Influence of grassland management on the biodiversity of plants and butterflies on organic suckler cow farms

Einfluss des Grünlandmanagements auf Phytodiversität und Tagfalter auf ökologisch bewirtschafteten Mutterkuhbetrieben

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Abstract

The intensification of agricultural practices has led to a severe decrease in grassland biodiversity. Although there is strong evidence that organic farming can reduce the negative impacts of land use, knowledge regarding the most beneficial management system for species richness on organic grasslands is still scarce. This study examines differences in the biodiversity of plants and butterflies on rotationally and continuously grazed pastures as well as on meadows cut twice per year on two large organic suckler cow farms in NE Germany. Vegetation and flower abundance, as factors likely to influence butterfly abundance and diversity, were compared and used to explain the differences. The data attained by vegetation assessments and monthly transect inspections from May to August were analyzed using descriptive statistics and nonparametric methods. The abiotic site conditions of the studied plots had more influence on plant species numbers than the management method. Dry and nutrient-poor areas (mainly poor types of *Cynosurion*) and undrained wet fens (*Calthion*) were important for phytodiversity, measured by the absolute number of species, indicator species for ecologically valuable grasslands and the Shannon Index. Meadows tended to have more indicator species than pastures, where small-scale special sites such as wet depressions were crucial for plant diversity. Butterfly diversity was very low, and 90% of the recorded butterflies were individuals of the generalist species *Pieris napi*. Butterfly abundance depended mainly on occurrence of specific habitat types and specific larval host plants. Supply of flowers was crucial only in certain time periods. Differences in butterfly abundance between the management systems could be explained by the site conditions of the studied grasslands. We conclude that meadows are more favorable to support ecologically valuable plant species; however, their extension is contradictory to the organic farming method of suckler cows maintained outside of stables. Rotationally grazed pastures could be a compromise that would enhance the temporal heterogeneity of flower abundance and vegetation structure. The plant diversity on pastures should be improved by less intensive grazing on special sites and plant species enrichment by means of hay transfer. For enhancing butterfly diversity we suggest to reduce land use intensity especially on poor soils. Considering the economic perspective of the farms, small parts of the agricultural area could be sufficient if connectivity to other suitable habitats is assured. Flower abundance and diversity of larval host plants could be promoted by high diversity of farming practices as well as preserving small uncut strips of meadows.

Keywords: cattle grazing, continuous pasture, land use impact, lowland fen, meadow, organic farming, plant community, rotational pasture, species diversity, wet grassland

Erweiterte deutsche Zusammenfassung am Ende des Artikels

1. Introduction

During the last decades, the intensification of agricultural practices in industrialized countries has led to a massive decrease in farmland biodiversity (e.g., TSCHARNTKE et al. 2005). This decrease is the result of increasing homogeneity in intensively used landscapes when habitats are removed (e.g. hedges and small ponds), or negatively affected by intensive fertilization or pesticide application (BENTON et al. 2003, GEIGER et al. 2010). The loss of species richness is especially apparent in grasslands, where species-rich mesic and wet grasslands have lost most of their area and species in Central Europe during the last 50 years (KRAUSE et al. 2011, WESCHE et al. 2012) and the abundance of grassland butterfly species has declined by 30% in Europe since 1990 (VAN SWAAY et al. 2015). Flower abundance has decreased to approximately one-third during the last two decades (KUUSSAARI et al. 2007), caused by the intensive management practices of grasslands and general eutrophication (WALLISDEVRIES et al. 2012).

Many studies have shown that organic farms have a greater biodiversity compared with conventionally managed farms (e.g., weeds: VAN ELSEN 2000, flora and fauna: MÄDER et al. 2002, RAHMANN 2011, TUCK et al. 2014, butterflies: FEBER et al. 2007, birds, vegetation: BELFRAGE et al. 2005, grassland vegetation: HAAS et al. 2001). This is most likely due to organic farming methods, especially the use of crop rotations, which increase spatial and temporal heterogeneity of farmland, and the abdication of pesticides and mineral nitrogen fertilizers (BENTON et al. 2003, RUNDLÖF & SMITH 2006, NORTON et al. 2009). Nevertheless, there are differences in the magnitude of the ecological advantages of different management systems within the organic sector (BELFRAGE et al. 2005, HOLE et al. 2005, MÜLLER-LINDENLAUF et al. 2010).

To promote biodiversity on organic farms, a pilot project is currently being implemented in northeast Germany. Farms that reach a certain nature conservation standard (according to a point system) receive a certification that can be used for marketing purposes (STEIN-BACHINGER et al. 2014, GOTTWALD et al. 2015). Earlier investigations of organic farms in this region showed that, on arable land, conflicts occurring with common management practices can be solved by a variety of nature conservation measures (FUCHS & STEIN-BACHINGER 2010, STEIN-BACHINGER & FUCHS 2012). However, there is still little knowledge regarding the grassland management system most beneficial for conservation purposes on large organic suckler cow farms. Within the project mentioned above, this study investigated the differences in the biodiversity of plants and butterflies for three grassland management methods common in northeast Germany. On two organic farms, we compared pastures that are continuously grazed, pastures that were rotated over five paddocks roughly every week, and meadows cut twice a year. The main objective was to evaluate different management practices with regard to their ability to enhance species diversity.

Plants are often used as indicators to assess the biodiversity of ecosystems because their species richness and composition respond to soil fertility and management practices (MARINI et al. 2007). Lepidopterans are often used as indicator species for insects because they are sensitive to changes in their environment (FARTMANN & HERMANN 2006, VAN SWAAY et al. 2006, SETTELE et al. 2009). Whereas most studies either concentrate on vegetation or insect diversity, we sampled both groups of organisms on the same plots in order to evaluate biodiversity on a wider basis. Furthermore, we investigated possible reasons for a higher or lower butterfly diversity and abundance, especially the amount of flowers and the vegetation structure. While abundance of nectar resources mainly affects densities of generalists, larval host plants are the key factor for habitat specialists (KRÄMER et al. 2012). We focused more on the amount of flowers than on the occurrence of larval host plants, as the occurrence of habitat generalists plays a major role on cultivated grassland (BÖRSCHIG et al. 2013).

While there are many studies comparing management methods on conservation grasslands (e.g., MOOG et al. 2002, STAMMEL et al. 2003), few studies assess biodiversity on commercially farmed pastures and meadows, where economic realities demand a relatively high forage production and, therefore, a certain intensity of use (Flora: PAVLŮ et al. 2003; Fauna: ZAHN 2006, FARRUGGIA et al. 2012).

We hypothesize that, due to the differing effects of mowing and grazing (KLAPP 1971, DIERSCHKE & BRIEMLE 2002, ELLENBERG & LEUSCHNER 2010) and of continuous and rotational grazing (Flora: DIERSCHKE & BRIEMLE 2002, PAVLŮ et al. 2003; Fauna: FARRUGGIA et al. 2012), the three differently managed grassland types will differ in (1) phytodiversity, (2) vegetation structure, (3) flower abundance and (4) diversity and abundance of butterflies (which in turn are influenced by (1), (2) and (3)). The results from this study contribute to the development and evaluation of nature conservation measures in organically managed grasslands (GOTTWALD & STEIN-BACHINGER 2015).

2. Materials and methods

2.1 Study sites and sampling design

The study sites are located on lowland pastures and meadows of two neighbored farms in northeast Germany in the federal state of Mecklenburg-Western Pomerania near the villages Walkendorf and Dalwitz, administrative district Rostock (53°57'–59'N, 12°28'–36'E). Mean annual precipitation is approximately 590 mm/year (weather station Güstrow, mean value for years 1951–1990; LIEDTKE & MARCINEK 1995). The annual mean temperature is approximately 9 °C (station Laage, mean values for years 1990–2013; www.wetteronline.de). The study area belongs to the natural landscape “Rückland der Mecklenburgischen Seenplatte“ (MEYNEN et al. 1953–1962). It is an agrarian landscape shaped by the last stadial of the Weichselian glaciation, in which ground moraines with undulating reliefs are interspersed with fens. The mineral soils are clayey to sandy Luvisols, that when stagnant wet show patches of oxidation. Lower areas are either drained fens, dominated by peaty organic soils in different states of degradation, or wet fens with ± intact peat layer.

One of the farms maintains c. 300 suckler cows and calves, a few sheep and c. 100 breeding horses on approximately 350 hectares of permanently grazed grassland. The other farm uses a rotational grazing system on 300 hectares of pastures to keep suckler cows and calves. The average livestock unit (LU) per hectare is 0.5, indicating a moderate land use intensity. Both farms operate according to the criteria of the German organic farming association Biopark e.V. (BIOPARK 2012).

Six lots (25–80 ha) were surveyed for this study: two permanently grazed pastures and one meadow cut twice per year on the first farm and two rotationally grazed pastures with five paddocks each and one meadow cut twice per year on the second farm (Table 1). All of these grasslands have been used

Table 1. Study design. Habitat types: DP – dry, sandy and poor, DS – dry and sandy, DC – dry and clayey, IF – intensively used, drained fen, SF – seasonally flooded and WF – wet fen.

Tabelle 1. Untersuchungsdesign. Habitattypen: DP – nährstoffarm, trocken und sandig, DS – trocken und sandig, DC – trocken und lehmig, IF – intensiv genutztes, entwässertes Niedermoor, SF – zeitweise überflutetes Niedermoor und WF – quellig-nasses Niedermoor.

Lot	**Size (ha)**	**Farm**	**Management type**	**Cattle**	**Area percentage of habitat types** (number of vegetation surveys / number of butterfly transects for samplings 2-4)						**Vegetation surveys**	**Butterfly transects**
					DP	**DS**	**DC**	**IF**	**SF**	**WF**		
1	80	1	Continuously grazed pasture (C)	mother cows, calves, young horses	-- (0/0)	25 (6/4)	10 (1/0)	55 (5/1)	10 (4/2)	< 1 (1/1)	17	8
2	40	1	Continuously grazed pasture (C)	mother cows, calves, young horses	-- (0/0)	30 (6/2)	-- (0/0)	45 (6/2)	15 (3/0)	10 (1/0)	16	4
3	40	2	Rotationally grazed pasture with 5 paddocks (R)	mother cows, calves	< 1 (1/0)	25 (6/2)	5 (2/2)	40 (4/3)	20 (2/1)	10 (3/1)	18	9
4	47	2	Rotationally grazed pasture with 5 paddocks (R)	mother cows, calves	15 (4/1)	45 (5/2)	-- (0/0)	25 (2/1)	15 (2/1)	-- (1/1)	14	6
5	48	1	Meadow cut twice a year in early to mid June and late August (M)	--	15 (3/2)	-- (0/0)	20 (5/5)	20 (3/2)	40 (7/4)	5 (1/0)	19	13
6	25	2	Meadow cut twice a year in early to mid June and late August (M)	--	-- (0/0)	-- (0/0)	3 (1/1)	7 (2/2)	15 (2/1)	75 (8/2)	13	6
Sum					**6 (8/3)**	**20 (23/10)**	**6 (9/8)**	**32 (22/11)**	**19 (20/9)**	**17 (15/5)**	**97**	**46**

organically for the last 20 years. There was no fertilization except for areas with mineral soils on one of the meadows, which receives a moderate amount of dung every 10 years. All lots except a part of lot 4 (former arable land) had been used intensively as pastures for cattle before 1990, including partial ploughing and seeding of grasses.

We arranged the sampling sites in a stratified random approach over the lots with three management types and the six existing habitat types. Generally, the very dry and wet habitats were more widespread on meadows and restricted to smaller areas on pastures. This resulted in different numbers of sampling sites dependent on the abundance of the according habitat types. The study design was limited by the non-existence of some combinations of management and habitat types (Table 1). Phytodiversity was surveyed on 97 sites. Additionally, where the surrounding habitat type was widespread and homogenous enough, 50 m long transects running through the sites were used to sample butterflies, vegetation structure and flower abundance (52 transects). Six of these transects on pastures (4 continuously grazed, 2 rotationally grazed) had to be abandoned after the first sampling due to unexpected management changes, i.e., they were left ungrazed and/or mown.

2.2 Plant diversity

Between May and August 2012 on 97 plots (25 m²), a vegetation assessment was conducted to estimate plant cover using the extended Braun-Blanquet scale (e.g., VAN DER MAAREL 1979). Taxonomy follows JANSEN & DENGLER (2008). The total number of species, the number of biodiversity indicator species per plot and their percentage of the total species number was determined. The indicator species were defined by KAISER et al. (2010) for the neighboring federal state, Brandenburg, to indicate species-rich and extensively managed grasslands by their occurrence and are given in Supplement S1. Note that *Galium palustre*/ *G. uliginosum*/ *G. verum*, *Stellaria graminea*/ *S. palustris*, *Carex acutiformis*/ *C. disticha* and *Carex elytroides*/ *C. muricata* agg. are pooled. Additionally, the Shannon diversity index was calculated. The R software packages "simba" (function "bb2num" to convert Braun-Blanquet values to numerical percentages; JURASINSKI & RETZER 2012) and "vegan" (function "diversity" to calculate Shannon index; OKSANEN et al. 2012) were used (R Version 2.14.1, R CORE TEAM 2011).

The vegetation of the 97 sites was classified using the program TABWIN (version 4.2.4, PEPPLER-LISBACH 2004). Initially, species in our dataset that were strict indicators for mowing and grazing were excluded to prevent clustering due to management type rather than soil properties. For grazing, these species were *Cirsium arvense*, *Elymus repens*, *Polygonum aviculare* and *Stellaria media*, and for mowing, they included *Anthriscus sylvestris, Cardamine pratensis*, *Persicaria amphibia* and *Rumex acetosa*. The other species were used to cluster the sites with the program function "classification", using the default settings with the modification of a slightly reduced number of runs (4), cluster levels (3) and minimum constancy (40%). Due to the complex structure of the vegetation data, we divided the data into two tables (dry and wet sites) according to the first level of clustering and repeated the procedure for each table. A manual sorting of species groups resulted in six different habitat types defined by their species composition (see Table 1 and Supplement S1).

Braun-Blanquet values were transformed to an ordinal scale (1–9, VAN DER MAAREL1979) and used for an NMDS ordination (package "vegan", function "metaMDS") in R (R CORE TEAM 2011) to plot the sites, with the following modalities: Bray-Curtis distance, 100 iterations to identify the starting configuration, 3 dimensions, and a stress value of 10.98%. Additionally, median Ellenberg species' indicator values for moisture, nitrogen, tolerance for grazing, cutting and trampling (DIERSCHKE & BRIEMLE 2002), and the numbers of species and indicator species were fitted onto the ordination as vectors using the function "envfit" (package "vegan", function "metaMDS").

Furthermore, boxplots and, due to the lack of normal distribution, Kruskal-Wallis (KW) tests and Wilcoxon rank sum tests with Bonferroni corrections were used to analyze the data. Because of non-uniform data distributions, results were assessed descriptively. Due to the lack of combinations of management and habitat types, the data had to be grouped into three categories (dry: types DP, DS and DC; medium: type IF; wet: types SF and WF) for some of the analyses.

2.3 Sampling of butterflies, vegetation structure and flower abundance

The 50 meter long transects were visited four times, at roughly the rate of once a month, from mid-May until mid-August 2012 to sample butterflies, vegetation structure and flower abundance. Butterflies (*Papilionoidea* and *Hesperiidae*; nomenclature follows SETTELE et al. 2009) were surveyed by using the "Pollard walk" method (POLLARD & YATES 1993). Briefly, this involved recording all butterflies species in 2.5 meter on both sides of the line, while walking down the 50 meter transect in 5 minutes. Vegetation structure was measured in four 25 m² plots, each at 10 meters distance, on the 50 meter transect. The height of the lower vegetation level (slower growing or grazed), the upper vegetation level (faster growing or ungrazed) and the protruding plants (e.g., flowering grasses) on the plots were measured and the cover percentage of these levels was estimated. The mean of these values was calculated for each transect. The flowers (defined here as either single blossoms, e.g., for *Ranunculaceae*, or whole inflorescences, e.g., for *Asteraceae* and *Trifolium* sp.) were counted on five 1 m² squares on the transects and the mean was calculated for each site. Data were analyzed using nonparametric tests as for the vegetation data (see above) and Spearman rank correlations (r_s).

3. Results

3.1 Vegetation characterization and diversity

Each of the six grassland habitat types based on the 97 vegetation plots (dry, poor and sandy – DP; dry and sandy – DS; dry and clayey – DC; intensively used, drained fen – IF; seasonally flooded fen – SF; wet fen – WF, Fig. 1) was characterized by a typical species composition independent of their management type (Supplement S1). However, the grassland management type influenced species composition of the studied sites; in particular, mown and grazed stands were differentiated by the presence or absence of certain plant species (see also materials & methods). For example, *Cardamine pratensis* as an important larval host plant for the most abundant butterfly species *Pieris napi* (see below) was characteristic for mown stands of IF, SF and WF sites.

The habitat types could be assigned to the following plant communities according to BURKART et al. (2004) and DIERSCHKE (1997, 2012): DP and DS: grazed grasslands *Cynosuro-Lolietum* Br.-Bl. et De Leeuw 1936, *Hypochaeris radicata* subassociation, mown grasslands poorer type of *Arrhenatheretalia* community; DC: grazed grasslands *Cynosuro-Lolietum*, central subassociation, mown grasslands richer type of *Arrhenatheretalia* community; IF intensively used grassland with elements of SF; SF: *Ranunculo repentis-Alopecuretum geniculati* Tx. 1937; WF: *Angelico-Cirsietum oleracei* Tx. 1937 nom. inv. with elements of SF. With the high constancy of *Capsella bursa-pastoris*, *Poa annua*, *Polygonum aviculare* and *Stellaria media*, *Lolio-Cynosuretum* stands of the DS and DC habitat types tended to the *Plantago major-Trifolium repens* community that DIERSCHKE (1997) describes for intensively grazed and trampled pastures.

Only on wet sites (WF) the number of plant species was significantly higher compared to the other habitat types, while both the wet (WF) and dry (DP) sites had higher numbers and percentages of indicator species (Table 2, Fig. 2). Grassland management had no influence on the number of species and little influence on the number of indicator species, with a tendency of higher numbers in mown grassland (Table 3, Fig. 2). As shown in Table 1, the distribution of habitat types is quite different among the management types. Due to the high influence of the habitat types on the plant numbers as well as on indicator species the management impact was covered. The Shannon index of WF is highest and different from DS

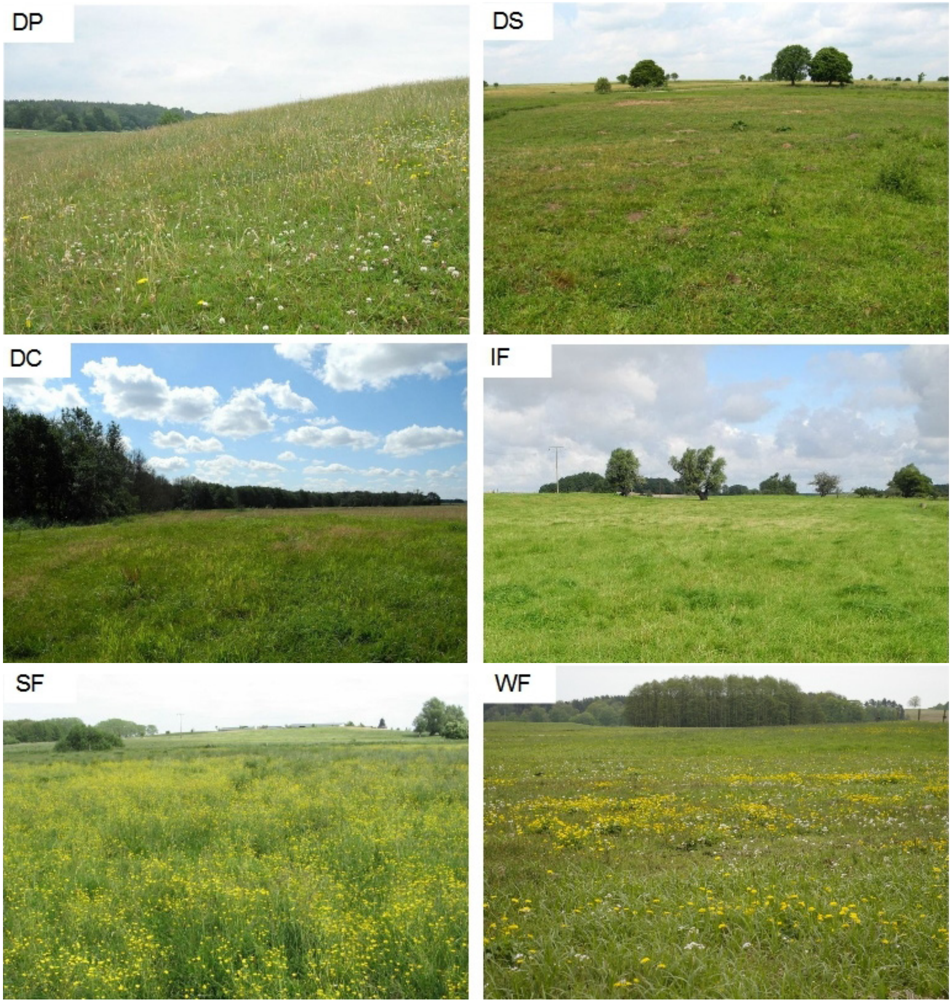

Fig. 1. Impressions of the six habitat types. First row: DP site on rotational pasture with *Anthoxanthum odoratum* (*Cynosuro-Lolietum*, *Hypochaeris radicata* subassociation), DS site on continuous pasture with ruderal species and trampling indicators (*Cynosuro-Lolietum*, central subassociation with elements of *Plantago major*-*Trifolium repens* community), second row: DC site on meadow with *Alopecurus pratensis* (richer type of *Arrhenatheretalia* community), species-poor IF site on rotational pasture, third row: SF site on rotational pasture with *Ranunculus acris* (*Ranunculo repentis-Alopecuretum geniculati*), WF site on meadow with *Caltha palustris* (*Angelico-Cirsietum oleracei* with elements of SF). For explanation of habitat types, see Table 1. (Photos: M. Kruse, 2012).

Abb.1. Impressionen der sechs Habitattypen. Erste Reihe: DP-Standort auf Umtriebsweide mit *Anthoxanthum odoratum* (*Cynosuro-Lolietum*, *Hypochaeris radicata*-Subassoziation), DS-Standort auf Standweide mit Ruderalarten und Trittzeigern (*Cynosuro-Lolietum*, zentrale Subassoziation mit Elementen der *Plantago major*-*Trifolium repens*-Gesellschaft), zweite Reihe: DC-Standort auf Wiese mit *Alopecurus pratensis* (reichere Ausprägung der *Arrhenatheretalia*-Gesellschaft), artenarmer IF-Standort auf Umtriebsweide, dritte Reihe: SF-Standort auf Umtriebsweide mit *Ranunculus acris* (*Ranunculo repentis-Alopecuretum geniculati*), WF-Standort auf Wiese mit *Calthapalustris* (*Angelico-Cirsietum oleracei* mit Elementen von SF). Für Erklärung der Habitattypen s. Tabelle 1. (Fotos: M. Kruse, 2012).

Table 2. Medians of phytodiversity, vegetation structure, flower abundance and butterfly abundance for habitat types and test results. Columns sharing the same letters are not significantly different. For explanation of habitat types see Table 1.

Tabelle 2. Mediane der Phytodiversität, Vegetationsstruktur, Blütenanzahl und Tagfaltervorkommen in den Habitattypen. Werte mit gleichem Buchstaben unterscheiden sich nicht signifikant. Für Erklärung der Habitattypen s. Tabelle 1.

Habitat categories	Dry			Drained	Wet		KW
Habitat types	DP	DS	DC	IF	SF	WF	*p* value
Phytodiversity							
n	8	23	9	22	20	15	
Species (No.)	15.5	17.0	16.0	19.0	17.0	25.0	<0.001
	a	a	a	a	a	b	
Indicator species (No./%)	2/14.4	0/0.0	1/4.8	0/0.0	1/5.3	4/13.3	<0.001
	c	a	a b	a b	b c	c	
Shannon-Index (H)	1.91	1.89	1.69	2.03	1.99	2.4	<0.001
	a, b	a	a	a, b	a, b	b	
Vegetation structure							
Protruding plants							
n	11	35	25	37	32	21	
Height (cm)	32.5	25.0	48.8	46.2	55.0	56.2	<0.001
	a b	a	b	b	b	b	
Cover (%)	1.0	0.2	2.0	0.6	2.0	1.0	0.052
Upper vegetation level							
n	12	40	40	45	37	37	
Height (cm)	15.2	12.2	22.2	19.2	19.8	24.0	<0.001
	a b	a	c	b c	b c	c	
n	12	40	33	45	37	22	
Cover (%)	24	22	50	41	49	36	<0.001
	a b	a	b	b	b	a b	
Lower vegetation level							
n	12	41	30	44	37	22	
Height (cm)	7.8	5.8	10.5	9.4	10.5	10.8	<0.001
	a b	a	b	b	b	b	
Cover (%)	97.1	96.8	97.1	98.0	98.3	96.3	0.143
Flower abundance							
n	12	41	33	45	37	22	
Total (No./m²)	1.0	4.4	1.0	2.4	2.2	3.7	0.027
	a b	a	b	a b	a b	a b	
Butterfly abundance							
n	12	41	33	45	37	22	
All species (Individuals/50 m transect)	0	0	1	1	1	4	0.092
Pieris napi (%)	58	80	84	89	96	94	

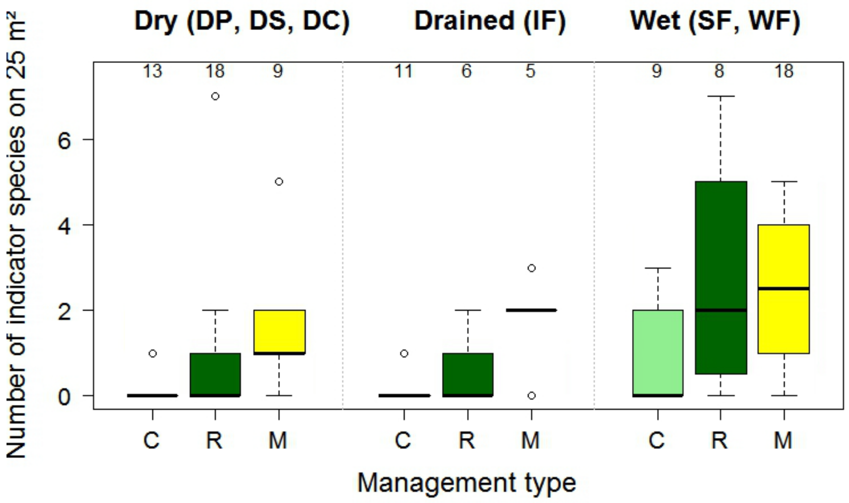

Fig. 2. Numbers of indicator species per vegetation assessment according to the management type (C - continuously grazed pasture, R - rotationally grazed pasture, M - meadow,) and divided into three habitat categories (see table 1 for explanation). Numbers at the top are the sample sizes. For explanation of habitat types see Table 1.

Abb. 2. Anzahl der Indikatorarten pro Vegetationsaufnahme in Abhängigkeit von der Nutzungsart (C - Standweiden, R - Umtriebsweiden, M - Mähwiesen,) aufgetrennt in drei Habitatkategorien (für Erklärung siehe Tabelle 1). Die obenstehenden Zahlen geben die Stichprobengröße an. Für Erklärung der Habitattypen s. Tabelle 1.

and DC (Table 2). As shown in Table 3, the Shannon index is lowest on lot 1 (continuously grazed) and significantly different from lot 4 (rotationally grazed) and lot 6 (meadow), indicating no clear influence of management types.

These results are supported by the NMDS ordination (Fig. 3). The vectors for the number of species (NS; $p < 0.05$) as well as indicator species (NIS; $p < 0.001$) are pointing in the direction of the (wet) meadows and in the opposite direction of the mean indicators for trampling (TT) and grazing tolerance (GT). This demonstrates that, in general, the pastures, especially the continuously grazed ones, possess fewer biodiversity indicator species. Additionally, the Ellenberg nitrogen values are generally lower on meadows.

3.2 Vegetation structure

Although the three vegetation levels were defined by their heights, we found some differences between the management types (Table 3). On the continuously grazed pastures, protruding structures such as flowering grasses or thistles tended to be shorter than those on meadows and rotationally grazed pastures (Table 3). Comparing habitats they were much lower for DP and significantly lower for DS (Table 2), while cover of protruding plants showed no clear effect (Table 3). Additionally, the upper and lower vegetation level of the continuously grazed pastures was significantly shorter than on the meadows, while no clear effect could be found on the cover (Table 3).

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Table 3. Median of phytodiversity, vegetation structure, flower abundance and butterfly abundance for management type and test results. Columns sharing the same letters are not significantly different.

Tabelle 3. Mediane der Phytodiversität, Vegetationsstruktur, Blütenanzahl und Tagfaltervorkommen in Abhängigkeit der Nutzungsart. Werte mit gleichem Buchstaben unterscheiden sich nicht signifikant.

Management type	continuously grazed (C)		rotationally grazed (R)		Meadow (M)		KW *p* value
Farm No.	1	1	2	2	1	2	
Lot No.	1	2	3	4	5	6	
Phytodiversity							
n	17	16	18	14	19	13	
Species (No.)	17	19	17	19	16	23	0.029
	a	a	a	a	a	a	
Indicator species (No./%)	0/0	0/0	0/0	1/4.4	1/9.1	2/10.3	<0.001
	a b	a	a b	b	a b	b	
Shannon-Index (H)	1.77	2.06	1.95	2.17	1.96	2.2	0.001
	a	a b	a b	b	a b	b	
Vegetation structure							
Protruding plants							
n	36	16	38	24	52	24	
Height (cm)	30.8	26.9	50.6	40.0	58.1	35.7	<0.001
	a	a	b	a b	b	a	
n	27	14	32	23	42	23	
Cover (%)	0.6	0.2	3.8	0.6	2.0	0.1	<0.001
	a b	b	a	a b	a	b	
Upper vegetation level							
n	36	15	38	24	52	24	
Height (cm)	15.0	13.8	22.1	15.1	22.0	20.1	<0.001
	a	a	b	a b	b	b	
Cover (%)	26	25	50	31	57	26	<0.001
	a	a	b c	a b	c	a	
Lower vegetation level							
n	36	16	38	24	48	24	
Height (cm)	6.9	5.5	10.0	7.2	10.9	10.4	<0.001
	a	a	b	a b	b	b	
Cover (%)	96.6	98.4	98.1	96.8	97.1	98.4	0.003
	a	a	a	a	a	a	
Flower abundance							
n	36	16	38	24	52	24	
Total (No./m²)	3.7	3.8	1.8	4.3	1.3	1.3	0.163
Butterfly abundance							
n	36	16	38	24	52	24	
All species	0	2	0	1	1	5	<0.001
(Individuals/50 m transect)	a	a b	a	a	a	b	
Pieris napi (%)	75	96	47	63	89	99	

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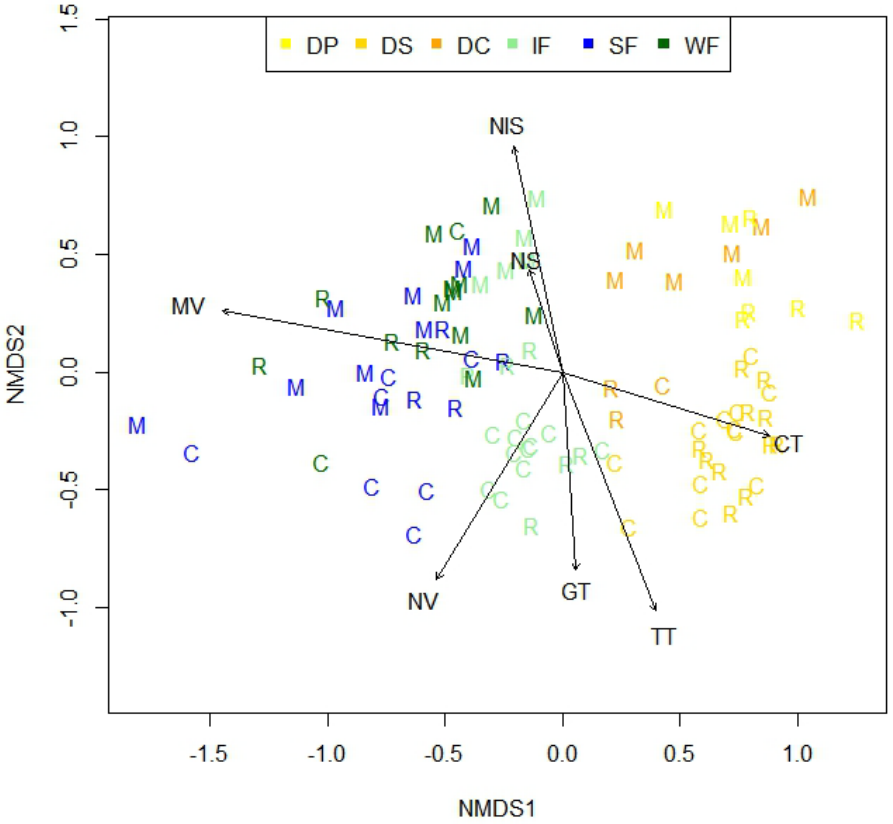

Fig. 3. NMDS ordination of the 97 sites (two of three dimensions are shown, and the stress value was 10.98%). Management types: C - continuously grazed, R - rotationally grazed pastures, M – meadows. Habitat types (see table 1 for explanation) of the sites are color-coded. Vectors show median indicator values for moisture (MV), nitrogen (NV), cutting (CT), grazing (GT) and trampling (TT) tolerance and the number of species (NS) and indicator species (NIS) at the sites.

Abb. 3. NMDS-Ordination der 97 Plots (nur zwei der drei Dimensionen sind hier dargestellt, der Stress-Wert beträgt 10,98 %). Nutzungstypen: C - Standweiden, R – Umtriebsweiden, M – Mähwiesen. Habitattypen sind farbcodiert (für Erklärung siehe Tabelle 1). Die Vektoren repräsentieren die Mediane der Zeigerwerte für Stickstoff (NV), Feuchte (MV), Mahd- und Beweidungstoleranz (CT und GT) sowie Trittverträglichkeit (TT) und die Anzahl der Arten (NS) und Indikatorarten (NIS) der Aufnahmen.

3.3 Flower abundance

A few plant species accounted for nearly all of the observed flowers with varying proportions over the vegetation period (Table 4). In May, *Ranunculus repens* was responsible for 60% of the counted flowers and together with *Ranunculus acris* agg., *Cardamine pratensis* and *Taraxacum* sect. *Ruderalia* accounted for almost the entire flower supply. Most of the flowers in the second and third sampling rounds in which slightly fewer flowers appeared were attributed to *Trifolium repens*, *Ranunculus repens* and *Rorippa palustris*. In August, especially flowerheads of *Achillea millefolium*, but also of *Leontodon autumnalis* and flowers of *Lythrum salicaria* were numerous.

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Table 4. Median of flower numbers, flowering species and butterfly individuals during the vegetation period (upper / lower quartile) and most frequent plant species.

Tabelle 4. Median des Blütenangebotes, der blühenden Pflanzenarten und Tagfalterindividuen während der Vegetationsperiode (unteres / oberes Quartil) sowie die häufigsten Pflanzenarten.

Date	Flowers n/m² (Q_{25}/Q_{75})	Flowering species Sum of all transects	Butterflies Individuals/ 50 m transect (Q_{25}/Q_{75})	most frequent species
May	4.3 (1.2/15.2)	12	0 (0/1)	*Ranuculus repens* (60%) *Ranuculus acris* agg (8%) *Cardamine pratensis (*15%) *Taraxacum* sect. *Ruderalia* (8 %)
June	1.9 (0.6/6.8)	15	0 (0/1)	*Trifolium repens* (40 %) *Ranuculus repens (*30%)
July	2.6 (0.6/6.6)	16	3.5 (0/9)	*Trifolium repens* (40 %) *Rorippa palustris (*32%)
August	1.4 (0/9)	16	3 (1/7)	*Achillea millefolium* (50%) *Lythrum salicaria* (25%) *Leontodon autumnalis* (5%)

In total, flower abundance was lowest on meadow sites (Table 3), but due to high seasonal variability (Fig. 4) no statistical significance was found. Comparing habitats, it was highest for DS and WF but only DS and DC with the highest and lowest abundance, respectively, differed significantly (Table 2). Depending on the different habitat preferences of the main flowering species and the management types, the amount of flowers varied between the habitat types over the sampling times (Fig. 4). In May, the nectar resources were most abundant on the WF sites, while in June and July, most flowers were found on the DS sites and in August on the DP sites. At the same time all other habitat types, except the WF type, showed only 1–2 flowers per m². Before cutting in early to mid-June, the meadows had slightly but not significantly more flowers than the pastures. Mowing reduced the number of flowers on meadows dramatically and led to a significantly higher flower abundance on pastures ($p < 0.001$) in the second sampling. In July and August, all three management types had a similar low flower abundance with single sites on meadows reaching high numbers (Fig. 4).

3.4 Butterfly abundance and diversity

In total, 712 individuals of 14 butterfly species were observed during the four samplings on the transects (Supplement E2). Nearly 90% of the observed butterflies were of one single species, the Green-veined White (*Pieris napi*). Other frequent species were *Pieris brassicae*, *P. rapae* and *Coenonympha pamphilus*. Temporarily numerous were, for instance, *Aglais urticae*, *Aphantopus hyperanthus* near trenches and *Araschnia levana* near forest edges. In May and June, few butterflies were observed, while in July and August, we encountered individuals on 50 to 60% of the sampling walks (Table 4).

Most butterflies were recorded on fen sites (IF, SF), especially wet fen (WF) (Table 2, Supplement E1). The proportion of *P. napi* was highest on wet sites (SF and WF), while the proportion of other species was highest on dry and poor (DP) sites (Table 2). Some species occurred exclusively on dry sites, resulting in a higher overall species richness on dry sites than on fen sites (Supplement E2).

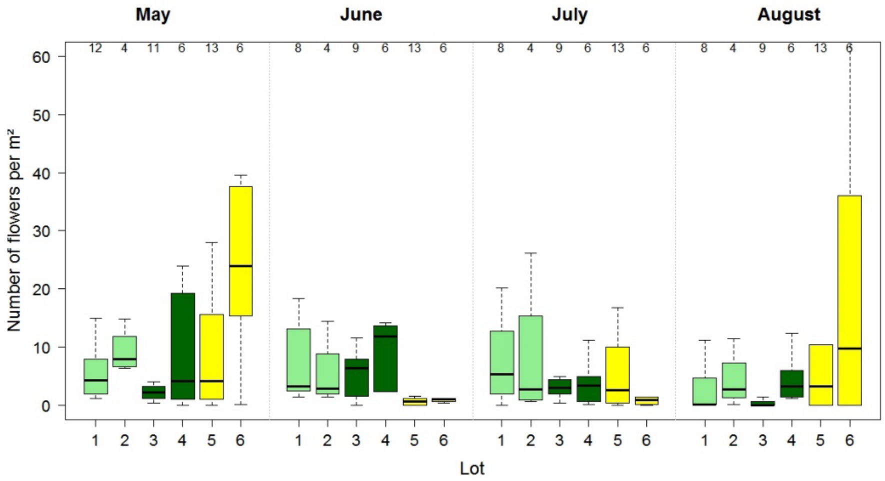

Fig. 4. Number of flowers per m² over the four samplings, according to the six lots (compare Table 1) (continuously grazed pastures - light green, rotationally grazed pastures - dark green, meadows - yellow). Cutting on the meadows took place in early to mid-June before the second sampling. Outliers were not plotted; numbers at the top are the sample sizes.

Abb. 4. Anzahl der Blüten pro m² über die vier Wiederholungen und in Abhängigkeit der 6 Schläge (vgl. Tab. 1) (Standweiden – hellgrün, Umtriebsweiden – dunkelgrün, Mähwiesen - gelb). Die Mähwiesen wurden Anfang bis Mitte Juni vor der zweiten Wiederholung gemäht. Ausreißer sind nicht dargestellt. Die oben stehenden Zahlen geben die Stichprobengröße an.

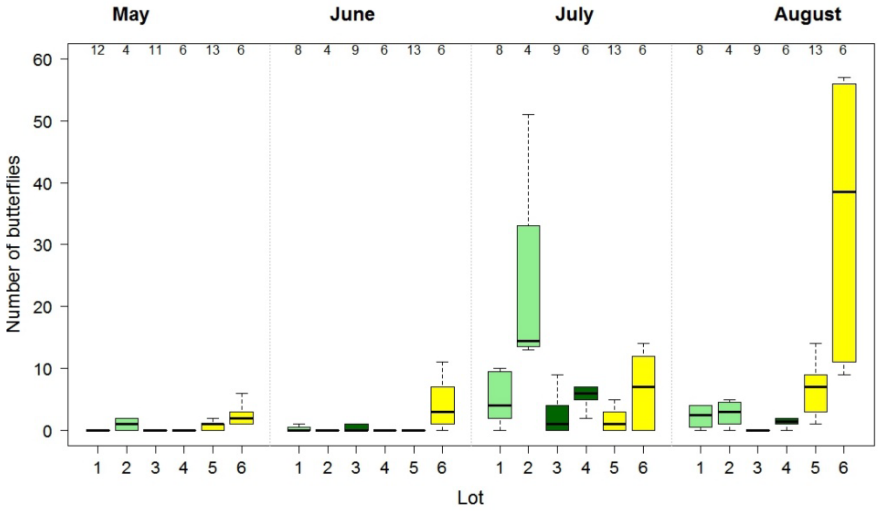

Fig. 5. Number of butterfly individuals over the four samplings, according to the six lots (compare Table 1) (continuously grazed pastures - light green, rotationally grazed pastures - dark green, meadows - yellow). Cutting on the meadows took place in early to mid-June before the second sampling. Outliers were not plotted; numbers at the top are the sample sizes.

Abb. 5. Anzahl der Tagfalterindividuen über die vier Wiederholungen und in Abhängigkeit der 6 Schläge (vgl. Tab. 1) (Standweiden – hellgrün, Umtriebsweiden – dunkelgrün, Mähwiesen - gelb). Die Mähwiesen wurden Anfang bis Mitte Juni vor der zweiten Wiederholung gemäht. Ausreißer sind nicht dargestellt. Die oben stehenden Zahlen geben die Stichprobengröße an.

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When comparing butterfly abundance between the management types, more individuals were recorded on lot 6 (meadow, dominated by wet fen, Table 1) than on continuously grazed pastures (lot 1 and 2, Table 3). In July, the highest number of butterflies was found on lot 2 on continuously grazed pastures (Fig. 5).

Considering the numbers of the most frequent species, *P. napi,* we found significantly more individuals on meadows than on rotationally grazed pastures (Table 3). There was a significant correlation over all transects and sampling rounds between the abundance of *P. napi* and the cover of its important larval host plant *Cardamine pratensis* (r_s = 0.29, $p < 0.001$, $n = 190$).

An influence of phytodiversity on butterfly abundance and diversity was not found. Flower abundance had no detectable effect on butterfly abundance (r_s = 0.02, n.s.). Vegetation structure only had a small influence on butterfly abundance (higher upper [r_s = 0.25, $p < 0.001$] and lower vegetation level [r_s = 0.31, $p < 0.001$]; higher vegetation cover of the lower level [i.e., less bare ground, r_s = 0.35, $p < 0.001$]). No significant influence of a higher and denser vegetation on butterfly diversity was found.

4. Discussion

4.1 Phytodiversity

Grassland communities were characterized both by the soil properties of the site, as soil type and moisture, and the management type. Most known indicators for the corresponding type of use were identified (KLAPP 1971, DIERSCHKE & BRIEMLE 2002, ELLENBERG & LEUSCHNER 2010), and on the dry sites, the vegetation could be assigned to plant communities described for meadows and pastures. As expected, rotationally grazed pastures showed intermediate characteristics compared with meadows and continuously grazed pastures. On these, as on meadows, the plants can grow without disturbance for a comparatively long time (PAVLŮ et al. 2003). Rotationally grazed pastures were more similar to continuously grazed pastures, though (see phytosociological assignment). *Alopecurus pratensis*, *Anthriscus sylvestris*, *Hypochaeris radicata* and *Veronica chamaedrys*, most of them known as indicators for mown grasslands (DIERSCHKE & BRIEMLE 2002), were found more often on rotationally than on continuously grazed grassland. This is at least partly in agreement with the findings of PAVLŮ et al. (2003). For the permanently grazed sites, we could confirm a decline of high-growing grasses, but in contrast to PAVLŮ et al. (2003), we did not find *Lolium perenne* and *Trifolium repens* more often.

To separate the effects of management from those of the soil properties of the site, the measures for phytodiversity were analyzed according to the six defined habitat types. However, this study design had its limits because not all combinations of management type and habitat type were similarly frequent. This most likely indicates a pre-selection by the farmer; e.g., very wet places cannot be grazed without affecting the grass sward or steep hills are more difficult to cut. The dry and poor (DP) sites on pastures were mainly on sandy hill edges, where nutrients are likely washed out sooner. On one of the two meadows, they covered larger, rather flat areas, indicating an enduring nutrient-loss through hay harvesting. This is also supported by the NMDS ordination according to which meadows harbor plants with lower nitrogen indicator values, and might explain why these sites showed higher numbers of indicator species *sensu* KAISER et al. (2010) though they were rather species-poor. The DP sites are valuable for the species diversity of the studied grasslands and grazed stands and can be assigned to a threatened plant community (poorer type of *Cynosuro-Lolietum*) in German lowlands (RENNWALD 2000). Although assigned to the same community, the equally species-poor communities on dry and sandy (DS) and on dry and clayey (DC) sites had on average less than one indicator species for valuable grasslands and were strongly affected by intensive grazing and trampling. Thus, these sites require improvement for nature conservation purposes. The same holds for the intensively used, drained fen (IF) sites, on which the slightly higher species number, especially on the pastures, was reached through the addition of plant species indicating disturbance and trampling. The wet fen (WF) sites possessed significantly more plant species than the other habitat types and had a similarly high percentage of indicator species as the DP sites. In general, the plant community of these sites, *Angelico-Cirsietum oleracei*, is highly threatened in lowland Germany (RENNWALD 2000) and should be maintained wherever possible. It should be mentioned that, except for the seasonally flooded (SF) sites, the species numbers of plant associations (*Angelico-Cirsietum* and subtypes of *Lolio-Cynosuretum*) were clearly (5–12 species) lower than they are in optimally developed stands in northern Germany (cf. BURKART et al. 2004, DIERSCHKE 2012). Also the number of biodiversity indicator species *sensu* KAISER et al. (2010) was much lower than the precondition for payments in a result-oriented nature conservation program (except for the *Angelico-Cirsietum*).

The lack of clear differences between the three management types underlines the difficulty in separating edaphic effects from management effects, especially between the two types of pastures (cf. PAVLŮ et al. 2003, D'ANIELLO et al. 2011). This corresponds with DIERSCHKE & BRIEMLE (2002) that meadows cut twice per year as the older, more extensive type of grassland tend to be more beneficial to phytodiversity, when defining this term according to the number of indicator plant species rather than the absolute species number. Pastures, when small-scaled special habitats are maintained, can contribute to plant species richness. The Shannon diversity index does not seem to represent the quality of the grassland because the species number, influencing the outcome of the index, is not a good measure, due to many additional ruderal and disturbance-indicating plants on intensively used sites.

4.2 Vegetation structure

The vegetation structure was shortest and most homogeneous on continuously grazed pastures. This may not be caused by the management method *per se* but by the grazing of both horses and cows. Each species grazes the dung patches of the other species, leading to a less heterogeneous appearance than a site grazed only by one species (DIERSCHKE & BRIEMLE 2002, ELLENBERG & LEUSCHNER 2010). Due to the different preferences of butterfly species, it is difficult to propose a specific management method to improve the vegetation structure. Structures should be as heterogeneous as possible to meet the requirements of many species (BENTON et al. 2003). Because a higher (but not too high) vegetation is beneficial for the species diversity of butterflies (KRUESS & TSCHARNTKE 2002, ÖCKINGER et al. 2006, PÖYRY et al. 2009), a slightly reduced grazing intensity could promote species richness, especially in permanent pastures. Alternatively, small areas protected from grazing by fences could enhance structural heterogeneity and provide save larval habitats (VAN NOORDWIJK et al. 2012).

4.3 Flower abundance

The flower abundance was influenced by management and habitat type, but not statistically significant due to our study design. The habitat type determined the occurrence of the flowering plant species and by that the attractiveness of the flowers for the butterflies. The species accounting for most of the flowers, such as *Ranunculus* spp. and *Achillea millefolium*, are only used by few butterfly species as a nectar resource (SETTELE et al. 2009), and attractive (violet) nectar plants, such as thistles, teasels or *Lythrum salicaria*, were found only rarely on the studied sites. Altogether, the flower abundance was quite low (Table 2, 3) consisting of only few, not-nectar-rich plant species (Table 4). Comparing the three management types in May, we found the highest flower abundance on the meadows in lot 6 (Fig. 4). As nearly all flowers had disappeared after the cut in early June, the importance of a small-scaled mosaic of different management methods and of different cutting dates becomes obvious (CIZEK et al. 2012). Rotationally grazed pastures had fewer flowers than meadows but, due to the short grazing and relatively long regeneration phase of the single paddocks, they can most likely offer a more stable flower supply. FARRUGGIA et al. (2012) suggest not grazing one paddock throughout one whole month during the main flowering period. For breeding periods of birds these time intervals should be even longer (GOTTWALD & STEIN-BACHINGER 2015).

4.4 Butterfly abundance and diversity

The result that we did not detect a correlation between butterfly numbers and flower abundance is most likely caused by two facts: i) the number of flowers is not equivalent to the quality and amount of nectar resources (see above), and ii) the abundance of the dominant species *Pieris napi* was mostly determined by habitat and occurrence of larval host plants.

Regarding the availability of larval host plants in the study area, some more butterfly species could have occurred (e.g. *Polyommatus semiargus*: *Trifolium pratense*; *P. amandus*: *Lathyrus pratensis, Vicia cracca*; *P. icarus*: *Trifolium* sp.; *Aricia agestis*: *Geranium molle* agg., *G. pusillum*; *Anthocharis cardamines*: *Cardamine pratensis*; *Lycaena tityrus*: *Rumex acetosa*, *R. acetosella*). Especially the absence of the common species *P. icarus* (on the transects, not in the study area) is surprising. Possible explanations for the low diversity of butterfly species on the study plots are: i) some preferred habitat types (e.g. dry grassland) occur only as small patches on the farms and possibly cannot hold viable populations; ii) low connectivity of habitat islands and missing habitats in the surrounding landscape; iii) land use intensity: especially on rotationally grazed pastures the density of cattle is high for certain time periods and larval stages living on the ground are sensitive to trampling.

We found 14 butterfly species, but nearly all of the individuals were of one species, the Green-veined White (*Pieris napi*). This species as a generalist can cope better with relatively intensive grassland use than more specialized species (VAN DYCK et al. 2009). The other frequent butterflies such as *Aglais urticae* or *Coenonympha pamphilus* are also not threatened, while more specialized species as *Lycaena phlaeas* and *Melanargia galathea* were encountered only on dry sites with single individuals. Therefore, butterfly diversity could be improved. In terms of butterfly numbers, the interaction between habitat and management types becomes obvious. Most individuals of *Pieris napi* were recorded on meadows (at least in August), most likely due to the high proportion of wet fen and seasonally flooded sites offering the highest densities of the species' favored larval host plant *Cardamine pratensis* in

NE German wet grasslands (cf. FARTMANN in BURKART et al. 2004). In general, characteristics of the six grassland habitats, independent of their type of use and changing over the months, seemed to primarily determine butterfly numbers rather than the management type.

4.5 Management recommendations

On meadows, a two-cut regime with moderate manuring is able to conserve a relatively high quality of grassland. However, extending meadows is contradictory to the organic farming method of suckler cows being maintained outside of stables. Therefore, rotationally grazed pastures could be a compromise to enhance the temporal heterogeneity of flower abundance and vegetation structure (BENTON et al. 2003). To maintain and further enhance plant species diversity on pastures (meaning high absolute species numbers as well as many species indicating ecologically valuable grassland), special sites should be conserved and/or created e.g. by reducing drainage or (re-)constructing reliefs. These small-scaled habitats such as seasonally flooded or wet fen ditches or dry hill edges can form a refuge for specialized species that cannot cope with the mostly still too intensive use of the rest of the areas.

Our study shows that, even despite long-term implementation of a relatively extensive land use, organic farming *per se* does not generally lead to species-rich grassland communities valuable for nature conservation on once intensively used sites. This might be a result of land use practices in times of the German Democratic Republic: Fens generally were drained, ploughed and re-seeded. This holds also for most of the study sites. As many grassland species only have transient or short-term persistent seed banks (BEKKER et al. 1998), they will not reestablish even if actual conditions are favorable (BOSSHARD 1999). Additionally, strong fertilization has long-term effects especially on clayey soils (ROSENTHAL & HÖLZEL 2009), and many sites of the study area are located on degraded peat soils that are characterized by a permanent mineralization of nutrients (ROSENTHAL & HÖLZEL 2009). Nevertheless, compared with intensively used and fertilized grassland the overall diversity of plant species has to be rated as relatively high.

To enhance the quality of the studied grasslands, transfer of fresh seed-containing hay, vacuum harvesting, or seeding of site-specific seed mixtures could be used to establish indicator species on adequate sites (e.g., KIEHL et al. 2010). At the same time it is necessary to extensify the land use intensity on parts of the agricultural area. This includes raising of water levels on fen sites and a reduction of grazing intensity on selected parts of pastures. Here, however, the conflict between economically sound fodder production and nature conservation demands becomes obvious. This underlines the need of individualized and habitat-adjusted management advice respecting economic necessities for enhancing species richness.

To increase the flower abundance on meadows, mosaic mowing (e.g., mowing at different times on different areas or leaving peripheral areas unmown) is recommended to guarantee a constant nectar resource throughout the cutting season (CIZEK et al. 2012). At the same time, a great variety of different larval host plants and habitat types are necessary to promote habitat specialists (KRÄMER et al. 2012). Rotationally grazed pastures could be more beneficial to the flower abundance than permanently grazed pastures (cf. FARRUGGIA et al. 2012), but this requires further investigation. Although thistles (e.g., *Cirsium palustre*) and teasels (*Dipsacus sylvestris*) are preferred nectar plants, there is an urgent need from the agricultural point of view to curb their spread by cutting problematic areas as organic farmers cannot use herbicides.

To enhance butterfly species diversity, the plant species richness should be increased and because the larval host plants of many unrecorded butterfly species were already growing on the studied sites, connectivity to other grassland patches in the surrounding landscapes should be established, thus enabling more butterfly species to colonize the sites (ÖCKINGER et al. 2006, PÖYRY et al. 2009). When – like in the studied region – arable land neighbors the grassland, flowering strips or extended field margins could fulfill this purpose (STEIN-BACHINGER et al. 2010, 2014). The influence of temporarily high cattle densities on the survival on larval stages needs further investigations.

Concluding, farmers could provide a small part of their fields for conservation purpose. On these special sites the intensity of mowing or grazing should be very low. Special measures include mosaic mowing, set-asides, field margins and the maintenance of uncultivated open plots on poor soils (FUCHS & STEIN-BACHINGER 2010, GOTTWALD & STEIN-BACHINGER 2015).

Erweiterte deutsche Zusammenfassung

Einleitung – In den letzten Jahrzehnten wurde in den Agrarlandschaften der Industrieländer ein erheblicher Rückgang der Artenvielfalt beobachtet (TSCHARNTKE et al. 2005). Grünland ist davon besonders stark betroffen. Obwohl der ökologische Landbau aufgrund des Verzichts auf Pestizide und mineralischen Stickstoffdünger sowie einer insgesamt weniger intensiven Bewirtschaftung bereits zu einer Verbesserung der Situation beiträgt (TUCK et al. 2014), kann durch zusätzliche Maßnahmen eine weitere Förderung der Biodiversität erreicht werden. Um zu untersuchen, welche Grünlandbewirtschaftungsform dafür empfehlenswert ist, wurden in dieser Studie Standweiden, Umtriebsweiden und Mähwiesen auf großen, ökologisch bewirtschafteten Mutterkuhbetrieben in Mecklenburg-Vorpommern hinsichtlich ihrer botanischen Artenzusammensetzung, der Tagfalterdiversität und -abundanzen, des Blütenangebotes und der Vegetationsstruktur untersucht. Die Ergebnisse fließen in ein Pilotprojekt zur Entwicklung eines Naturschutzstandards für ökologisch bewirtschaftete Betriebe ein (STEIN-BACHINGER et al. 2014, GOTTWALD et al. 2015). Dieser Standard stellt eine zusätzliche Qualifikation für besondere Leistungen zur Förderung der Biodiversität dar und wird auch für Vermarktungszwecke genutzt (GOTTWALD & STEIN-BACHINGER 2015).

Material und Methoden - Auf zwei seit 20 Jahren ökologisch wirtschaftenden Mutterkuhbetrieben mit einem Tierbesatz von 0,5 Großvieheinheiten pro Hektar landwirtschaftlicher Nutzfläche in Mecklenburg-Vorpommern nahe Rostock wurden auf je zwei Standweiden (Mutterkühe und wenige Pferde), Umtriebsweiden (Mutterkühe) und zweischürigen Mähwiesen (Gesamtgröße 280 ha) von Mai bis August monatliche Begehungen auf ca. 50 Transekten (je 50 m) zur Erhebung von Tagfalterabundanz, Blütenangebot und Vegetationsstruktur sowie knapp 100 Vegetationsaufnahmen durchgeführt. Letztere wurden genutzt, um die Plots anhand einer Klassifikation mit dem Programm TABWIN sechs Habitattypen zuzuordnen und so die erhobenen Daten aufgetrennt nach den natürlichen Standortbedingungen auszuwerten. Auf den untersuchten Flächen dominieren Niedermoor mit Torfböden – je nach Stärke der Entwässerung in verschiedenen Stadien der Degradierung – sowie mineralische, sandige oder lehmige Braunerden. Eine NMDS-Ordination mit Umweltvektoren (Zeigerwerte für Stickstoff, Feuchte, Mahd- und Beweidungstoleranz und Trittverträglichkeit) wurde durchgeführt, um die Aufnahmeflächen ökologisch zu charakterisieren. Die Phytodiversität, gemessen als absolute Artenzahl, Anzahl an Indikatorarten für artenreiches Grünland *sensu* KAISER et al. (2010) und Shannon-Index, wurde mit nicht-parametrischen Tests sowohl zwischen den Habitattypen, als auch zwischen den Parzellen mit unterschiedlicher Nutzung verglichen. Tagfalterabundanz, -diversität, Blütenangebot und Vegetationsstruktur wurden ebenfalls mit nicht-parametrischen Methoden verglichen und auf Korrelationen getestet.

Ergebnisse – Sandige und trockene Standorte waren – sofern beweidet – durch die *Hypochaeris radicata*-Subassoziation des *Cynosuro-Lolietum* gekennzeichnet, während den lehmigen Standorten Magerkeitszeiger fehlten (Beilage S1). Auf entwässertem Niedermoor fand sich artenarmes Intensivgrünland mit Flutrasen-Arten, während zeitweise überflutetes Niedermoor durch Flutrasen des *Ranunculo-Alopecuretum geniculati* und quellig-nasses Niedermoor durch Bestände des *Angelico-Cirsietum oleracei* mit Flutrasen-Arten gekennzeichnet war. Die Anzahl der Pflanzenarten war auf quellig-nassen Niedermoorstandorten signifikant am höchsten (Tab. 2). Auf diesen und auf mager-trockenen Standorten fanden wir die meisten Indikatorarten für ökologisch wertvolles Grünland (Tab. 2) und im Norddeutschen Tiefland stark gefährdete Pflanzengesellschaften. Die beiden Mähwiesen besaßen insgesamt trotz etwas geringerer Artenanzahl mehr Indikatorarten für ökologisch wertvolles Grünland (Tab. 3). Das Blütenangebot war mit einem Median von max. ca. 4 Blüten pro m² insgesamt niedrig und wurde über alle Parzellen hinweg hauptsächlich von für Falter weniger attraktiven Arten gebildet. Auf den Standweiden war die Vegetation generell kürzer als auf den Umtriebsweiden und Mähwiesen (Tab. 3). Wir beobachteten 14 Tagfalterarten auf den Flächen, wobei der Grünader-Weißling *Pieris napi* mit etwa 90 % der gezählten Falter die mit Abstand häufigste Art darstellte. Der Anteil von Individuen dieser Art und auch die Gesamtfalteranzahl waren auf den feuchten Standorten (mit hoher Abundanz der Larvenfutterpflanze (*Cardamine pratensis*) am höchsten (Tab. 2). In der Summe wurden auf den Mähwiesen über alle Habitattypen hinweg die meisten Tagfalter beobachtet (Tab. 3), zwischen den vier Wiederholungen während der Vegetationsperiode gab es jedoch starke Schwankungen (Abb. 5). Hinsichtlich der Falterdiversität gab es keine eindeutigen Unterschiede zwischen den Managementtypen. Die trockenen Habitate (mit höherem Anteil in den Umtriebsweiden) wiesen in der Summe eine höhere Gesamtartenzahl als die Niedermoorflächen auf; spezialisierte Falterarten kamen aber nur vereinzelt vor (Anhang E2).

Diskussion – Trotz der deutlichen Unterschiede in der Artenzusammensetzung zwischen Mähwiesen und Weiden waren vor allem die Bodenbedingungen ausschlaggebend für die Phytodiversität und das Vorkommen von Indikatorarten für wertvolles Grünland. Umtriebsweiden waren erwartungsgemäß Standweiden ähnlicher als Mähwiesen. Zweischürige Mähwiesen sind bei der vorliegenden Bewirtschaftung auf Niedermoorstandorten in der Lage, eine relativ hohe botanische Artenvielfalt zu gewährleisten. Da dies jedoch der in Mecklenburg-Vorpommern häufig praktizierten Weidehaltung mit Mutterkühen widerspricht, könnten Umtriebsweiden einen Kompromiss bieten. Durch die Rotation der Beweidung erhöht sich die zeitliche Heterogenität der Flächen, was einen positiven Effekt auf die Artenvielfalt haben kann (BENTON et al. 2003). Das Blütenangebot steht hier konstanter zur Verfügung als auf Mähwiesen, auch wenn die Phytodiversität auf den untersuchten Flächen stark verbesserungswürdig ist. Die hohe Zahl von Indikator-Pflanzenarten auf trockenen und nährstoffarmen bzw. nassen Sonderstandorten unterstreicht deren besondere Bedeutung auf Weiden. Insgesamt zeigt unsere Studie, dass auch bei langandauernder ökologischer Bewirtschaftung nicht *per se* artenreiches und für den Naturschutz wichtiges Grünland entsteht. Ein angemessenes Vorkommen von bedeutsamen Futterpflanzen ist jedoch für die Betriebe ökonomisch notwendig. In diesem Spannungsfeld ist eine Förderung der Artenvielfalt nur über stärker an die Standorte angepasste Bewirtschaftungsverfahren unter Berücksichtigung der ökonomischen Erfordernisse möglich; daneben ist die Einbringung von Diasporen von nach zurückliegender Intensivierung nicht mehr vorhandenen Pflanzenarten etwa über Mahdgutübertragung zu empfehlen. Auch die Tagfalterdiversität ist auf den untersuchten Flächen bisher nicht zufriedenstellend, da nahezu alle beobachteten Schmetterlinge wenigen generalistischen Arten angehören. Die Artvorkommen und die Falterabundanzen wurden neben den Habitattypen offenbar auch von den vorkommenden Larvalpflanzen bestimmt. Weitere mögliche, aber nicht eindeutig identifizierte Faktoren sind das Blütenangebot, die Flächengröße und Isolation bzw. Konnektivität spezieller Habitattypen sowie möglicherweise eine kurzfristig hohe Besatzdichte der Weideflächen, die zu einer Schädigung von Larvalstadien führen kann. Maßnahmen zur Förderung der Tagfalter sind zum Beispiel eine kleinteilige Mahd (CIZEK et al. 2012, GOTTWALD & STEIN-BACHINGER 2015) oder eine veränderte Rotation auf Umtriebsweiden (FARRUGGIA et al. 2012). Im Untersuchungsgebiet könnte auch die Vernetzung von Grünlandhabitaten (ÖCKINGER et al. 2006) sowie die Anlage und optimierte

Pflege eines Verbundsystems von Sonderstrukturen im angrenzenden Ackerland (z. B. Blühstreifen, Hecken) (STEIN-BACHINGER et al. 2010) die Lebensraumqualität für Tagfalter und andere Insekten deutlich verbessern.

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Supplements

Supplement S1. Vegetation relevés of differently managed grasslands from two organic suckler cow farms in Mecklenburg.

Beilage S1. Vegetationstabelle unterschiedlich bewirtschafteten Grünlands auf zwei biologisch bewirtschafteten Mutterkuhbetrieben in Mecklenburg.

Additional supporting information may be found in the online version of this article.

Zusätzliche unterstützende Information ist in der Online-Version dieses Artikels zu finden.

Supplement E1. Origin of the relevés.

Anhang E1. Herkunftsnachweis der Vegetationsaufnahmen.

Supplement E2. Number of observations of butterfly species in each of the six habitat types as well as larval host plants and mobility of each species.

Anhang E2. Zahl der Beobachtungen der Tagfalter-Arten in jedem der sechs Habitattypen, Larvenfutterpflanzen und Mobilität der Arten.

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Supplement S1. Vegetation relevés of differently managed grasslands from two organic suckler cow farms in Mecklenburg. Management type: C continuously grazed, R rotationally grazed, M mowed. Lot: L Lühburg, S Strietfeld, Walkendorf , We Wesselstorf. Indicators for grazing / mowing: G grazing, M mowing (indicator for whole data set), G* grazing, M* mowing (indicator only for certain habitat types). Character species (no letter) and differential species (D) according to Burkart et al. (2004) and Dierschke 1997, 2004): C class, O order, V alliance; Arrh. *Arrhenateretalia* , Calth. *Calthion palustris* , Cynos. *Cynosurion* , Lol.-Pot. *Lolio-Potentillion anserinae* , Mol. *Molinietalia* , Mol.-Arrh. *Molinio-Arrhenatheretea* . Biodiversity indicator species according to Kaiser et al. (2010) are in bold. * *Rumex conglomeratus* , *R. crispus* and *R. obtusifolius* .

Beilage S1. Vegetationstabelle unterschiedlich bewirtschafteten Grünlands auf zwei biologisch bewirtschafteten Mutterkuhbetrieben in Mecklenburg. Bewirtschaftungstyp: C Standweide, R Rotationsweide, M Mahd. Fläche L Lühburg, S Strietfeld, Walkendorf , We Wesselstorf. Indikatoren für Beweidung / Mahd: G Beweidung, M Mahd (indikator für den gesamten Datensatz), G* Beweidung, M* Mahd (indikator nur für bestimmte Habitattypen). Charakterarten (ohne Buchstabe) und Differentialarten (D) nach Burkart et al. (2004) und Dierschke 1997, 2004): C Klasse, O Ordnung, V Verband; Arrh. *Arrhenateretalia* , Calth. *Calthion palustris* , Cynos. *Cynosurion* , Lol.-Pot. *Lolio-Potentillion anserinae* , Mol. *Molinietalia* , Mol.-Arrh. *Molinio-Arrhenatheretea* . Indikatorarten für Biodiversität nach Kaiser et al. (2010) in Fettdruck. * *Rumex conglomeratus* , *R. crispus* and *R. obtusifolius* .

Habitat type	Plot no.	Plant community
DP dry, poor and sandy	1-3	*Arrhenatheretalia* community (mown stands, poorer type)
	4-8	*Cynosuro-Lolietum* Br.-Bl. et De Leeuw 1936, *Hypochaeris radicata* Subassociation (poorer type)
DS dry and sandy	9-31	*Cynosuro-Lolietum* Br.-Bl. et De Leeuw 1936, Hypochaeris radicata-Subassociation (richer type)
DC dry and clayey	32-37	*Arrhenatheretalia* community (mown stands, richer type)
	38-40	*Cynosuro-Lolietum* Br.-Bl. et De Leeuw 1936, Central Subassociation / impoverished stands
IF intensively used, drained fen	41-62	Intensively used grassland with elements of *Ranunculo repentis-Alopecuretum geniculati* Tx. 1937
SF seasonally flooded fen	63-82	*Ranunculo repentis-Alopecuretum geniculati* Tx. 1937
WF wet fen	83-97	*Angelico-Cirsietum oleracei* Tx. 1937 nom. inv., with elements *Ranunculo repentis-Alopecuretum geniculati*

Syntaxonomy	Grazing/Mowing	TABWIN group in level (1 2 3)		Plots 1–97 (DP 1–8, DS 9–31, DC 32–40, IF 41–62, SF 63–82, WF 83–97)
			Plot number	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
			Management type	M M M R R R R R R R R R R R R R R R R C C C C C C C C C C C C M M M M M M R R C M M M M M R R R R R R C C C C C C C C C C C M M M M M M M M M R R R R C C C C C C C M M M M M M M M M R R R R C C
			Lot	L3 L3 L3 W2 W2 W1 W2 W2 W1 W1 W2 W2 W1 W1 W1 W1 W2 W2 W2 L2 S L2 L1 L1 L1 S S L2 S S S L3 We L3 L3 L3 L3 W1 W1 L2 L3 We We L3 L3 W1 W1 W2 W1 W1 W2 L2 S L2 S S L2 L2 L2 S S S We We L3 L3 L3 L3 L3 L3 L3 W1 W1 W2 W2 L1 L2 S L1 L2 S S We We We We We We We L3 We W1 W2 W1 W1 S L2
			Height herb layer [cm]	20 20 25 15 5 15 10 10 30 35 15 10 25 15 25 25 10 10 12 15 20 8 12 5 6 5 5 15 25 15 23 20 30 20 30 15 40 15 25 15 30 15 12 30 30 17 12 35 17 25 20 50 30 20 10 25 23 20 15 12 20 23 70 15 25 20 15 4 20 20 15 40 20 30 25 20 35 80 30 20 15 25 15 17 45 30 15 25 12 30 20 100 60 25 80 90 60
			Cover herb layer [%]	97 90 98 89 95 80 97 88 99 85 93 96 98 100 99 99 97 98 98 97 99 97 93 96 99 97 98 99 98 100 99 95 98 97 95 92 98 95 97 99 99 95 95 98 98 100 99 99 100 100 99 100 99 94 100 100 100 100 99 100 99 99 93 99 98 100 80 50 99 95 93 100 100 98 100 99 95 100 99 100 100 100 100 100 100 100 98 99 97 100 100 100 97 95 100 100 96
			Cover moss layer [%]	plot 2: 25; 4: 7; 6: 3; 7: 2; 8: 6; 9: 25; 18: 1; 32: 5; 36: 20; 37: 1; 43: 3; 44: 5; 69: 3; 84: 1; 97: 1
			Species number	22 10 15 30 15 20 13 16 15 11 18 16 16 18 18 16 19 22 21 19 20 16 17 16 11 16 20 15 19 19 17 13 12 13 16 13 17 17 21 18 19 15 21 25 19 17 17 24 19 17 19 20 23 23 20 21 17 15 19 15 22 22 18 18 23 11 10 7 11 25 18 16 17 20 19 19 8 17 17 13 16 18 25 25 24 25 24 23 23 23 29 18 30 31 41 19 41
			D1	
		1/1	**Anthoxanthum odoratum**	[illegible]
		1/1	**Stellaria graminea**	[illegible]
DO Arrh.		1/1	**Veronica chamaedrys agg.**	[illegible]
		1/1	Festuca ovina agg.	[illegible]
DO Arrh.		1/1	**Luzula campestris**	[illegible]
	G		Rumex acetosella agg.	[illegible]
			D1-2	
DO Arrh.		1	Agrostis capillaris	[illegible]
DO Arrh.	G		Hypochaeris radicata	[illegible]
			Geranium molle agg.	[illegible]
	G*		Geranium pusillum	[illegible]
	G*		**D1-3**	
C Mol.-Arrh.		1	Achillea millefolium	[illegible]
		1	Plantago lanceolata	[illegible]
O Arrh.		1	Dactylis glomerata	[illegible]
A Cynos.	G*	1	Leontodon autumnalis	[illegible]
			D1-4	
C Mol.-Arrh.			Poa pratensis agg.	[illegible]
DA Arrh.		1 2/1	Bromus hordeaceus	[illegible]
		2/1	Capsella bursa-pastoris	[illegible]
		2/1	Glechoma hederacea agg.	[illegible]
DA Arrh.		2/1	Veronica arvensis	[illegible]
			Grazing indicators, D2-5	
DA Lol.-Pot.	G		Elymus repens	[illegible]
	G		Cirsium arvense	[illegible]
	G		Polygonum aviculare agg.	[illegible]
	G		Stellaria media agg.	[illegible]
			D2-6	
C Mol.-Arrh.		1/2	Ranunculus repens	[illegible]
DA Cynos.	G*	1/2	Plantago major agg.	[illegible]
			D3-6	
			Poa trivialis agg.	[illegible]
C Mol.-Arrh.		2 1/2	Alopecurus pratensis	[illegible]
O Mol.		2 1/2	Deschampsia cespitosa	[illegible]
			D4-6	
A Lol.-Pot.		2	Agrostis stolonifera	[illegible]
A Lol.-Pot.		2	Potentilla anserina	[illegible]
A Lol.-Pot.		2	Alopecurus geniculatus	[illegible]
A Lol.-Pot.		2	Carex hirta	[illegible]
		2	Phalaris arundinacea	[illegible]
			Persicaria hydropiper	[illegible]
C Mol.-Arrh.			Festuca pratensis	[illegible]
C Mol.-Arrh.			**Ranunculus acris agg.**	[illegible]
			Rorippa palustris	[illegible]
A Calt.		2/2	**Lotus pedunculatus**	[illegible]
C Mol.-Arrh.	M		**Cardamine pratensis**	[illegible]
			D5-6	
A Calt.		2 2/2	Juncus effusus	[illegible]
DA Lol.-Pot.		2 2/2	Glyceria fluitans agg.	[illegible]
			D6	
DA Lol.-Pot.	M		Persicaria amphibia var. terrestris	[illegible]
		2/2	Juncus articulatus	[illegible]
A Calt.		2/2	Myosotis scorpioides agg.	[illegible]
DOM		2/2	Equisetum palustre	[illegible]
C Mol.-Arrh.		2/2	**Lathyrus pratensis**	[illegible]
O Mol.		2/2	**Lythrum salicaria**	[illegible]
A Calt.		2/2	Scirpus sylvaticus	[illegible]
O Mol.		2/2	**Silene flos-cuculi**	[illegible]
		2/2	Mentha arvensis	[illegible]
A Calt.		2/2	**Caltha palustris**	[illegible]
	M*	2/2	**Carex x elytroides**	[illegible]
C Mol.-Arrh.	M*	2/2	Bellis perennis	[illegible]
	G*	2/2	Epilobium cf. hirsutum	[illegible]
	G*		Ranunculus sceleratus	[illegible]
DO Mol.	G*	2/2	**Galium palustre**	[illegible]
DO Mol.	G*	2/2	**Carex acutiformis**	[illegible]
	G*	2/2	Veronica beccabunga	[illegible]
	G*		**Stellaria palustris**	[illegible]
			Other mowing and grazing indicators	
C Mol.-Arrh.	M		Rumex acetosa agg.	[illegible]
DO Arrh.	M		Anthriscus sylvestris	[illegible]
A Cynos.	G*		Lolium perenne	[illegible]
A Cynos.	G*		Phleum pratense s.str.	[illegible]
			Molinio-Arrhenatheretea species:	
C Mol.-Arrh.			Trifolium repens	[illegible]
C Mol.-Arrh.			Taraxacum sect. Ruderalia	[illegible]
C Mol.-Arrh.			Cerastium holosteoides	[illegible]
C Mol.-Arrh.		1	Holcus lanatus	[illegible]
C Mol.-Arrh.			**Trifolium pratense**	[illegible]
A Calt.			**Cirsium oleraceum**	[illegible]
C Mol.-Arrh.			Vicia cracca agg.	[illegible]
C Mol.-Arrh.			Ajuga reptans	[illegible]
O Arrh.			Cynosurus cristatus	[illegible]
			Other species:	
		1	Rumex sp.*	[illegible]
			Urtica dioica s.str.	[illegible]
			Chenopodium album agg.	[illegible]
			Brachythecium rutabulum agg. (M)	[illegible]
			Sisymbrium officinale	[illegible]
			Epilobium cf. parviflorum	[illegible]
			Festuca rubra agg.	[illegible]
			Rumex thyrsiflorus	[illegible]
			Artemisia absinthium	[illegible]
			Stellaria aquatica	[illegible]
			Medicago lupulina	[illegible]
			Veronica serpyllifolia	[illegible]
			Cirsium vulgare	[illegible]
			Galium cf. x pomeranicum	[illegible]
			Ranunculus ficaria	[illegible]
			Bidens frondosa	[illegible]
			Filipendula ulmaria	[illegible]
			Ranunculus flammula agg.	[illegible]
			Hypericum tetrapterum	[illegible]
			Carex disticha	[illegible]
			Juncus inflexus	[illegible]

Species occurring in less than three relevés:
Agrimonia eupatoria 4:r; Alisma plantago-aquatica 93:1; Aphanes arvensis 29:+; Arctium sp. 53:r, 55:r; Arrhenaterum elatius 35:1; Artemisia vulgaris 21:r; Atriplex patula 10:r; Brachythecium albicans (M) 6:1; Carex muricata agg. s.l. 22:1; Cerastium semidecandrum 5:1, 9:1m; Chaerophyllum temulum 32:+; Cirsium palustre 55:r; Convolvulus arvensis 4:1; Crepis capillaris 36:r; dicot. sp. 96:1m; Eleocharis palustris agg. 66:1; Epilobium cf. palustre 71:+; Epilobium cf. tetragonum 45:+; Equisetum arvense 4:1, 19:1m; Equisetum fluviatile 85:1, 95:1; Erodium cicutarium 11:r; Galium uliginosum 65:+, 95:+; Geranium pratense 13:r; Gnaphalium uligonosum 93:+; Heracleum sphondylium 44:+; Hieracium pilosella 4:1m; Hottonia palustris 93:+; Hypericum maculatum agg. 4:r, 37:+; Iris pseudacorus 93:r; Juncus acutiflorus 85:1, 91:+; Knautia arvensis 4:1; Linaria vulgaris agg. 70:1; Lycopus europaeus 78:1, 97:1; Lysimachia nummularia 97:+; Malva sylvestris 13:+, 21:+; Matricaria recutita 52:r; Ornithopus perpusillus 6:1; Persicaria cf. lapathifolia 93:+; Persicaria maculosa 48:+, 97:r; Poaceae sp. 36:1, 84:+; Polytrichum juniperinum (M) 6:1; Prunella vulgaris 76:+; Ranunculus bulbosus 53:1, 88:1; Rorippa sylvestris agg. 52:r; Sagina procumbens 71:1; Sambucus nigra 70:r; shrub sp. 41:+; Sium latifolium 93:1; Stellaria alsine 94:+; Symphytum officinale 63:1; Tee seedling 69:r, 87:r; Trifolium arvense 4:+, 5:+; Trifolium hybridum 97:1; Tripleurospermum maritimum agg. 53:r; Veronica anagallis-aquatica agg. 96:2a; Veronica scutellata 93:+.