassland habitats. Thus far, the Šumava NP Authority has organized simple monitoring in some managed sites. This paper presents the results of the first five years of monitoring. Results are discussed, along with field experiences, and recommendations for management that is more effective are proposed.

Methods

Study area

The Bohemian Forest is one of the largest forested landscapes in Central Europe, located along the Czech–Bavarian and Czech–Austrian borders. Large mountain forests together with clear mountain streams and glacial lakes, pristine wetlands, peat bogs, and mountain meadows and pastures make it a refuge for many endangered species of plants and animals. This cross-border area is home to several iconic species, such as the lynx (*Lynx lynx*), the moose (*Alces alces*), capercaillie (*Tetrao urogallus*) and the freshwater pearl mussel (*Margaritifera margaritifera*), each of which now occurs in Central Europe only in several viable populations. Typical mountain plants, such as Hungarian gentian (*Gentiana pannonica*) or mountain arnica (*Arnica montana*), flower in meadows and pastures which are remnants of traditional mountain settlements. Two national parks, the Bavarian Forest National Park (Bavarian Forest NP, Germany) and the Šumava National Park (Šumava NP, Czech Republic) were established in the Bohemian Forest in 1970 and 1991, respectively, and protect the area with the highest conservation value (Křenová and Kindlmann 2015, 2018). In their respective home countries, each National Park is among the largest terrestrial sites in the Natura 2000 network, i.e. networks of protected areas established under the Habitats Directive (92/43 / EEC) and the Birds Directive (2009/147 / EC) and designated in all 27 EU countries to protect the most valuable European habitats and species (Sundseth and Creed 2008).

The Special Area of Conservation Šumava (SAC Šumava) was designated by Czech Government Order No. 132/2005. SAC Šumava covers the entire territory of the Šumava NP and the Šumava Protected Landscape Area (Šumava PLA; Fig. 1). Twenty-one natural habitats, eight animal and three plant species (see Appendix 1 for full list of habitats and species) are subjects of protection here and are important for definition of conservation targets of the Šumava NP and Šumava PLA (Bláha et al. 2013). Grassland habitats, i.e. habitats 4032, 5130, 6230, 6410, 6430, 6510, 6520, 7110, 7120, 7140, occupy approximately 8.2% of the area of the SAC Šumava. The Šumava NP Authority, a state administration office for SAC Šumava, has selected 16 study sites for monitoring of Natura 2000 grasslands in SAC Šumava (Fig. 1; Appendix 2).

Target habitats

During the Natura 2000 habitats mapping (Härtel et al. 2009), upon the Czech Republic implementation of the Natura 2000 Directives as a part of the EU-integration process, more detailed vegetation units called biotopes (Chytrý et al. 2001, 2010) were mapped and later aggregated for habitats. Usually 1–3 biotopes form one habitat in *sensu* Annex I of Habitats Directive 92/43/EEC (Appendix 1).

Each of 16 study sites hosts one of the following biotopes:

- T2.3B – Submontane or montane *Nardus* meadows without *Juniperus communis*.
- T1.9 – Intermittently wet *Molinia* meadows.
- R2.2 – Acidic moss-rich fens.

Nardus meadows

Biotope T2.3B belongs to habitat 6230 – Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and submountain areas, in Continental Europe). It is a priority habitat in *sensu* of Habitats Directive 92/43/EEC.

In the Bohemian Forest region, meadows of this vegetation type can be species-poor or species-rich. Different

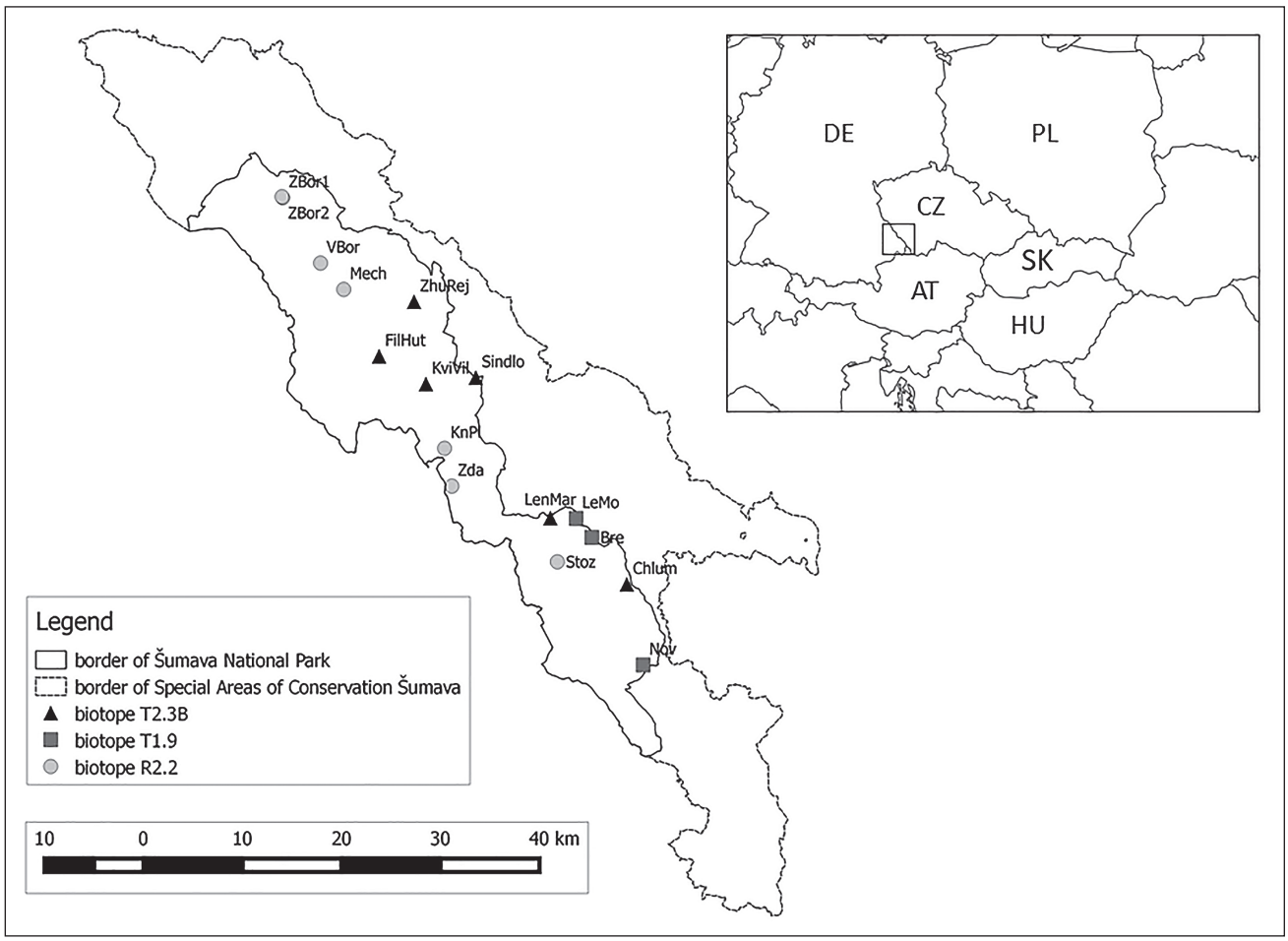


Fig. 1 The map of the study area and study sites: ZBo1 – Zadní Bor, ZBo2 – Zadní Bor 2, VBor – Velký Bor, Mech – Mechov, ZhuRej – Zhůří near Rejštějn, FilHut – Filipova Huť, KviVil – Kvilda Vilémov, Sindlo – Šindlov, KnPl – Knížecí Pláně, Zdar – Žďárek, LenMar – Lenora Markovec, LenMo – Lenora Molinion, Bre – Březina, Stoz – Stožecké louky, Chlum – Chlum, Nov – Nová Pec. Different symbols are used to distinguish sites of different biotopes.

subtypes of this habitat can be found depending on local habitat conditions, depending upon the content of nutrients and soil moisture. In drier subtypes of this habitat, especially on steeper slopes and grazed areas, sparse vegetation is often formed, in which some drought tolerant species can occur (e.g. *Thesium pyrenaicum, Antennaria dioica*). In wetter sites (e.g. at the edges of transitional peatlands or in areas with higher precipitation), moisture-loving species are more common. *Arnica montana, Gentiana pannonica* (Hofhanzlová and Křenová 2007; Ekrtová 2013) and other iconic species of this habitat grow. We can also find a wide range of orchids (e.g. *Gymnadenia conopsea*, *Pseudorchis albida*) in richer *Nardus* meadows.

The degradation of stands due to abandonment or machine mowing reduce the number of species and support increasing abundance of dominants. In SAC Šumava, 2053 hectares of this habitat are mapped.

Molinion meadows

Biotope T1.9 is the habitat 6410 – M*olinia* meadows on calcareous, peaty or clayey-silt laden soils (*Molinion caeruleae*). In the past, these alternately moist *Molinia* meadows were quite abundant (for example within the montane floodplain of the Upper Vltava River; Sádlo and Bufková 2002). These meadows were primarily late, single-mown meadows. In some traditionally managed sites, their water regime was modified with shallow drainages. During the second half of the 20th century, the *Molinia* meadows have degraded and gradually transformed into other types of vegetation. Many *Molinion* meadows have been disturbed by deep drainages, fertilization or inappropriate mowing times. A bluegrass (*Molinia coerulea*), a diagnostic species, can even be missing in strongly degraded meadows where other dominants are common. Mowing twice a season as well as abandonment of these meadows cause degradation of the habitat quality and decrease of species diversity.

This vegetation type occurs on a nutrition gradient between richer *Arrhenatherum* meadows and oligotrophic pastures. On a hydrological gradient, the *Molinia* meadows are between wet *Cirsium* meadows and oligotrophic peatlands. Certain endangered species (e.g. *Dianthus superbus, Gentiana pneumonanthe*) can occur in these

meadows. Currently, only 36 hectares of this biotope occur in SAC Šumava.

Fen meadows

Biotope R2.2 belongs to the habitat 7140 – Transition mires and quaking bogs. These meadows, both with lower or higher species diversity, are primarily lower to medium-high grasslands with predominant sedges. Mosses are a critical aspect of this habitat and their cover is gradually decreasing with increasing soil humidity. The variability of this habitat is considerable in the Bohemian Forest region. Fen meadows are formed on acidic substrates, in nutrient-poor places with mineral substrates, during initial stages of paludification. With optimal development and conditions, fen meadows are short grasslands, with a predominance of herbs or sedges, but without a significant dominant. Change of water regime (i.e. drainages) and overgrowing with shrubs and trees are major threats to this habitat. A total of 575 hectares of this habitat are currently mapped in SAC Šumava.

Design of monitoring and data analyses

In each of sixteen study sites, paired permanent plots with analogous vegetation were set side by side. Pairs were planned as managed and unmanaged (i.e. control) plots, which in the original concept was to represent an unmown meadow and a meadow mown with an appropriate technique considered optimal in terms of the meadow phenology at the time. However, mowing has occasionally been replaced by grazing in some sites, or the plots intended to be regularly managed have remained unmown in some years. For this reason, in statistical analyses, plots were differentiated according to the planned management (treatment – MngYES / MngNO) and their actual management (mown / unmown), if necessary.

Table 1 Parameters recorded during monitoring and used in statistical analyses.

Parameter	Description
E_{total} [%] – Total cover	Total vegetation cover in a permanent plot.
E_0 [%] – Moss cover	Moss cover in a permanent plot.
Number of species	The number of all plant species recorded in a permanent plot.
Diversity [%]	% of species from the total number of species recorded in all localities of the given habitat (i.e. for T2.3B, T1.9 and R2.2 separately)
Treatment MngYES / MngNO	A categorical variable. MngYES = a plot designated to be managed, MngNO = a plot designated as a control plot, without management.
Management MOWN / UNMOWN	A categorical variable. MOWN = planned management, mowing chiefly performed; UNMOWN = management not performed.

The plots are 4 × 4 m and separate by a four-meter gap between plots to avoid an edge effect. The areas are marked with wooden sticks in the field. Blue stick marked plots are designated as managed, and unmanaged (i.e. control) plots are marked with red sticks. Permanent plots were established in seven study sites (Knížecí Pláně, Mechov, Stožecké louky, Šindlov, Velký Bor, Zadní Bor 1, Zadní Bor 2) in 2014 and monitoring of another nine study sites (Březina, Filipova Huť, Chlumské stráně, Kvilda Vilémov, Lenora Molinion, Lenora Markovec, Nová Pec, Zhůří near Rejštejn, and Žďárek) began in 2016. In this paper, we analyze data from 2014 and 2016–2020.

Annually, phytosociological relevés are performed in all plots, according to the combined Braun-Blanquet scale (Moravec 1994). Coverage values are recorded in percentages. Monitoring always took place at the end of June or the beginning of July, to capture approximately the same phenological phase of meadow vegetation. Recorded data (Table 1) were analyzed separately for each of the target Natura 2000 habitats.

We recorded the total number of species in the monitored plots and the diversity, calculated as a % of species out of the total number of species recorded in all localities of the given habitat. We tested differences among study sites and in the case of statistically significant differences, a subsequent comparison of study sites was performed (post-hoc comparison, Bonferroni test). We also tested differences in species abundance, diversity, total coverage (E_{total}) and moss cover (E_0) between plots with different treatment, i.e. planned management (MngYES / MngNO). If the real management differed from the planned management, we also tested differences in the numbers of species, diversity, total coverage (E_{total}) and moss cover (E_0) between plots actually managed and unmanaged (mown / unmown). Repeatedly collected data were evaluated using ANOVA, Repeated measures, General Linear Models in STATISTICA 13.3 (StatSoft, Inc. 2012).

Results

T2.3B – Submontane or montane Nardus meadows without *Juniperus communis*

Monitoring of this biotope was carried out in six study sites (Fig. 1). One of them – the Šindlov study site was monitored beginning in 2014, the other sites were monitored from 2016. The highest number of plant species, 36, was recorded in the managed plot located in the Chlum study site in 2020 (Table 2). The study sites of this biotope differed in the number of recorded species and in diversity, which was expressed as % of species out of the total number of species recorded in all localities of T3.2B biotope (ANOVA, $p < 0.01$; Fig. 2).

There were no statistical differences in diversity and total coverage between managed and unmanaged (i.e. control) plots. Due to the fact that real management differed in some cases from the planned management

Table 2 The T2.3B biotope study sites. The numbers of recorded species and diversity, calculated as a % of species out of the total number of species recorded in all T3.2B biotope study sites, are shown. Mean, maximum (Max) and minimum (Min) values are presented.

Study site	Number of species			Diversity		
	Mean	Max	Min	Mean	Max	Min
Filipova Huť	21.2	29	15	55.8	76.3	39.5
Chlum	32.4	38	29	74.7	92.1	55.3
Kvilda Vilémov	28.4	35	21	81.1	100.0	60.0
Lenora za Markovcem	26.4	30	23	88.0	100.0	76.7
Šindlov	23.8	29	20	82.2	100.0	69.0
Zhůří	8.6	10	7	22.6	26.3	18.4

Table 3 The T1.9B biotope study sites. The numbers of recorded species and diversity, calculated as a % of species out of the total number of species recorded in all T1.9 biotope study sites, are shown. Mean, maximum (Max) and minimum (Min) values are presented.

Study site	Number of species			Diversity		
	Mean	Max	Min	Mean	Max	Min
Březina	33.0	41	26	80.5	100.0	63.4
Lenora Molinion	23.9	28	21	58.3	68.3	51.2
Nová Pec	24.3	31	19	59.3	75.6	46.3

method, we also tested differences between plots actually managed and unmanaged, however, no statistically significant differences were found in this case either.

The total coverage and diversity differed among study sites as well as within some study sites during our study period (Fig. 3). Year-on-year changes varied slightly including variations between managed and unmanaged plots. However, these differences were not statistically significant.

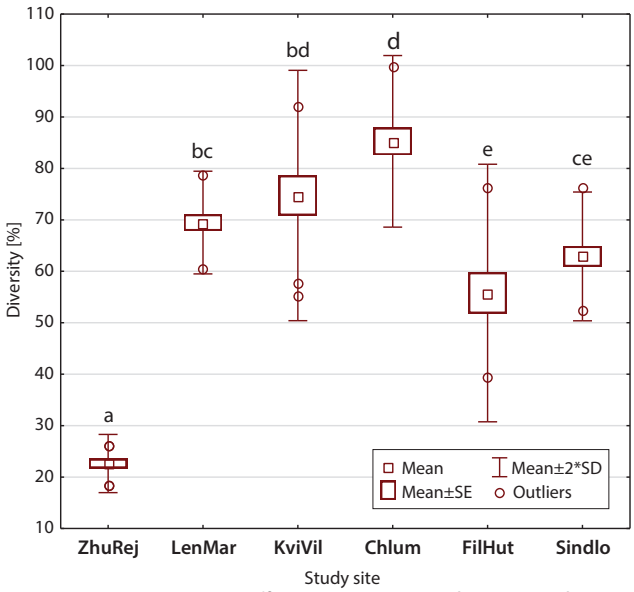


Fig. 2 One-way ANOVA. Differences among study sites in diversity calculated as a % of species out of the total number of species recorded in all T3.2B biotope study sites are shown. Mean values (points), SE (boxes) and SDs (bars) are displayed. Letters above the bars indicate results of post-hoc comparisons; i.e. different letters mark statistically different values. Study sites: ZhuRej – Zhůří near Rejštějn. LenMar – Lenora Markovec, KviVil – Kvilda Vilémov, Chlum – Chlum, FilHut – Filipova Huť, Sindlo – Šindlov.

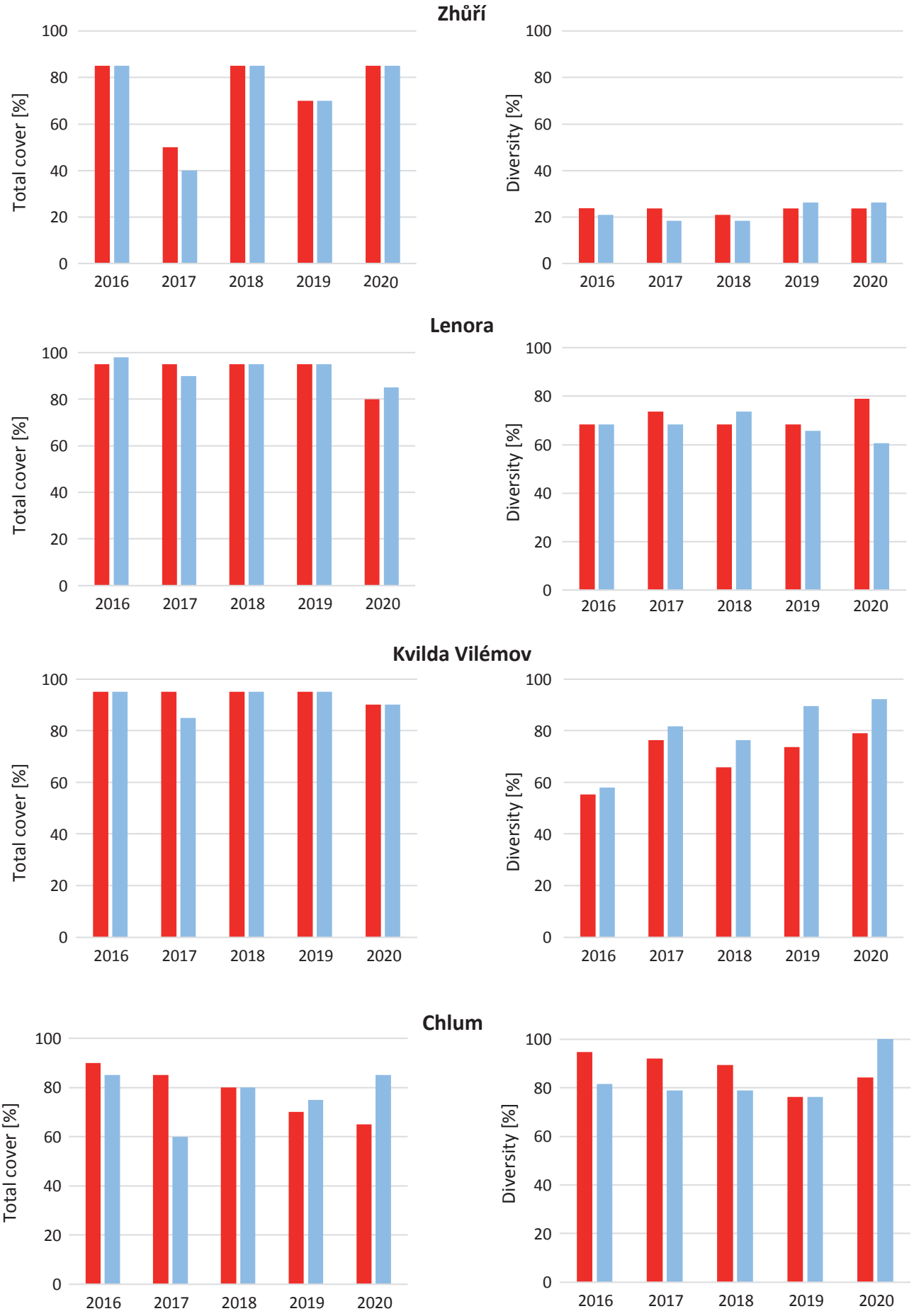
Repeated measures ANOVA analysis failed to reveal the effect of time. No statistically significant differences in diversity, total coverage or moss cover were found during our study period. This applies both to the complete analysis of all monitored plots and to the separately analyzed managed and unmanaged (i.e. control) plots.

T1.9 – Intermittently wet *Molinia* meadows

Monitoring of *Molinia* meadows was carried out in the years 2016–2020 in three study sites (Fig. 1). The highest number of plant species, 41, was recorded in 2017 in the unmanaged plot located in the Březina study site (Table 3).

There were no statistically significant differences in total coverage among the study sites, however statistically significant differences in moss cover and diversity were found (both $p < 0.01$). The highest diversity values were recorded in the Březina study site, which also had the lowest moss cover. The highest moss cover was found in the Nová Pec study site.

With regard to the fact that in 2017, 2018, 2019 and 2020 the plots determined as managed were not mowed in the Lenora Molinion study site, analyses of differences between plots with different treatments, i.e. planned management (MngYES / MngNO) were useless and comparisons of plots with different real management (mown / unmown) were performed. There were no statistically significant differences in the total coverage between mown and unmown plots. However, a comparison of mown and unmown plots revealed statistically significant differences in moss cover ($p < 0.01$; Fig. 4) and diversity ($p < 0.05$; Fig. 5). The mown plots showed significantly higher moss cover and diversity.


Zhůří
Total cover [%]
Diversity [%]
Lenora
Total cover [%]
Diversity [%]
Kvilda Vilémov
Total cover [%]
Diversity [%]
Chlum
Total cover [%]
Diversity [%]
0
20
40
60
80
100
2016
2017
2018
2019
2020

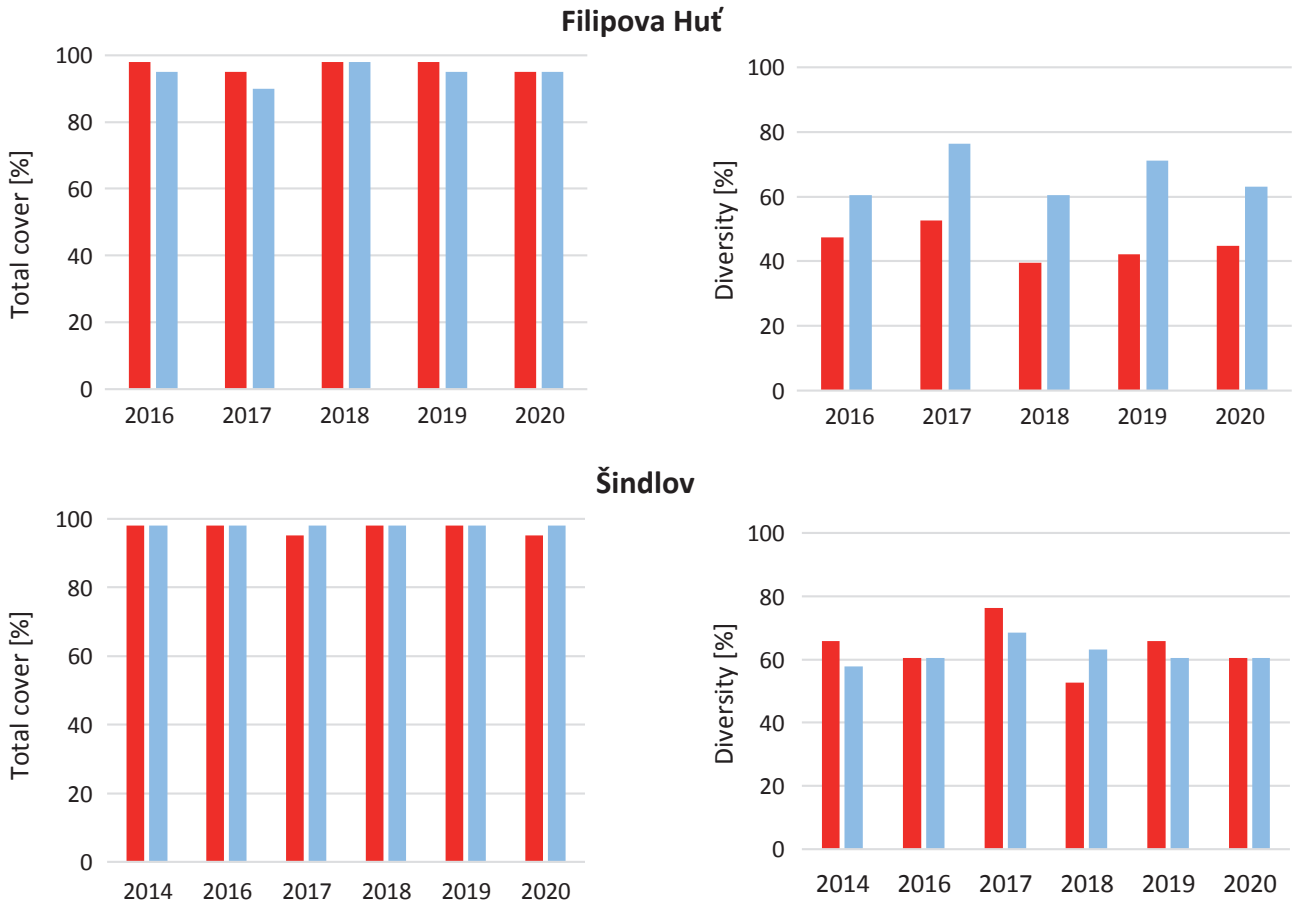


Fig. 3 Total coverage and diversity recorded in study sites in 2014 and 2016–2020. Red columns – unmanaged (i.e. control) plots, blue columns – managed plots.

Because a statistically significant effect of time was found, repeatedly measured analyses were performed. Analysis of repeated measurements of total coverage showed statistically significant differences between mown and unmown plots over time ($p < 0.001$; Fig. 6). The cover both in mown and unmown areas was quite high over the years, reaching values of 95–98%. Nevertheless, it significantly increased in 2020 in unmown plots, especially in the Nová Pec study site where it was only 80% (Fig. 7).

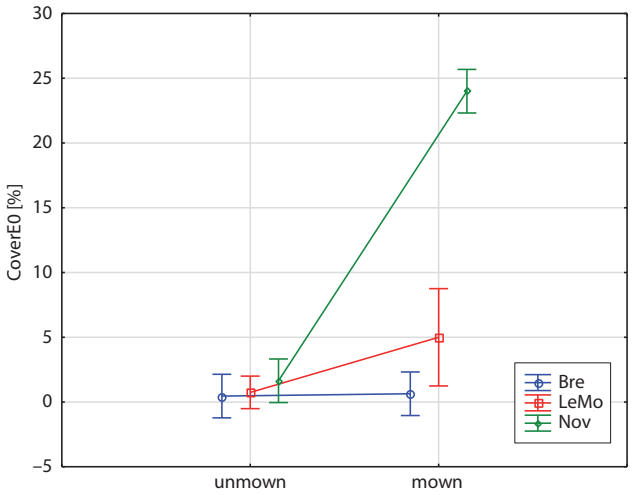


Fig. 4 Moss cover recorded in unmown and mown plots located in study sites of T1.9 biotope: Bre – Březina, LeMo – Lenora Molinion, Nov – Nová Pec. Mean (points) and 95% confidential intervals (bars) are shown.

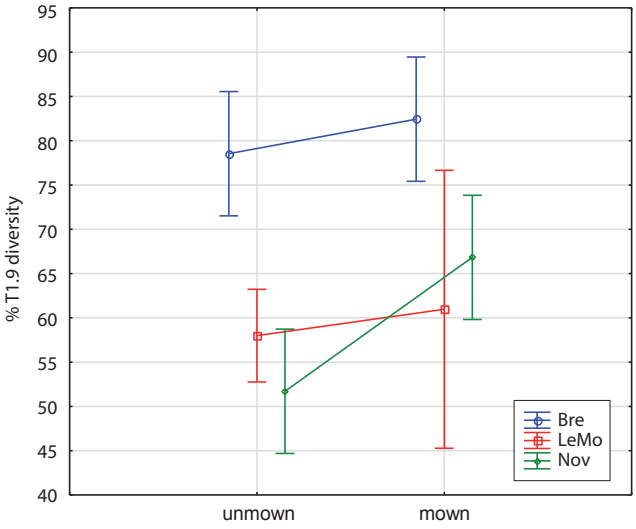


Fig. 5 Diversity recorded in unmown and mown plots located in the T1.9 biotope study sites: Bre – Březina, LeMo – Lenora Molinion, Nov – Nová Pec. Mean (points) and 95% confidential intervals (bars) are shown.

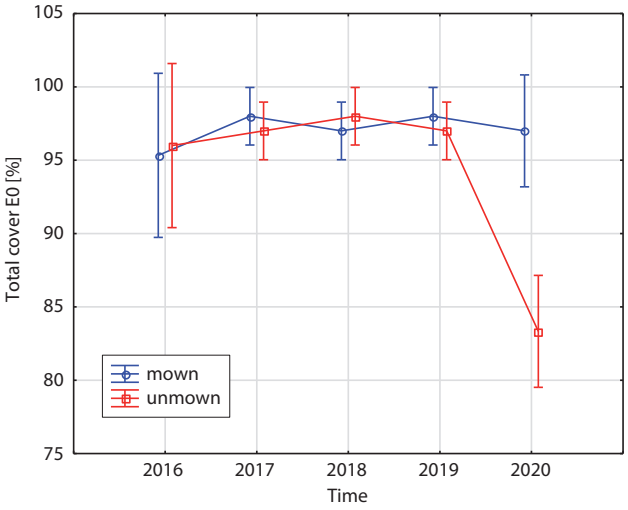


Fig. 6 Total coverage recorded in unmown and mown plots located in the T1.9 biotope study sites. Mean (points) and 95% confidential intervals (bars) are shown.

Additionally, moss cover significantly differed between mown and unmown plots during our study period ($p < 0.05$; Fig. 8). Lower moss cover was found in unmown plots in all study sites. The largest differences were recorded in the Nová Pec study, where the moss cover in the mown plot reached 20–25%, but in the unmown (control) plot decreased from 7% in 2016 to 0.1% in 2017 and slightly increased to 1% in 2020. Significant differences in the moss cover between the mown and unmown plots were recorded at Březina locality too. No significant differences in moss cover were found in the Lenora study, which was left without regular management since 2017.

No statistically significant differences in biodiversity between mown and unmown plots were found in all three-study sites (Figs. 7, 9). The smallest differences in diversity between managed and unmanaged plots were recorded in the Lenora study site, where the plot designated for regular management was mown only in 2016

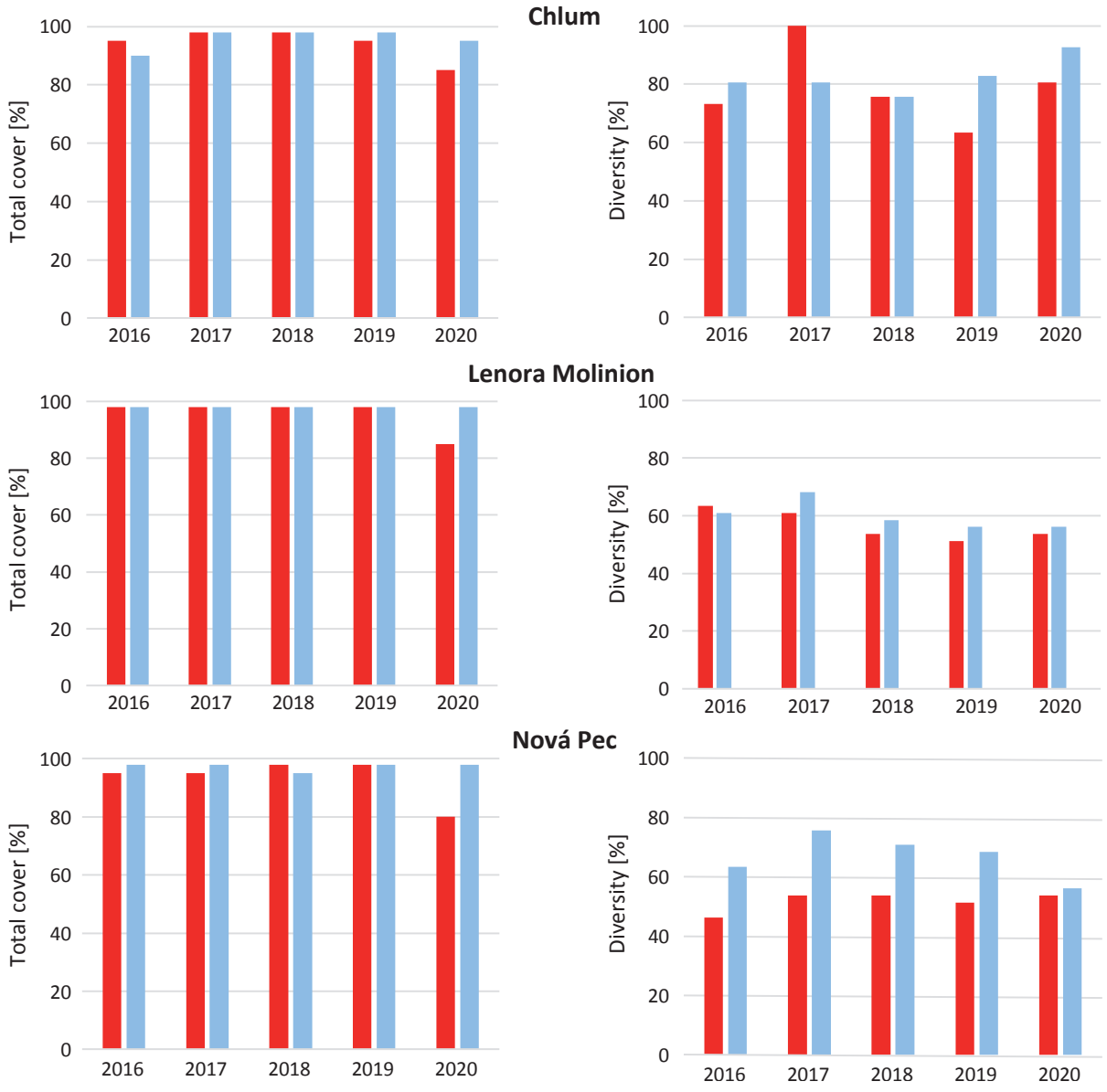


Fig. 7 Total coverage and diversity recorded in study sites in 2014 and 2016–2020. Red columns – unmanaged (i.e. control) plots, blue columns – managed plots.

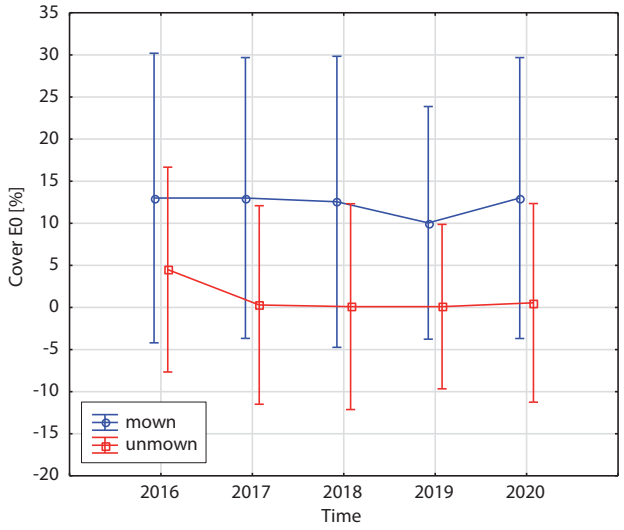


Fig. 8 Moss cover (Eo) in mown (blue) and unmown (red) plots in T1.9 biotope study sites. Mean (points) and 95% confidential intervals (bars) are shown.

and left unmanaged since that year. In the Nová Pec study site, the diversity of the mown plot slowly decreased during the study period. The largest variation in diversity was recorded in the Březina study site, both in the mown and unmown plot.

R2.2 – Acidic moss-rich fens

Seven study sites of this biotope were monitored in 2014 and 2016–2020 (Fig. 1). The highest number of plant species, 40, was recorded in 2014 in the unmanaged (control) plot in the Velký Bor study site (Table 4).

Statistically significant differences in total coverage ($p < 0.05$, Fig. 10), moss cover and diversity (both $p < 0.001$, Figs 11, 12) were found among the study sites.

Repeated measures ANOVA showed statistically significant differences in moss cover ($p < 0.05$; Fig. 13) and biodiversity ($p < 0.01$; Fig. 14) between managed and unmanaged plots during our study period. In cases of total

Table 4 The R2.2B biotope study sites. The numbers of recorded species and diversity calculated as a % of species out of the total number of species recorded in all R2.2 biotope study sites are shown. Mean, maximum (Max) and minimum (Min) values are presented.

Study site	Number of species			Diversity		
	Mean	Max	Min	Mean	Max	Min
Knížecí Pláně	32.7	37	28	32.7	37	28
Mechov	25.8	29	21	25.8	29	21
Stožecké louky	19.8	22	16	19.8	22	16
Velký Bor	33.8	40	31	33.8	40	31
Zadní Bor 1	28.0	35	21	28.0	35	21
Zadní Bor 2	25.8	30	21	25.8	30	21
Žďárek	31.5	36	28	31.5	36	28

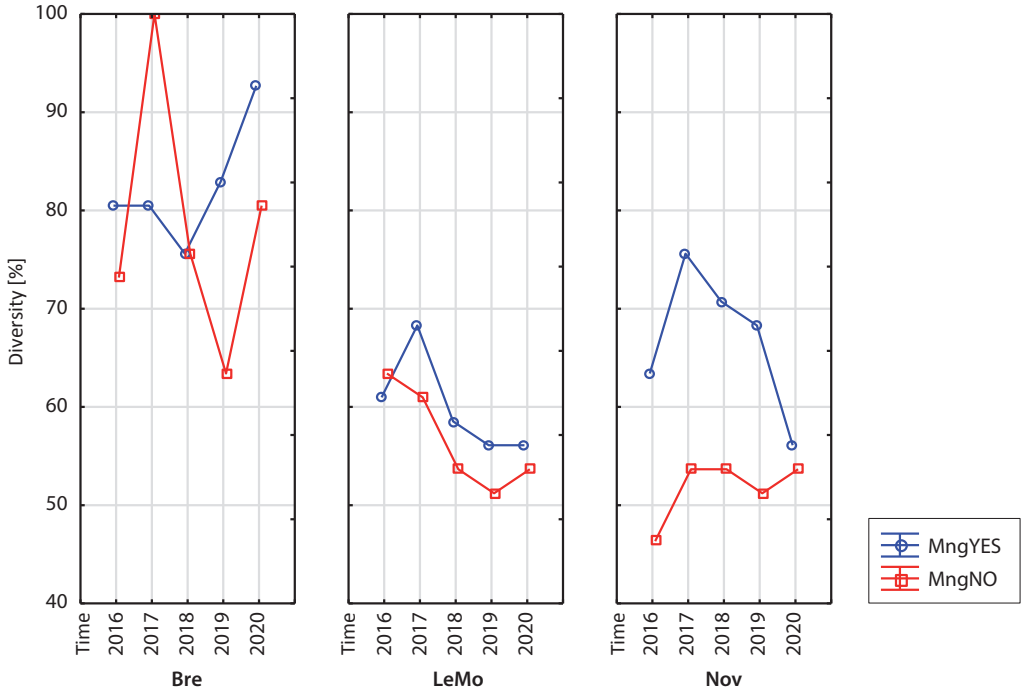


Fig. 9 Biodiversity of unmanaged (MngYES, blue) and unmanaged (MngNO, red) plots in T1.9 biotope study sites: Bre – Březina, LeMo – Lenora Molinion, Nov – Nová Pec. A plot designated as managed in the Lenora Molinion site was left unmown since 2017.

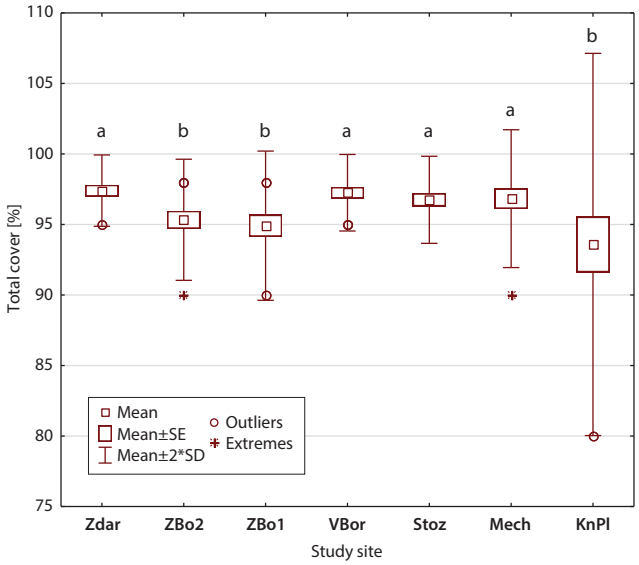


Fig. 10 One-way ANOVA. Differences among study sites in total cover are shown. Mean values (points), SE (boxes) and SDs (bars) are displayed. Letters above the bars indicate results of post-hoc comparisons; i.e. different letters mark statistically different values. Localities: Zdar – Žďárek, ZBo2 – Zadní Bor 2, ZBo1 – Zadní Bor, VBor – Velký Bor, Stoz – Stožecké louky, Mech – Mechov, KnPl – Knížecí Pláně.

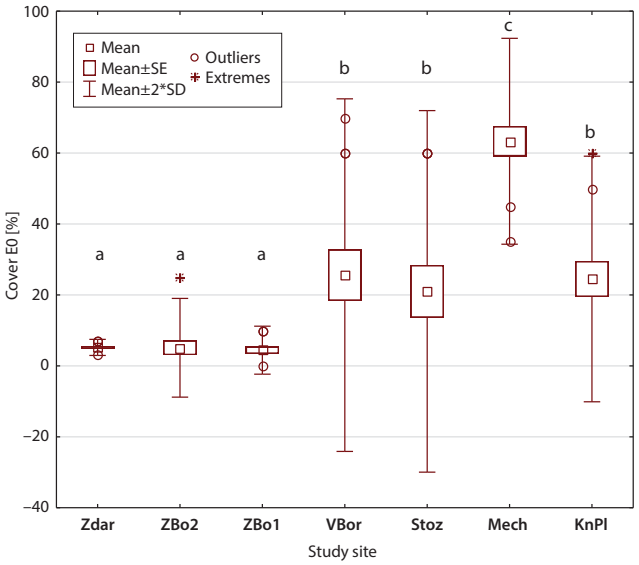


Fig. 11 One-way ANOVA. Differences among study sites in moss cover are shown. Mean values (points), SE (boxes) and SDs (bars) are displayed. Letters above the bars indicate results of post-hoc comparisons; i.e. different letters mark statistically different values. For names of localities see Fig. 10.

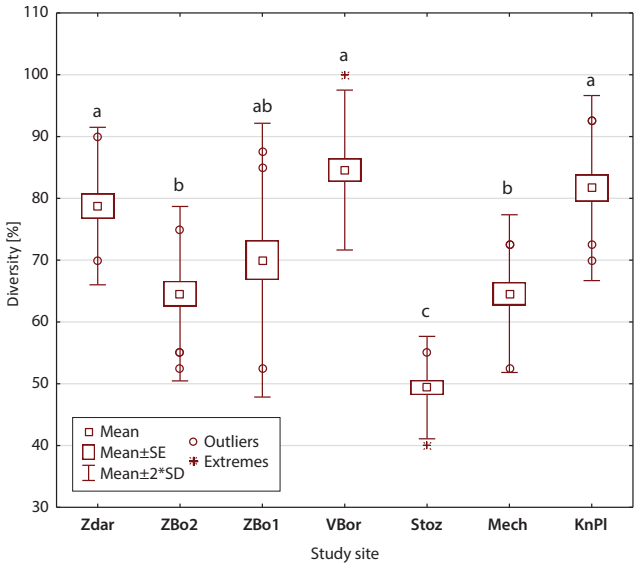


Fig. 12 One-way ANOVA. Differences among study sites in diversity calculated as a % of species out of the total number of species recorded in all R2.2 biotope study sites are shown. Mean values (points), SE (boxes) and SDs (bars) are displayed. Letters above the bars indicate results of post-hoc comparisons; i.e. different letters mark statistically different values. For names of localities see Fig. 15.

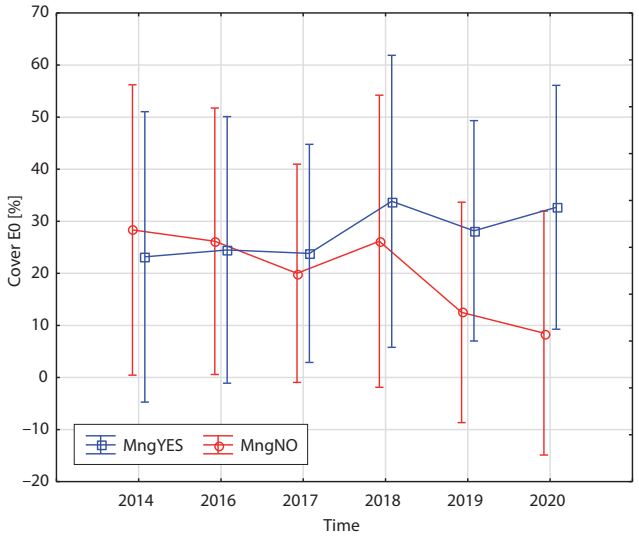


Fig. 13 Moss covers (Eo) in managed (MngYES, blue) and unmanaged (MngNO, red) plots in R2.2 biotope study sites. Mean (points) and 95% confidential intervals (bars) are shown.

coverage, no statistically significant differences between managed and unmanaged plots were found.

The moss cover differed significantly among the study sites (Figs 11, 15) as well as between managed and unmanaged plots within single study sites (Figs 13, 15). In the Zadní Bor 1 and Žďárek study sites, the moss cover did not exceed 10% during the entire monitoring period. On the contrary, the moss cover was approximately 80% in the Mechov and Velký Bor study sites. Different study sites varied in moss cover during our study period. For example, in the Knížecí Pláně study site, which was planned for mowing but remained unmown in 2019 and 2020, the moss cover increased. Similar trends were recorded in the Stožecké louky study site, where the plot, planned to be managed, was left unmown in 2019 and 2018. In this case, the 10% moss cover recorded in 2014

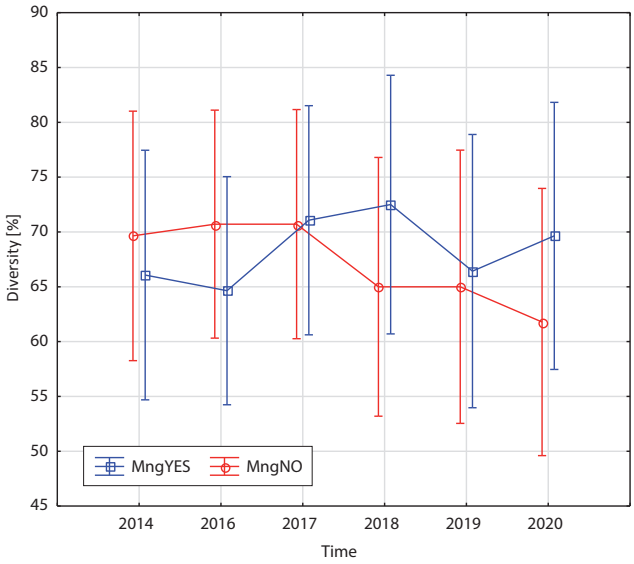


Fig. 14 Diversity in managed (MngYES, blue) and unmanaged (MngNO, red) plots in R2.2 biotope study sites. Mean (points) and 95% confidential intervals (bars) are shown.

increased to 60% in 2018–2020. At the same locality, the moss cover in the control, unmanaged plot, fluctuated between only 1–3% throughout the monitoring period. Significantly higher moss cover in a control plot, i.e. unmanaged, was recorded in the Velký Bor study site, where 70% of moss cover recorded in 2014 decreased to only 10% in 2020. Moss cover in the managed plot of this study site fluctuated between 5–15% during the entire study period.

Study sites differed in their diversity calculated as a % of species recorded in all R2.2 biotope study sites (Figs 12, 15). The highest diversity was found in the Velký Bor study site, where 40 plant species were found in the unmanaged plot in 2014 when monitoring began. In 2020, only 33 species were recorded in the same plot. Its paired managed plot hosted 31–34 plant species during the entire study period. With a few exceptions, there were no significant differences in the diversity of managed and unmanaged plots within single study sites. The Zadní Bor 1 and Žďárek study sites showed slightly higher diversity in the managed plots. Diversity slightly increased in managed plots in the Knížecí Pláně and Stožecké louky study sites, however, these plots were unmown in 2019 and 2020.

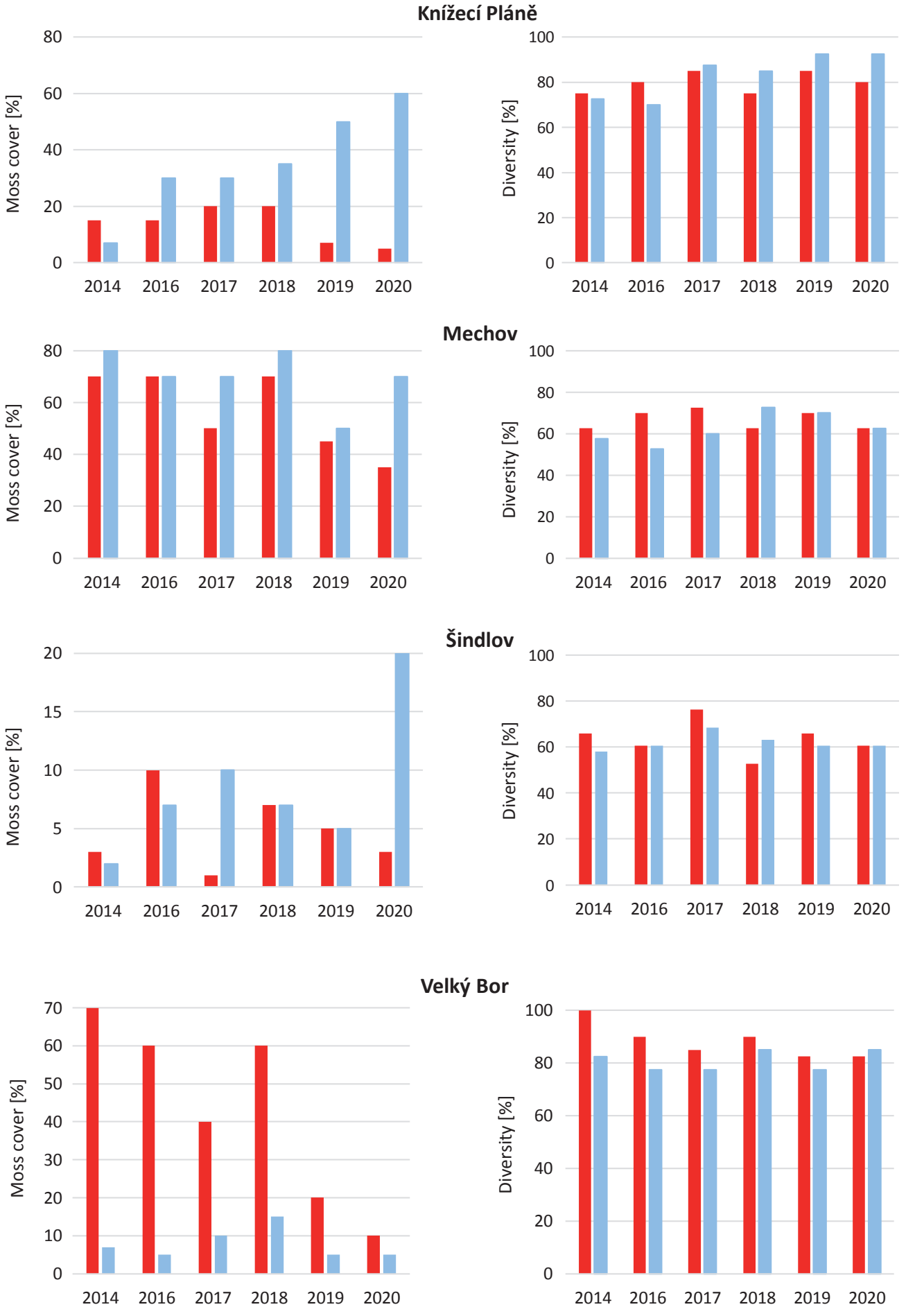
Discussion

Several gaps and changes in regular management of meadows, where permanent plots were located, partly affected the results of this study (Table 5). There were various reasons for missing seasonal mowing, usually logistical obstacles faced by the owners or tenants of these meadows. These consequences are discussed in detail for individual types of meadow habitats.

Logistical obstacles and lack of capacity partly limited the design of our monitoring too. To avoid the effect of subjective evaluation, a team of only two highly experienced botanists collected data from all study sites during the entire study period. Because of this time-consuming fieldwork, no replications of monitored pair plots could be set in each study site. We believe that despite these shortcomings in monitoring design, the results of this preliminary study elucidate numerous relevant findings and experiences.

Analyzes of data from the **T2.3B biotope** study sites confirmed our field observations and experiences. There are significant differences among the monitored study sites, which are caused both by geographical differences among the study sites (discrete altitudes, hydrological and soil conditions etc.) and by their differing management histories. However, our results from a majority of study sites show that thorough management is necessary for successful conservation of this biotope. Mowing, a combination of grazing and mowing, grazing, or grazing with mowing of the remainder are considered suitable management practices for the *Nardus* grasslands (Háková et al. 2000; Korzeniak 2016). Machine mowing is insufficient to improve the condition of the habitat and increase species diversity, as it leaves grass insufficiently cropped, with grass litter remaining onsite. Careful digging and removal of biomass is crucial. During machine hay raking, the moss layer is usually not disturbed sufficiently and thus no gaps occur, a requirement for regeneration of many plant species. Therefore, some authors suggest using rotators to support the creation of gaps in dense *Nardus* meadows (Kurtogullari et al. 2019).

There was an increase of biodiversity, particularly in the managed plot recorded in the Kvilda Vilémov study site, which was mowed in 2016 and 2019 and grazed in 2017, 2018 and 2020, each year at a different time. This result could indicate that a combination of mowing and grazing can support biodiversity of the T2.3B biotope. The Filipova Huť and Chlum study sites were mown only in 2016 and 2017. They have been unmanaged since 2018 (Table 5). However, the changes in these two sites were ambiguous. In the Filipova Huť study site, (planned but unmown since 2018), plot diversity fluctuated slightly year to year. However, this plot's diversity was slightly higher than in the unmanaged (control) plot from the beginning until the end of the monitoring period. A different situation was recorded in the Chlum study sites, unmanaged since 2018. In this study site, total coverage increased with the end of management, with 38 species recorded in 2019. It was the highest number of species recorded in monitored plots of the T2.3B biotope. Species from the surrounding unmanaged areas of the study site (e.g. *Calluna vulgaris*, *Lembotropis nigricans*) have invaded the previously mown area. There were also problems with appropriate management in the Lenora and Šindlov study sites, which were mown according to plan in 2016–2018, but in 2019 and 2020 only the monitored plots were


Knížecí Pláně
Moss cover [%]
Diversity [%]
Mechov
Moss cover [%]
Diversity [%]
Šindlov
Moss cover [%]
Diversity [%]
Velký Bor
Moss cover [%]
Diversity [%]
2014
2016
2017
2018
2019
2020

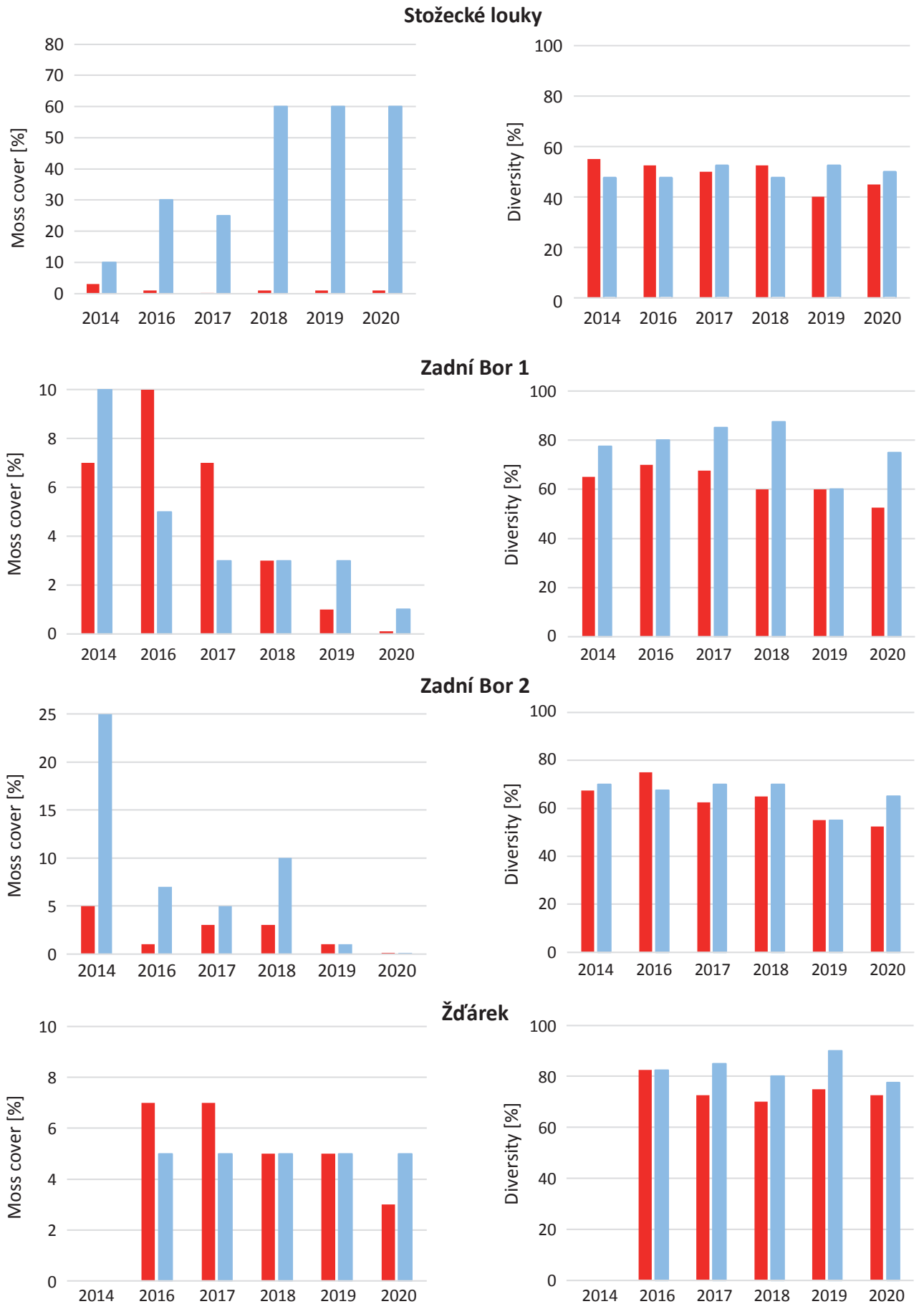


Fig. 15 Moss cover and diversity recorded in study sites in 2014 and 2016–2020. Red columns – unmanaged (i.e. control) plots, blue columns – managed plots. Different scales were used for y-axes to improve visibility of moss cover.

Table 5 Real management measures applied in plots with planned mowing in 2014, 2016 – 2020. M – mown, G – grazed, 0 – without management.

	Study site	2014	2016	2017	2018	2019	2020	Notes
T2.3B	Filipova Huť		M	M	0	0	0	
	Chlum		M	G	0	0	0	unmown only grazed in May 2017
	Kvilda Vilémov		M	G	G	M	G	unmown only grazed in Aug 2017, Oct 2018, Sep 2020
	Lenora Markovec		M	M	M	M	M	
	Šindlov	M	M	M	M	M	M	
	Zhůří near Rejštejn		M	M	M	M	G	only machine mowing in 2019
T1.9	Březina		M	M	M	M	M	
	Lenora Molinion		M	0	0	0	0	
	Nová Pec		M	M	M	M	M	
R2.2	Knížecí Pláně	M	M	M	M	0	0	
	Mechov	M	M	M	M	0	M	
	Stožecké louky	M	M	M	M	0	0	
	Velký Bor	M	M	M	M	M	0	
	Zadní Bor 1	M	M	M	0	M	0	
	Zadní Bor 2	M	M	M	0	M	0	
	Ždárek		M	M	M	M	M	

hand mown (Table 5). The Zhůří site is the most disparate from this group of study sites. This is a former fallow, which was managed irregularly after the end of plowing in the 1990's. The site was mown by hand in 2016–2018, machine mown in 2019 and not mowed but grazed by sheep in September 2020. The increase of diversity here has been very gradual – from 21% in 2016 to 26.3% in 2020. One of the central problems is the lack of diasporas of the target species, chiefly due to the large area of this site and very slow spread of seeds (e.g. through ants).

We can summarize that regular mowing, raking and a mix of mowing and grazing are the best measures for *Nardus* meadows. In the Kvilda and Lenora study sites, we note that good management can improve the condition of grasslands. The Šindlov and Filipova Huť study sites host more or less stable plant communities and with management no significant changes will likely occur. However, without maintenance management, negative changes – particularly a decline in species diversity – could occur in ten or more years.

In the **T1.9 biotope**, it is obvious that the three monitored study sites each show marked differences. The Březina study site represents a species-richer drier type of *Molinion* meadow, the Lenora Molinion study site is a floodplain type and the Nová Pec study site is a poor acidic type. Unfortunately, management of these *Molinion* meadows has been poor, without the regular mowing and high-quality biomass excavation considered crucial for this type of habitat (Kulik 2014). The Lenora Molinion study site was mown only in 2016 and left unmanaged since 2017. This is why the results on the unmown plot and the plot planned to be mown differ little. This locality has to be excluded from some analyses.

In the Nová Pec study, higher diversity was recorded in the managed plot than in the control plot, however there has been a partial decrease in the managed plot since 2018. A possible cause is a change in management methods, noted in the quality of litter raking.

Diversity slightly increased in the mown plot located in the Březina study site, which was the only regularly mown T1.9 biotope during the entire study period. This study site shows lower cover of mosses since the beginning of monitoring. However, we found a statistically significant difference in moss cover and diversity between mown and unmown plots during the study period. In this study site, the mown plot showed higher moss cover and higher diversity. Differences of moss cover between mown and unmown plots were not as significant as found in the Nová Pec study site. Diversity recorded in the mown plot located in the Březina study site slowly increased during our study period – from 80.5% in 2016 to 93% in 2020.

Our study results and field experience show that current management, recently carried out in the monitored *Molinion* meadows (T1.9 biotope), does not effect species diversity significantly. We surmise that inconsistent and poor quality management explain this situation. Experience from other areas, for example SAC Boletice (Vydrová and Grulich 2018), shows that regular mowing positively affects species diversity. With well-executed management, differences in the species richness of *Molinion* meadows should be visible and recordable after several (three-five) years.

The largest group of study sites, seven, were assigned to the **R2.2 biotope** – fen meadows. Monitoring of fen meadows began in 2014, in 2015 the monitoring was suspended and from 2016 to 2020 the areas were monitored

annually. In the case of fen meadows, the planned management was imperfectly performed in all study sites in each year. Some plots, which were planned to be managed, were not mown one or more times during the entire study period (Table 5).

We found differences in the total coverage, the moss cover and diversity among study sites. They differ in their abiotic conditions (principally hydrology), history of management and human intervention (drainages etc.).

The Knížecí Pláně, Velký Bor and Žďárek study sites are in relatively good condition, with only slight degradation. These species-rich sites are also more stable, so changes are likely to be slow. The Mechov study site represents a different vegetation type (transitional mire) with a significantly higher moss cover. In the long term, it will be appropriate to monitor the spread of *Carex brizoides* in this site. The Stožecká louka study site is of another vegetation type with the strong effect of wetting probably a cause of the lowest species diversity.

The Zadní Bor 1 and 2 study sites are significantly affected by successive changes because their water regime was fundamentally damaged in the past. Their vegetation is unstable and both study sites show a similar trend in the decrease of moss cover during the study period. The results thus far suggest that mowing will probably not have a very large and rapid effect on improving the quality of the habitat in these previously drained study sites. However, the observed changes to date may also be influenced by the fact that in 2018 and 2020 the managed plot was left unmown.

Water regime quality is a crucial parameter for fen meadows (R2.2 biotope), however their restoration is possible (Isselstein et al. 2002; Billeter et al. 2007). Regular and well-executed management must be ensured. Even in sites with only slightly changed water regimes, long-term management is necessary and significant transformation is likely to take several years (five or more). In sites with strong wetting (the Stožecké louky study site), again, high quality management measures are crucial. The results strongly demonstrate the failures of proper management, both in terms of fluctuations in dominants and changes in the moss cover.

Conclusions

We can conclude that appropriate and carefully executed management is a necessary tool for ensuring proper care of conservationally valuable habitats, including grasslands of European importance protected under the Natura 2000 network. Monitoring is an essential tool to observe management quality and improve care. Results of this preliminary study deliver a substantial set of experiences that can be used to improve the management and monitoring of Natura 2000 habitats and other species rich meadows occurring in the Šumava NP.

Acknowledgements

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REFERENCES

Billeter R, Peintinger M, Dieme M (2007) Restoration of montane fen meadows by mowing remains possible after 4–35 years of abandonment. Bot Helv 117: 1–13.

Bláha J, Rumpolt D, Křenová Z (2013) Can Natura 2000 mapping be used to zone the Šumava National Park? Eur J Environ Sci 3: 57–64.

Chytrý M, Blažková D (2007) Třída *Molinio-Arrhenatheretea* Tüxen 1937. In: Chytrý M (ed) Vegetace České republiky. 1. Travinná a keříčková vegetace, Academia, Praha, pp 166–168.

Chytrý M, Kučera T, Kočí M (eds) (2001) Katalog biotopů České republiky. Agency for Nature Conservation and Landscape Protection of the Czech Republic.

Chytrý M, Kučera T, Kočí M, Grulich V, Lustyk P (eds) (2010) Katalog biotopů České republiky. 2nd ed. Agency for Nature Conservation and Landscape Protection of the Czech Republic.

Ekrtová E (2013) Co se můžeme dozvědět o historii výskytu hořce panonského (*Gentiana pannonica*) v centrální oblasti Šumavy z jeho současného rozšíření, stanovištních vazeb a historického využívání krajiny. Zprávy Čes Bot Společ 48: 293–324.

Hájková P, Roleček J, Hájek M, Horsák M, Fajmon K, Polák M, Jamrichová E (2011) Prehistoric origin of the extremely species-rich semi-dry grasslands in the Bílé Karpaty Mts (Czech Republic and Slovakia). Preslia 83: 185–204.

Háková A, Klaudisová A, Sádlo J (eds) (2004) Zásady péče o nelesní biotopy v rámci soustavy Natura 2000. PLANETA: roč. XII, č. 8., MŽP, Praha.

Härtel H, Lončáková J, Hošek M (eds) (2009) Mapování biotopů v České republice. Východiska, výsledky, perspektivy. Agency for Nature Conservation and Landscape Protection of the Czech Republic.

Hofhanzlová E, Křenová Z (2007) Pollination strategy and reproductive success of *Gentiana pannonica* in natural population. Silva Gabreta 13: 83–94.

Isselstein J, Tallowin JRB, Smith REN (2002) Factors affecting seed germination and seedling establishment of fen-meadow species. Rest Ecol 10: 173–184.

Korzeniak J (2016) Mountain *Nardus stricta* grasslands as a relic of past farming – The effects of grazing abandonment in relation to elevation and spatial scale. Folia Geobotanica 51: 93–113.

Křenová Z, Kindlmann P (2015) Natura 2000 – Solution for Eastern Europe or just a good start? The Šumava National Park as a test case. Biol Conserv 186: 268–275.

Křenová Z, Kindlmann P (2018) Transboundary cooperation – the best way to share common responsibility for future. In: Suratman MN (ed) National Parks – Management and Conservation. InTechOpen, pp 35–53.

Kurtogullari Y, Rieder N, Arlettaz R, Humbert J-Y (2019) Conservation and restoration of *Nardus* grasslands in the Swiss northern Alps. Appl Veg Sci 23: 26–38. doi: 10.1111/avsc.12462.

Moravec J (1994) Fytocenologie (Nauka o vegetaci). Academia, Praha.

Sádlo J, Bufková I (2002) Vegetation of the Vltava river alluvial plain in the Šumava Mts (Czech Republic) and the problem of relict primary meadows. Preslia 74: 67–83.

StatSoft, Inc. (2012) Electronic Statistics Textbook. Tulsa, OK: StatSoft. http://www.statsoft.com/textbook

Sundseth K, Creed P (2008) Natura 2000: protecting Europe's biodiversity. Office for Official Publications of the European Commission, Luxemburg.

Vydrová A, Grulich V (2018) Rekonstrukční management bezkolencových luk ve VÚ Boletice. In: Jongepierová I, Pešout P, Prach K (eds) Ekologická obnova v České republice II. 1. vyd. Praha: Agentura ochrany přírody a krajiny České republiky, pp 102–106.

Záruba V, Koblasa P (2000) Šumava. Místopisný slovník. Vlastním nákladem, České Budějovice.

Appendix 1: Habitats that are subject to protection in SAC Šumava. Priority habitats are marked by *. Grassland habitats are in bold.

Code	Habitats of Annex I of Habitats Directive	Biotop units for mapping (see Chytrý et al. 2001, 2010)
3130	Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*	M2.2 – Annual vegetation on wet sands M3 – Vegetation of perennial amphibious herbs V6 – *Isöetes* vegetation
3150	Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* – type vegetation	V1 – Macrophyte vegetation of naturally eutrophic and mesotrophic still waters
3160	Natural dystrophic lakes and ponds	V3 – Macrophyte vegetation of oligo lakes and ponds
3260	Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	V4A – Macrophyte vegetation of water streams with currently present aquatic macrophytes
4030	**European dry heaths**	T8.2B – Secondary submontane and montane heaths without *Juniperus communis*
5130	***Juniperus communis* formations on heaths or calcareous grasslands**	T8.2A – Secondary submontane and montane heaths with *Juniperus communis*
6230*	**Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and submountain areas, in Continental Europe)**	T2.1 – Subalpine *Nardus* meadows T2.3B – Submontane or montane *Nardus* meadows without *Juniperus communis*
6410	**M*olinia* meadows on calcareous, peaty or clayey-siltladen soils (*Molinion caeruleae*)**	T1.9 – Intermittently wet *Molinia* meadows
6430	**Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels**	A4.2 – Subalpine tall-forb vegetation A4.3 – Subalpine tall-fern vegetation T1.6 – Wet *Filipendula* grasslands
6510	**Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*)**	T1.1 – Mesic *Arrhenatherum* meadows
6520	**Mountain hay meadows**	T1.2 – Montane *Trisetum* meadows
7110*	**Active raised bogs**	R3.1 – Open rised bogs R3.3 – Bog hollows
7120	**Degraded raised bogs still capable of natural regeneration**	R3.4 – Degraded raised box
7140	**Transition mires and quaking bogs**	R2.2 – Acidic moss-rich fens R2.3 – Transition mires
8220	Siliceous rocky slopes with chasmophytic vegetation	S1.2 – Chasmophytic vegetation of siliceous cliffs and boulder screes A6B – Acidophilous vegetation of alpine cliffs
9110	*Luzulo-Fagetum* beech forests	L5.4 – Acidophilous beech forests
9130	*Asperulo-Fagetum* beech forests	L5.1 – Herb-rich beech forests
9180*	*Tilio-Acerion* forests of slopes, screes and ravines	L4 – Ravine forests

Appendix 2: Study sites. A description of the study sites, their brief histories, management and phytosociological classification following Moravec (1994) are presented together with positions of permanent plots, their codes, GPS coordinates and elevations.

Name	**Březina**	Code	Bre	Biotope	T1.9
GPS coordinates	48°53´58.78˝N, 13°50´55.54˝E			Elevation [m a.s.l.]	754
The study plots, located on a gentle SE slope above the Vltava river floodplain, were established in 2016. Vegetation type corresponds to the *Junco effusi-Molinietum caeruleae* ass., Tüxen 1954. The area is without significant wetting, grasses dominate here. The canopy is tall, uniform, without visible gaps nor open spots. In the past, this meadow was likely mowed regularly. Currently, machine mowing is applied. No significant negative effects were recorded here.					
Name	**Filipova Huť**	Code	FilHut	Biotope	T2.3B
GPS coordinates	49°01´47.62˝N, 13°31´16.4˝E			Elevation [m a.s.l.]	1105
The study plots, established in 2016, are located on a gentle slope with a south exposition between a main road and the Filipohuťský creek. Local vegetation is close to the *Festuco capillatae-Nardetum strictae* ass., Klika et Šmarda 1944. In the past, drainages likely disturbed the water regime of this site. More intensive management measures were applied before the Šumava NP was established. The area is without visible wetting, the canopy is lower with predominate grasses. Currently, machines are used for mowing. The eutrophication effects coming from the nearby road were detected in the area, however, not yet within our study plot. Some larger grass species, e.g. *Dactylis glomerata*, have expanded from the road ditches.					
Name	**Chlumské stráně**	Code	Chlum	Biotope	T2.3B
GPS coordinates	48°51´46.51˝N, 13°54´18.36˝E			Elevation [m a.s.l.]	764
The study plots, established in 2016, are located on a gentle SW slope above the Vltava river floodplain. It is in the vicinity of a biotope T8.2B – *Secondary submontane and montane heaths*. Local vegetation is classified as a transition between the *Campanulo rotundifoliae—Dianthetum deltoidis* ass., Balátová-Tuláčková 1980 and *Vaccinio-Callunetum vulgaris* ass., Büker 1942. The vegetation is not homogeneous. In the past, the site was likely grazed. The site was damaged by drought in 2019 and strongly marked by game in 2020. The NP Administration has failed to ensure regular management of this site since 2018.					
Name	**Knížecí Pláně**	Code	KnPl	Biotope	R2.2
GPS coordinates	48°57´27.8˝N, 13°37´44.6˝E			Elevation [m a.s.l.]	990
The study plots, established in 2014, are located on a NNE gentle slope above the Vltavský creek. Vegetation corresponds to the *Caricetum nigrae* ass., Braun 1915. There are visible remnants of old drainages (created before 1945), apparently this site was grazed or harvested for litter. The canopy is homogeneous, dense, with predominant sedges and grasses. Currently, machines are used for mowing of the site. However, the remains of unharvested grass and litter remain.					
Name	**Kvilda – Vilémov**	Code	KviVil	Biotope	T2.3B
GPS coordinates	49°0´42.7˝N, 13°35´18.27˝E			Elevation [m a.s.l.]	1139
The study plots, established in 2016, are located on a steep south slope above a local road from Kvilda to Borová Lada, in the Vltava river valley. The vegetation corresponds to the *Campanulo rotundifoliae — Dianthetum deltoidis* ass., Balátová-Tuláčková 1980. This historically grazed grassland was mown with machines in 2016 and 2019 and sheep-grazed in 2017, 2018, and 2020. The canopy is a quite tall and dense. Grasses predominate and members from the *Apiaceae* family are abundant too. The current expansion of *Arrhenatherum elatius* indicates eutrophication, probably a result of air pollution.					
Name	**Lenora – Molinion**	Code	LeMo	Biotope	T1.9
GPS coordinates	48°54´49.69˝N, 13°49´23.42˝E			Elevation [m a.s.l.]	751
The study plots, established in 2016, are located in the Vltava floodplain and the Olšinka creek flows nearby. Vegetation is approaching the *Junco effusi-Molinietum caeruleae* ass., Tüxen, 1954. In the past, the site was most likely mowed. The canopy is tall, very dense; patches of grasses, sedges and herbaceous plants alternate. The site was flooded in 2019. Machines are used for mowing of this site, however some unmown segments together with decomposed litter are very common here.					
Name	**Lenora – za Markovcem**	Code	LenMar	Biotope	T2.3B
GPS coordinates	48°54´37.37˝N, 13°47´14.02˝E			Elevation [m a.s.l.]	769
The study plots, established in 2016, are located on a gentle NW slope above the Řasnice river floodplain. The vegetation is classified as the *Festuco capillatae-Nardetum strictae* ass., Klika and Šmarda 1944. Historically, the site was probably grazed and some intensification of management were tried before 1990. The canopy is dense and lower grass species predominate here. Currently, machine mowing is applied. Collecting of hay is imperfect and litter accumulates on the site.					
Name	**Mechov**	Code	Mech	Biotope	R2.2
GPS coordinates	49°05´04.0˝N, 13°27´37.5˝E			Elevation [m a.s.l.]	848
The study plots, established in 2014, are located on a gentle W slope between the Vchynice-Tetov floating channel and the Plavební creek. Vegetation was classified as the *Caricetum nigrae* ass., Braun 1915. In the past, this site was probably mowed for litter. Historical interventions in the water regime are evident. *Carex brizoides* spreads from the edges of this site. Currently, machine mowing is used, nevertheless collecting of hay and removing of litter is imperfect.					

Name	**Nová Pec – Molinion**	Code	Nov	Biotope	T1.9
GPS coordinates	48°47´38.72˝N, 13°56´34.46˝E			Elevation [m a.s.l.]	730
The study plots, established in 2016, are located on a flat terrace above the Jezerní creek floodplain. Vegetation is classified as the *Junco effusi-Molinietum caeruleae* ass., Tüxen 1954. It is a drier and species-poorer type of this association. In the past, the site was probably regularly mown, then abandoned, and a succession of woody species began. *Carex brizoides* invades this meadow too. Currently, the site is mown with machines; hay and litter are not carefully removed.					
Name	**Stožecké louky**	Code	Stoz	Biotope	R2.2
GPS coordinates	48°52´24.9˝N, 13°48´21.9˝E			Elevation [m a.s.l.]	805
The study plots, established in 2014, are located in a flat spring area near the Mlýnský creek. Vegetation is classified as the transition between the *Caricetum nigrae* ass., Braun 1915 and *Sphagno recurvi-Caricetum rostratae* ass., Steffen 1931. In the past, the site was likely mowed for litter and the water regime modified. A succession of tall vegetation (e.g. *Filipendula ulmaria, Scirpus sylvaticus* and *Carex brizoides*) has began since the site was abandoned. The canopy is tall, medium dense, species of the *Cyperaceae* family are common. Machine mowing of this site commenced in 2014.					
Name	**Šindlov**	Code	Sindlo	Biotope	T2.3B
GPS coordinates	49°01´28.9˝N, 13°39´28.9˝E			Elevation [m a.s.l.]	936
The study plots, established in 2014, are located on a terrace between the Vydří and Studený creeks. The vegetation is close to the *Festuco capillatae-Nardetum strictae* ass., Klika and Šmarda 1944. It is a species-poorer type of this association. The canopy is homogeneous over a large area, medium-high, medium-dense. The site is mown with machines.					
Name	**Velký Bor**	Code	VBor	Biotope	R2.2
GPS coordinates	49°06´15.2˝N, 13°25´24.2˝E			Elevation [m a.s.l.]	838
The study plots, established in 2014, are located on a gentle SE slope above the Křemelná river. Vegetation was classified as the *Caricetum nigrae* ass., Braun 1915. This is a species-richer type of the association with a dense canopy. In the past, the site was likely mowed for litter. Old drainages are still visible and partially functional. Currently, machines are used for mowing of this site.					
Name	**Zadní Bor 1**	Code	ZBor1	Biotope	R2.2
GPS coordinates	49°09´24.2˝N, 13°21´28.6˝E			Elevation [m a.s.l.]	857
The study plots, established in 2014, are located on a gentle SE slope above the nameless right-hand tributary of the Křemelná river. The vegetation is classified as a degraded type of the *Caricetum nigrae* ass., Braun 1915. In the past, this large area was drained and managed as a litter meadow. The flow of the nameless stream was artificially deepened and many drainages are connected to it. Machines are used for mowing of this site, nevertheless quality of management is poor. Repeatedly, large unmown segments and much unremoved litter were observed on this site.					
Name	**Zadní Bor 2**	Code	ZBor2	Biotope	R2.2
GPS coordinates	49°09´26.5˝N, 13°21´26.3˝E			Elevation [m a.s.l.]	859
The study plots, established in 2014, are located on a gentle SE slope above the nameless right-hand tributary of the Křemelná river, close to the plot ZBor1. The vegetation is classified as the *Caricetum nigrae* ass., Braun 1915, a degraded type. In the past, this large area was drained and mown for litter. The flow of the unnamed stream was artificially deepened and many drainages were connected to it. Machines are used for mowing of the site, nevertheless management is poor. Repeatedly, large unmown segments and much unremoved litter were observed on this site.					
Name	**Zhůří u Rejštejna**	Code	ZhuRej	Biotope	T2.3B
GPS coordinates	49°04´56.4˝N, 13°33´30.2˝E			Elevation [m a.s.l.]	1146
The study plots, established in 2016, are located on a gentle W slope above the road Horská Kvilda – Rejštejn. The vegetation can be classified as an uncertain type of the *Violion caninae* ass., Schwickerath in 1944. Species diversity is low, grasses dominate and dicotyledonous plants are rare. The area was plowed up until about 1990 and then abandoned for 30 years. Machine mowing was applied in 2016–2018. In 2019, the whole site (including a control plot) was grazed by sheep. Sheep grazing took place again in 2020; the control plot remained untouched.					
Name	**Žďárek**	Code	Zda	Biotope	R2.2
GPS coordinates	48°55´33.89˝N, 13°38´50.9˝E			Elevation [m a.s.l.]	1051
The study plots, established in 2016, are located on a gentle SSE slope in a spring area of the Židovský creek valley. The vegetation is classified as the *Caricetum nigrae* ass., Braun 1915. It is a species rich community. The canopy is dense, without gaps. In the past, the site was probably mown for litter. Several old drainages exist at the edges of this site. At present, machines are used for mowing of this site.					