

# Article

# The Plant Species Composition of an Abandoned Meadow as an Element of an Ecosystem Mosaic within an Urban-Industrial Landscape

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**Abstract:** The absence of traditional management in grasslands is responsible for the consequent changes in plant community species composition and diversity of this habitat in Europe. The common reason for these changes is the spread of expansive native species such as *Calamagrostis epigejos* (L.) Roth and their subsequent dominance over other component species. The aim of the study was to determine the effect of management treatments (e.g., mowing, harvesting biomass) and their frequency of application (e.g., once or twice a year) on the cover abundance of *C. epigejos* (L.) Roth and the subsequent changes in component grassland species richness and diversity (Shannon–Wiener index) of an abandoned meadow in Silesia in S. Poland. A difference in species richness was found after five years of mowing, but an increase in species diversity appeared only after seven years of the treatments. Significant increases in species richness and Shannon–Wiener index and a significant decrease in cover abundance of *C. epigejos* (L.) Roth were recorded after different periods and for different treatments.

**Keywords:** meadow; meadow management; plant diversity; enhancement of biodiversity; cutting frequency; biomass removal



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## 1. Introduction

Human activities such as changes in land use, nutrient enrichment (eutrophication), habitat fragmentation, and melioration have reduced plant species diversity (succession and landscape context can affect biodiversity) in all ecosystems, particularly meadow and grassland communities [1]. The restoration of an ecosystem and its diversity has become one of the most critical issues for different habitats (e.g., regulating services or supporting services) and in restoration ecology and conservation, especially of semi-natural habitats such as meadows and other grassland types [1,2]. The diversity of the remaining grasslands in southern Poland has declined mainly due to the lack of traditional management (regular mowing and grazing) [3]. This has resulted in the widespread increase in the abundance of some species, particularly grasses. The dominance of grass species in meadows and other grassland vegetation communities results in a decline in botanical/taxonomical species diversity. An increase in the abundance of expansive species changes the quantitative and qualitative proportions of the constituent species and the spatial characteristics of the component species within the vegetation. There are some species which are essential for

meadow ecosystem functioning, such as the water retention abilities of a meadow and their above- and below-ground (e.g., bacteria and fungi) species composition diversity, both in terms of preservation of its diversity and productivity [4–6]. These specific meadow species, which decline after the regular mowing has ceased, are considered to be the significant ‘target species’ in restoration work (sensu Bartha et al. [7]). The lack of mowing causes the spread of expansive grass species, and frequently causes a decrease in species composition beyond the expected meadow species. In abandoned meadows, the spread and abundance of some plant species have been observed following land use changes (e.g., cessation of mowing) [8].

Several native grass species are spreading quickly in disturbed habitats. These species often become the dominant species in disturbed natural and semi-natural plant communities. Among these species are grasses such as *Phragmites australis* (Cav.) Trin. ex Steud. [9], *Brachypodium pinnatum* (L.) P. Beauv. [10], *Molinia caerulea* (L.) Moench [11], and *Calamagrostis epigejos* (L.) Roth [12]. It has also been observed in recent decades that *Calamagrostis epigejos* (L.) Roth is spreading in abandoned grasslands [13] and other habitats. *C. epigejos* (L.) Roth is also becoming more frequent and abundant in urban-industrial areas [14–16], post-industrial, post-mineral-excavation, and brownfield sites [17–19]. The dominant plant-species richness relationship reflects the global plant species richness–biomass–productivity relationship, known as the biomass–diversity trade-off. This relationship is a central notion of the long-standing theory of biodiversity–ecosystem functioning and is still fascinating to many ecologists [20]. This phenomenon is of high theoretical interest and has an actual application in biodiversity protection and conserving conservation value. Understanding and controlling the population growth of expansive and invasive species is one of the most critical issues for biodiversity conservation [21].

Many countries have applied restoration actions to reduce the decline in grassland biodiversity and to recover the native vegetation [22]. Restoration actions are generally efforts to manipulate vegetation development in a targeted, desirable direction [23]. Achieving a successful decline in the cover abundance of dominant species such as *Calamagrostis epigejos* (L.) Roth is not easy. Some types of treatments can be considered as ecological disturbances and can be caused by an increase in nutrients [8,24]. Mowing, with the removal of biomass, increases and maintains plant species richness, particularly in mountain hay meadows [8]. Regular mowing without grazing is widely suggested to conserve and improve species richness [25]. Studies on this phenomenon, the dominance–species richness relationship in different habitats, have supplied important data for theoretical ecology and ecosystem restoration [26]. Some studies have presented the adverse effects of dominant species on diversity (e.g., refs. [27,28]) and the influence of tree species. The authors have observed that herbaceous vegetation under the studied trees is species-poor. They also emphasized that other vascular plants are not appearing at all [29]. However, no comparative studies are available on the relative importance of dominant grass species controlling local diversity in grasslands and their role in these vegetation dynamics.

We aimed to analyze the specific responses of meadow species to the effects of mowing in an urban-industrial landscape and to evaluate the necessity for biomass removal after mowing. In particular, we tested the following hypotheses: (i) Species richness and cover abundance of target species (meadow grasses and forbs) is higher in mown than in abandoned grassland stands; (ii) Mowing has a more direct effect on the diversity (the number and biomass of target meadow forb species in plots) where hay (biomass) is removed; (iii) Specifically, we expected that frequent mowing (twice) and removal of the biomass would cause an unequivocal decrease in the cover abundance of *C. epigejos* (L.) Roth, and an increase in the number and cover abundances of meadow species over time, in the subsequent years of experimental observations. The study’s objectives were to apply treatments of mowing and harvesting biomass with differing frequencies (once or twice a year) and to record any changes in the cover abundance of *Calamagrostis epigejos* (L.) Roth and the associated grassland species diversity.

## 2. Materials and Methods

### 2.1. Study Area

The study was conducted in the Silesian Uplands—a macro-region agglomeration and a vast urban-industrial landscape in southern Poland. The Silesian Uplands are characterized by a varied topography and are influenced by a temperate, transitional climate. Despite a long history of mineral excavation and industrial development in the Silesian Uplands, large areas have been occupied by agriculture for a long time, including hay meadows [11,14,19]. In recent decades, small patches of land used for non-intensive agriculture (such as meadows), located mainly on the outskirts of cities, have been affected by the ongoing recession in agriculture. Additionally, due to having ageing owners, these fields and meadows have been abandoned and have consequently undergone spontaneous succession. It is a common phenomenon that this process begins with the meadows becoming overgrown by expansive (e.g., *Calamagrostis epigejos* (L.) Roth) or invasive species (e.g., *Solidago* sp.).

The study was conducted within a meadow of a few hectares in area, which had been abandoned since the 1990s. The study site is located within the administrative borders of Katowice (50°12′00″ N, 18°57′31″ E). Initially, it was a damp meadow, regularly mown with the biomass removed once a year, and representative of the community association of *Cirsietum rivularis* Nowiński 1927 [30]. *Cirsium rivulare* (Jacq.) All. was present with *Poa pratensis* L., *Ranunculus acris* L., *Lychnis flos-cucculi* L., *Comarum palustre* L., *Dactylorhiza majalis* (Rchb.) P. F. Hunt and Summerh., *Rumex acetosa* L., *Cirsium palustre* (L.) Scop., *Angelica sylvestris* L., *Filipendula ulmaria* (L.) Maxim, and *Heracleum sphondylium* L. (Błońska, author's own observations). At the start of the experiment, the study meadow was heavily overgrown by *Calamagrostis epigejos*, which had become dominant over a large area, and the occurrence of other meadow species had declined over the years since active management.

### 2.2. Studied Species

*Calamagrostis epigejos* (L.) Roth is a tall (60–200 cm) perennial grass with long and robust rhizomes, which can spread up to several meters. According to Kacki [2], this species typically grows in moderately moist, mesotrophic sites, poor in organic matter, and is characterized by moderate acidity and full-light conditions but can also occur in a wide range of habitat conditions [24]. It is widespread in Eurasia and is described [31] as a constant component of the natural vegetation on dunes, river floodplains, fens, steppes, and sub-alpine grasslands. Studies show that its natural habitats are rare in central Europe, and data suggest that it often occurs following the abandonment of human management of semi-natural vegetation [31]. This grass grows over a wide range of soil nutrient conditions, though its growth and reproduction are enhanced in open, moist, and nutrient-rich conditions [24]. It has also been recorded from a range of habitats such as abandoned vineyards [32], hay meadows [33], and pastures [13] in Poland and all over the world. The post-abandonment spread of this species is facilitated by its ability to spread from creeping rhizomes. Total rhizome expansion of *Calamagrostis epigejos* (L.) Roth can be up to 150 cm per year in one direction. Additionally, rhizomes grow to a depth of 3–20 (–35) cm [24]. Presumably, the *C. epigejos* rhizomes grow and spread faster than other species can regenerate by seed, or it grows faster than other rhizomatous species [8,24]. It can be expected that in plots with high nutrient input (where there is no mowing and dead material is decaying and adding nutrients back into the meadow) these are used more quickly by *C. epigejos* (L.) Roth than the other constituent species.

This grass possesses the traits of an expansive plant, such as high plasticity in respect of its morphology and physiology, long rhizomes [34], and a high growth rate [24]. Due to its high growth rate, *C. epigejos* (L.) Roth can produce large amounts of biomass [35] and thus it quickly out-competes other species, particularly those forb species which are small, and light-demanding [36]; producing a particularly dense and thick litter layer, which prevents the germination of other species [36]. It has been stated that *C. epigejos* (L.) Roth requires an intense intake of nitrogen from the soil and can store it in its root and shoot

bases. Moreover, it can also translocate nutrients from dying organs [34]. Its high tolerance to abiotic stress factors provides *C. epigejos* (L.) Roth with an advantage when colonizing new habitats [37].

### 2.3. Field Data Collection

To study the effect of mowing and biomass removal on the composition and cover abundance of vascular plant species, meadow patches for the planned treatment application (plots for mowing, hay left, and hay removed) were selected. Species composition and their corresponding cover abundances were sampled twice a year, over eight years, along five transects established in the middle of the meadow patches dominated by *Calamagrostis epigejos* (L.) Roth. For each treatment, a set of plots consisting of five areas of 1 m<sup>2</sup> was established. Each of the 25 plots (five plots for four treatments and five as controls) was separated from the others by a 1 m buffer strip (the vegetation was homogeneous over all the plots) and the following treatments were applied:

- Treatment CTRL—no treatment,
- Treatment MOL—mown once a year with the biomass left,
- Treatment MTL—mown twice a year with the biomass left,
- Treatment MOH—mown once a year with the biomass removed,
- Treatment MTH—mown twice a year with the biomass removed.

Mowing was carried out to an approximate height of 5 cm in spring (June) in all plots except the controls and in autumn (September) on plots MTL and MTH. Immediately after mowing the plots, MOH and MTH had the resulting biomass removed. The plots were surveyed twice a year, in spring (June) and autumn (September), before management took place, with each plot being assessed for species composition and cover abundance. Cover abundance was assessed using a modified 13-step Braun–Blanquet scale (1%, 2%, 5%, 10%, 20%, . . . 100%). Treatments and surveys took place between 2007 and 2013. Nomenclature follows Mirek et al. [38].

### 2.4. Data Analysis

Species richness was tallied and species diversity, expressed using the Shannon–Wiener index [39], was calculated for each plot along a transect and for each treatment plot per year. The presence and cover abundance of *Calamagrostis epigejos* (L.) Roth were not included in the diversity indices. Changes in species richness *S*, Shannon–Wiener index *H*, and total cover of *Calamagrostis epigejos* (L.) Roth among treatments were tested with linear mixed-effects models (LMM). The calculated parameters: *S* and *H*, and cover abundance of *C. epigejos* (L.) Roth were treated as dependent variables within these models. Three models were constructed: (1) models with all possible main effects, (2) simplified models without variables, and (3) simple models with the interactions of selected effects treated as factors.

For the first group of models the independent variables were mowing (0 = no mowing, e.g., control, 1 = mowing once and 2 = mowing twice), biomass (0—left in situ, 1 = removed, 0.5 = control—this is fuzzy coding because plants are not moved and living biomass is left or removed), season (0 = spring, 1 = autumn) year (0–7). Codes for each plot served as a random effect to account for pseudo-replication throughout the experiment. In the third group of models, treatment (mowing, biomass removal, and control) was regarded as a factor (five groups were distinguished). Chi-square tests and Akaike’s Criterion (AIC) were used to assess the significance of the built models using the package lme4 in R software [40]. An indirect, unconstrained ordination was run to analyze the differences in species composition resulting from the influence of the independent variables. Detrended Correspondence Analysis (DCA) was run, and independent variables were used as passive vectors fitted into the ordination results and plotted on a DCA biplot. Permutational ANOVA with 999 iterations was adopted using the benefit function from the software package Vegan. In order to examine the dependence of species on treatments, the IndVal method was applied based on the Lands software package R.

### 3. Results

A comparison of all nine constructed linear mixed-effects models (LMMs) showed that models with treatments considered as factors were characterized by lower AIC values except for the model with cover abundance of *Calamagrostis epigejos* (L.) Roth as the dependent variable. In this case, the model with Biomass, Mowing, and Year was the model of best fit (Table 1). Year was a significant variable in those models which included all the studied dependent variables (Table 1). However, in the case of the cover abundance of *Calamagrostis epigejos* (L.) Roth this decreased. It was similar in all distinguished groups of plots (treatment and control) (Figure 1), except for the transect with mowing with the biomass left (MOL and MTL). In the second year, no significant changes in cover were observed (Table 2). Mowing and biomass removal did not significantly influence the cover abundance of *Calamagrostis epigejos* (L.) Roth (Table 1).

**Table 1.** Relationships between the measured diversity parameters, the applied treatments, and the model used. Single term deletions from model building with AIC and significance using chi-square tests; \*  $p < 0.01$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.001$  was the opposite of the above-mentioned variables.

	<i>C. epigejos</i> (L.) Roth Percent Cover Abundance	S	H
Biomass	2379.2	-	-
Mowing	2376.8	-	-
Year	2410 ***	924.15 ***	200.99 ***
Treatment (Mowing × Biomass + Control)	-	894.37 **	171.66 *
Total AIC of model	2378.5	887.1	168.7

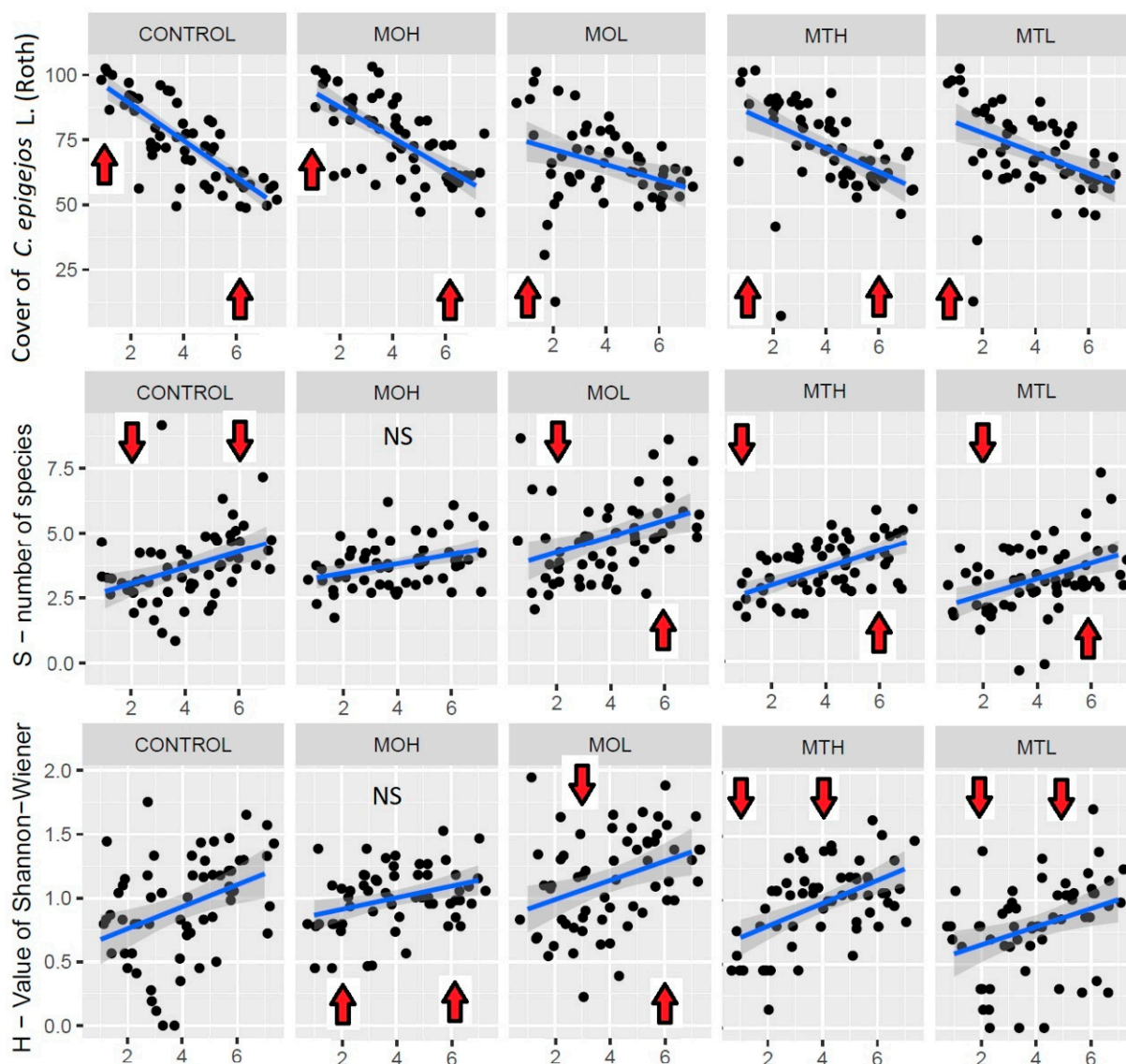
**Table 2.** Results of post-hoc tests between years in studied variables. Explanation: CTRL: no treatments, MOH—mowing once a year with the biomass removed, MOL—mowing once a year with the biomass left, MTH—mowing twice a year with the biomass removed, MTL—mowing twice a year with the biomass left. The groups differed significantly when they do not share the same letters.

Year	Cover of <i>C. epigejos</i> (L.) Roth					Species Richness					Shannon–Wiener H				
	CTRL	MOH	MOL	MTH	MTL	CTRL	MOH	MOL	MTH	MTL	CTRL	MOH	MOL	MTH	MTL
1	d	d	b	C	b	ab	A	abc	a	ab	ab	a	ab	a	ab
2	cd	cd	a	abc	a	a	A	a	ab	a	a	a	ab	ab	a
3	bcd	bcd	a	Bc	a	ab	A	ab	ab	ab	a	a	a	ab	ab
4	abc	abc	a	abc	a	ab	A	ab	ab	ab	a	a	ab	b	ab
5	ab	ab	a	A	a	ab	A	abc	ab	ab	ab	a	ab	ab	b
6	a	a	a	A	a	b	A	c	b	b	b	a	b	b	b
7	a	a	a	Ab	a	b	A	bc	ab	ab	ab	a	ab	ab	ab

Explanations: Control: no treatments, MOH—mowing once a year with the biomass removed, MOL—mowing once a year with the biomass left, MTH—mowing twice a year with the biomass removed, MTL—mowing twice a year with the biomass left. Red arrows indicate years where significant changes occurred in comparison to other years. NS—non-significant.

Both variables S (the number of species) and H (value of Shannon–Wiener diversity index) increased over time and differed significantly among treatment plot groups (Table 1). The changes in cover abundance of *Calamagrostis epigejos* (L.) Roth were also a significant factor. However, it was the opposite of the variables mentioned above. Only biomass had no significant influence on species composition (Table 2).



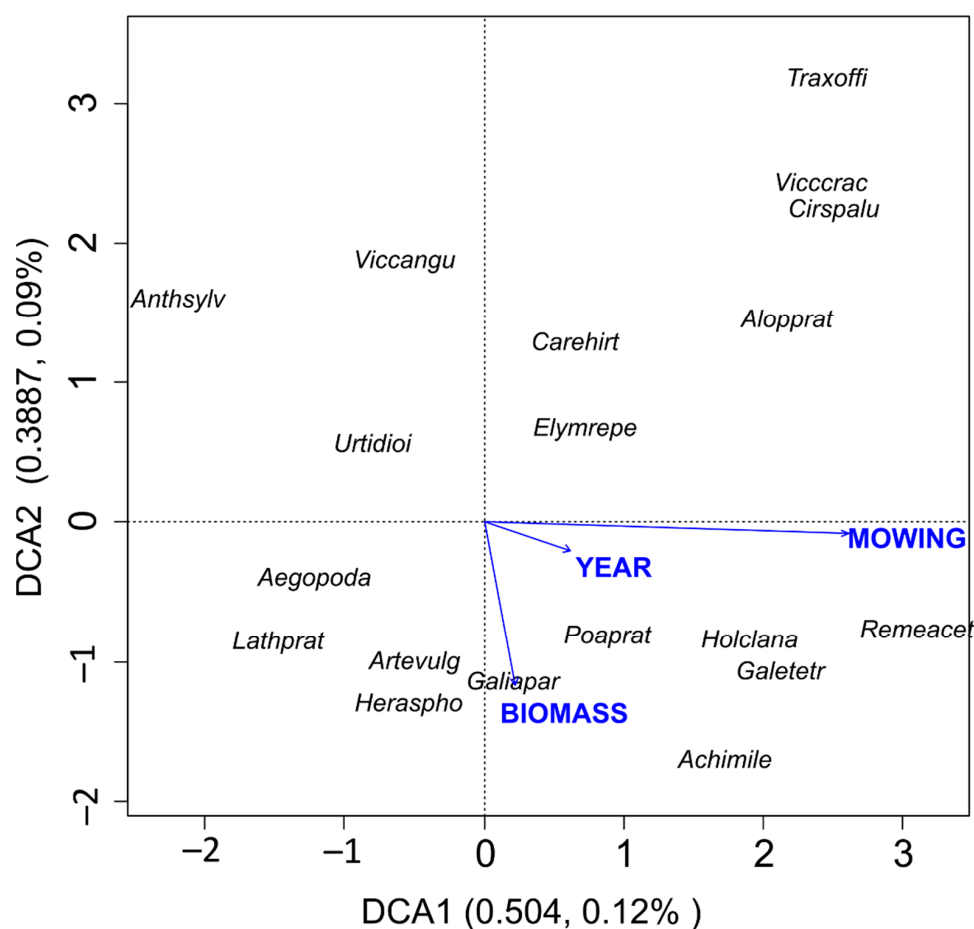


**Figure 1.** Changes in the mean percentage cover abundances of *Calamagrostis epigejos* (L.) Roth, species richness, and Shannon–Wiener index in relation to the applied treatments over time according to Linear-Mixed Effect Models. Red arrows indicate years where significant changes occurred in comparison to other years. NS—non-significant. Dots represent observations, blue line—regression line and shaded area—confidence interval.

The cover of *C. epigejos* (L.) Roth in the control plots (CTRL) became significantly different from the 5th year concerning the first year and the 6th year compared with the first three years. Only in the control plots was the first year always significantly different from all the others. The treatment of mowing once a year and biomass removed (MOH) caused no significant differences between years in terms of species richness. There were no differences between the first year and the other years, and there were differences between years 2, 6, and 7 in plots under the MOL treatment when considering the number of species in the studied plots. For the value of the Shannon–Wiener index, no significant changes between the years were found for the treatment of mowing once a year and removal of biomass (MOH). The treatment of mowing once a year and leaving the biomass (MOL) caused differences in the value of the Shannon–Wiener index. This result was recorded for the years 2, 6, and 7. For the mowing and biomass removal treatment, changes in the value of the Shannon–Wiener index were observed only for years 1 and 6. Regardless of the treatments applied an increase in species number was noted, however, significant

changes were mostly between the 2nd (mean number of species amounted to ca. 2.6) and 6th year (mean number varied between 4.5 to 5.5 in control and mowing once a year with the biomass left respectively (Figure 1, Table 2). As with species richness, the value of the Shannon–Wiener index increased in all the studied plots from ca 0.5 (control) to 1.5 in plots with mowing once a year with the biomass left (Figure 1).

The first two axes of DCA explained 21% of the species variation. The first DCA axis is positively correlated with mowing and time (repeated treatment) and negatively correlated with cover abundance of *Calamagrostis epigejos* (L.) Roth (not shown) in explaining species composition. The second DCA axis negatively correlates with biomass retention in explaining species composition (Figure 2, Table 3).



**Figure 2.** Biplot of DCA ordination based on species cover and variables associated with treatments (MOWING, YEAR, BIOMASS) and cover abundance of *Calamagrostis epigejos* (L.) Roth that were regarded as passive vectors to the ordination results. The first four letters of the genus and species names are given to identify the species. Only significant variables are shown.

Considering individual plant species (Figure 2), *Rumex acetosa* L. was associated with mowing, whereas *Poa pratensis* L., *Holcus lanatus* L., and *Galeopsis tetrahit* L. occurred more frequently. Several species, such as *Urtica dioica* L. and *Cirsium arvense* (L.) Scop., were common accompanying species with *Calamagrostis epigejos* (L.) Roth (Figure 2). More insight into these relationships between species and treatments was given by the IndVal analysis (Appendix A).

**Table 3.** The influence of treatments on species composition in experimental transects (set of plots) with *Calamagrostis epigejos* (L.) Roth. Parameters of environmental variables fitted to the DCA analysis results.

Parameter	Abbreviation	DCA1	DCA2	r2	p-Value
Mowing (once, twice per year)	MOWING	0.99953	−0.03066	0.551	0.001
Biomass left	BIOMASS	0.18737	−0.98229	0.1145	0.001
Cover abundance of <i>C. epigejos</i> (L.) Roth	CAL.EPI	−0.63871	0.76945	0.0026	0.734
Year of the study	YEAR	0.9505	−0.31072	0.0342	0.015

#### 4. Discussion

##### 4.1. *Calamagrostis epigejos* (L.) Roth—A Widespread Grass in Poland, and all over the World

The large-scale phenomenon of widespread, expansive species, such as *Calamagrostis epigejos* (L.) Roth, typical of several native European perennial C3 types of grass, is considered a significant threat to European biodiversity and is comparable, in some respects, to biological invasions by alien plant species [41,42]. Many studies have proven that *C. epigejos* (L.) Roth spreads once established [7,24]. Several studies have analyzed how dominant, fast-spreading species, such as *C. epigejos* (L.) Roth, can extend so efficiently and have looked to establish a way to prevent these grasses from causing a decline in biodiversity (ref. [8] and the references cited therein).

##### 4.2. The Difference in Diversity, Mowing, and Time

Some studies have suggested that grassland biodiversity can increase after frequent mowing in abandoned grasslands because the species richness has increased due to the reduced vigour of competitive species. Regular mowing has been a potential management tool for excluding clonal grasses and maintaining grassland biodiversity [43]. There are also many reports showing that the response to mowing treatment was slow. For instance, a significant difference in species richness appeared after 5–8 years of regular mowing [24,27]. Bartha et al. [44], who focused on vegetation study scale-dependence and the length of study units in restoration, stated that 5–10 years of treatment were necessary to observe an increase in species number. Rebele and Lehmann [24] also reported a long-time response when they studied *Calamagrostis epigejos* (L.) Roth populations growing in ruderal vegetation on a landfill site. These authors found that species richness was significantly affected by mowing. Comparing species richness in mown and control plots yielded significant differences, detected in the fifth to the tenth year. Our results showed that an effective slow response only occurred after some years. The time of response was different depending on the diversity measure used.

##### 4.3. The Response of Plants to Applied Treatments—The Impact of Subsequent Treatments on the Value of the Assessed Parameter

The slow response to treatment could be explained differently. The results of Házi et al. [27] revealed that the decrease in cover of *C. epigejos* (L.) Roth did not always cause an increase in the number of meadow species but could sometimes result in an increase in abundance of another fast-growing competitor, e.g., *Brachypodium pinnatum* (L.) P. Beauv. Rebele and Lehmann [24] revealed different results, showing that mowing twice a year effectively decreased the cover of *C. epigejos* (L.) Roth. However, a significant decrease appeared only in the third year. The two years between the start of mowing and the reduction of *C. epigejos* (L.) Roth were reported by these authors from various habitats. Another possible explanation for the slow response to mowing treatment could be due to the accumulation of nutrients in the rhizomes of these grasses [33], which allows the grass to continue to grow after being damaged. Earlier, Rebele [12] stated that the availability of phosphorus and potassium facilitates the growth of *C. epigejos* (L.) Roth. It has been found that regardless of the high biomass loss due to frequent cutting, *C. epigejos* (L.) Roth populations can still survive for several years due to nutrients stored within their organs [45]. Our results revealed that mowing twice a year was probably sufficient to exploit the nutrients stored in the grass rhizomes and produce a negative nutrient budget for this species.



Another reason for the slow response to mowing treatment and the negative effect of *C. epigejos* (L.) Roth on overall diversity might be connected with the establishment restrictions it has on other species. The frequent mowing causes a decrease in the cover abundance of *C. epigejos* (L.) Roth and the amount of litter it generated. The mowing treatment probably reduced the establishment limitation and enabled colonization by herbaceous species of a so called “successional window” [46]. An explanation for the persistence of *C. epigejos* (L.) Roth and its slow response to treatment might be that symbiotic endophytes and AMF enhance this grass. Such symbiosis is stated up to now only in extreme habitats [11,19]. The study of successional development in various habitats has revealed that *C. epigejos* (L.) Roth is a common grass that colonizes during the early stages of succession [47]. Therefore, Házi et al. [27] predicted that early successional stage species, such as *C. epigejos* (L.) Roth, could have been present for at least 30 years at the abandoned vineyard site. These authors studied the delay in response to the applied treatment and explained this as being due to the colonizing potential of *C. epigejos* (L.) Roth and the presence of considerable nutrient reserves. Our results showed that several target species were able to establish after mowing and removal of biomass, and this is likely due to a reduction in the high cover abundance of *C. epigejos* (L.) Roth and a decrease in the production of its litter.

The slow response of the vegetation to the treatments might be possibly due to propagule limitation. The local seed bank of the meadow used in this study was relatively rich, and potential immigrant species were present within the close surroundings of the permanent plots studied. However, regardless of the proximity of the target species to the study area, it still took several years for them to reach the treatment plots. The slow rate of diversity increase found in our study underlines the importance of fine-scale within-stand dispersal limitation and other fine-scale spatial constraints which determine the rate and direction of the vegetation dynamics, which were also considered by Bartha et al. [44]. The results of our experiment also revealed the decrease in cover abundance of *C. epigejos* (L.) Roth in the control plots. As in our study, Házi et al. [27] also obtained a surprising result with a decrease in the cover abundance of *C. epigejos* (L.) Roth in their control plots. In the control plots of the study by Házi et al. [27], where the cover abundance of *C. epigejos* (L.) Roth spontaneously decreased, species richness and diversity increased. Our study showed that *C. epigejos* (L.) Roth could also decrease spontaneously in plots without treatments. The slow process mentioned by Bartha et al. [44] and lag effects found in the mown plots explains this result. A significant decrease of *C. epigejos* (L.) Roth in the control plots was detected after 6–7 years. It is essential to consider that, particularly in human-modified habitats, conditions are changing significantly over short periods, and the abandonment of traditional management, including the lack of grazing and mowing, has become typical in recent decades in this region [48]. Eutrophication of the environment, particularly the increasing amount of nutrients deposited in terrestrial and aquatic habitats, has also caused many environmental shifts [49]. It is likely that *C. epigejos* (L.) Roth might be favored in such altered environments, and its spread will likely increase to achieve dominance in a wide range of habitats. Our study also showed that the mowing treatment needed to be applied for a reasonably long time because each *C. epigejos* (L.) Roth population responded slowly to the treatment. This result suggests that meadow restoration experiments should be planned for at least eight to ten years to gain accurate results in these types of communities because of the dynamics of the successional development. This long-term permanent plot field experiment focused on applying different treatments. It allowed us to be able to study the response to this restoration management and the spontaneous dynamics of the vegetation not possible in a laboratory-based experiment. The mechanisms of these changes still require further study in order to provide explanations. While mowing reduces aggressive grasses and herbs, it may damage other grasses and broad-leaved forb species that are desirable components of the target community [7,37].

A further disadvantage of mowing is that it is expensive and often difficult to implement. Therefore, it is helpful to consider alternative restoration measures and conservation

management tools in the long-term. Prescribed burning is still controversial and cannot be considered a viable alternative, and according to Marozas et al. [50], it increases the dominance of *C. epigejos* (L.) Roth. Therefore, we agree with Dostálek and Frantík [51] that after a long (ca. 7 years) period of regular mowing, grazing should be reintroduced to the area of biodiversity interest. Most researchers consider *C. epigejos* (L.) Roth an expansive grass that is dangerous to plant diversity, but this is not necessarily true. In the early stage of the regeneration process, it can have positive effects (for example, by controlling soil erosion) [8]. Our results also suggest that its adverse effects on diversity are not permanent if the management of a site is strictly implemented.

#### 4.4. Directions for Maintaining an Ecosystem Mosaic in an Urban-Industrial Landscape

Many authors pay attention to the need for proper management of anthropogenic areas in an urban-industrial landscape [1,6,14,26,27,33,43]. In the literature, results of long-term studies can be found focusing on the influence of the species in question on the biodiversity of different habitats [52–54]. The results of this study also provide a broader perspective of the consequences of meadow, or grassland, abandonment for plant species diversity loss. This knowledge is essential for maintaining an ecosystem mosaic which is reflected by the plant species composition of the vegetation in an urban-industrial landscape.

## 5. Conclusions

Frequent mowing is an effective management tool for controlling and reducing the cover abundance of *C. epigejos* (L.) Roth in mid-successional grasslands. Contrary to our expectations, the treatment of mowing twice a year with the biomass removed (MTH) did not cause a distinct cumulative decline (over time) in the cover abundance *C. epigejos* (L.) Roth nor an increase in meadow species diversity and abundance. Nevertheless, significant changes in the measured parameters were recorded after different times and treatments depending on the measured plant diversity parameter.

The proper management and enhancement of habitats and vegetation mosaics will result in a spontaneous biodiversity increase. The spontaneously developed diversity of primary producers, mostly plant species, will reflect the variety of habitat conditions. The plant species composition of diverse vegetation unavoidable will lead to the biodiversity increase of above- and below-ground living organisms.

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## Appendix A

**Table A1.** The list of species with their indicator values IndVal in distinguished groups. The significantly higher values are in bold.

	CONTROL	MOH	MOL	MTH	MTL	p-Value
<i>Achillea millefolium</i> L.	0.17	0.10	0.43	0.07	<b>0.55</b>	<b>0.001</b>
<i>Aegopodium podagraria</i> L.	<b>0.98</b>	0.55	<b>0.95</b>	0.00	0.00	<b>0.001</b>
<i>Alopecurus pratensis</i> L.	0.00	0.00	0.02	0.00	0.00	NS
<i>Anthriscus sylvestris</i> (L.) Hoffm.	<b>0.13</b>	0.00	0.00	0.00	0.00	<b>0.001</b>
<i>Artemisia vulgaris</i> L.	0.30	<b>0.58</b>	<b>0.60</b>	0.10	0.28	<b>0.001</b>
<i>Carex hirta</i> L.	0.27	0.70	0.70	0.53	0.52	NS
<i>Cirsium arvense</i> (L.) Scop.	0.28	<b>0.37</b>	0.30	<b>0.68</b>	0.17	<b>0.001</b>
<i>Cirsium palustre</i> (L.) Scop.	0.00	<b>0.15</b>	0.00	0.02	0.00	<b>0.001</b>
<i>Dactylis glomerata</i> L.	0.20	0.03	0.18	0.18	0.00	NS
<i>Daucus carota</i> L.	<b>0.12</b>	0.03	0.00	0.00	0.05	<b>0.005</b>
<i>Elymus repens</i> (L.) Gould	0.63	0.95	0.78	1.00	0.82	<b>0.008</b>
<i>Festuca rubra</i> L.	0.00	0.00	0.02	0.00	0.00	NS
<i>Galeopsis tetrahit</i> L.	0.03	0.02	0.00	<b>0.08</b>	<b>0.08</b>	NS
<i>Galium aparine</i> L.	0.00	<b>0.13</b>	0.00	<b>0.10</b>	0.08	<b>0.019</b>
<i>Heracleum sphondylium</i> L.	0.00	0.00	0.58	0.02	0.15	<b>0.001</b>
<i>Holcus lanatus</i> L.	0.00	0.00	0.00	0.00	0.02	NS
<i>Lathyrus pratensis</i> L.	0.00	0.00	0.03	0.00	0.00	NS
<i>Poa pratensis</i> L.	0.10	0.15	0.25	<b>0.33</b>	0.00	<b>0.001</b>
<i>Rumex acetosa</i> L.	0.00	0.00	0.00	0.02	0.00	NS
<i>Taraxacum officinale</i> F. H. Wigg.	0.00	0.00	0.00	0.00	0.02	NS
<i>Urtica dioica</i> L.	<b>0.40</b>	0.05	0.00	0.07	0.12	<b>0.001</b>
<i>Vicia angustifolia</i> L.	0.07	0.00	0.00	0.03	0.03	NS
<i>Vicia cracca</i> L.	0.00	0.00	0.02	<b>0.37</b>	<b>0.28</b>	<b>0.001</b>

Explanations: Control: no treatments, MOH—mowing once a year with the biomass removed, MOL—mowing once a year with the biomass left, MTH—mowing twice a year with the biomass removed, MTL—mowing twice a year with the biomass left.

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