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The Species Diversity of Grasslands in the Middle Wieprz Valley (PLH060005) Depending on Meadow Type and Mowing Frequency

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1. Introduction

Permanent grasslands cover about 21% of agricultural land in Poland (about 35% in Europe) and are the main sanctuary of biological diversity in agricultural areas. The sustainability of these grassland communities depends on their utilisation (cutting or grazing), i.e. the harvesting of biomass. However, according to the National Environmental Monitoring conducted in the years 2007-2012, the assessment of the conservation status of most natural habitats and many plant species occurring in agricultural areas yields unfavourable results. The predominant status of meadow, grassland and peat-bog habitats is unsatisfactory (U1) or bad (U2) (Program… 2015). The Middle Wieprz Valley (Dolina Środkowego Wieprza, PLH060005) comprises a mosaic of habitats with varying moisture levels, which is conducive to the occurrence of varied plant communities (Stamirowska-Krzaczek 2008, Warda et al. 2013). As many as 80% of the habitats in Poland undergo transformations due to natural processes such as plant succession or synanthropisation. The unfavourable changes in biological diversity result from natural biotic and abiotic processes caused by changes in land use (Czyż et al.

2013, Grzegorczyk et al. 1999, Kulik et al. 2017, Norderhaug 2000). The reduction or abandonment of use of meadows and pastures is a particularly negative influence. These changes lead to decreasing floristic diversity of meadow communities (Baryła & Urban 1999, Kryszak et al. 2010), manifested in the reduced numbers of species forming the particular communities (Kryszak et al. 2007, Kulik et al. 2016, Stypiński & Grobelna 2000) or disappearance of characteristic species of typical plant communities (Myśliwy & Bosiacka 2009) as well as increased presence of species that previously occurred sporadically (Kotańska et al. 2016, Ratyńska et al. 2007, Stamirowska-Krzaczek 2015, Warda et al. 2018).

The study objective was to assess the diversity of the species composition of selected grassland communities in different habitat conditions, depending on the frequency of mowing (0, 1 and 2).

2. Material and methods

2.1. The study area

The studies were conducted on grasslands in the middle Wieprz valley. The Wieprz river in its middle course is a natural, highly meandering river and is a right-hand tributary of the Vistula. Meadows are mainly associated with the floodplain of the Wieprz valley (Janiec & Rederowa 1992). The Wieprz Middle Valley is situated in the Nadwieprzański Landscape Park (Lublin Region). The meadow complex covers approximately 25% of the Park area (Stamirowska-Krzaczek 2008). A Natura 2000 area (PLH060005) was established in 2008 to protect the natural values of the meadows and slopes of the Wieprz valley within the Park.

2.2. Field study

Phytosociological investigations of grasslands in the middle Wieprz valley were carried out in 2017 (before the first cut: 3rd decade of May – 1st decade of June, and supplemented in July and August) using the Braun-Blanquet method (1964). Phytosociological relevés were made of an area of 25 m^2, representative of meadow phytocoenoses (Dzwonko 2007). The investigations focused on the vegetation of wet meadows *Molinietalia* order (mainly *Alopecuretum pratensis*, *Cirsietum rivularis*, *Deschampsia caespitosa* community), hay (fresh) meadows *Arrhenatheretalia* order (mainly *Arrhenatheretum elatioris*), meadows with communities of the *Molinio-Arrhenatheretea* class forming a mosaic, with species from both of the above-mentioned orders (e.g. *Poa pratensis-Festuca rubra* community), and rush meadows *Phragmitetea* class (mainly *Phalaridetum arundinaceae*, *Caricetum gracilis*, *Phragmitetum australis*). The types of meadows under study covered areas of varying size; hence the number of phytosociological

relevés varied (respectively: 24, 44, 74 and 23). The adopted nomenclature of species was according to Mirek et al. (2002) while the taxonomy and nomenclature of communities according to Matuszkiewicz (2008). The 2-cut meadows were mowed after June 1 or 15 in the first cut and usually in August in the second cut. The 1-cut meadows were mowed usually after June 15 or July 1. The abandoned meadows were not mowed for a long time.

Apart the on-the-ground phytosociological investigations, an aerial studies with gyrocopter use before first regrowth and in September were carried out. The remote detection system is mounted on an ultralight gyrocopter flying at low altitudes, thanks to which it provides high-resolution images. Combined with data obtained from the gyrocopter, the on-the-ground data prepared in this study will enable a more precise assessment of the degradation of meadows in a spatial distribution in the Middle Wieprz Valley.

2.3. Data analysis

The floristic diversity of the grassland communities was determined based on two indices, namely the number of species (SN) and the Shannon-Wiener index H′ ($H' = \sum_{i=1}^{SN} p_i \ln (p_i)_i$, where p_i denotes cover-abundance by species i). In order to detect statistically significant differences between the obtained values of these indices for the particular grasslands (taking into account the research factors), a variance analysis was carried out, taking into account the Linear Model (LM) for the Shannon-Wiener index and a Generalised Linear Model (GLM) for the number of species on the assumption of the Poisson distribution of this variable. If significant differences were found in the values of the diversity indices due to one of the examined factors, Tukey's multiple comparison tests were carried out post hoc for non-equipotent groups. The aim of the tests was to indicate between which specific combinations (meadow type x utilisation frequency) statistically significant differences occur with regard to their species diversity.

In addition, a Multidimensional principal component analysis (PCA) (Jolliffe 2002) was carried out to detect the variation of the analysed dataset with regard to the values of the ecological indices (Ellenberg et al. 1992). Climatic conditions (L – light, T – temperature, K – continentality) and edaphic conditions (F – moisture, R – soil reaction, N – nitrogen content) were taken into account in the assessment. The method made it possible to identify the factors that differentiated the studied communities the most. Furthermore, it enabled the visualisation of these differences according to grassland community and mowing frequencies. Owing to the similar scale of the indices, the covariance matrix was used to estimate the components. The analyses were conducted using the R statistical software. The *vegan* library was used to compute the value of the Shannon-Wiener index, and the *rcompanion* library was used to analyse the multiple comparisons for counted observations.

3. Results and discussion

The number of plant species is the basic index of floristic diversity of grassland communities (Kostuch 1995). The results of the conducted (2017) phytosociological survey concern condition of the vegetation of the *Molinio-Arrhenatheretea* class, *Molinietalia* and *Arrhenatheretalia* order and *Phragmitetea* class. In the grassland under study, the value of this parameter varied depending on the type of meadow and mowing frequency (Table 1).

Table 1. Ranges of species number in the selected meadow communities

Cutting frequency	*Arrhenatheretalia*	*Molinietalia*	*Molinio-Arrhenatheretea*	*Phragmitetea*
0	18-23	14-31	15-23	3-25
1	22-34	13-27	15-32	4-21
2	25-37	26-37	15-29	1-19

Meadows with vegetation of the *Arrhenatheretalia* order had the greatest number of species. Furthermore, the number of species was found to increase with the growing frequency of use. The species composition of traditional hay meadows is the result of a complex combination of abiotic and biotic factors, management regimes, continuity of management and varying dispersal conditions (Norderhaug 2000). The least numerous communities occurred in rush meadows (*Phragmitetea* class). A more frequent use of the sward of these communities led to a decreased number of species. With reference to the research results discussed in an earlier study (Warda et al. 2018), the vegetation cover of rush meadows occurring in the Middle Wieprz Valley underwent small changes. In the other communities under study, no specific trends were observed with regard to changes in the number of species in the more frequently cut meadows.

As was the case with the number of species, the highest values of the Shannon-Wiener index were found in meadow communities representing the *Arrhenatheretalia* order, and the lowest values – communities of the *Phragmitetea* class. The scopes of the observed numbers of plant species and the obtained Shannon-Wiener index values are shown in box plots in Fig. 1 and 2.

The box plots take into account the types of meadows and cutting frequency as well as the combination of meadow type x cutting frequency. In general, both indices of floristic diversity have similar trends although certain differences occur between the specific groups of the analysed values.

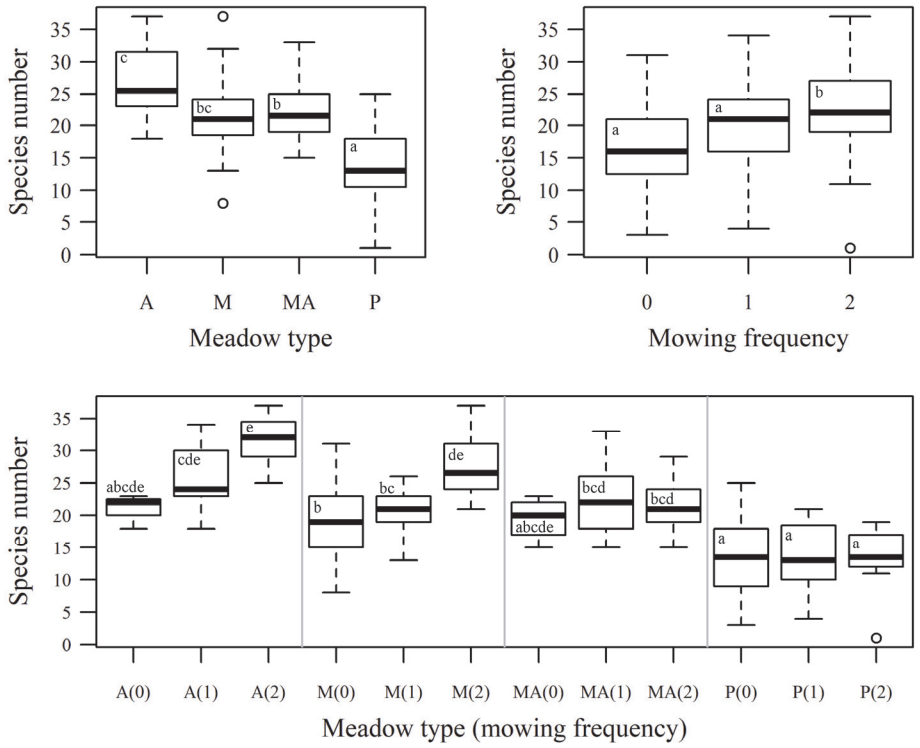

Fig. 1. Box plots for the number of species different letters indicate significant differences at $p < 0.05$; A - *Arrhenatheretalia*, M - *Molinietalia*, MA – *Molinio-Arrhenatheretea*, P - *Phragmitetea*

The investigation results concerning the number of species and Shannon-Wiener index values were processed statistically. A variance analysis was carried out; its results are presented in Table 2. They indicate a significant influence of both research factors (meadow type and cutting frequency) on the floristic diversity of the communities under study. The interaction between these factors was recognised as statistically significant in the case of species number, and insignificant in the case of the Shannon-Wiener index (even though it was close to being significant with $p = 0.07$).

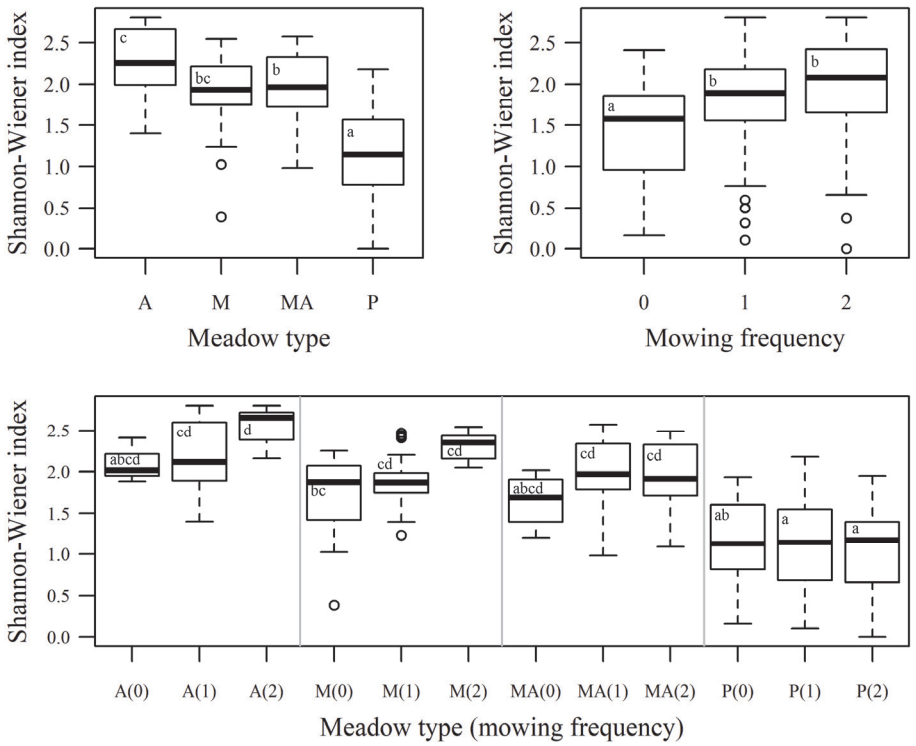

Fig. 2. Box-plots for values of the Shannon-Wiener index different letters indicate significant differences at $p < 0.05$; A - *Arrhenatheretalia*, M - *Molinietalia*, MA – *Molinio-Arrhenatheretea*, P - *Phragmitetea*

The statistical tests used in the species diversity assessment of the grassland communities under study confirmed the biggest significant differences between communities of the *Arrhenatheretalia* order and *Phragmitetea* class ($p < 0.0001$ for both indices). In the case of cutting frequency, significant differences in diversity always occur between the vegetation of unused meadows (no cutting) and meadows cut twice ($p = 0.0031$ for the number of species, $p < 0.0001$ for the Shannon-Wiener index). The assessment results for meadows cut once was different, however. Based on the number of species, these meadows are in the same homogeneous group as uncut meadows, while based on the Shannon-Wiener index, they are in the same group as meadows cut once. Homogeneous groups, i.e. groups similar in terms of floristic diversity indices, were marked with letters on box plots 1 and 2. The analysis of homogeneous groups divided into communities (grassland) and cutting frequency (lower diagrams on Fig. 1 and 2) indicate that

the biggest influence of cutting frequency on the increased species diversity occurred in meadows with communities of the *Arrhenatheretalia* and *Molinietalia* order, and the lack of influence was observed in meadows with communities of the *Phragmitetea* class. However, the multiple comparison tests confirm the correlation only in the case of communities of the *Molinietalia* order. This, however, can result from the fact that some subgroups (community x cutting frequency) are not numerous, which results in long confidence intervals and the groups being indistinguishable based on floristic diversity indices.

Table 2. Variation analysis for the number of species and values of the Shannon-Wiener index

Species number (GLM)						
Factor	Likelihood ratio		DF	Chi	*p*-value	
Type (T)	21.728		3	138.67	0.00007	**
Mowing frequency (MF)	10.403		2	13.65	0.00551	**
T * MF	19.700		6	19.70	0.00313	**
Shannon-Wiener index (LM)						
	SS	DF	MS	F	*p*-value	
Intercept	366.37	1	366.37	1935.13	<0.0001	**
Type (T)	24.80	3	8.26	43.66	<0.0001	**
Mowing frequency (MF)	1.59	2	0.79	4.19	0.0166	*
T *MF	2.24	6	0.37	1.97	0.0718	
Error	35.97	190	0.19			

** significant differences at level α=0.01 * significant differences at level α=0.05
T – meadow type (A, M, MA, P)

The deterioration of meadow communities is manifested in the reduced numbers, cover-abundance and, subsequently, disappearance of characteristic species (Warda et al. 2018). Unfavourable changes in the species composition of communities start with the primary syntaxon, i.e. a plant community, and progress in communities of a higher order in the phytosociological hierarchy if they are still affected by unfavourable factors. This leads to a change of the plant formation. The degenerative changes in meadow communities observed in the study area are have reached an advanced stage because the species characteristic of an order are already disappearing and the number of class indicator species is decreasing (Faliński 1991).

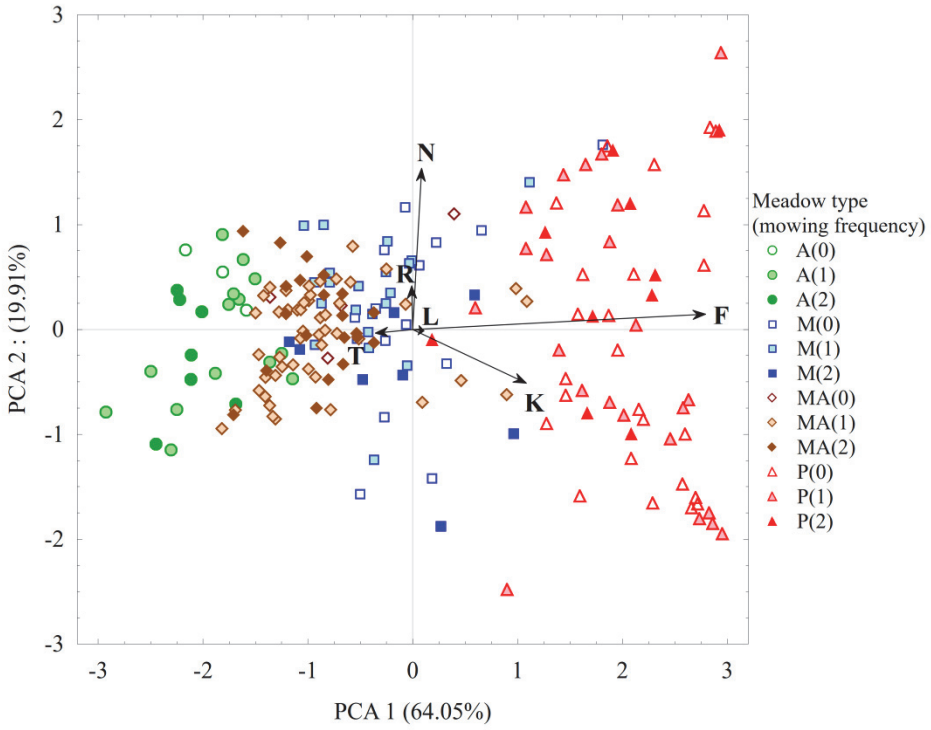

Fig. 3. PCA ordination graph for different types of communities based on Ellenberg's indices

In addition, a multidimensional principal component analysis (PCA) was carried out to detect the variation of the analysed dataset with regard to the conditions of occurrence of the studied grassland communities, described by values of the ecological indices. The PCA indicated that the first two principal components account for about 84% of the variation of the dataset (including, respectively, the first component, PCA1, accounts for 64%, and the second component, PCA2, accounts for 20%). The values of the first component are most closely linked with the values of the humidity index (F) and, to a smaller degree, the continentality index (K). Habitat humidity is the main factor determining the type of community and its species diversity. The values of the second component are most closely linked with the values of the soil nitrogen index (N). The ordination graph of the analysed communities, obtained by means of PCA, is presented in Fig. 3. An analysis of the data on the graph confirms that the communities are most distinguishable according to the values of the first component (linked with the values of the soil humidity index). The highest values of this component were

obtained for communities of the *Phragmitetea* class, while the lowest – for communities of the *Arrhenatheretalia* order. Communities of the *Molinietalia* order are concentrated around the centre of the coordinate system determined by the principal components, while communities of the *Molinio-Arrhenatheretea* class share the characteristics of wet and fresh meadows. In addition, the ordination diagram indicates that the group of meadows of the *Phragmitetea* class is more diverse floristically due to the values of the second principal component (the differential of PCA2 values is twice as big). This is indicates the significance of soil nitrogen content for the diversity of the analysed group of communities. The results of the analysis do not confirm the influence of the manner of meadow utilisation on the values of the principal components. The points referring to the communities with different cutting frequencies cover similar areas of the graph within the individual meadow community types.

4. Conclusions

The phytosociological investigations were carried out in 2017 on the grasslands in the Middle Wieprz Valley. The floristic diversity of the grassland communities was determined based on two indices, namely the number of species (SN) and the Shannon-Wiener index H′. The investigations focused on the vegetation of wet meadows (*Molinietalia* order), hay (fresh) meadows (*Arrhenatheretalia* order), meadows with other communities of the *Molinio-Arrhenatheretea* class, and rush meadows (*Phragmitetea* class).

Similar trends were observed in the case of the number of species and the Shannon-Wiener index values. These indices varied depending on the type of meadow and mowing frequency.

Meadows with vegetation of the *Arrhenatheretalia* order had the greatest number of species. Furthermore, the number of species was found to increase with the growing frequency of use. The least numerous communities occurred in rush meadows (*Phragmitetea* class). A more frequent use of the sward of these communities led to a decreased number of species.

The results of a variance analysis indicate a significant influence of both research factors on the floristic diversity of the grasslands under study. The biggest significant differences were confirmed between meadow vegetation of the *Arrhenatheretalia* order and *Phragmitetea* class. The biggest influence of cutting frequency on the increased species diversity occurred in meadows with communities of the *Arrhenatheretalia* and *Molinietalia* order.

According to a multidimensional principal component analysis (PCA) indications, habitat humidity is the main factor determining the type of meadow community and its species diversity.

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Abstract

The studies were conducted on grasslands in the middle Wieprz valley in 2017. The aim of study was to assess the diversity of the species composition of selected grassland, depending on the frequency of mowing. The investigations focused on the meadow vegetation of *Molinietalia* order, *Arrhenatheretalia* order, the *Molinio-Arrhenatheretea* class and *Phragmitetea* class. The floristic diversity of the grassland communities was determined based on two indices, namely the number of species (SN) and the Shannon-Wiener index H′. In order to detect significant differences between the obtained values of these indexes for the particular grasslands (taking into account the research factors),

a variance analysis was carried out, taking into account the Linear Model (LM) for the Shannon-Wiener index and a Generalised Linear Model (GLM) for the number of species on the assumption of the Poisson distribution of this variable. In addition, a Multidimensional principal component analysis (PCA) (Jolliffe 2002) was carried out to detect the variation of the analysed dataset with regard to the values of the ecological indices (Ellenberg et al. 1992). In the grassland under study, the number of species varied depending on the type of meadow and mowing frequency. Meadows with vegetation of the *Arrhenatheretalia* order had the greatest number of species. Furthermore, the number of species was found to increase with the growing frequency of use. The least numerous communities occurred in rush meadows (*Phragmitetea* class). A more frequent use of the sward of these communities led to a decreased number of species. Similar trends were observed in the case of the Shannon-Wiener index values. A variance analysis was carried out and its results indicate a significant influence of both research factors (meadow type and cutting frequency) on the floristic diversity of the communities under study. The biggest significant differences were confirmed between meadow vegetation of the *Arrhenatheretalia* order and *Phragmitetea* class. The biggest influence of cutting frequency on the increased species diversity occurred in meadows with communities of the *Arrhenatheretalia* and *Molinietalia* order. According to a multidimensional principal component analysis (PCA) indications, habitat humidity is the main factor determining the type of meadow community and its species diversity.

Keywords:
grassland, vegetation, floristic diversity, meadow type, mowing frequency, Middle Wieprz Valley

Różnorodność gatunkowa użytków zielonych w Dolinie Środkowego Wieprza (PLH060005) w zależności od typu łąki i częstotliwości koszenia

Streszczenie

Badania fitosocjologiczne przeprowadzono w 2017 roku na użytkach zielonych w dolinie środkowego Wieprza. Dolina Środkowego Wieprza (PHL060005) stanowi mozaikę siedlisk o zróżnicowanym uwilgotnieniu, co sprzyja występowaniu różnorodnych zespołów roślinnych. Celem badań była ocena zróżnicowania składu gatunkowego wybranych użytków zielonych, w zależności od częstotliwości koszenia. Przedmiotem badań była szata roślinna łąk rzędu *Molinietalia*, *Arrhenatheretalia*, klasy *Molinio-Arrhenatheretea* i *Phragmitetea*. Różnorodność florystyczną badanych zbiorowisk roślinnych oceniono za pomocą dwóch wskaźników, jakimi są liczba gatunków (SN) oraz indeks Shannona-Wienera H′. W celu wykrycia istotnych różnic między uzyskanymi wartościami tych wskaźników dla poszczególnych zbiorowisk (z uwzględnieniem czynników badań) wykonano analizę wariancji z uwzględnieniem modelu liniowego (LM) dla indeksu Shannona-Wienera oraz uogólnionego modelu liniowego (GLM) dla liczebności gatunków przy założeniu rozkładu Poissona tej cechy. Dodatkowo wykonano wielowymiarową analizę głównych składowych PCA (Jolliffe 2002) w celu wykrycia zmienności

analizowanego zbioru danych, ze względu na wartości wskaźników ekologicznych (Ellenberg et al. 1992). Na badanych użytkach zielonych, wartość tego parametru wykazywała zróżnicowanie w zależności od typu łąki oraz częstotliwości koszenia. Łąki porośnięte roślinnością rzędu *Arrhenatheretalia* były najbardziej liczne gatunkowo. Stwierdzono ponadto zwiększanie się liczby gatunków w zbiorowisku wraz z rosnącą częstotliwością użytkowania. Najmniej liczne zbiorowiska występowały na łąkach z roślinnością klasy *Phragmitetea*. Częstsze użytkowanie runi tych zbiorowisk przyczyniało się do zmniejszenia liczby gatunków. Podobne trendy stwierdzono w przypadku wartości indeksu Shannona-Wienera. Wykonano analizę wariancji, której wyniki świadczą o istotnym wpływie obu uwzględnionych czynników (typ łąki oraz częstotliwość koszenia) na zróżnicowanie florystyczne badanych zbiorowisk. Największe istotne różnice potwierdzono między szatą roślinną rzędu *Arrhenatheretalia* i klasy *Phragmitetea*. Największy wpływ częstotliwości koszenia na wzrost różnorodności gatunkowej zaznaczył się na łąkach z roślinnością rzędu *Arrhenatheretalia* i *Molinietalia*. Wskazaniem wielowymiarowej analizy głównych składowych PCA jest, że wilgotność siedliska jest tu głównym czynnikiem decydującym o typie szaty roślinnej i jego zróżnicowaniu gatunkowym.

Słowa kluczowe:
użytki zielone, szata roślinna, różnorodność florystyczna, typ łąki,
częstotliwość koszenia, Dolina Środkowego Wieprza