Performance of extensive cattle stocking on a reclaimed minerotrophic wet grassland

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SUMMARY

Extensive stocking with cattle is a common type of grassland management in reclaimed fen sites. However, due to the high productivity of grassland on organic soil with a history of intensive management, stocking at low rates may not allow an adequate balance of herbage production and utilisation. In the present study we examined the agronomic performance of an established (6-year) extensive cattle grazing system on a reclaimed fen grassland site in north-western Germany during the course of the grazing season. We regularly quantified the amount and energy content of herbage on offer based on compressed sward height (CSH), the spatial extent of patches of various degrees of grazing intensity (heavily or moderately grazed, non-grazed), and the chemical composition of the herbage, and assessed energy uptake and livestock performance in terms of live weight gain of the cattle. We deduced herbage utilisation from these data and quantified functional relationships between cattle grazing and the properties of the sward. Our data show that there was an inadequate balance between quantity and quality of forage on offer on the one hand, and demand and forage consumption by livestock on the other. As a result, live weight gains showed a seasonal pattern with a minimum in summer. The amount of energy on offer *per* animal unit had a significant effect on the sward structure, i.e. on both the area proportion of heavily grazed patches and the heterogeneity of CSH. These findings may be of interest in the context of conservation management of reclaimed fen grasslands, as they may contribute to the design of grazing regimes aiming to create particular sward structures, e.g., to provide habitat for individual target species.

KEY WORDS: herbage quality, livestock performance, lowland fen, selective grazing, sward structure

INTRODUCTION

After significant losses of pristine lowland fen area in the course of the last 100 years (Parish *et al.* 2008), many restoration projects have been initiated during recent decades in view of the importance of fens for biodiversity conservation and the provision of various ecosystem services (Bragg & Lindsay 2003). Restoration commonly involves re-wetting and management as extensively farmed grassland (Klimkowska *et al.* 2010). Concerning biodiversity conservation, besides the re-establishment of specific plant communities, certain insect taxa (e.g., Görn *et al.* 2014) and meadow-breeding birds which have suffered pronounced declines during past decennia (Wilson *et al.* 2005) are often the priority target.

Sustainable concepts of wet grassland restoration implement management schemes that reconcile biodiversity conservation targets with a profitable agricultural land use (Plachter 2010). Stocking with cattle is of particular interest in the context of grassland management for biodiversity conservation purposes. It ensures adequate usage of the forage produced on site and, as a consequence of selective grazing and undergrazing (depending on the grazing pressure), it creates patches of heterogeneous sward height combining large open areas with patches of taller vegetation at different spatial scales and with a comparatively high stability (Van den Bos & Bakker 1990, Rook *et al.* 2004). Heterogeneous sward structures are an important determinant of nest site selection and habitat quality for birds (Verhulst *et al.* 2011), habitat provision for insects (Jerrentrup *et al.* 2014) and the floristic diversity of the sward (Wrage *et al.* 2012). Grazing with heifers or beef cattle offers a promising option for herbage utilisation in these settings. Due to selective grazing, animals take up diet of better quality than the average of the herbage on offer (Phillips 2002). Therefore, when stocked at an adequate intensity, even grassland of low productivity can be used for efficient livestock farming and allow good animal performance in terms of live weight gains (Isselstein *et al.* 2005, Pavlů *et al.* 2006, Isselstein *et al.* 2007). Site-specific stocking management is a prerequisite to achieving the targets of both profitable livestock production and biodiversity conservation in grassland (Rook 2000, Plachter 2010).

So far, most studies on stocking management in the context of conservation efforts have focused on mesic grassland sites that feature medium levels of forage productivity. In contrast, little information is as yet available on extensive grazing systems on reclaimed minerotrophic grasslands following restoration of the initial hydrology. Grazing management on such sites faces particular challenges. As the sites are still highly productive as a result of formerly intensive nutrient inputs and mineralisation of organic material, it is particularly difficult to balance herbage production and utilisation by extensive stocking systems, which involve low stocking densities. To overcome these difficulties and achieve successful management, knowledge of the spatial and temporal sward dynamics is of particular interest.

The present study was carried out in the nature conservation area 'Lake Dümmer' in north-western Germany. The Dümmer is a Natura 2000 site with a transnational significance for biodiversity conservation and as a breeding, resting and wintering habitat of reed, wading, water and meadow birds. In this study we examined a cattle grazing system on a reclaimed lowland fen site with a history of intensive silage cutting, which had been managed as a set-stocked extensive pasture for six years after restoration of the original hydrology. We (i) estimated the agronomic performance of the grazing system from the viewpoint of livestock production based on herbage production and quality, as well as cattle live weight gains, and (ii) determined functional relationships between the grazing cattle and the sward within the implemented stocking system.

METHODS

Site

The study site was located on the Osterfeiner Moor, in the vicinity of Langenteilen/Damme in the Dümmer area of Lower Saxony, north-western Germany (52° 30' 0″ N, 8° 20' 0″ E), on a fen soil. From the 1970s until 1992, the wet grasslands of this area were subjected to drainage and subsequent intensive management for grass silage cutting involving regular fertiliser applications mainly in the form of slurry. Fertilisation and liming ceased in 1992. The site was subsequently re-wetted and year-round regulation of the water table was installed. The study site comprised a total of 6 ha of pasture land arranged in two replications of 3 ha. The peat layer was of variable depth ranging from 0.3 m to 1.2 m within each pasture replication, and there were some minor outcrops of mineral soil (gley) in parts where the peat layer was shallow and the water table comparatively low. Soil chemical properties as determined by the double lactate method (0.02 M Ca lactate and 0.02 M HCl for extraction from 5 g dry soil) varied from P, K and Mg concentrations of 155, 240 and 175 mg kg^{-1}, respectively, in the more humic areas of the pastures to 62, 142 and 116 mg kg^{-1}, respectively, in the minerotrophic peat areas. Soil pH ranged from 4.6 in humic to 4.1 in minerotrophic areas.

In the more humic areas of the pasture with lower water table, the vegetation represented a typical *Lolio-Cynosuretum* of the *Alopecurus geniculatus* variant with *Holcus lanatus* (36 %), *Lolium perenne* (16 %), *A. geniculatus* (8 %), *Poa trivialis* (8 %) and approximately 14 % of unpalatable species, the most important of these being *Cirsium arvense* (7 %) and *Urtica dioica* (4 %). Humic areas with higher water table were occupied by a *Lolio-Cynosuretum lotetosum uliginosi* of the *Alopecurus geniculatus* or *Glyceria fluitans* variants and, in marginal locations, of the *Agrostis canina* or *Carex fusca* variants. These areas comprised up to approximately 45 % *H. lanatus*, 17 % *G. fluitans*, 9 % *Agrostis stolonifera* and approximately 15 % of unpalatable species, the most important one being *Juncus effusus* (13 %). During the six years preceding this study the site had been managed as an extensively grazed set-stocked cattle pasture (see below); during this period, as a consequence of the selective grazing by the cattle, a heterogeneous sward structure had become established with a relatively stable distribution of patches of different sward height which was clearly perceivable at the start of the present study (Lenker, K.-H., Goethe-Universität Frankfurt, personal communication; data not shown).

During the two years of the present study, 1999 and 2000, the annual average of air temperatures corresponded to the long-term average. During the grazing period (May–October) the average monthly temperature was 15.7 °C in 1999 and 15.0 °C in 2000, which is 1.5 °C and 0.8 °C higher than the long-term (1961–1990) average. Precipitation amounted to 647 mm in 1999 and 691 mm in 2000, which is close to the long-term average of 695 mm. The water table was on average at 0.2 m below ground level; in September 1999, it sank to 0.5 m below ground level because of low precipitation and comparatively high temperatures, whereas the summer minimum in 2000 was 0.3 m below ground level (Figure. 1).

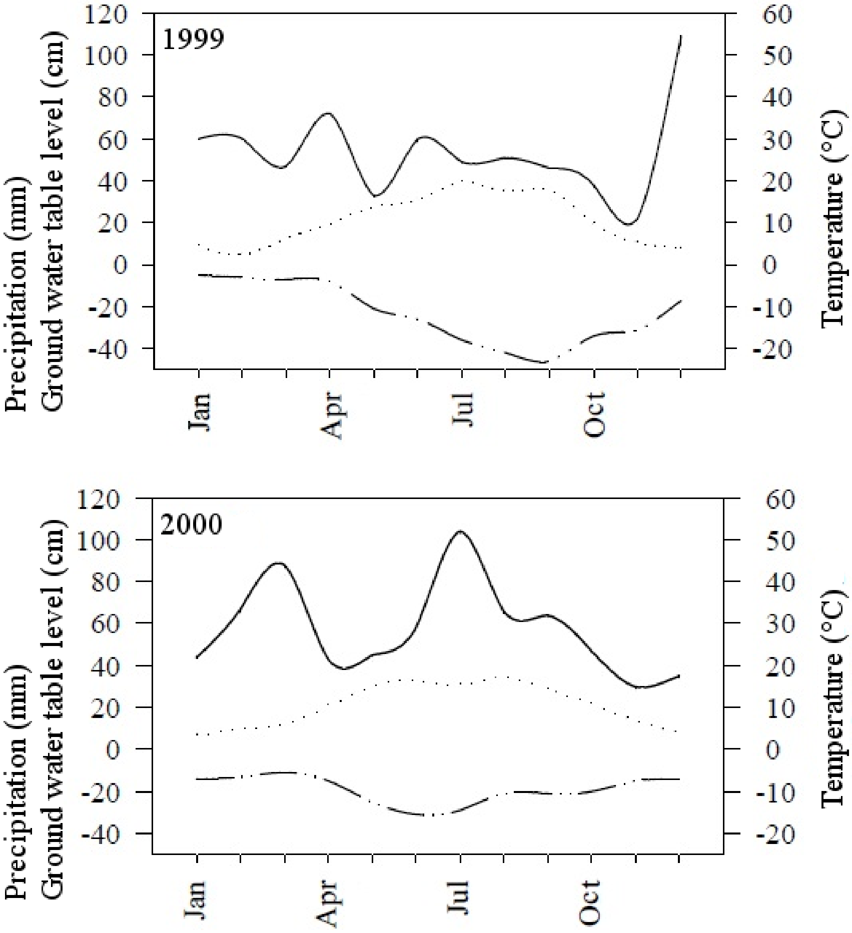

Figure 1. Temperature (dotted line, right y-axis), precipitation (solid line, left y-axis), and water table level (broken line, left y-axis) averaged across the total pasture area for the first year (1999, above) and second year (2000, below) of the study.

Grazing regime

Cattle grazing of the study site at 3 head ha^{-1}, as prescribed for conservation of meadow-breeding birds to limit the risk of nest losses by trampling (Pakanen *et al*. 2011), was initiated in 1993. During the six years preceding the present study, Replication 1 was stocked with nine Holstein Frisian steers and heifers, and Replication 2 with nine Galloway steers and heifers, at a stocking rate of 2.1–2.9 animal units (AU) ha^{-1}, with 1 AU = 500 kg live weight (Allen *et al*. 2011). As the differences in grazing between traditional and conventional breeds are considered to be marginal (Scimone *et al.* 2007), we presumed there were no significant effects of the grazing regime implemented before the present study. Additional management comprised mowing without removal of the grass cuttings at the end of the grazing season.

In both years of this study, the pasture was set-stocked with 9 Limousin heifers *per* replication from mid-May to mid-October (1999: average stocking rate 1.9 AU ha^{-1}, average live weight 282 kg at turnout; 2000: average stocking rate 2.7 AU ha^{-1}, average live weight 394 kg at turnout). From mid-October, when the animals were not on pasture, they were fed hay and grass silage from extensively managed grassland.

Sampling

To quantify the central functional relationships of the investigated pasture system in the course of the grazing period, we firstly assessed the sward height structure, which is an important prerequisite for the achievement of various biodiversity conservation targets in grassland and results from the selective grazing behaviour of the cattle. In situations when the metabolisable energy on offer from standing herbage exceeds the energy requirement of the animals and when the energy content or the botanical composition of the herbage on offer varies across the total of the pasture area, the animals selectively consume forage of above-average quality (Wallis de Vries &

Daleboudt 1994). We estimated the agronomic effectiveness of the studied grazing system on the basis of herbage utilisation and animal live weight gains.

Sward structure

Sward height structure was measured in spring before turnout at one date (late May) in 1999 and at two dates (early April and early May) in 2000, and at regular intervals during the grazing period (on four dates in 1999 and seven dates in 2000). We assessed compressed sward height (CSH) and defoliation intensity at a total of 900 permanent sampling points along three fixed transects *per* pasture replication. Each transect comprised 150 sampling points at intervals of 2 m. The transects were positioned to represent three hydrologically and botanically divergent areas of each pasture. CSH was measured with a rising-plate-meter (Correll *et al.* 2003) which returned the average sward height at a sampling ‘point’ which covered a circular area of 0.07 m^2.

Using the indicator values given by Klapp (1965), the vegetation at each sampling point was classified as either palatable (indicator value >1) or unpalatable. The Klapp classification assigns a value of -1 to poisonous plants and a value of 0 or 1 to species (e.g., *Cirsium*, *Juncus*) that cattle commonly do not browse. Vegetation palatability at each sampling point was classified according to the plant species which accounted for the largest proportion of the standing biomass. At sampling points classified as palatable, defoliation intensity was characterised using three categories: non-grazed (plant shoots show no signs of biting), moderately grazed (traces of biting at shoot tips), and heavily grazed (more than 50 % of the shoots show at least traces of biting). When a sampling point combined an area of very short sward (CSH <10 cm) with an adjacent tall stand, the sampling point was recorded as heavily grazed even if the proportion of shoots showing traces of biting was below 50 %. Heterogeneity of sward height was measured as the difference between the 90 % and 10 % quantiles of CSH in the palatable pasture area.

Quantity and quality of herbage on offer

To quantify the energy content of pasture herbage on offer, on each date of sward structure measurement during the grazing period of 2000, one herbage sample was clipped to ground level at each of 60 randomly chosen transect points that had been classified as palatable. The metabolisable energy *ME* (MJ) and the digestibility of organic matter *DOM* (%) of herbage on offer were calculated following GfE (1998) and Weißbach *et al.* (1999). Calculations were based on the chemical composition (crude protein *XP*, crude fibre *XF*, non-enzyme soluble organic substance *EULOS*) as determined by near infrared spectrometry NIRS (by the VDLUFA Qualitäts-sicherung NIRS GmbH Kassel, Germany, using a large dataset of calibration samples and calibrated for a wide range of intensively as well as extensively managed grassland types; see, e.g., Kesting *et al.* 2009) and on herbage crude ash content (*XA*) as determined by heating samples in a muffle furnace:

$$ME = 12.47 - 0.00686XF + 0.00388XP - 0.01335XA \quad [1]$$

$$DOM = 100 \times \left(\frac{940 - XA - 0.62\,EULOS - 0.000221\,EULOS^2}{1000 - XA}\right) \quad [2]$$

The metabolisable energy on offer was calculated for the total palatable pasture area, from herbage metabolisable energy content and the amount of herbage on offer as derived from CSH measurements, following the double sampling method described by Correll *et al.* (2003). The productivity of the site was deduced from peak standing crop biomass in the non-grazed palatable areas, *per* pasture replication, based on CSH measurements.

Grazing selectivity and cattle performance

We used the difference between the *DOM* of ingested herbage and the average *DOM* of herbage on offer as a measure of horizontal grazing selectivity (Phillips 2002, Dumont *et al.* 2007). We determined the *DOM* (%) of ingested herbage from the crude ash and N content of faeces (Schmidt *et al.* 1999)

$$DOM = \frac{95.90 - \frac{460}{FaecesN} - 0.1582GD + 0.00062GD^2}{100} \quad [3]$$

where *FaecesN* is the N content (g kg^{-1}) of faecal organic matter (excluding ash) and *GD* is the number of grazing days from 30 April. Sampling was carried out at six dates in 2000 (shortly after turnout and on the five dates when vegetation structure was recorded) by randomly collecting five fresh faeces samples from each pasture replication.

Animal live weights were determined regularly using one automatic weighing device (Texas Trading Ltd., Windach, Germany) *per* pasture replication. Mean daily live weight gains *per* head were calculated based on the live weight values measured on the five dates of vegetation structure sampling by dividing the difference of weights obtained at two subsequent sampling dates by the number of days covered by this interval.

For the five dates of vegetation structure sampling during the grazing period in 2000, we additionally calculated the metabolisable energy on offer *per* AU, i.e. the ratio of metabolisable energy on offer from the total pasture area to AU of the grazing herd based on cattle live weights at the respective dates. This approach follows the concept of forage allowance (Allen *et al*. 2011). We derived herbage utilisation by the grazing cattle based on this value. We used metabolisable energy on offer *per* AU to explain heterogeneity of CSH and the proportion of heavily grazed patches in relation to the total pasture area.

Statistical Analysis

Linear mixed effect models (lmer function, package lme4, of the software R, version 2.15.1, R Development Core Team 2011) were calculated in order to quantify the effect of metabolisable energy on offer *per* AU (i) on sward structure as given by the heterogeneity range of sward height in terms of the difference between the 10th and 90th percentiles of CSH and (ii) on the area proportion of heavily grazed patches. Data for the proportion of heavily grazed patches - being percentage values - were arcsine square root transformed for analysis. The nested error structure of pasture replications and repeated sampling on the individual pasture replications were represented by the random term.

RESULTS

Quality and quantity of herbage on offer

DOM of herbage on offer was 0.81 before turnout. In the course of the grazing period, average *DOM* decreased to a minimum of 0.61 by late June and recovered to 0.75 by the end of the grazing period; values varied among patches of different grazing intensity (heavily grazed, moderately grazed, non-grazed). At the beginning of the grazing period, the average metabolisable energy of herbage on offer

Table 1. Standing herbage biomass (dry matter, DM), metabolisable energy (*ME*) on offer *per* animal unit (AU), average digestibility of organic dry matter (*DOM*), crude protein (*XP*) and crude fibre (*XF*) content of herbage on offer in the heavily (H), moderately (M) and non-grazed (N) patches of the palatable pasture area; average digestibility of organic dry matter (*DOM*) of ingested herbage and average live weight per animal at individual sampling dates; average daily live weight gain for the period between the sampling date indicated in the column head and the subsequent one. Data shown were obtained before turnout (Early May) and during the grazing period (other dates) of the second year of the study (2000).

	Time of sampling					
	Early May	Late May	Late June	Late July	Late August	Mid-October
Standing crop DM (t ha^{-1})	3.7	3.4	3.1	2.7	2.4	1.4
ME (GJ AU^{-1})	-	16.8	14.3	12.3	10.9	5.9
DOM of herbage on offer	0.81					
H		0.72	0.62	0.67	0.67	0.75
M		0.73	0.61	0.65	0.66	0.75
N		0.71	0.61	0.64	0.66	0.67
XP (%) of herbage on offer	18.3					
H		18.1	13.3	16.3	17.4	18.2
M		18.3	12.9	15.8	17.4	18.3
N		17.7	12.9	15.6	17.2	14.0
XF (%) of herbage on offer	15.8					
H		22.3	25.6	25.2	24.9	21.2
M		22.2	26.0	25.8	25.3	21.3
N		22.4	26.2	26.0	24.6	20.6
DOM of ingested herbage	-	0.76	0.72	0.71	0.72	0.73
Live weight (kg)	400.7	411.7	435.6	450.6	468.5	495.1
Live weight gain (g d^{-1})	798.2	853.5	534.6	638.7	634.30	

amounted to 16.8 GJ AU^{-1} and decreased to approximately 6 GJ AU^{-1} by mid-October (Table 1). The area fraction of non-palatable vegetation was close to 10 % in spring 1999 and increased in the course of the two years of the present study to slightly above 20 %. The peak standing crop biomass (dry matter) of the site in late May amounted to 0.5 kg m^{-2}.

Performance of cattle and grazing selectivity

At turnout, the average live weight *per* head was approximately 400 kg. The animals yielded an average total weight gain of approximately 100 kg *per* head until the end of the grazing period. Animal performance was high at the beginning of the grazing period, with live weight gains of up to 850 g $head^{-1}$ d^{-1} from late May to late June. In July, live weight gains decreased to approximately 530 g $head^{-1}$ d^{-1} and levelled at approximately 630 g $head^{-1}$ d^{-1} from late July onwards (Table 1). The chemical composition of faeces indicated an average *DOM* of ingested herbage of 0.81 shortly after turnout in mid-May. Values progressively decreased, reached a minimum of 0.71 in late July and stabilised at 0.72 for the rest of the grazing period (Table 1). During most of the grazing period cattle ingested herbage for which *DOM* values were higher than the average *DOM* of the herbage on offer. Horizontal grazing selectivity was medium at the beginning of the grazing season, reached its highest values in late June and decreased to close to zero towards the end of the grazing period.

Sward height structure

During the grazing period, the area proportion of palatable pasture area grazed at each of the three levels of intensity (heavily, moderately, non-grazed) changed strongly over time. After turnout in late May, only 10–20 % of the pasture area was heavily grazed, whereas in October the proportion of heavily grazed pasture area amounted to almost 70 %. In contrast, the proportion of non-grazed palatable area continually declined and was close to zero in mid-October (Figure 2). Standard deviation of CSH decreased in parallel with average CSH during both grazing periods (Table 2). In the non-grazed palatable areas, CSH was 20 cm in late May and decreased towards the end of the grazing period due to lodging.

Interrelations between metabolisable energy on offer and herbage utilisation by cattle

The amount of metabolisable energy on offer *per* AU had a significant negative effect on the share of the heavily grazed pasture area ($P < 0.001$) and a significant positive effect on heterogeneity of CSH ($P < 0.01$); hence, cattle consumed the herbage on offer more homogeneously with declining amount of metabolisable energy on offer *per* AU (Figure 3).

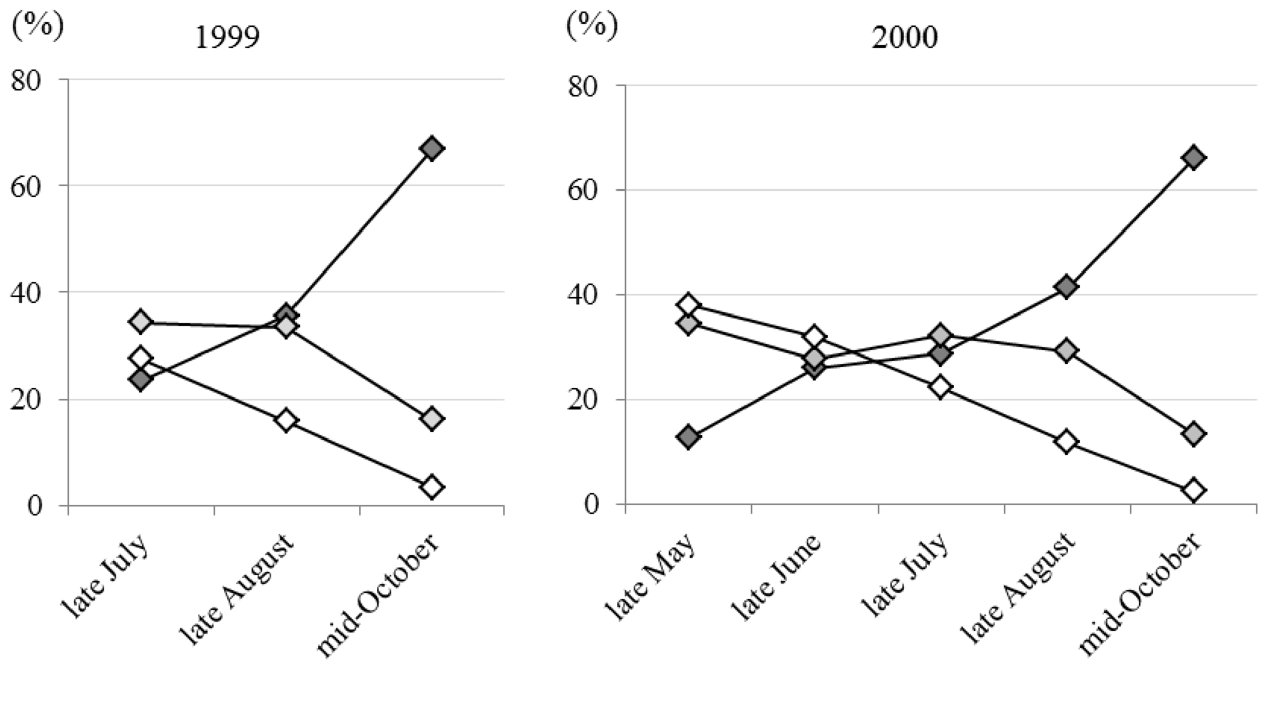

Figure 2 Average proportion (% of the total pasture area) of patches of different grazing intensity during the grazing season in the first year (1999, left) and the second year (2000, right) of the study. Dark grey: proportion of heavily grazed patches; light grey: moderately grazed; empty diamonds: non-grazed.

Table 2. Compressed sward height (cm) (in brackets: standard deviation) in pasture areas with palatable vegetation grazed by cattle at differing intensity and in areas with unpalatable vegetation during the grazing periods or shortly after the end of grazing, for the two years of the study.

1999 date of turn out: 24 May, end of grazing period: 18 October					
			Late July (28 July)	Late August (29 August)	Mid-October (13 October)
	--------------------------------- (cm) ---------------------------------				
Palatable, of which					
heavily grazed			8.9 (4.1)	7.5 (2.4)	6.5 (2.0)
moderately grazed			13.2 (5.3)	10.7 (3.4)	10.5 (2.8)
non-grazed			17.5 (9.3)	15.9 (10.3)	20.3 (9.0)
Unpalatable			37.7 (18.2)	33.3 (17.0)	31.3 (17.9)
2000 date of turn out: 11 May, end of grazing period: 09 October					
	Late May (30 May)	Late June (29 June)	Late July (26 July)	Late August (22 August)	Mid-October (16 October)
	--------------------------------- (cm) ---------------------------------				
Palatable, of which					
heavily grazed	10.0 (4.1)	7.6 (2.6)	7.0 (2.5)	7.2 (2.5)	6.3 (2.3)
moderately grazed	15.8 (7.0)	13.5 (6.1)	11.9 (4.5)	12.5 (5.2)	10.8 (2.9)
non-grazed	19.6 (7.9)	16.7 (8.5)	15.6 (6.5)	16.7 (10.1)	12.8 (6.6)
Unpalatable	28.6 (11.9)	31.2 (15.3)	30.9 (15.3)	33.7 (16.0)	30.0 (14.9)

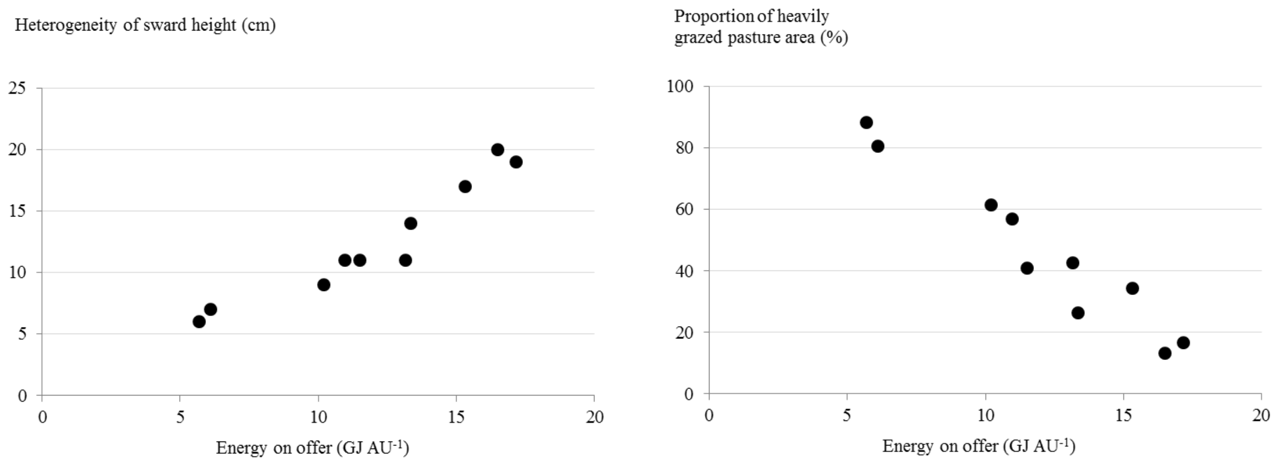

Figure 3. Heterogeneity of compressed sward height ($Q_{90} - Q_{10}$) (left) and proportion of heavily grazed pasture area (right) as a function of the energy on offer *per* animal unit. Data obtained during the grazing season of 2000, on five consecutive sampling dates (see Table 2) and two pasture replications.

DISCUSSION

For livestock production purposes, a fast weight gain of heifers and a comparatively young age at first calving are desirable. Livestock performance on the studied site (slightly above 600 g d^{-1} on average over the total grazing period) was below the range of values presented by Isselstein *et al.* (2007) for various extensive cattle grazing systems in three European countries, and below the live weight gains that can be achieved at common stocking rates on comparable pasture sites in north-west Germany (Benke & Isselstein 2001). In this study we observed strong seasonal variation in live weight gains with comparatively high values at the beginning of the grazing period, a decline in mid-summer and a moderate recovery towards the end of the grazing period. The pattern of animal performance followed the variation in digestibility of ingested herbage, which again resulted from the unbalanced relationship between herbage accumulation and herbage utilisation over the course of the vegetation period. Because of the high values of metabolisable energy on offer *per* animal unit and the heterogeneity in composition of herbage on offer across the pasture area, the animals initially selectively ingested herbage of above-average quality from a relatively small fraction of the pasture area, and subsequently consumed regrowth herbage from these previously grazed patches, which had high energy content. Herbage on a large part of the pasture area, which was moderately or not grazed at the beginning of the grazing period, subsequently developed into generative (reproductive) and senescent states featuring a lower forage quality. During summer, because of the seasonal decrease in overall biomass accumulation, horizontal selectivity decreased as cattle consumed larger shares of herbage from previously non-grazed patches. At the end of the grazing period, a large proportion of the pasture area had been at least moderately grazed and the cattle had a large amount of high-quality regrowth herbage at their disposition, which led to a further decline of horizontal selectivity (Wrage *et al*. 2011). For the final sampling date our data showed that the digestibility of ingested forage was close to that of the herbage on offer. Overall, the accumulation of non-grazed herbage in considerable areas of the pasture in spring and early summer and the decline of animal performance in the middle of the grazing season indicate inefficiencies of forage utilisation at the studied site.

Our data indicate that herbage allowance (metabolisable energy on offer *per* animal unit) is an important determinant of the sward structure; it had a significant effect on both the heterogeneity of CSH and the area proportion of heavily grazed patches. The significant effect of herbage allowance on both the heterogeneity of CSH and the area proportion of heavily grazed patches highlights that the ratio between energy on offer and energy demand by the cattle shaped the sward structure of the grassland site investigated. According to peak standing crop biomass, the study site can be classified as highly productive (Wheeler & Shaw 1991). In highly productive grassland that is extensively grazed, the patches of different sward height and grazing intensity are very stable (Van den Bos & Bakker 1990, Dumont *et al.* 2012). Therefore, the vegetation structures measured during the two years of the present study can be expected to represent the long-term pattern resulting from the grazing management applied at the investigated site. For these reasons we assume that the functional relationships between grazing selectivity and sward structure that we quantified during Year 2 of this study are representative of the grazing system under these site conditions and that, despite the limited extent of this study, our results are a robust representation of the grazing system studied.

For the minerotrophic grassland studied here, which had a history of intensive management, stocking with cattle at a fixed rate of 3 head ha^{-1} (as prescribed for conservation of meadow-breeding birds) throughout the grazing season appears to be of limited suitability. In wet grassland where high water table precludes the turnout of cattle before mid-May, and where high soil moisture may cause uneven frequentation by cattle at the beginning of the grazing period (Güsewell *et al.* 2007), the establishment of extensive areas of short sward by the end of the grazing period of the preceding year appears to be of prime importance. To this end, an increase in stocking rate from mid-June onwards, after the breeding period of most waders, should be considered as it would encourage a more even utilisation of the total palatable herbage. We propose that the potential of seasonally adaptating stocking density in settings of highly productive wet grassland should be evaluated in further studies. In addition, mowing in late autumn (which is needed to control patches of unpalatable vegetation) involving removal of the cuttings can contribute to a reduction in trophic status of the soil and add to the long-term limitation of nutrient availability that is brought about by grazing (Kooijman & Smit 2001).

Finally, even though the present case study provided data from only one site, we feel that knowledge of the interrelationships between herbage allowance and the resulting sward structure is of central interest to stocking management for conservation purposes. Application of this knowledge may help practitioners to devise stocking regimes that meet the distinct and specific requirements of the target taxa. Discrepancies between herbage growth and grazer demand during the course of the season are common in grazing systems, and their seasonal dynamics have been investigated in great detail particularly for intensively managed systems. We think that this point warrants consideration in further research on extensive stocking systems, and we recommend that future studies should also cover a larger range of site conditions.

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