Journal for Nature Conservation 18 (2010) 268–277

Contents lists available at ScienceDirect

Journal for Nature Conservation

journal homepage: www.elsevier.de/jnc

Grazing with Galloway cattle for floodplain restoration in the Syr Valley, Luxembourg

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ARTICLE INFO

Article history:
Received 9 July 2009
Accepted 3 December 2009

Keywords:
Conservation management
Ecological restoration
Foraging behaviour
Grazing
Habitat use
Riparian areas
Wetlands

ABSTRACT

Three years after a river restoration scheme in the Syr Valley (Luxembourg) we investigated habitat development and habitat use of Galloway cattle deployed in a low-intensity grazing system on a permanent floodplain pasture. Habitats were delimited with a mobile GPS/GIS mapping system and their spatial development was assessed over three consecutive years. During these three years, the patches of the six habitats decreased to 40% of mean initial size, and a rapid net area expansion of wetland habitats (large sedge swamps: +100%, marsh and tall forb grasslands: +43%) was observed. The behavioural patterns and grazing preferences of the cattle were observed directly during the vegetation period in June, August and November. These observations were complemented by a transect analysis of cattle impact indicators in June and November. The cattle grazed the different habitats very selectively, as they preferred the mesophilic, and ruderal grasslands 1.6, and 5.6 times more than expected respectively. During the growing season, the grazing niche breadth declined (3.92 in June to 2.68 in November), and less preferred forage habitats like large sedge swamps were grazed primarily in the autumn. We used bite and step rates to investigate grazing intensity by habitat type. During summer, grazing intensity correlated with forage quality in the different habitat patches, whereas in autumn it was obviously influenced by the effort required to access the desired forage plants in a given habitat. The impact indicators revealed a matter transfer from riparian areas to the valley edge. Here, we give a first insight into habitat development and habitat use of Galloway cattle in a recently restored floodplain area and derive recommendations for the adaptive management of future projects.

Introduction

The development of European agricultural landscapes during the 20th century – with the intensification of agriculture on fertile sites and the concurrent abandonment of traditional practices in marginal areas – led to a rapid decline in semi-natural grassland ecosystems (Pykälä, 2000). Areas of floodplain grasslands and wetlands in Europe especially have been reduced dramatically as a consequence of river canalisation, drainage measures and land use intensification (Paul & Meyer, 2001; Ward et al., 1999). Natural and semi-natural floodplain ecosystems are characterised by high biodiversity, and are of recreational and aesthetic value (Middleton, 1999; Tockner & Stanford, 2002). Consequently, attention is increasingly being given to conservation and restoration of such floodplains in national and European landscape protection policies and research (Isselstein et al., 2005; Joyce & Wade, 1998).

In Europe, grazing is frequently used in the management of grasslands, mainly as a tool to hinder forest encroachment and preserve and enhance biodiversity (Bakker, 1998; Pykälä, 2004; Sutherland, 2002). The potential of such management schemes to restore different habitats has been discussed for mesic grasslands (Pykälä, 2003), subalpine grasslands (Jewell et al., 2005) and inland sand ecosystems (Stroh et al., 2002; Suess, 2005). In contrast, there has been little research into the use of low-intensity grazing to restore degenerated floodplain grasslands. Since low-intensity grazing, in particular, can mimic the impact of wild megaherbivores and represents a cost-efficient management option, this strategy is also recommended for re-establishing spatial and temporal dynamics in wetland ecosystems (Gander et al., 2003; Wallis de Vries, 1995).

The effects of free-ranging livestock on ecosystem characteristics are expected to be far more complex and dynamic than other landscape management tools, e.g., mowing. Habitat selection by, and the diets of, domestic livestock are determined by environmental factors such as forage quality (Bailey et al., 1996), plant community structure (Distel et al., 1995), topography (Ganskopp et al., 2000; Gómez-Sal et al., 1992), water supply, mineral sources, and fences and buildings (Ganskopp, 2001). At the same time, animal-related factors like type and breed (Rook, Dumont, et al., 2004), familiarity with the grazing area

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doi:10.1016/j.jnc.2009.12.001

(Ganskopp & Cruz, 1999) and individual preferences (Laca et al., 2001) influence livestock grazing patterns. Given the wide variety of wetland types on the one hand, and the many types and breeds of domestic livestock on the other hand, only limited knowledge is available about the behavioural patterns of the different types of livestock and their effects on wetland habitats. Consequently, quantitative data for the establishment of guidelines for appropriate grazing management are lacking in many regions (Gander et al., 2003; Menard et al., 2002; Rook, Dumont, et al., 2004).

We aimed to quantitatively assess the development of habitat types and patterns of habitat use by Galloway cattle on a floodplain pasture in the Syr Valley (Luxembourg) after rewetting. For the low-intensity, year-round grazing regime planned, Galloway cattle were selected because they endure cold weather conditions, are light in weight and able to graze fibre-rich forage. We hypothesised that cattle would use all habitats on the restored floodplain. To assess the potential of low-intensity grazing to restore the floodplain, and to derive recommendations for adaptive management for conservation, we investigated cattle behaviour in this restoration programme from the outset. The following research questions were addressed in the study:

- Do Galloway cattle use the mosaic of habitat types initiated by the river restoration selectively?
- Do cattle also reveal specific foraging behaviour and preferences in the different habitats?
- Is cattle grazing associated with a matter transfer across the floodplain?

Methods

Study site

The vegetation development study was conducted in a 20 ha floodplain pasture in the upper part of the Syr Valley in south-eastern Luxembourg between 2004 and 2006, and the grazing behaviour and its impact monitored over several months in 2006. The site is located within the boundaries of the municipalities Betzdorf, Niederanven and Schuttrange (49°38′N, 6°17′E) and extends 2 km along the Syr River. The upper Syr Valley geomorphology is characterised by softly undulating downs, with slopes of 0-10°, and wide open valley bottoms. The climate of the region is temperate; western European-type with mild, rainy winters and warm, humid summers. The area receives rainfall of between 700-750 mm annually and the annual temperature averages between 9-9.5 °C (Administration des Eaux et Forêts, 1995). The floodplain soil is a 4-5 m thick loamy gley on alluvial and keuper formations. The mean discharge from the Syr River in September 1999 was 305 l s^{-1}.

Due to the occurrence of wetland, and meadow breeding birds, the study area has been declared part of the EU NATURA 2000 network. Formerly, the drained floodplain was used for hay cutting twice a year. Consequently, open mesic grasslands with little structural diversity dominated the floodplain before restoration measures were implemented. In winter 2003, the Syr River was restored by redirecting it from a channel at the valley edge into a partly modelled river bed in the valley bottom. In August 2004, a low-intensity, year-round grazing system with Galloway cattle was introduced on the rewetted floodplain meadows.

Grazing management

The experimental herd, which consisted of Galloway cows, bulls and their offspring, was managed in a year-round grazing system. Galloway cattle for this trial stem from rotational pastures (1-3 ha sizes) of a nearby low mountain range in Germany. There they grazed wet grasslands, sedge swamp and reed habitats in the valley bottoms as well as mesic and dry grasslands at the hillsides before they came to the Syr valley. The number of cattle on the Syr pasture was managed to permit selective grazing and to ensure adequate forage to maintain the physiological condition of the cattle throughout the study period. Permanent barbwire fencing kept cattle in the 20 ha area. The River Syr supplied water. To ensure the health of the animals, a shelter was established on the pasture. During the observation period, which spanned June to November 2006, a stocking density of 1.0 livestock units ha^{-1}, comprising breeding or lactating cows, eight heifers, one adult bull, and two young bulls, was maintained on the study site. No supplementary forage was given during the study period.

Botanical composition of the pasture

We surveyed the habitat development of the study site over three consecutive years from 2004 to 2006. Vegetation types were classified and vegetation patches distinguished, first according to the dominant plant species ($>$ 25% of total vegetation cover) and then on the basis of physiognomic vegetation parameters and site characteristics (Bonham, 1989). The vegetation patches were delimited as GIS polygons in the field using a GPS/GIS professional data mapper. Position data were corrected differentially using the satellite-based European Geostationary Navigation Overlay Service (EGNOS), thereby minimising the potential spatial error to $<$ 3 m. To evaluate habitat selection by Galloway cattle at an scale appropriate for animals of this size, we pooled physiognomically similar vegetation types into habitat types (Duncan, 1983). We identified six vegetated habitat types (Table 1).

Direct observation of cattle behaviour

A focal animal sampling design based on Altmann (1974) was chosen for the direct observation of cattle activities. This approach allowed multiple data (animal location, feeding behaviour, forage plant selection) to be collected simultaneously with a large number of replications to provide a statistically apt representation of the whole herd. Intensive daytime observations were carried out on six focal animals within the herd, marked with coloured collars. Lactating or pregnant cows (high energy demand) over two years of age (grazing experience on Syr floodplain pasture) were selected as focal animals (Bailey et al., 1996; Blanchard, 2005). Prior to data collection, a four day period served to familiarise the herd with the observer. Afterwards, one focal animal was observed per day over a period of six hours. We monitored the animals for 48 days in total over three periods in the grazing season; 12 days in June, 24 days in August and 12 days in November. Due to diminishing daylight hours in the autumn, we observed the animals for 18 days in the morning, 19 days in the afternoon and 11 days in the evening. The focal animal observed was chosen randomly before beginning each observation session.

The behaviour of the focal animal was recorded at 10-minute intervals to avoid auto-correlation effects, as the animal could potentially reach any position on the pasture within this interval. At each recording we noted the habitat type occupied by cattle, the exact position using a hand-held GPS and the main activity according to one of three categories: (a) grazing; (b) resting; and, (c) other such as moving, social behaviour, drinking or defecating. If the focal animal was grazing, forage was specified at the plant functional group level and, in a 3-minute period, a bite and step

Table 1
Classification of habitat types in the Syr Valley study area with descriptions and areas (2006). Vegetation groups corresponding to each habitat type and the dominant plants are listed separately (nomenclature according to Colling (2005)).

Code	Habitat type	Description, vegetation groups and relative landscape position	Dominant plants	Area 2006	
				ha	%
MG	Mesophilic grasslands	Coarse grasslands with mesic to dry moisture levels, Arrhenatherion alliance, valley edges	*Alopecurus pratensis* L., *Arrhenatherum elatius* (L.) Beauv. ex J. & C. Presl., *Festuca pratensis* Huds., *Lolium perenne* L.	5.86	29.3
LS	Large sedge swamps	Seasonally flooded and riparian sedge swamps, Magnocaricion alliance, watersides and flood troughs	*Carex acutiformis* Ehrh., *Carex riparia* Curt., *Carex acuta* L:, *Carex disticha* Huds.	4.61	23.1
ML	Marsh and tall forb grasslands	Groundwater influenced wet grasslands and tall forb meadows, Filipendulion and Calthion alliance, between high water zone and valley edge	*Filipendula ulmaria* (L.) Maxim., *Persicaria amphibia* (L.) S. F. Gray, *Scirpus sylvaticus* L., *Equisetum palustre* L.	3.40	17.0
FM	Flood meadows	Alternating wet and dry grasslands, Agropyron-Rumicion alliance, high water zones	*Agrostis stolonifera* L., *Ranunculus repens* L., *Carex hirta* L., *Mentha aquatica* L.	2.42	12.1
RE	Reeds	Deep or riparian marsh dominated by Phragmition, Magnocaricion alliance, water course and watersides	*Phragmites australis* L., *Phalaris arundinacea* L.	2.07	10.4
RG	Ruderal grasslands	Ruderal and nitrophytic communities, Aegopodion podagrariae and Polygonion avicularis alliance, valley edges and cattle attraction sites	*Plantago spec.*, *Cirsium vulgare* (Savi) Ten., *Urtica dioica* L., *Rumex obtusifolius* L.	0.79	3.9
–	Water course	Water courses and water filled drainage ditches	–	0.77	3.9
–	Miscellaneous	Lanes, ditches, dense shrubs, stable	–	0.05	0.3
	Total			19.96	100.0

count was conducted by habitat type visited by the animals (Henley et al., 2001; Holechek et al., 1982). We distinguished five plant categories (*Poaceae*, *Cyperaceae*, *Phragmites australis* L., herbs, and woody vegetation) for the determination of diet. Quantitative information on forage intake intensity was provided by the number of bites and steps (a forward motion by either of the front legs counted as a step) (Ruckstuhl et al., 2003). The bite-step count was aborted if the focal animal stopped grazing, lifted its head and walked at least three steps or switched to another activity for a certain period of time (Rook, Harvey, et al., 2004). A total of 1690 direct observations of focal animals were recorded and 541 bite-step grazing periods were sampled.

Measurement of cattle impact indicators

The direct observation periods were complemented by a survey of grazing impact indicators along belt transects 15.5 m long and 1.3 m wide in early June 2006, which was replicated in late November 2006. Transects were established across the floodplain pasture in a stratified random design based on habitat type (Table 1) and hydrological zone (slope zone with a mean distance of 126 m to the River Syr; outer floodplain zone, 66 m; medium floodplain zone, 44 m; interior floodplain zone, 25 m; riparian zone, 12 m). The intensity of use of the different habitat types was estimated based on faecal counts along the 20 m^2 belt transect. A short transect length was chosen to sample small habitat patches in a representative manner. The transects were established perpendicular to the slope contour and aligned parallel to the Syr River. The number of transects was proportional to the area of each habitat type and the hydrological zone (Tate et al., 2003). We positioned the transect starting points randomly in a 50 m sector along the Syr River using the random walk procedure (Kent & Coker, 1992). A total of 115 transects were sampled on the floodplain pasture.

The mean vegetation height was measured on 4 m^2 sampling plots randomly placed on the transect as an indicator of biomass depletion caused by animal grazing. The plot was separated into four equal sectors and the mean vegetation height was calculated based on the height in each sector, where a 0.25 m^2 styrofoam-quadrat (180 g) stopped falling (Stammel et al., 2003). The trampling and grazing intensity was assessed in each sampling plot visually. The trampling intensity was derived from the hoof print area (as a percent), and the grazing intensity from the proportion of vegetation in the plot < 15 cm in height (Lederbogen et al., 2004).

Data analysis

The area of each habitat type was determined with ArcMAP 9.1. The observation data were analysed using three measures for habitat use and preference: (a) use (U_i); (b) preference (P_i); and (c) niche breadth (D_i). U_i is the percentage of the total cattle activity observed in a particular habitat type *i* during a certain period of time. Hunter's (1962) index of preference P_i was used to detect selection or avoidance of different habitats by cattle, and for a between-season comparison of habitat use:

$$P_i = \frac{U_i}{A_i},$$

where A_i is the percentage of the study site occupied by habitat type *i*. The index varies from 0 (total avoidance) through 1.0 (no preference) to higher values indicating increasing levels of preference. The index was also used to quantify preference values from the variable dung density. We performed a χ^2-test for goodness of fit and calculated standardised residuals (std. res.) to analyse whether cattle habitat use in general, or particular cattle activities, showed significant positive or negative correlations with the six habitat types in our study area. The cattle fodder spectrum in different seasons was analysed by calculating Simpson's index of niche breadth (Begon et al., 1996):

$$D_i = \frac{1}{\sum_{i=1}^{n} P_i^2},$$

where n is the total number of habitat types available. When the use of each of the six habitat types was equal, the index value was highest, namely six. Uneven use is reflected by values less than six.

The arithmetic means of bites minute^{-1}, steps minute^{-1}, bite-step rate, and the four grazing impact indicators were used to compare forage intake behaviour in different seasons and habitats. Spearman's correlation coefficients were calculated to evaluate internal consistency of the grazing impact indicators. When the impact indicators correlated with at least two other indicators, they were judged reliable. All data were tested for normality, and differences between the habitat types were analysed by performing either a one-way ANOVA, the Kruskal-Wallis or the Wilcoxon test. The balance of matter transfer by cattle in the different hydrological zones was evaluated by means of a quotient of two cattle impact indicators, which compared the relative abundance of cattle dung and the highest values of grazing intensity as an indicator of biomass depletion (percentage of grazing intensity classes 2-4 in the hydrological zone) (Gómez-Sal et al., 1992). We used SPSS 15.0 for all analyses.

Results

Habitat development after restoration

During the three-year period from summer 2004 to summer 2006, the vegetation in all the six habitat types identified altered considerably (Fig. 1). The patches of ruderal grasslands (RG), flood meadows (FM) and mesophilic grasslands (MG) diminished in size by 39%, 25% and 23% respectively. With a loss of only 3%, the reed areas (RE) effectively maintained their initial area. In contrast, the large sedge swamps (LS) and marsh and tall forb grasslands (ML) increased by 100% and 43% respectively. The MG habitat type revealed the highest loss in absolute terms, with a net reduction of 1.7 ha (from 7.6 ha in 2004 to 5.9 ha in 2006), whereas LS showed the greatest gain in area of all habitat types with a net increase of 2.3 ha (2.3 ha to 4.6 ha). In addition to this habitat shift, a general decline in the mean patch size of all habitat types was revealed over the three-year period (Table 2).

Habitat use by Galloway cattle

Direct observation showed that the Galloway cattle generally used all of the habitats (Fig. 2a), but with seasonal variation (χ^2=120.3, df=10, $p<0.000$). The cattle used different habitats in the floodplain pasture selectively, with the χ^2-test revealing a significant deviation between the habitat types in all periods

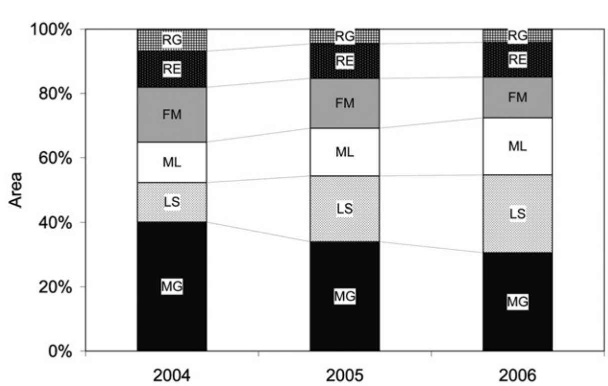

Fig. 1. Development of habitat type areas (in percent) on the floodplain pasture in the three years after Syr restoration (MG=mesophilic grasslands, LS=large sedge swamps, ML=marsh and tall forb grasslands, FM=flood meadows, RE=reeds, RG=ruderal grasslands).

Table 2
Development of mean patch sizes (mean in $m^2 \pm SD$) of habitat types[a] in the floodplain pasture after Syr restoration.

	2004	2005	2006
MG	4005 ± 4302	2141 ± 4243	1502 ± 2997
LS	501 ± 956	359 ± 653	397 ± 639
ML	770 ± 797	359 ± 328	347 ± 481
FM	1543 ± 1807	574 ± 328	362 ± 555
RE	519 ± 696	451 ± 666	376 ± 660
RG	1083 ± 901	577 ± 848	395 ± 690

[a] MG=mesophilic grasslands, LS=large sedge swamps, ML=marsh and tall forb grasslands, FM=flood meadows, RE=reeds, RG=ruderal grasslands.

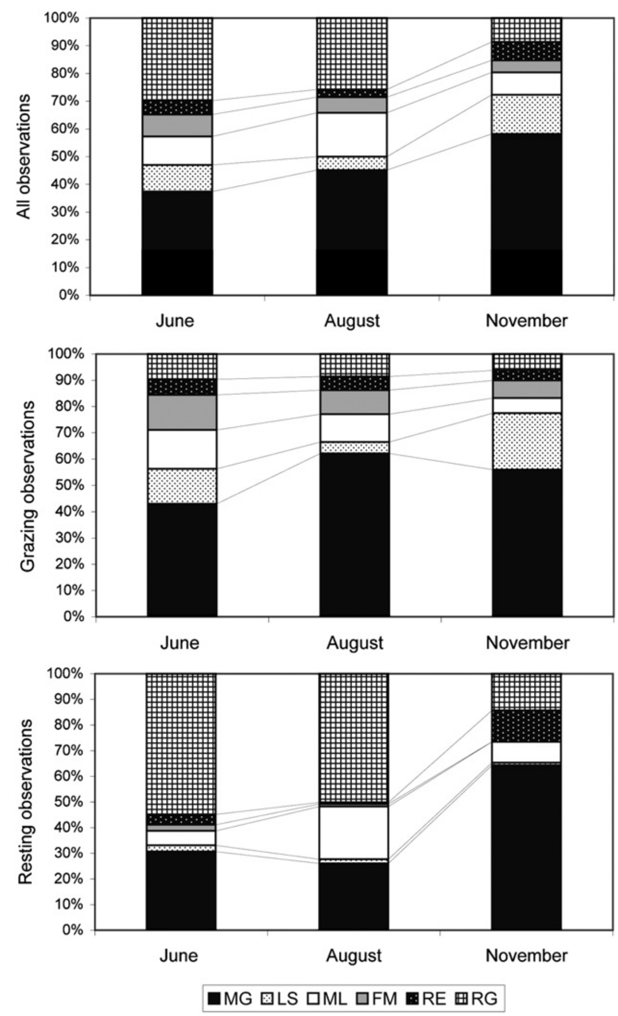

Fig. 2. Seasonal changes in (a) the overall use of the habitat types within the Syr Valley floodplain pasture by the Galloway cattle, and in their use for (b) grazing and (c) resting (MG=mesophilic grasslands, LS=large sedge swamps, ML=marsh and tall forb grasslands, FM=flood meadows, RE=reeds, RG=ruderal grasslands).

(Table 3). The three cattle impact indicators judged as reliable, namely dung number, vegetation height and grazing intensity ($p<0.001$), highlighted the selective use of habitats in summer and autumn (Table 4). In all periods, habitat use was concentrated on the mesophilic grasslands (MG) and ruderal grasslands (RG), accounting for 67-71% of all direct observations. Habitat selection for the main activities of grazing and resting varied considerably (Fig. 2b, c), also between the seasons (grazing: χ^2=55.3, df=10, $p<0.000$; resting: χ^2=107.2, df=10, $p<0.000$). The cattle also demonstrated a clear preference for MG and RG patches in all

Table 3
Seasonal selection or avoidance of the habitats[a] in the Syr Valley floodplain by Galloway cattle (Hunters Index p_i: only significant values of the index are shown[b]).

		MG	LS	ML	FM	RE	RG	χ^2	df	*p*
June (*n*=302)	All observ.	1.22*	0.40***	0.58***	0.63**	0.46***	7.23***	538.40	5	< 0.001
	Grazing	1.47**	0.56*				2.53***	26.78	5	< 0.001
	Resting		0.08***	0.35***	0.16***	0.39**	13.92***	823.92	5	< 0.001
	Others						5.20***	36.84	5	< 0.001
August (*n*=764)	All observ.	1.53***	0.22***		0.49***	0.29***	6.58***	1117.02	5	< 0.001
	Grazing	2.11***	0.17***	0.65***		0.48***	2.28***	210.67	5	< 0.001
	Resting		0.09***		0.08***	0.09***	12.66***	1731.62	5	< 0.001
	Others	1.49**				0.09***	2.59***	31.94	5	< 0.001
November (*n*=347)	All observ.	1.98***	0.60***	0.47***	0.33***	0.68**	2.28***	160.63	5	< 0.001
	Grazing	1.91***		0.35***	0.58*	0.37***		78.93	5	< 0.001
	Resting	2.18***	0.04***	0.66**			3.54***	75.04	4	< 0.001
	Others	1.80**	1.13*					17.19	5	< 0.005
Total (*n*=1413)	All observ.	1.60***	0.35***	0.76***	0.66***	0.39***	5.57***	1547.85	5	< 0.001
	Grazing	1.94***	0.48***	0.59***	0.74**	0.48***	2.03***	278.21	5	< 0.001
	Resting		0.09***		0.08***	0.37***	11.39***	2322.22	5	< 0.001
	Others	1.52***	0.94**		0.61*	0.30***	3.02***	68.22	5	< 0.001

[a] MG=mesophilic grasslands, LS=large sedge swamps, ML=marsh and tall forb grasslands, FM=flood meadows, RE=reeds, RG=ruderal grasslands.
[b] Standardised residuals: deviation of the observed from the expected value > 2 is significant (*), ≥ 2.6 very significant (**), and ≥ 3.0 highly significant (***) indicating avoidance or selection.

Table 4
Seasonal variation in grazing pressure indicators: dung numbers per transect (mean), dung p_i as a parameter for selection or avoidance[b] of habitats[a] for defecation, trampling intensity (mean), grazing intensity (mean) and vegetation height (mean in cm).

Period	Indicator	MG	LS	ML	FM	RE	RG	χ^2/K-S-Z	df	p
June	Dung	3.7	0.1	0.9	0.4	0.2	2.8	273.05	5	< 0.001
	Dung p_i	1.48**	0.04***	0.60	0.39*	0.24*	8.39***			
	Trampling	2.9	1.5	2.3	1.8	2.3	3.6	2.02	5	< 0.001
	Grazing	2.6	0.3	0.6	1.1	1.2	1.4	2.92	5	< 0.001
	Sward height	10.1	43.1	36.9	20.7	110.7	19.4	2.58	5	< 0.001
November	Dung	3.6	1.7	1.9	0.9	2.2	1.8	31.42	5	< 0.001
	Dung p_i	0.99	0.56*	0.90	0.62	1.72*	3.26***			
	Trampling	2.3	2.1	2.5	1.8	2.4	3.8	1.76	5	< 0.05
	Grazing	3.7	1.6	1.8	2.7	2.1	3	3.23	5	< 0.001
	Sward height	5.1	20.4	13.5	8.8	57.3	9.8	3.18	5	< 0.001

[a] MG=mesophilic grasslands, LS=large sedge swamps, ML=marsh and tall forb grasslands, FM=flood meadows, RE=reeds, RG=ruderal grasslands.
[b] Standardised residuals: deviation of the observed from the expected value > 2 is significant (*), ≥ 2.6 very significant (**), and ≥ 3.0 highly significant (***) indicating avoidance or selection.

seasons, both in terms of grazing activity and in terms of habitat use generally (Table 3). Dung numbers were also highest in MG and RG, and the p_i values showed – except for MG in November – significantly higher dung numbers than expected in relation to the habitat size (Table 4). In the large sedge swamps (LS), dung p_i showed a significant under-representation of dung in both periods, whereas the reed habitat (RE) was characterised by a significant defecation avoidance in June, and a preference in November. The highest grazing impact values and lowest vegetation heights were also found on MG and RG habitat types. The direct study of grazing activity also revealed a certain seasonality of habitat use, as cattle avoided LS in early summer, LS, marsh and tall forb grasslands (ML) and RE in late summer and ML, flood meadows (FM) and RE patches in autumn (Table 3). For the purposes of resting, the only significant preference was for RG (with the exception of the preferred selection of MG in November), the use of which was more than eleven times that which might be expected for the area present (0.8 ha).

The proportion of daytime allotted to feeding activities increased from 32% in June to 59% in November. Over the same period, the time spent resting decreased from 56% to 30%. The vegetation height decreased significantly in all habitats from June to November (Z= 9.003, $p < 0.001$, N=115 each), while the grazing impact increased significantly (Z=7.335, $p < 0.001$). The seasonality of niche breadth for grazing was considerable, ranging from 3.92 in June to 2.68 in November, yet relatively similar seasonal values were calculated for resting (2.50 in June, over 2.76 in August to 2.20 in November). The highest values were recorded for grazing in June and for resting in August, indicating a certain diversification of habitat use in early and late summer. Seasonality was very obvious in LS and RE habitats. In the former, the grazing activity increased dramatically in November, whereas, in the latter, only resting took place in November.

In the November period, there was a significant positive correlation between the use of a habitat type for grazing and for resting (r=0.876, p=0.022, N=6 in each case). However, in the early and late summer period the main habitats for both activities differed (r=0.244 to 0.279 n.s.). The influence of weather conditions on resting activities was indicated by the increase in resting observations from 16% under low temperatures (mean daily temperature < 22 °C) to 59% under high temperature extremes (> 22 °C) in the shade-providing RG patches, compared to 69% under low and only 27% under high temperature conditions in MG patches.

Foraging behaviour and diet selection

Bite rate (bites minute^{-1}) differed significantly by habitat type in all seasons (Table 5). The total bite rate of the Galloway cattle for the entire observation period revealed high bite rates

Table 5
Means of behavioural variables for Galloway cattle grazing in the Syr Valley floodplain pasture by season and habitat type[a] (bite rate=bites per minute, step rate=steps per minute).

		MG	LS	ML	FM	RE	RG	F/χ^2	df	p
June	Bite rate	55.9	37.6	53.4	55.7	26.8	24.3	19.45	5	< 0.001
	Step rate	4.4	3.3	3.7	3.0	3.0	2.8	2.25	5	0.054
	Bite/step ratio	15.8	15.7	18.8	23.6	11.5	11.7			
August	Bite rate	58.6	45.9	46.1	52.9	37.2	42.6	14.44	5	< 0.001
	Step rate	4.6	3.7	4.3	5.0	4.6	3.1	3.36	5	< 0.01
	Bite/step ratio	15.4	13.7	12.3	13.5	9.2	15.2			
November	Bite rate	47.9	24.0	38.8	41.5	26.7	37.6	15.9	5	< 0.001
	Step rate	4.7	2.4	4.2	3.7	2.2	4.4	33.73	5	< 0.001
	Bite/step ratio	12.8	16.8	13.0	13.0	14.3	9.7			
Total	Bite rate	55.2	31.7	48.3	51.2	31.1	38.2	151.97	5	< 0.001
	Step rate	4.6	2.7	4.0	4.0	3.5	3.5	49.81	5	< 0.001
	Bite/step ratio	14.7	15.9	15.2	16.7	11.2	13.3			

[a] MG=mesophilic grasslands, LS=large sedge swamps, ML=marsh and tall forb grasslands, FM=flood meadows, RE=reeds, RG=ruderal grasslands.

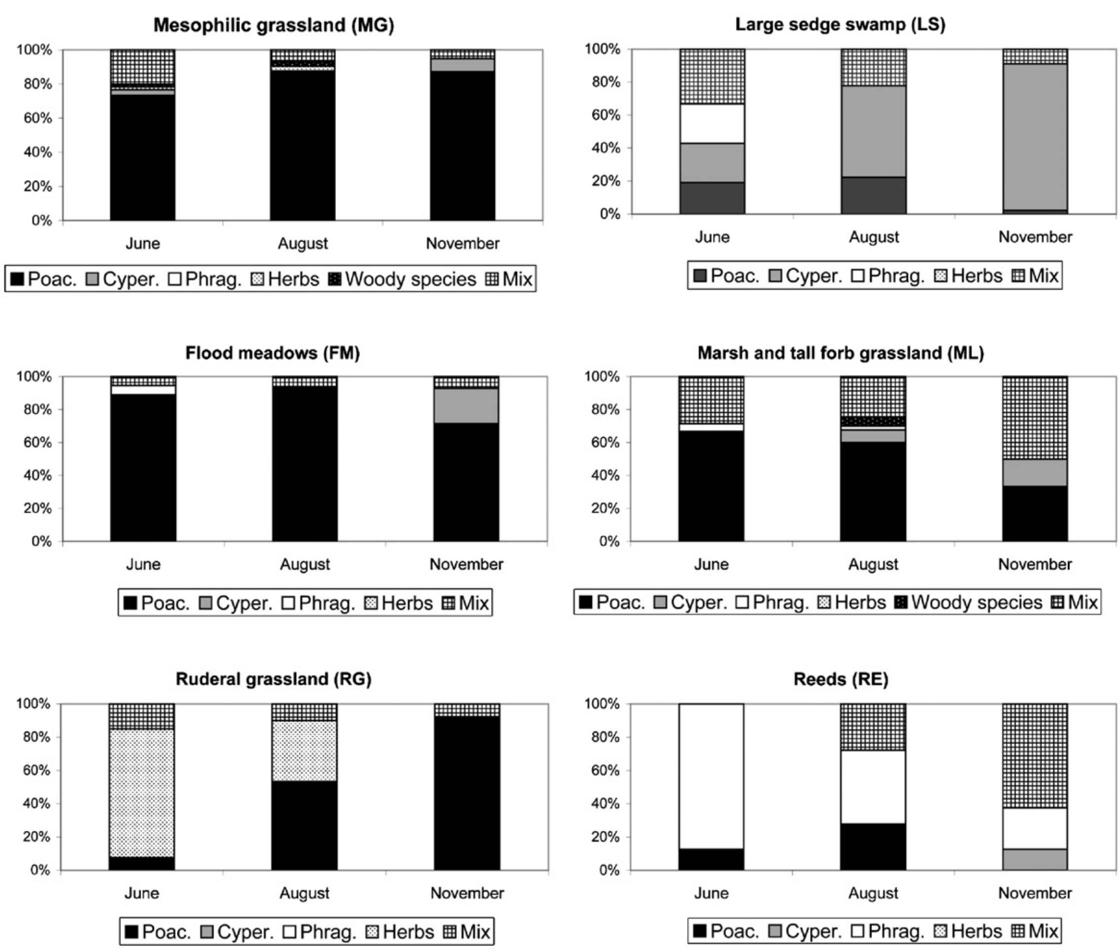

Fig. 3. Seasonal variation of the forage plants selected in different habitat types by Galloway cattle (Poac.=*Poaceae*, Cyper.=*Cyperaceae*, Phrag.=*Phragmites australis*, Mix=combination of two or more plant categories).

(> 50 bites minute^{-1}) on mesophilic grasslands (MG) and flood meadows (FM). The bite rate slowed (< 35 bites minute^{-1}) in the large sedge swamp (LS) and reed (RE) patches, where the cattle had to search for desirable forage. When foraging on patches of marsh and tall forb grasslands (ML) and ruderal grasslands (RG), the bite rate was intermediate (35-50 bites minute^{-1}). The rate of animal movement (steps minute^{-1}) also differed significantly by habitat type, except in June (Table 5). The cattle moved fastest while grazing MG (4.6), followed by FM and ML (4.0 each). Animal movement rates were also lower in habitats with lower bite rates. The grazing efficiency, indicated by the bite-step ratio, varied considerably between the different study periods. The cattle

Table 6
Percentage dung events (X), percentage grazing intensity (Y), and index (X/Y) of nutrient depletion (index < 1) or aggregation (index > 1) comparing the relative abundance of X and Y along the topographic gradient in the floodplain pasture by recombining different adjacent hydrological zones (sector 1 at water course, sector 5 at valley edge) during the summer and autumn.

June	Hydrological zone[a]								
	1		2		3		4		5
% dung events (X)	**11**		**7**		**15**		**33**		**34**
% grazing index (Y)	**14**		**7**		**23**		**32**		**25**
X/Y	0.78		0.95		0.66		1.05		1.39
X/Y	0.78		0.95		0.66			1.18	
X/Y		0.86			0.66		1.05		1.39
X/Y			0.75				1.05		1.39
X/Y				0.87					1.39
X/Y			0.75					1.18	
X/Y		0.86					1.03		
X/Y	0.78					1.02			
X/Y	0.78			0.77				1.18	
X/Y		0.86			0.66			1.18	
November	Hydrological zone[a]								
	1		2		3		4		5
% dung events (X)	**6**		**11**		**21**		**32**		**30**
% grazing index (Y)	**15**		**15**		**19**		**30**		**21**
X/Y	0.40		0.73		1.10		1.07		1.43
X/Y	0.40		0.73		1.10			1.22	
X/Y		0.57			1.10		1.07		1.43
X/Y			0.78				1.07		1.43
X/Y				0.89					1.43
X/Y			0.78					1.22	
X/Y		0.57					1.19		
X/Y	0.40					1.11			
X/Y	0.40			1.11				1.22	
X/Y		0.57			1.14			1.22	

[a] Hydrological zones refers to the mean transect distance to the water course: zone 1=12 m; zone 2=25 m; zone 3=44 m; zone 4=66 m; and, zone 5=126 m.

grazed FM patches most efficiently in June, MG in August and LS in November. They foraged least efficiently on RE patches in June and August, and RG patches in November.

The principal food plants were *Poacea*e, comprising over 50% of forage in all seasons (with the highest value of 76% in August). Seasonality caused important shifts in cattle diet. *Phragmites australis* contributed 11% to the diet in June (only 1% in November), and *Cyperaceae* contributed 25% in November (only 6% in June). Herbs and woody vegetation contributed only 7% and 2% respectively. However, herbs were under-represented to some extent as the cattle ate them mostly together with other vegetation types. The selection of plant groups for forage in the different habitat patches revealed clear seasonal patterns for most habitats (Fig. 3). For example, in June, the forage intake on LS was rather diverse, whereas in November it was more than 90% *Cyperaceae*. The opposite was observed on RE, where *Phragmites australis* was the principle forage resource in June, compared to a mixture of *Cyperaceae*, *Poacaeae* and *Phragmites* in November. On RG patches, herbs were substituted by *Poaceae* as the main forage from June to November. In three habitats (FM, ML and RE) the spectrum of forage resources became more diverse from summer to autumn, whereas the diversity decreased in the other three (MG, LS and RG).

Matter transfer

Shifting the focus to the geomorphological gradient in the valley, the selective use of different hydrological zones – areas at different distances from the Syr River – by Galloway cattle again were apparent from the cattle impact indicators, dung number, vegetation height and grazing impact (K-S test, $p < 0.001$). Patterns of matter transfer, indicated by a quotient comparing the relative abundance of dung and the highest grazing intensity values, were relatively similar in both seasons (Table 6). In the June period, the lowest hydrological zones (1+2) and the intermediate zone (3) showed a predominance of biomass extraction over dung deposit, whereas the highest zones (4+5) revealed the opposite. In November, the quotient indicated biomass extraction for the lowest zones, with dung deposits in the intermediate and higher zones. The categorisation of pasture into two (1+2+3, 4+5) and three sectors (1+2+3, 4, 5) produced quotient values revealing a clear increasing trend with distance to the Syr River in both seasons, and with geomorphological gradient.

Discussion

Habitat development

Our study revealed that, even in the short-term, river restoration and low-intensity grazing had a considerable impact on vegetation development in the Syr Valley. The results e.g. from Kellogg et al. (2003) and Schrautzer et al. (1996) suggest that the river restoration, which caused a swift rise in the groundwater table and rapid change in site conditions, was the principal driving force for the fast vegetation conversion to wetland habitats. Other studies also highlighted the important role of grazing management on structural heterogeneity and plant interactions in grasslands (Bakker, 1998; Rook, Dumont, et al., 2004). During the three-year study period, we found that the mean patch size declined continuously for all habitat types, and consequently the patchiness of habitats increased in the floodplain. In other studies of wetland vegetation, this increase in patchiness resulted in an increase in biodiversity (Moran et al., 2008; Pollock et al., 1998). In the restoration trial design conducted in this study the effect of river restoration on vegetation development could not be distinguished from that of the grazing regime. However, from the investigation of habitat use and foraging behaviour of cattle in the initial phase of floodplain restoration, an estimation of the potential of incorporating cattle grazing in wetland restoration programmes was possible.

Patterns of habitat use

Information on habitat use patterns of the Galloway cattle in the highly dynamic floodplain area is important to gauge the effect of grazing management. In small pastures of about 20 ha, pasture is grazed evenly, leading to the assumption of inhomogeneous habitat use if pasture size increases (Hart et al., 1993). In contrast, the Galloway cattle in the Syr Valley used all the existing habitat types, but with pronounced seasonal preferences. However, our results correspond with the findings of heterogeneous wetland habitat use by livestock in other studies (Ausden et al., 2005; Duncan, 1983; Menard et al., 2002; Putfarken et al., 2004).

Patchy cattle grazing patterns are observed particularly on pastures with heterogeneous habitat compositions because the animals select patches with high quality forage more frequently (Bailey, 1995; Bailey et al., 1996). On the basis of an estimation of the food quality values of different habitat types and their dominant species (Klapp, 1965), the habitat types identified in our study area can be ranked according to decreasing nutrient concentrations and digestibility as follows: mesophilic grasslands (MG); flood meadows (FM); ruderal grasslands (RG); marsh and tall forb grasslands (ML); reeds (RE); and, large sedge swamps (LS). This ranking reflects the habitat use patterns of cattle in our study area. Although they can feed on, and digest plants of lower nutrient content and high crude fibre proportions, in our study, Galloway cattle typically selected the most nutritious fodder available. This result contrasts with Putfarken et al. (2004) who found that robust cattle on wetland pastures preferred large sedge swamps and wet, marshy grasslands over mesophilic grasslands in summer.

Apart from forage quality, resource selection by large herbivores also relates to other factors like forage quantity, topography, physical constraints, stocking density, distribution of dung and sites attractive to cattle as well as rumen condition, individual experiences and the degree of adaptation of a certain breed to habitat conditions (Bao et al., 1998; Distel et al., 1995; Ganskopp et al., 2000; Mayer & Huovinen, 2007; Provenza, 2008). Since all animals involved in our field trial stem from pastures on which they have been exposed to habitat conditions comparable to the study area, we assume our results reliably represent cattle habitat selection characteristic for grazing floodplain pastures. Seasonal shifts in habitat use in the Syr Valley might be attributable to other determinants as, e.g. from June to November, vegetation height decreased to below the height limit necessary for cattle mouths to reach (Menard et al., 2002). A rejection of grazing in habitats where dung droppings are frequent (RG, MG) could not be detected in our study. The avoidance of dung reportedly increases selection in rotational grazing systems and under higher stocking rates (Bao et al., 1998), yet seemed negligible in the low-intensity grazing management in the Syr Valley. In riparian areas, the remaining stubble height is reported to be a reliable means of ascertaining the time animals spent grazing the site, and is therefore a valuable indicator for range management (Clary & Leininger, 2000; Menard et al., 2002). However, in our case, the grazing observation data does not explain the decrease in the mean vegetation height in RE and LS patches. This may be due to the greater impact of trampling on wet and swampy sites.

In the summer periods particularly, habitat selection in the Syr floodplain pasture was distinctive for resting activity, whereas in autumn the cattle rested mainly where they fed. High summer temperatures often forced the dark, densely furred cattle to seek out habitats for shade. The excessive use of ruderal grassland (RG) patches for resting in summer was triggered mainly by structural pasture components, since one RG patch received shade from a poplar stand and another was located near the shelter.

The tendency of cattle to avoid certain habitat types has been identified as a serious problem for the hindrance of succession in wetlands (White et al., 2001). As the study revealed selective habitat use by the cattle, the possibility of some future expansion, e.g. of shrublands, cannot to be excluded in our study area. However, year-round grazing on a relatively small pasture area can solve this problem to some extent because, over the course of the year, the cattle will also graze the less preferred habitat patches. De Bruijn & Bork (2006) demonstrated that rotational grazing systems are much better for controlling the spread of species unpalatable for cattle such as *Cirsium arvense* (L.) Scop. The encroachment of woody species and unpalatable plants might be halted by introducing other livestock in addition to cattle, which may even lead to higher plant and structural diversity than single species grazing (Loucougaray et al., 2004). Cattle and horses can complement one another because horses graze swards and cattle are forced to graze less palatable plants and shrubs (Menard et al., 2002). The temporary inclusion of goats may also help to combat the succession of woody plants and species rejected by cattle (Papanastasis et al., 2008).

The seasonal shift in the daytime activity pattern of cattle between autumn and summer, which was also identified in other wetlands (Menard et al., 2002), may be explained by two factors. First, the decreasing biomass and nutrient content of the existing habitat mosaic is compensated for by longer grazing periods in autumn (Broom & Arnold, 1986). The resultant reduction in biomass reduces the potential bite size, which means cattle require more time to satisfy their energy demands (Rook, Harvey, et al., 2004). Second, cattle reduce their forage intake in summer in the hot temperatures so that they can maintain normal body temperature (Warwick, 1976).

Role of foraging behaviour and diet selection

Data on foraging behaviour also suggest that forage quality may be a decisive factor for grazing decisions and intensity. Yet the relatively slow grazing of ruderal grassland (RG) patches, although of a higher nutritional value than RE and LS patches, suggests another aspect may affect foraging behaviour. RG patches in the Syr Valley are characterised by a high degree of horizontal pasture heterogeneity with a high proportion of exposed soil (highest trampling intensities of all habitat types), sparse vegetation, and high diversity of functional plant groups. Bite rate and other foraging behaviour indicators are largely determined by vegetation structure (height and horizontal mosaic) and the senescence of the specific habitat types (Wallis de Vries & Daleboudt, 1994). Furthermore, the habitat patches in the Syr Valley with homogeneous horizontal vegetation structures and short vegetation, the MG and FM patches, were grazed faster than those patches with tall vegetation (LS, RE) or with considerable within-patch horizontal structural variation (RG).

The study revealed two seasonal bite rate patterns from June to November in the Syr Valley subject to habitat type: (a) a decrease in grazing rates in MG, FM and ML patches; and (b) similar rates in RG, RE and LS patches in June and November with a maximum in August. In other studies herbivores often compensated for the depletion of pasture resources with higher bite rates (Broom & Arnold, 1986; Hudson & Nietfeld, 1985; Ruckstuhl et al., 2003). This phenomenon is explained by diminishing bite sizes on short swards, and the inverse relationship between bite size and bite rate (Spalinger & Hobbs, 1992). The contrasting observations from the Syr Valley may be due to the increase in time spent searching for isolated, tall stands of the preferred *Poaceae*, by abiotic constraints such as the partially inundated habitat patches or by the higher nutrient contents of resprouting *Poaceae* on wetland sites.

Although cattle are reported to be less selective in their forage choices than other domestic livestock (Menard et al., 2002), they showed definite preferences for certain plant groups (particularly *Poaceae*) in the different habitat patches in the Syr Valley pastures. Other studies also revealed cattle preferences for grass species (Mayer & Huovinen, 2007; Pordomingo & Rucci, 2000). This is one explanation for the selection of habitats with high abundances of *Poaceae*. However, this plant group was also frequently selected by the Galloway cattle in large sedge swamp (LS) and ruderal grassland (RG) patches. The decrease in the area of flood meadows (FM), mainly through the invasion of *Carex* species, is probably also partly related to a change in the inter-species competition due to selective grazing (Lederbogen et al., 2004). *Cyperaceae* is rarely browsed in other wetland areas (Zahn et al., 2003), yet our results showed a considerable intake of *Cyperaceae* in November in the different habitats. This phenomenon created a more diverse forage spectrum in autumn.

The pronounced tendency of cattle to select certain herbs and *Phragmites australis* L. during specific seasons – when their nutrient content and when fibre proportion was highest – was similar to the findings of other studies (Ausden et al., 2005; Lederbogen et al., 2004). The ‘avoidance’ of *Phragmites* in RE patches, combined with the inaccessibility of certain sites due to inundation, may have been the reason for the largely stable reed area in the Syr Valley pasture, although a spatial-temporal variation in reed occurrence (Ailstock et al., 2001) was also evident. The observed stability of the total reed area contrasts with rewetted and abandoned (Esselink et al., 2002), or other grazed floodplain sites (Ausden et al., 2005; Zahn et al., 2003). If this tendency is confirmed by monitoring over the coming years, this form of low-intensity grazing can facilitate the preservation of habitats for reedbed specialist birds as well as for meadow breeding birds dependent on open wetlands.

Effects of matter transfer by cattle

As dung droppings occur randomly during the day (White et al., 2001), habitat types with an overall surplus of resting to grazing activities received a net nutrient increase. This leads to a nutrient and biomass transfer, where the flood meadow (FM) patches are the net losers and the ruderal grasslands (RG) the net winners. Results from extensive grazing systems on subalpine pastures show that such patterns of nutrient transfer are relatively stable over time and can lead to uneven nutrient distribution (Jewell et al., 2007). However, a decrease in the productivity of habitats acting as nutrient sources is unlikely because they are characterised by high nutrient loads due to the high groundwater levels and the regular occurrence of river inundations.

The cattle were found to exploit biomass in pastures near the river, whereas the zones at the edge of the valley benefited from nutrient deposition from cattle dung. Our results confirmed the findings from Gómez-Sal et al. (1992) that cattle matter transfer counteracts the natural nutrient flow across the valley and balances productive and less productive sites. However, given the relatively short study period, the vegetation pattern, and hence the matter balance, may change in the long-term. Butler et al. (2008) detected a high transfer of total suspended solids and total N concentrations from cattle dung in intensively used pastures in surface runoff. As cattle dung is mostly found in the valley edge zone in our study, the potential deterioration in water quality arising from cattle dung is limited.

Conclusions

Our study shows that Galloway cattle use the floodplain pasture very selectively and prefer mesophilic grasslands and *Poaceae* for grazing. However, when their preferred forage resources are depleted in the autumn period they increasingly graze the characteristic wetland habitats. The spatial correlation between dung accumulation and biomass extraction through grazing is not very pronounced, which induces a matter transfer between habitats and from the valley bottom to the edges. Cattle obviously contribute to a large-scale variation in vegetation structure in the floodplain that fosters the establishment of typical wetland habitat types. These findings suggest that selective use of pasture in low-intensity grazing systems could enhance wetland diversity, and could probably even provide niches for typical wetland species that do not tolerate grazing. Yet, cattle preferences for certain habitat types and forage in them could foster the spread of certain unpalatable and woody species. This may lead to a reduction in biodiversity in the long run and, together with the observed short-term loss of preferred habitat types like mesophilic grasslands from rewetting, jeopardise cattle nutrition. The development of characteristic wetland diversity and the deceleration of natural succession require a year-round grazing system, the inclusion of mesophilic grasslands on mineral soils, careful management of cattle numbers and provision of shelter. However, the long-term monitoring of vegetation development and cattle impacts is vital to enable decisions to be made about stocking densities and additional management and conservation measures, e.g. variations in the grazing management, combinations with other livestock types or selective cutting regimes.

Acknowledgements

Research was funded by a research grant from the State Ministry of Culture, Higher Education and Research, Luxembourg. We would like to thank Werner Konold, Andrea Mayer and Tobias Plieninger for discussions and helpful comments on the manuscript. We are also grateful to the farmers and owners of the Syr Valley Project pasture for their support during fieldwork.

References

Administration des Eaux et Forêts, U. (1995). *Naturräumliche Gliederung Luxemburgs. Ausweisung ökologischer Regionen für den Waldbau*. Luxemburg: Administration des Eaux et Forêts de Luxembourg.

Ailstock, M. S., Norman, C. M., & Bushmann, P. J. (2001). Common reed *Phragmites australis*: control and effects upon biodiversity in freshwater nontidal wetlands. *Restoration Ecology*, *9*, 49–59.

Altmann, J. (1974). Observational study of behaviour: sampling methods. *Behaviour*, *49*, 227–267.

Ausden, M., Hall, M., Pearson, P., & Strudwick, T. (2005). The effects of cattle grazing on tall-herb fen vegetation and molluscs. *Biological Conservation*, *122*, 317–326.

Bailey, D. W. (1995). Daily selection of feeding areas by cattle in homogeneous and heterogeneous environments. *Applied Animal Behaviour Science*, *45*, 183–200.

Bailey, D. W., Gross, J. E., Laca, E. A., Rittenhouse, L. R., Coughenour, M. B., & Swift, D. M., et al. (1996). Mechanisms that result in large herbivore grazing distribution patterns. *Journal of Range Management*, *49*, 386–400.

Bakker, J. P. (1998). The impact of grazing on plant community. In M. F. Wallis de Vries, J. P. Bakker, & S. E. Van Wieren (Eds.), *Grazing and Conservation Management* (pp. 137–184). Dordrecht, The Netherlands: Kluwer.

Bao, J., Giller, P. S., & Stakelum, G. (1998). Selective grazing by dairy cows in the presence of dung and the defoliation of tall grass dung patches. *Animal Science*, *66*, 65–73.

Begon, M., Harper, J. L., & Townsend, C. R. (1996). *Ecology: Individuals, Populations and Communities*. Oxford, United Kingdom: Blackwell Science.

Blanchard, P. (2005). On lactation and rumination in bighorn ewes (*Ovis canadensis*). *Journal of Zoology*, *265*, 107–112.

Bonham, C. D. (1989). *Measurements for Terrestrial Vegetation*. New York, NY, USA: John Wiley & Sons.

Broom, D. M., & Arnold, G. W. (1986). Selection by grazing sheep of pasture plants at low herbage availability and response of the plants to grazing. *Australian Journal of Agricultural Research*, *37*, 527–538.

Butler, D. M., Ranells, N. N., Franklin, D. H., Poore, M. H., & Green, J. T., Jr. (2008). Runoff water quality from manured riparian grasslands with contrasting drainage and simulated grazing pressure. *Agriculture, Ecosystems & Environment*, *126*, 250–260.

Clary, W. P., & Leininger, W. C. (2000). Stubble height as a tool for management of riparian areas. *Journal of Range Management*, *53*, 562–573.

Colling, G. (2005). *Red List of the Vascular Plants of Luxembourg. Ferrantia 42*. Luxemburg: Musée national d'histoire naturelle Luxembourg.

De Bruijn, S. L., & Bork, E. W. (2006). Biological control of Canada thistle in temperate pastures using high density rotational cattle grazing. *Biological Control*, *36*, 305–315.

Distel, R. A., Laca, E. A., Griggs, T. C., & Demment, M. W. (1995). Patch selection by cattle: maximization of intake rate in horizontally heterogeneous pastures. *Applied Animal Behaviour Science*, *45*, 11–21.

Duncan, P. (1983). Determinants of the use of habitat by horses in a Mediterranean wetland. *Journal of Applied Ecology*, *52*, 93–109.

Esselink, P., Fresco, L. F. M., & Dijkema, K. S. (2002). Vegetation change in a man-made salt marsh affected by a reduction in both grazing and drainage. *Applied Vegetation Science*, *5*, 17–32.

Gander, A., Rockmann, A., Strehler, C., & Güsewell, S. (2003). Habitat use by Scottish Highland cattle in a lakeshore wetland. *Bulletin of the Geobotanical Institute ETH*, *69*, 3–16.

Ganskopp, D. (2001). Manipulating cattle distribution with salt and water in large arid-land pastures: a GPS/GIS assessment. *Applied Animal Behaviour Science*, *73*, 251–262.

Ganskopp, D., & Cruz, R. (1999). Selective differences between naive and experienced cattle foraging among eight grasses. *Applied Animal Behaviour Science*, *62*, 293–303.

Ganskopp, D., Cruz, R., & Johnson, D. E. (2000). Least-effort pathways?: a GIS analysis of livestock trails in rugged terrain. *Applied Animal Behaviour Science*, *68*, 179–190.

Gómez-Sal, A., Rodríguez, M. A., & De Miguel, J. M. (1992). Matter transfer and land use by cattle in a dehesa ecosystem of Central Spain. *Vegetatio*, *99-100*, 345–354.

Hart, R. H., Bissio, J., Samuel, M. J., & Waggoner, J. W.J. (1993). Grazing systems, pasture size, and cattle grazing behavior, distribution and gains. *Journal of Range Management*, *46*, 81–87.

Henley, S. R., Smith, D. G., & Raats, J. G. (2001). Evaluation of 3 techniques for determining diet composition. *Journal of Range Management*, *54*, 582–588.

Holechek, J. L., Vavra, M., & Pieper, R. D. (1982). Botanical composition determination of range herbivore diets: a review. *Journal of Range Management*, *35*, 309–315.

Hudson, R. J., & Nietfeld, M. T. (1985). Effect of forage depletion on the feeding rate of Wapiti. *Journal of Range Management*, *38*, 80–82.

Hunter, R. F. (1962). Hill sheep and their pasture: a study of sheep grazing in south east Scotland. *Journal of Ecology*, *56*, 989–999.

Isselstein, J., Jeangros, B., & Pavlu, V. (2005). Agronomic aspects of biodiversity targeted management of temperate grasslands in Europe – a review. *Agronomy Research*, *3*, 139–151.

Jewell, P. L., Güsewell, S., Berry, N. R., Käuferle, D., Kreuzer, M., & Edwards, P. J. (2005). Vegetation patterns maintained by cattle grazing on a degraded mountain pasture. *Botanica Helvetica*, *115*, 109–124.

Jewell, P. L., Käuferle, D., Güsewell, S., Berry, N. R., Kreuzer, M., & Edwards, P. J. (2007). Redistribution of phosphorus by cattle on a traditional mountain pasture in the Alps. *Agriculture, Ecosystems & Environment*, *122*, 377–386.

Joyce, C. B., & Wade, P. W. (1998). Wet grasslands: a European perspective. In C. B. Joyce, & P. M. Wade (Eds.), *European Wet Grasslands – Biodiversity, Management and Restoration* (pp. 1–12). Chichester, United Kingdom: John Wiley & Sons.

Kellogg, C. H., Bridgham, S. D., & Leicht, S. A. (2003). Effects of water level, shade and time on germination and growth of freshwater marsh plants along a simulated successional gradient. *Journal of Ecology*, *91*, 274–282.

Kent, M., & Coker, P. (1992). *Vegetation Description and Analysis: A Practical Approach*. Chichester, United Kingdom: John Wiley & Sons.

Klapp, E. (1965). *Grünlandvegetation und Standort. Nach Beispielen aus West-, Mittel- und Süddeutschland*. Hamburg, Germany: Paul Parey.

Laca, E. A., Shipley, L. A., & Reid, E. D. (2001). Structural anti-quality characteristics of range and pasture plants. *Journal of Range Management*, *54*, 413–419.

Lederbogen, D., Rosenthal, G., Scholle, D., Trautner, J., Zimmermann, B., & Kaule, G. (2004). *Allmendweiden in Südbayern: Naturschutz durch landwirtschaftliche Nutzung*. Bonn-Bad Godesberg, Germany: Bundesamt für Naturschutz.

Loucougaray, G., Bonis, A., & Bouzille, J. B. (2004). Effects of grazing by horses and/or cattle on the diversity of coastal grasslands in western France. *Biological Conservation*, *116*, 59–71.

Mayer, A. C., & Huovinen, C. (2007). Silvopastoralism in the Alps: native plant species selection under different grazing pressure. *Ecological Engineering*, *29*, 372–381.

Menard, C., Duncan, P., Fleurance, G., Georges, J.-Y., & Lila, M. (2002). Comparative foraging and nutrition of horses and cattle in European wetlands. *Journal of Applied Ecology*, *39*, 120–133.

Middleton, B. (1999). *Wetland restoration, Flood Pulsing, and Disturbance dynamics*. New York, NY, USA: John Wiley & Sons.

Moran, J., Sheehy Skeffington, M., & Gormally, M. (2008). The influence of hydrological regime and grazing management on the plant communities of a karst wetland (Skealoghan turlough) in Ireland. *Applied Vegetation Science*, *11*, 13–24.

Papanastasis, V. P., Yiakoulaki, M. D., Decandia, M., & Dini-Papanastasi, O. (2008). Integrating woody species into livestock feeding in the Mediterranean areas of Europe. *Animal Feed Science and Technology*, *140*, 1–17.

Paul, M. J., & Meyer, J. L. (2001). Streams in the urban landscape. *Annual Review of Ecology and Systematics*, *32*, 333–365.

Pollock, M. M., Naiman, R. J., & Hanley, T. A. (1998). Plant species richness in riparian wetlands – a test of biodiversity theory. *Ecology*, *79*, 94–105.

Pordomingo, A. J., & Rucci, T. (2000). Red deer and cattle diet composition in La Pampa, Argentina. *Journal of Range Management*, *53*, 649–654.

Provenza, F. D. (2008). What does it mean to be locally adapted and who cares anyway?. *Journal of Animal Science*, *86*, E271–E284.

Putfarken, D., Grell, H., & Härdtle, W. (2004). Raumnutzung von Weidetieren und ihr Einfluss auf verschiedene Vegetationseinheiten und junge Gehölze am Beispiel des F+E-Vorhabens "Halboffene Weidelandschaft Höltigbaum". *Schriften-Reihe für Landschaftspflege und Naturschutz*, *78*, 145–160.

Pykälä, J. (2000). Mitigating human effects on European biodiversity through traditional animal husbandry. *Conservation Biology*, *14*, 705–712.

Pykälä, J. (2003). Effects of restoration with cattle grazing on plant species composition and richness of semi-natural grasslands. *Biodiversity and Conservation*, *12*, 2211–2226.

Pykälä, J. (2004). Cattle grazing increases plant species richness of most species trait groups in mesic semi-natural grasslands. *Plant Ecology*, *175*, 217–226.

Rook, A. J., Dumont, B., Isselstein, J., Osoro, K., Wallis De Vries, M. F., & Parente, G., et al. (2004). Matching type of livestock to desired biodiversity outcomes in pastures - a review. *Biological Conservation*, *119*, 137–150.

Rook, A. J., Harvey, A., Parsons, A. J., Orr, R. J., & Rutter, S. M. (2004). Bite dimensions and grazing movements by sheep and cattle grazing homogenous perennial ryegrass swards. *Applied Animal Behaviour Science*, *88*, 227–242.

Ruckstuhl, K. E., Festa-Bianchet, M., & Jorgenson, J. T. (2003). Bite rates in Rocky Mountain bighorn sheep (*Ovis canadensis*): effects of season, age, sex and reproductive status. *Behavioral Ecology and Sociobiology*, *54*, 167–173.

Schrautzer, J., Asshoff, M., & Müller, F. (1996). Restoration strategies for wet grasslands in Northern Germany. *Ecological Engineering*, *7*, 255–278.

Spalinger, D. E., & Hobbs, N. T. (1992). Mechanisms of foraging in mammalian herbivores: new models of functional response. *The American Naturalist*, *140*, 325–348.

Stammel, B., Kiehl, K., & Pfadenhauer, J. (2003). Alternative management on fens: Response of vegetation to grazing and mowing. *Applied Vegetation Science*, *6*, 245–254.

Stroh, M., Storm, C., Zehm, A., & Schwabe, A. (2002). Restorative grazing as a tool for directed succession with diaspore inoculation: the model of sand ecosystems. *Phytocoenologia*, *32*, 595–625.

Suess, K. (2005). *Succession vs. grazing: effects on the vegetation of inland soil ecosystems.* Ph.D. thesis. Technische Universität Darmstadt.

Sutherland, W. J. (2002). Openness in management. *Nature*, *418*, 834–835.

Tate, K. W., Atwill, E. R., McDougald, N. K., & George, M. R. (2003). Spatial and temporal patterns of cattle feces deposition on rangeland. *Journal of Range Management*, *56*, 432–438.

Tockner, K., & Stanford, J. A. (2002). Riverine flood plains: present state and future trends. *Environmental Conservation*, *29*, 308–330.

Wallis de Vries, M. F. (1995). Large herbivores and the design of large-scale nature reserves in Western Europe. *Conservation Biology*, *9*, 25–33.

Wallis de Vries, M. F., & Daleboudt, C. (1994). Foraging strategy of cattle in patchy grassland. *Oecologia*, *100*, 98–106.

Ward, J. V., Tockner, K., & Schiemer, F. (1999). Biodiversity of floodplain river ecosystems: ecotones and connectivity. *Regulated Rivers: Research & Management*, *15*, 125–139.

Warwick, E. J. (1976). Climatic factors affecting red meat production. *International Journal of Biometeorology*, *20*, 186–192.

White, S. L., Sheffield, R. E., Washburn, S. P., King, L. D., & Green, J. T., Jr. (2001). Spatial and time distribution of dairy cattle excreta in an intensive pasture system. *Journal of Environmental Quality*, *30*, 2180–2187.

Zahn, A., Meinl, M., & Niedermeier, U. (2003). Auswirkungen extensiver Rinderbeweidung auf die Vegetation einer Feuchtbrache – Vegetationsentwicklung und Verbiss einer Galloway-Standweide über fünf Jahre. *Naturschutz und Landschaftsplanung*, *35*, 171–178.