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Is Grazing Good for Wet Meadows? Vegetation Changes Caused by White-Backed Cattle

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Abstract: Wetland ecosystems are highly productive and valued for numerous reasons including wildlife habitat, biodiversity, water quantity and quality, and human uses. Grazing livestock on wet grasslands can sometimes be controversial due the humidity of the habitat, but on the other hand, it plays an important role in grassland preservation. Therefore, we evaluated the impact of Polish white-backed cattle grazing on changes in the vegetation (13 phytosociological relevés taken in years 2016–2019) of wet meadows as well as forage quality based on the species composition. Biodiversity was estimated based on species richness, Shannon–Wiener diversity and evenness indices, and Rényi diversity profiles. The peatland featured mostly high-sedge and wet meadows communities of the *Magnocaricion* and the *Calthion* alliances. The species and biodiversity indices demonstrated significant rising trends. Extensive grazing resulted in the decreased cover of the dominant species of rush meadows, e.g., the common reed, acute, and tufted sedge. The gaps that had emerged thanks to the reduced cover of the dominant species were filled by meadow plants, which led to increased biodiversity. During the four years of grazing, the cattle obtained satisfactory weight gains, particularly in 2019, which indicates that wet meadows are suitable for grazing and can provide sufficient feed for cattle.

Keywords: pasture; Rényi diversity profile; wetlands; polish cattle breeds; active meadow protection; biodiversity

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1. Introduction

Wetland ecosystems are highly productive and valued for numerous reasons including wildlife habitat, biodiversity, water quantity and quality, and human uses [1,2]. Mowing is the most common form of wet meadow management [2]. Wet meadows provide numerous ecosystem services, including the production of high-quality forage for livestock [3]. Another type of wet meadows use is grazing livestock, but due to the humidity of the habitat, it can sometimes be controversial. Grazing plays an important role in the preservation of many grasslands [4–9]. However, unmanaged, excessive grazing can degrade ecosystems and the associated goods and services [3,10,11].

Since livestock are thought to damage the physical, chemical, and biological integrity of these systems, they are subject to government regulations ranging from seasonal use requirements to complete livestock removal [1].

Cattle grazing, especially when it is intensive, has a great influence on water quality. Summer grazing of cattle on high-altitude pastures causes a significant growth of pathogenic bacteria in the water, regardless of the changing climatic conditions [12].

The removal of livestock grazing resulted in increased levels of nitrate in wetland waters and thus higher levels of nitrate pollution compared with spring grazing [1].

In wet habitats, flood control and grazing are proposed as the best practices that favor vegetation diversity and prevent plant community degradation [5].

The examination of management practices (e.g., prescribed grazing) on a larger, watershed scale, contributes to the development of more effective strategies to strengthen the resilience of these valuable ecosystems [13].

Different wetlands are grazed by all kinds of wildlife as well as by livestock. Grazing has evolved along with these ecosystems and constitutes their integral part. The plants, wildlife, and domestic grazers have adapted and continue to adapt to each other [1].

The effects of grazing in wetlands are manifested, among others, by changes in species diversity and cover [4,9], channel morphology [1], fauna diversity [14], greenhouse gases as well as water quality [12]. Grazing primarily ensures the welfare of animals, affecting their health and condition [7]. Many studies show a different (from positive to negative) effect of grazing animals on wetlands depending on many factors such as the intensity of grazing, stocking, groundwater level, and climatic conditions. This demonstrates the need for long-term studies in different habitats to find trade-offs for different management scenarios and different measured environmental factors [4,7–9,12,13].

The aim of this paper was to evaluate the impact of white-backed cattle grazing on changes in the vegetation of wet meadows. We can ask the following questions: Are wet meadows suitable for grazing? Can they provide sufficient feed for the animals?

2. Materials and Methods

2.1. Study Area

The "Kazicha" peatland complex is located in the Skierbieszów Landscape Park (eastern Poland), in the valley of the Wolica river, near of the town Iłowiec. It covers an area of about 70 ha. The study site is covered primarily by marsh, peat-mud, and mud soils. The climate is characterized by significant annual precipitation totals (550–600 mm), while the average temperature of the year is 7.03 °C. The growing season lasts 214 days, and the snow cover lasts 86 days [15]. The research was conducted in 2016–2019. The basic weather conditions during the study period are presented in Table 1.

Based on meteorological data, the following indicators were estimated: Selyaninov hydrothermal index (K) according to Skowera and Puła [16]. The Selyaninov hydrothermal index is now widely used as the main quantitative indicator of the ratio of heat and moisture [17]. The values of the coefficient are determined by the following formula:

$$K = P/0.1\sum t$$

where P—monthly sum of precipitation (mm); $\sum$t—monthly sum of temperature >0 °C. The coefficient has 10 classes of values [16]: exd—extremely dry $k \leq 0.4$; vd—very dry $0.4 < k \leq 0.7$; d—dry $0.7 < k \leq 1.0$; qd—quite dry $1.0 < k \leq 1.3$; o—optimal $1.3 < k \leq 1.6$; qw—quite wet $1.6 < k \leq 2.0$; w—wet $2.0 < k \leq 2.5$; vw—very wet $2.5 < k \leq 3.0$; exw—extremely wet $k > 3.0$. The values of the K index during the study period are presented in Table 2.

Polish white-backed, black-white, and red-white cattle were grazing on wet meadows covering 48.19 ha (50°50′10″ N, 23°23′56″ E) and featuring mainly high sedge and proper rushes with the common reed. In the 20th century, the area was regularly grazed, mainly by cattle belonging to local farmers. In the 1990s, grazing and any use were discontinued. After Poland's accession to the EU in 2004, mowing was carried out for several years. Grazing was restored in 2016.

Table 1. Values of basic meteorological conditions (temperature and precipitation) for the months and years during the study period 2016–2019. Data are reported by weather station no. 125,950 (Zamość N 50°7′, E 23°25′, altitude: 213 m a.s.l.).

Month	2016	2017	2018	2019
	Average Air Temperature (°C)			
Jan	−3.9	−5.7	−0.2	−3.5
Feb	3.3	−1.6	−4.3	2.1
Mar	3.5	5.8	−1	5
Apr	9.5	7.7	13.1	9.4
May	14.1	13.5	16.4	12.7
June	18.3	17.9	18	20.9
July	19.3	18.3	19.8	18.4
Aug	18.2	19.7	20.1	19.6
Sept	15.1	13.7	15.7	14.3
Oct	6.8	9.2	9.7	10.8
Nov	2.6	3.8	4.5	6.3
Dec	−0.2	1.8	0.3	2.6
Year average	8.9	8.8	9.5	9.9
	Total rainfall and/or snowmelt (mm)			
Month	**2016**	**2017**	**2018**	**2019**
Jan	27.17	4.82	12.69	22.86
Feb	26.4	20.05	25.91	12.95
Mar	40.64	32.76	24.12	27.94
Apr	79.75	31.25	35.57	45.72
May	84.58	58.99	49.79	109.72
June	46.99	50.29	51.58	23.62
July	85.86	87.12	111.99	53.33
Aug	45.71	25.15	31.23	79.49
Sept	13.71	123.45	19.05	19.56
Oct	92.46	88.14	28.97	26.4
Nov	53.58	28.71	9.13	51.56
Dec	35.3	36.33	39.11	52.32
Sum	632.15	587.06	439.14	525.47

Table 2. Values and classes of the Selyaninov hydrothermal index (K) for the vegetative seasons during the study years. See above for explanations of the abbreviations.

	K Index Values					**K Index Classes by [16]**			
	Year					**Year**			
	2016	**2017**	**2018**	**2019**		**2016**	**2017**	**2018**	**2019**
Month					**Month**				
Jan					Jan				
Feb					Feb				
Mar					Mar				
Apr	2.8	1.35	0.91	1.62	Apr	vw	o	d	qw
May	2	1.46	1.01	2.88	May	qw	o	qd	vw
June	0.86	0.94	0.96	0.38	June	d	d	d	exd
July	1.48	1.59	1.89	0.97	July	o	o	qw	d
Aug	0.84	0.43	0.52	1.35	Aug	d	vd	vd	o
Sept	0.3	3	0.4	0.46	Sept	exd	vw	exd	vd
Oct	4.53	3.19	1	0.81	Oct	exw	exw	d	d
Nov					Nov				
Dec					Dec				

2.2. Animal Management

All Polish white-backed cattle introduced into the study were purchased. The animals were outdoors all year round; they grazed and received a supplement of conserved grass and maize silage during winter. Animal stocking rates varied from year to year (they were included in the experiment successively and were slaughtered at about 24 months of age); the rates are shown in Table 3. For this paper, the number of animals was determined at the end of each year of the study and in 2019 at the end of the experiment. Conversion of livestock unit (LSU) factors were applied according to Eurostat methodology [18].

Table 3. Animal stocking rate in each year of the study. LSU (livestock unit): cattle under one year old = 0.4 LSU; from 1 to less than 2 years old = 0.7 LSU; male cattle 2 years old and over = 1.0 LSU.

Year	2016	2017	2018	2019
Livestock (pcs.)	15	43	38	28
LSU	6.0	21.7	54.3	28.0
Stocking rate LSU ha^{-1}	0.12	0.45	1.12	0.58

2.3. Field Study

Vegetation research was conducted in the growing season from May to August (before grazing and during the grazing period). The selection of plots for the study was made during the initial field visit in 2016. From 2016 to 2019, 13 phytosociological relevés, each covering 25 m^2, were performed in homogeneous patches representing the dominant plant communities (areas most intensively used by animals were excluded from the research, i.e., within 40 m from the shelter). The relevés taken using the Braun-Blanquet [19] method were mapped with a GPS receiver MobileMapper 10 and its geographical coordinates were recorded. The relevés could be repeated in the same places in the following years. The names of vascular species are used according to Mirek et al. [20]. The phytosociological taxonomy of the plant communities is based on Matuszkiewicz and Mucina et al. [21,22]. Plants were identified directly in the field, no plant samples were collected.

2.4. Statistical Analyses

Changes in the plant cover and forage quality as a result of animal grazing were subjected to statistical analysis. To assess forage quality, the evaluation of grassland quality index (E_{GQ}) proposed by Novák [23] was used, with forage value (FV) assigned to the individual species. One-way ANOVA with repeated measurements was used to demonstrate differences in E_{GQ} values in the consecutive years. For the evaluation of the grassland quality the following formula was used:

$$E_{GQ} = \frac{\sum(D \times FV)}{8}, \text{ where :}$$

E_{GQ}—evaluation of grassland quality, D (%)—percentage of species, FV—fodder value of species.

To compare the number of plant species (S) occurring in the particular years, the GLM model with Poisson distribution for count data was used. To demonstrate the differences between each pair of years, multiple comparison tests with Tukey's amendment were used. This amendment was aimed at controlling type 1 error for comparisons of many groups [24]. In the analysis, the significance level of α = 0.05 was adopted. Plant diversity within communities was estimated and compared based on species richness (S)—number of species in the community, Shannon–Wiener diversity index (H), and evenness index (J). Besides the analysis of the number of species, Rényi diversity profiles (H_α) were constructed [25–27] to compare the effects of grazing on plant diversity. Diversity profiles play an important role in diversity comparisons and use parametric families of diversity indices instead of a diversity index with a numerical value. In the case of Rényi diversity profiles, a series is constructed and expressed with the following formula:

$$H_\alpha = \frac{1}{\alpha - 1} \ln \sum\nolimits_{i=1}^{S} p_i^\alpha, \text{ where :}$$

S—number of species, p_i—Shannon–Wiener diversity index, α—index order, $\alpha = 0$, the value is equal to number of species (S), for order α close to 1 go to Shannon–Wiener index. The indices of lower orders refer to species richness (they are sensitive to more rarely occurring species), while those of higher orders refer to species evenness (they are sensitive to the dominant species). A given community is regarded as more diverse than another community if, for all α orders, the index values are higher than in the other community.

In addition, a multidimensional principal component analysis (PCA) was carried out to present the changes in plant communities as well as the climatic and edaphic conditions [28]. The analysis considered species characteristic of the *Phragmitetea* (ChAll. *Magnocaricion*, ChAll. *Phragmition*) and *Molinio-Arrhanatheretea* class (O. *Molinietalia*, All. *Calthion palustris*). The assessment of climate and edaphic conditions was conducted based on ecological indicator values (L—light, T—temperature, K—continentality, F—moisture, R—water/soil pH, N—nitrogen content). The indicator values described the most typical habitat conditions of the species in which it most often grows in Poland and based on the results of field studies [29]. For each study patch in each year, the weighted average (Wa) of the aforementioned ecological indicators was calculated with a formula proposed by Czarnecka and Chabudziński (2014) [30]: WA = Σni = 1 (A2 × I)/Σni = 1 A2i, where WA—the weighted average; Ai—abundance of cover of the i-th species in a given niche; Ii—ecological indicator value for the i-th species, and n—number of species in the study patch.

The PCA method enabled the identification of the main patterns describing the differences among data in the set. Additionally, it enabled the visualization of the changes that occurred in the study years as a result of livestock grazing. R v. 3.5 software was used for analysis [31], particularly the *vegan* package [32] to analyze the diversity of communities and construct the Rényi diversity profiles.

3. Results

3.1. Plant Cover and Their Changes vs. Habitat Conditions

The peatland featured mostly high-sedge communities of the *Magnocaricion* Koch 1926 alliance (*Caricetum gracilis* (Graebn. et Hueck 1931) R.Tx. 1937, *Caricetum elatae* Koch 1926, *Caricetum distichae* (Nowiński 1928) Jonas 1933) and reed rushes (*Phragmitetum australis* (Gams 1927) Schmale 1939). There were also some patches of wet meadows of the *Calthion* alliance, but with a high share of sedge and rush species. Sedge species such as *Carex gracilis*, *Carex elata* or *Carex disticha* and *Phragmites australis* predominated in the area.

The number of species is one of the basic elements of biodiversity (floristic diversity in the case of the flora itself). When analyzing the number of species in the individual patches in the study ears, significant differences were found (GLM model). Multiple comparison tests demonstrated a significant rising trend in the number of the occurring plant species. In comparison with 2016 ($z = -4.95$; df = 48; $p < 0.001$) and 2017 ($z = -3.73$; df = 48; $p = 0.001$), the number of species was significantly the highest in 2019. A significant difference was also found between 2016 and 2018 ($z = -2.96$; df = 48; $p = 0.016$). In the remaining cases, significant differences were not observed ($z = -2.037$, df = 48, $p = 0.174$ for 2018 and 2019; $z = -1.715$, df = 48, $p = 0.316$ for 2017 and 2018; $z = -1.259$, df = 48, $p = 0.599$ for 2016 and 2017). The box plot (Figure 1, Table S1) confirms the growing trend in the number of species in the consecutive years of the study. The grazing of white-backed cattle led to an increase in the number of vascular plant species in the communities analyzed.

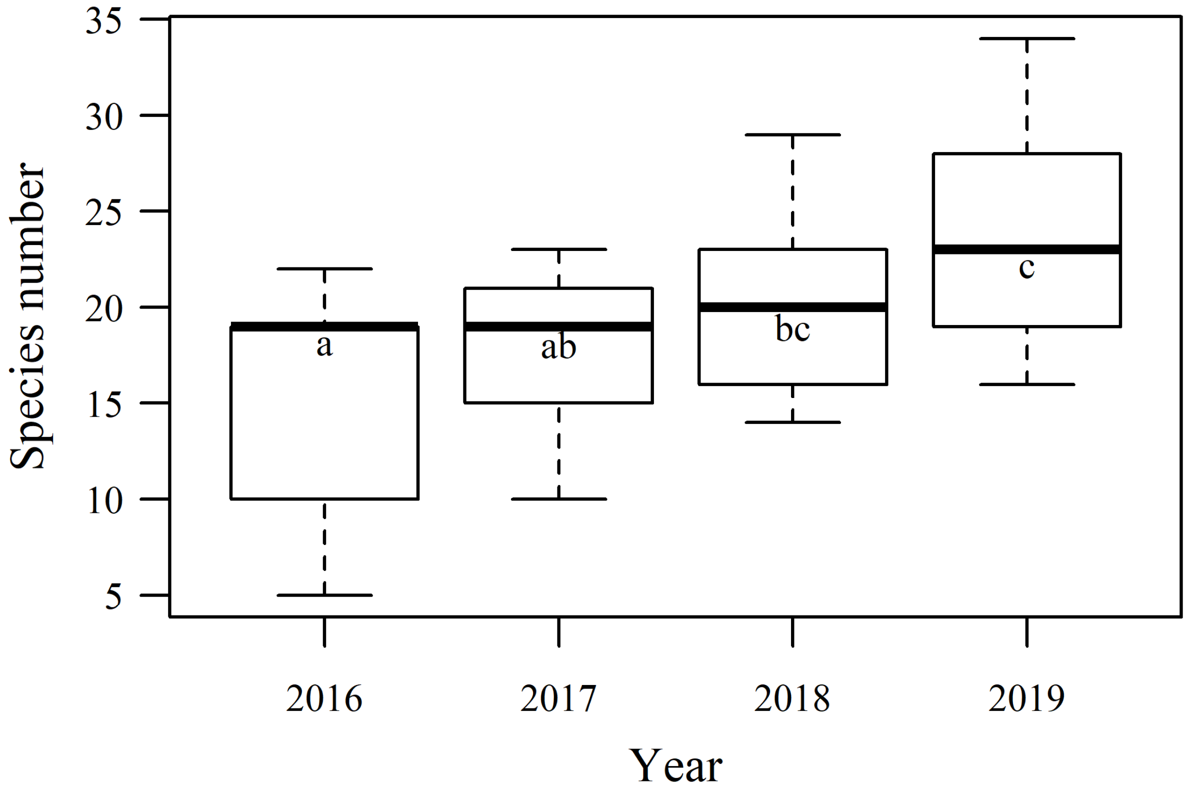

Figure 1. The results of a one-way analysis of variance (ANOVA) for the total number of species. Different letters indicate significant differences (p = 0.05).

The principal component analysis (PCA) carried out to assess cover-abundance changes of the individual species of plant communities in the *Phragmitetea* and *Molinio-Arrhenatheretea* class, made it possible to create two variables, PCA1 and PCA2, that jointly account for 86.66% of the variability in the dataset—PCA1 accounts for 69.61% while PCA2 for 17.05% (Figure 2; Table S2 and Table S3). When analyzing the factor loadings of the individual plant communities, it was found that the greatest impact on the PCA1 variable was exerted by species characteristic of All. *Magnocaricion* (negative) as well as All. *Phragmition* and All. *Calthion palustris* (positive). The PCA2 variable, on the other hand, allows differentiating the communities based on species characteristic of All. *Phragmition* (positive influence) and All. *Calthion palustris* (negative influence). The distribution of phytosociological relevés was shown in an arrangement defined by two principal components, PCA1 and PCA2, determined according to the cover-abundance of individual plant species in the analyzed patches (Figure 2). In addition, scaled vectors (black solid line) were added to the chart to show the contribution of the individual species in the values of the principal components as well as vectors (orange dotted line) representing the trend of changes for the particular phytosociological relevés in 2016–2019. An analysis of the ordination diagram makes it possible to distinguish two groups according to the cover-abundance of the individual species (positive and negative values of the first principal component PCA2). In the study years, a trend of changes in the cover-abundance of the particular species is visible in the vegetation patches analyzed. In most patches, one can observe an increasing cover-abundance for species characteristic of the *Molinio-Arrhenatheretea* class, including the *Molinietalia* order and *Calthion palustris* alliance (Figure 2).

The principal component analysis (PCA) carried out to assess the climatic and edaphic conditions (Figure 3; Table S3 and Table S4) made it possible to create two variables that jointly account for 90.25% of the variability in the dataset (PCA1 accounts for 49.84% while PCA2 for 40.41%). When analyzing the factor loadings of the individual phytosociological relevés, the greatest contribution to the PCA1 variable was found for the following indices:

acidity R and continentalism K (negative) as well as humidity F, and nitrogen content N (positive). The greatest contribution to the PCA2 variable was found for the following indices: acidity R and light L (positive) as well as continentalism K (negative). The distribution of phytosociological relevés in a system defined by two principal components, PCA1 and PCA2, determined by Ellenberg indices is shown in Figure 3. In addition, scaled vectors (black solid line) were added to the chart to show the contribution of the individual indices in the values of the principal components as well as vectors (orange dotted line) representing the trend of changes in 2016–2019. What can be observed most frequently in the chart is the rising trend of the values of R and K indices (Figure 3).

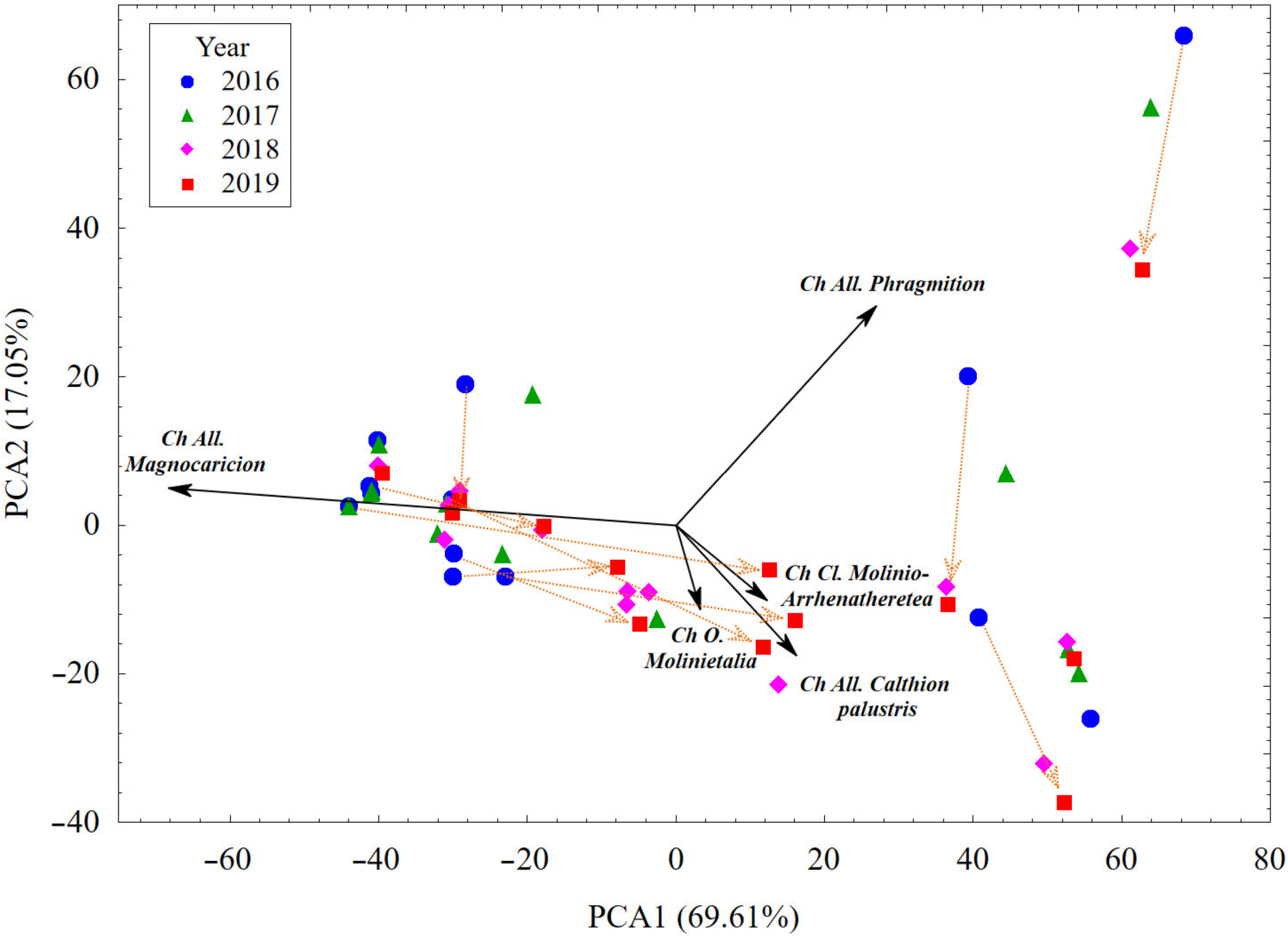

Figure 2. The PCA analysis scaled scatter plot of phytosociological relevés according to cover abundance of the characteristic species. Black solid vectors show the contribution of the individual species in the values of the principal components, while the orange dotted line vectors represent the trend of changes in the species cover for the particular phytosociological relevés in 2016–2019.

3.2. Biodiversity Dynamics

The Rényi diversity profiles (H_α) also confirm the changes occurring in the communities (Figure 4). Values of H_α range from about 0.6. to 3.5. The figure shows the median values from all relevés as well as the ranges of the obtained Rényi index (H) values in the individual years. In the course of the conducted observations, the value of the Shannon diversity index ($H_\alpha = 1$) increased significantly. Its value was 1.5 in the years 2016–2017, 2.0 in 2018, while in 2019 it increased above 2.0. The greatest floristic diversity occurred in the last year of the study (2019) when the median values of the indices for all the orders α were the highest. A slightly lower diversity was observed in the preceding year (2018). The values of the indices for the years 2016–2017 show a similar diversity in all orders and are lower than in the two subsequent years. In 2019, the number of species was the highest (order $\alpha = 0$) in comparison with the other years. The lower boundary of the range shows that the number of species in some phytosociological relevés was significantly smaller in the first year (2016) than in the other years. The values of indices of higher orders are greater for the last two years of the study (2018 and 2019) than for 2016 and 2017, which evidences the decreasing domination of the species with the greatest cover abundance because indices of higher orders indicate the occurrence of dominant species. For the H index of order, we received information about the dominance of a species with the greatest cover abundance in the individual relevés. The dominant species in the patches were mainly *Carex gracilis*, *Carex elata* and *Phragmites australis*. The greatest cover abundance of the dominant species was observed in the first study year (2016). The upper limit of the obtained values of indices of higher orders was considerably lower than in the subsequent years (Figure 4). In 2017, although the median value of the indices approximated the value from 2016, relevés already appeared where the observed values approximated those occurring in subsequent years (maximum values).

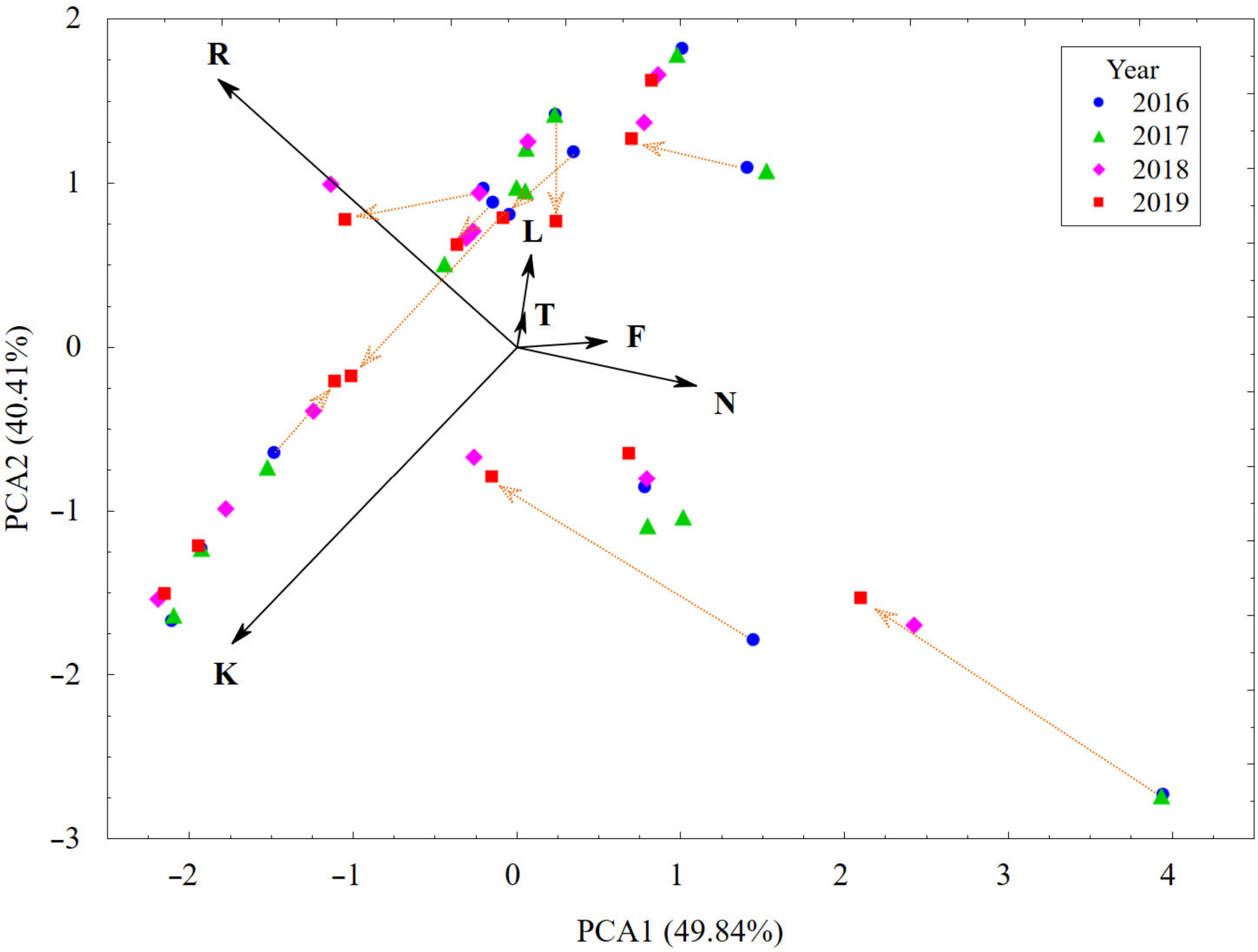

Figure 3. The PCA analysis scaled scatter plot of phytosociological relevés by Ellenberg ecological indices where: L—light, T—temperature, K—continentality, F—moisture, R—water/soil pH, N—nitrogen content. Black solid vectors show the contribution of the individual indices in the values of the principal components, while the orange dotted line vectors represent the trend of changes in indices for the particular phytosociological relevés in 2016–2019.

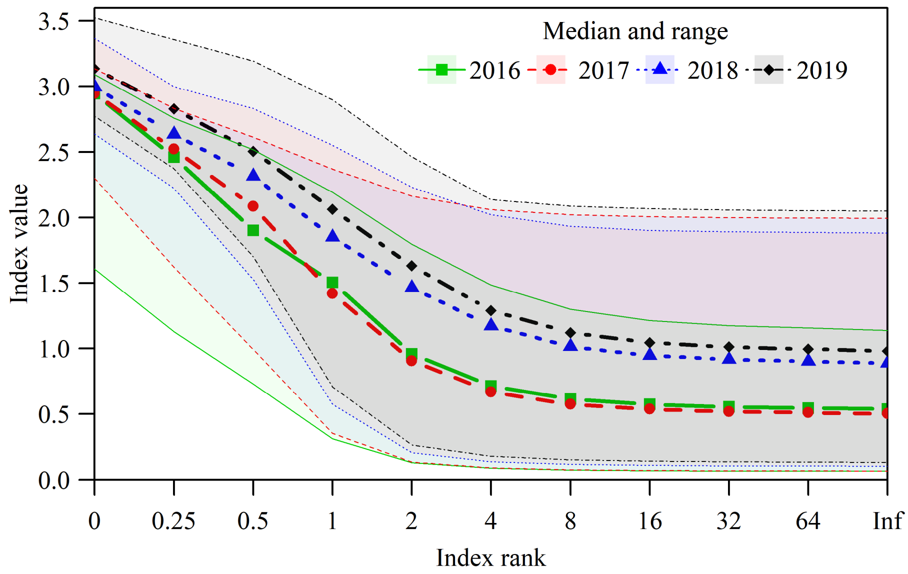

Figure 4. Rényi diversity profiles (H_α) for patches in the successive years of the study.

3.3. Dynamics of Pastures Forage Quality

The communities of the wet meadows analyzed do not yield forage of sufficient quality for livestock. Therefore, an evaluation of grassland quality was conducted according to Novák [23]. In the successive years of the study, a rising trend in the value of forage, expressed with E_{GQ}, was observed. The results of a one-way analysis of variance (ANOVA) with repeated measurements showed significant differences in the values of the E_{GQ} index in the successive years (F = 9.08, df = 3, $p < 0.001$). Multiple comparison tests demonstrated that E_{GQ} values in 2019 were the highest in comparison with the previous years (Tukey $q_s = 6.372$, $p < 0.001$ when compared with 2016; $q_s = 6.41$, $p < 0.001$ compared with 2017 and $q_s = 4.02$, $p = 0.035$ compared with 2018; in all cases df = 36 and $q_{crit} = 3.457$). Statistically significant differences were not found between the values of the index for the earlier years ($q_s = 2.35$, $p = 0.359$ between 2018 and 2016; $q_s = 2.38$, $p = 0.347$ between 2018 and 2017; $q_s = 0.03$, $p = 0.999$ between 2016 and 2017; in all cases df = 36 and $q_{crit} = 3.457$) (Figure 5).

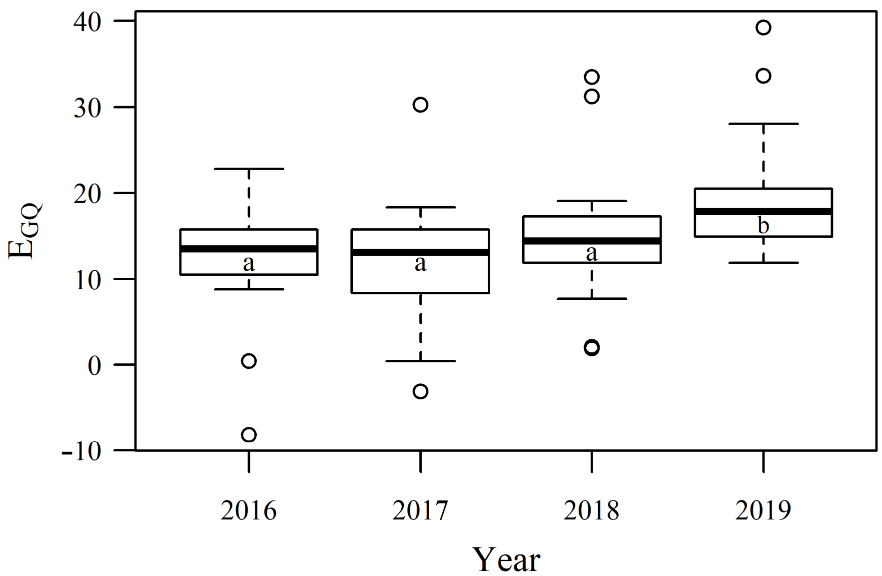

Figure 5. The results of a one-way ANOVA for evaluation of grassland quality (E_{GQ}) formula. Different letters indicate significant statistical differences ($p = 0.05$).

4. Discussion

Riparian meadows provide a suite of ecosystem benefits around the world. These diverse ecosystems deliver clean water, flood attenuation, nutrient sequestration, and wildlife habitat [33–36]. There is clear evidence that livestock should be managed to conserve and enhance ecosystem services in grazed landscapes [3,37,38], especially in the context of adequate stocking density according to the type of meadow. The proper management of wet meadows involves controlling the timing, duration, and intensity of grazing and varying periods of use and recovery of plant species composition [39].

Species richness, i.e., the number of species existing within a habitat, is often used as a measure of plant diversity. It was one of the most frequently measured variables in the grazing studies reviewed [40]. Almost as many studies reported increased species richness as those that reported its decline. The four-year analysis of species richness, biodiversity and species cover in the analyzed pastures confirms the results obtained in the studies above only partially. The change in species richness shows a positive correlation with time. It increases monotonically in time, very much as expected. Species richness remained stable in the first two years of grazing in Iłowiec, increased slightly in the third year of the study, and reached its highest values in the last year of grazing on wet meadows. Our results are confirmed by numerous studies of this type of plant community [41]. Although the number is not a completely reliable criterion for the association, comparing the observed divergence between the two metrics shows a complementary and reliable increase [42–45].

Usually, an increase in species richness occurred when grazing reduced the dominant species that had been excluding less competitive species [46,47]. In the pastures studied, there was no decline in cover among the typical species that usually dominate wet meadows. This seems to confirm the tendency of riparian plants to adapt and recover from natural stresses and changes in the riparian conditions and valley landforms. The adaptive characteristics of riparian plants enable them to recover from short-term grazing events and the accumulated stresses resulting from problematic grazing management. The restoration of plant health can be rapid (within a few months of the growing season), even if the plants have been weakened, provided that the physical environment has not changed the plants' access to water [48]. Where the vegetation composition has changed, systems will recover, but a few years may be required [49]. The common reed *Phragmites australis*, acute sedge *Carex gracilis*, and tufted sedge *C. elata* are the dominant species in the described communities, with a high cover in the surveyed pastures. They represent a number of characteristics thanks to which they adapt well to the occupied habitats. These include the CS life strategy that is an intermediate type of strategy between competitors and stress-tolerators [50,51]. A large proportion of species exhibiting a CS strategy and generalist species, understood as being able to thrive in a variety of environmental conditions and able to utilize a wide range of resources [52], were shown, similarly to our study, in studies comparing extensively grazed and uncultivated Hungarian steppe-wetland pastures [53]. The CS strategy manifests itself in intensive vegetative growth (formation of rhizomes and/or stolons) that allows rapid regeneration after gnawing, and production of a large number of small seeds that form a sustainable seed bank. At the same time, the above-mentioned plant species are characterized by a high sensitivity to typical pasture use, i.e., grazing and mowing, as well as trampling by animals (trampling) [54,55]. Their high proportion in the sward of the studied pastures, after four years of use, indicates that extensive grazing with low stocking rates is the key factor for preserving the species structure of wet meadows. During the study, stocking rates ranged from 0.12 to 1.12 LSU ha^{-1}. A well-chosen stocking density of grazing animals is especially important in environmentally valuable areas where moderate use allows for the protection and conservation of various types of meadow habitats [7,9,56].

The Rényi diversity profiles showed increased tendencies in Iłowiec wet meadows, thus confirming that grazing exhibits similar effects in wet grasslands all around the world [40]. These values were higher in the case of drier areas, which confirms that, due to intensive grazing, low management pressure led to an increase in diversity, which is consistent with literature data [57–59].

The analysis of the Ellenberg indices [29] shows another dimension of the effect of grazing on the qualitative characteristics of wet meadow vegetation (Figure 3). In the third and fourth year of grazing, the number of nitrophilous (N) species increased, which may be a result of the eutrophication of the habitat. Eutrophication can be prevented by means of extensive or rotational grazing. In the absence of grazing, plant litter is returned to the soil, and organic matter from the decomposing plant tissue accumulates in soil with a spatially homogeneous distribution. A major effect of grazing at the ecosystem level is the decoupling of carbon (C) and nitrogen (N) in plant organic matter, with C respired to the atmosphere as CO_2 and CH_4, and N returned to the soil via urine in patches of high concentration [60,61]. At the same time, a high proportion of heliophytes (L) and moist-habitat plants (F) was recorded in the sward of the studied meadows, which indicates the absence of adverse changes in moisture conditions in the studied patches and the absence of tree and shrub succession.

Grazing carried out in the studied wet meadow patches should provide adequate forage for the animals and their welfare. Average daily weight gains of the animals were a measure of the efficiency of the grazing conducted. In the first year of the study, when the purchased calves were introduced, despite the lowest stocking rate, the daily gains obtained by animals in the spring-autumn period ranged between 0.33 and 0.85 kg, while in 2017: between 0.6 and 1.18 kg of gain per day. The calves that were introduced in the first year of the study already gained 0.630–0.830 kg/day. On the other hand, in spring-autumn 2018, at the highest stocking rate of 1.12 LSU/ha, the daily gains varied from 0.4 to 0.9 kg. Considering the method of maintenance (pasture feeding from spring to early autumn) and the species composition of the pasture, the daily gains obtained should be considered satisfactory. A study by Bedoin and Kristensen [62], where animals were also kept outdoors all year round and the animals' energy needs were met with roughage derived mainly from semi-natural grassland, the daily gains were 0.2–0.4 kg/day. Tate et al. [63] found that moist meadow communities are characterized by a high yield of forage. Dry meadow communities produce less forage (80% less than moist and 73% less than wet meadow communities). According to these authors, the weight gains of cattle grazing on wet meadows varied during the season between 0.57 and 0.83 kg, 0.72 and 0.84 kg on wet meadows and 0.43 and 0.79 kg on dry meadows. Other studies also confirm higher yields from wet meadows [6]. On the other hand, dry meadows are characterized by a large diversity of plant species [56]. Pasture productivity is undoubtedly affected by weather conditions. Among the most important are the amount of precipitation and temperature [64,65]. Analyzing the moisture and thermal conditions during the present study, it was determined that they were not favorable for the forage productivity of the wet meadows under study (Tables 1 and 2). Considering the temperature, the seasons of 2016 and 2017 were defined as very dry and 2018 and 2019 as dry. The hydrothermal index (K), calculated for the growing season (April–October), showed that the period under study was extremely dry. The driest year was 2018, with an average value of K = 0.96, and the months of June and August, when the average value was K = 0.79 (Table 2). This negatively affected the coverage of the dominant forage species and the biodiversity of the grasslands (Figure 1). At the same time, it negated the negative impact of trampling during grazing. Trampling is one of the negative effects of grazing on wet meadows [66].

5. Conclusions

The summer grazing of white-backed cattle on wet meadows led to some changes in the species composition. Extensive grazing (0.12–1.12 LSU ha^{-1}) resulted in the decreased cover of typical dominant species of rush meadows such as the common reed, the acute sedge (*Carex acuta*), or the tufted sedge (*Carex elata*). The percentage share did not change significantly, but some gaps emerged thanks to the reduced cover of the species that predominated in terms of cover and size. These gaps were filled by other plant species, particularly meadow plants, which led to increased plant diversity. During the four years of grazing, the cattle obtained satisfactory weight gains, particularly in the last year of the study, which indicates that wet meadows are suitable for grazing and can provide sufficient feed for cattle.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture13020261/s1, Table S1: Factor loadings of PCA based on analysis according to species cover; Table S2: Summary statistics (mean and standard deviation) of plant species cover by year; Table S3: Summary statistics (mean and standard deviation) of phytosociological relevés characteristics by year; Table S4: Factor loadings of PCA based on analysis according to Ellenberg ecological indices.

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