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Grazing and fouling behaviour of cattle on different vegetation types within heterogeneous semi-natural and naturalised pastures

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ABSTRACT

In a two-year study, grazing, resting and fouling behaviour of cattle grazing on heterogeneous semi-natural/naturalised continuously grazed, fenced pasture areas (sites), were examined using two and nine sites in year 1 and 2. Five vegetation types were identified and mapped out on the sites used in the study: four typical species-rich semi-natural vegetation types (dry, mesic, wet, shaded), and one naturalised, grass-dominated type on former fertilised arable land. The two sites used in year 1 and seven sites in year 2 contained all five vegetation types, while one or two vegetation types (dry and wet) were absent on the remaing two sites in year 2. Behaviour was recorded over 24 h on three occasions in year 1, and on one occasion in year 2. During observation hours, animal behaviour (grazing/resting/other) and vegetation type grazed were recorded at 5-minute intervals and time and location of defecation and urination were recorded continuously. Vegetation types were sampled for herbage analysis directly after behaviour observations by cutting the vegetation in three random plots per type. Relative preference for grazing, resting and fouling was calculated for each vegetation type by dividing proportion of behaviour observations spent on a specific vegetation type by proportion of total area occupied by this vegetation type. The results showed that during both years, animals showed the greatest relative preference for the naturalised vegetation type when grazing or fouling (urination and defecation). The naturalised vegetation type also had the greatest content of metabolisable energy (from 9.8 to 10.1 MJ/kg DM) and crude protein (from 131 to 157 g/kg DM) and the least content of neutral detergent fibre (from 453 to 456 g/kg DM).

1. Introduction

For centuries, domesticated grazing animals have played crucial roles in shaping and preserving Scandinavian semi-natural pastures (Dahlström et al., 2006). These semi-natural pastures are largely not influenced by tillage or fertilisation and have a long history of grazing (Cousins et al., 2015). They have large biodiversity values and often contain boulders, rock outcrops and variable tree and shrub cover (Söderström et al., 2001; Berg et al., 2019). There are approximately 452 000 ha of permanent pasture in Sweden (SBA 2019), of which approximately 248,400 ha (at 51,000 sites) are registered as semi-natural pastures with substantial biological or cultural value. The nutritive value of most vegetation on semi-natural pastures is generally lesser than that of pasture on former arable land (Spörndly and Glimskär, 2018). It is therefore well suited for animals with moderate nutrient demands, such as growing heifers or suckler cows with offspring, but less suited for high-producing dairy cows. Due to the substantial biological and recreational values, Swedish society wants to maintain semi-natural pastures, and therefore supports their grazing through agri-environmental payments for biodiversity (Berg et al., 2019). A recent inventory of a stratified sample of 343 pasture areas demonstrated that despite agri-environmental subsidies, semi-natural pastures are often left ungrazed or abandoned (Spörndly and Glimskär, 2018), with their inherent biological values endangered by shrub encroachment and gradual afforestation (Cousins et al., 2015; Auffret et al., 2018). The average grazing site is <5 ha (SBA, 2019), so one strategy for maintaining semi-natural pastures in Sweden is to combine several smaller pastures into a larger area, thereby rationalising management (Schmid et al., 2017; Holmström et al., 2018). This may require farmers to include some adjacent permanent grassland areas with naturalised, nutrient-rich pasture vegetation. It has been hypothised, amongst others by policy makers and researchers in Sweden (Eriksson, 2007) that in a pasture with both nutrient-rich and nutrient-poor vegetation, animals may prefer to graze on the former and rest, urinate and defecate on the latter. Moreover, botanically diverse semi-natural pastures in Sweden are often drier and sometimes at

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a slightly higher elevation (Cousins and Eriksson, 2001), conditions that attract cattle during resting periods (Redbo et al., 2001). Since cattle defecate and urinate after long rest periods (Aland et al., 2002; Hirata et al., 2011) it has been assumed they would then impose a comparatively large nutrient load on botanically diverse semi-natural pasture vegetation. According to this hypothesis, this could over time reduce biological biodiversity and total species richness (Kleinebecker et al., 2018; Diekmann et al., 2019). However, this hypothesis has not been studied on these types of pastures and therefore research on the grazing and fouling behaviour of animals on different vegetation types in heterogeneous pasture is needed. The grazing behaviour of cattle has been extensively researched (reviews by Schutz et al., 2018; Soder et al., 2009). However, questions remain regarding dietary choice and nutrient cycling in multi-species pastures (Creamer et al., 2019). The effects of grazing pressure and season on nutrient recycling via excreta to semi-natural pastures (Orr et al., 2012) and the diurnal pattern of excretion (Hirata et al., 2011) have been described. However, the effect of semi-natural vegetation quality and type on grazing and fouling behaviour on different types of heterogenous pastures needs to be determined to achieve a better understanding of factors influencing botanical biodiversity and to improve pasture management (Pykälä, 2005; Jewell et al., 2007; Diekmann et al., 2019). Therefore, the main objective of this study was to examine the grazing, resting, and fouling behaviour of cattle, especially the location of urine and faeces deposition (fouling), and of grazing, to see if there are indications that cattle grazing and fouling behaviour will create substantial nutrient transport when nutrient rich pasture areas are merged with biodiverse, nutrient poor semi-natural grazing areas.

2. Material and methods

2.1. Study sites, observations and sampling

Behavioural observations were performed on cattle grazing heterogeneous permanent pasture, containing both naturalised and semi-natural vegetation (Allen et al., 2011), on three occasions at two fenced, continuously grazed semi-natural grazing areas (sites) in year 1 and on one occasion at nine sites in year 2. Observations covered location of activities, i.e. type of pasture vegetation, on which animals chose to graze, rest and deposit of urine and faeces. At the same occasion as observations were performed, different pasture types were sampled for determination of herbage mass and nutrient content. The average study site was 14 ha (range from 5.5 to 28 ha). All study sites were grazed in a continuous 24-hour grazing system without supplements and with access to the entire pasture area (with access to all vegetation types in the site) throughout the study. The sites were in east-central Sweden and were grazed at stocking rates from 0.5 to 1.6 livestock units (LU)/ha to ensure sufficient feed and space for cattle to freely choose location for the activities studied. The stocking rates during the one week observation periods were well below the estimated level of approximately 2.2 LU/ha and season that are recommended on these types of pastures at 70% pasture utilization (Spörndly and Glimskär, 2018).

Four semi-natural vegetation types dry (D), mesic (M), wet (W) and shaded (S) and naturalised pasture (NP) were identified at the sites (see Table 1). As seen in Table 1, the different vegetation types in semi-natural pastures are mainly defined by moisture conditions and by the type of species found in unfertilised grasslands. The naturalised pasture type was mainly mesic and dominated by species that are favoured by nitrogen fertilisation. The area and location of each vegetation type was defined on site maps using inventories, aerial photographs and digital maps (ArcGIS® Desktop 9.3, ESRI, New York, USA). All vegetation types were present at both sites in year 1 and at five of the nine sites in year 2 (types D and W were not present at one and four sites, respectively, in year 2). In year 1, drinking water and minerals were located on NP in one site and on M on the other site, while in year two, they were located on NP vegetation on six of the nine sites and on M vegetation on the remaining sites.

Behaviour observations took place in June to August (variable month), using three randomly selected females (not calves) on each site as focal animals. The grazing animals were of different breeds and ages. Five of the nine sites were grazed by suckler cows with calves of the breeds Hereford (4 sites) or Charolais (1 site). The remaining 4 sites were grazed predominantly by dairy heifers (with dry cows on one site) of the Swedish Red and/or Swedish Holstein breeds (1 site of each and 2 sites with mixed breeds). Observations were divided into 6-hour sessions on consecutive days (prevented only by heavy rain) until an entire 24-h period had been covered. Weather conditions were recorded at each behaviour recording session. During each session, occurrence and location of three kinds of behaviour (grazing, resting, other) were recorded at 5-min intervals, where ‘other’ behaviour did not fall into the first two categories. Continuous recording of defecation and urination behaviour took place throughout the sessions. Each time a focal animal was recorded as grazing, a herbage sample from the vegetation in the immediate vicinity of her mouth (selected vegetation) was collected, stored in a portable cooler, frozen and pooled per 24-h periods for analysis of nutrient content of herbage consumed. Point locations for recorded activities were then superimposed on the map of vegetation types for each site.

When a 24-h behaviour observation session was completed, three 1 m x 1 m random plots in each vegetation type were cut to 1 cm height for determination of forage composition and herbage mass. Herbage samples of selected vegetation and of the cut samples from each of the five vegetation types were analysed for dry matter (DM), ash, crude protein (CP) and neutral detergent fibre (NDF) using conventional laboratory methods as described by Spörndly and Widén (2007). Metabolisable energy (ME) was determined by a 96-h in vitro (VOS) method described by Lindgren (1979).

2.2. Calculations and statistical analysis

Behaviour and vegetation data were analysed using the MIXED procedure in SAS (SAS Institute Inc., Cary, NC, USA). Main effects and interactions were considered significant at $P < 0.05$. Pair-wise comparisons of means were considered significant at $P < 0.05$. Statistical analysis of behavioural data was performed using relative preference (RP) of the animals for different vegetation types, calculated by the method of van Dyne and Heady (1965). Relative preference was calculated for the behaviours grazing, resting, urination and defecation and was defined as the ratio between percentage of recordings of a certain behaviour on a vegetation type and percentage area at a study site occupied by that vegetation type. For example, if 16% of grazing events occurred on a vegetation type that occupied 32% of the total area, the RP for grazing behaviour on that vegetation type was 0.5 (16/32). Vegetation types with RP < 0.8, RP = from 0.8–1.2 and RP > 1.2 were defined as avoided, indifferent and preferred, respectively.

Behavioural observations were not normally distributed, so they were log-transformed using the natural logarithm. Relative preference values of zero were replaced with the value of 0.001, and this was approximately 1/10 of the smallest recorded value (von Brömssen, 2020, pers.comm.). Reported data on significant differences and pair-wise comparisons of RP values are based on log-transformed data and are presented together with standard error (SE), while median values are presented in graphs to illustrate the RP values of behaviours performed on different vegetation types. In year 1, RP values for grazing, resting, urination and defecation were analysed for the effects of vegetation type, month (June, July, August) and study site, and their interactions. Animal within study site (animal*site) was treated as a random effect and animal within month within study site (animal*month*site) as a repeated subject. In year 2, the final model only included the effect of vegetation type and site.

The effect of vegetation type on herbage mass and nutrient content

Table 1
Definitions of the four semi-natural vegetation types (*D* = dry; *M* = mesic; *W* = wet; *S* = shaded) and naturalised pasture (NP) included in the study and the range and median of the proportion of area covered by each vegetation type on the nine sites.

Name	Site area	Characteristics	Common species
D	0–13% Median: 4%	Found mainly on well-drained or nutrient-poor soil, on ridges or hills. Characterised by high biodiversity with mainly thin-leaved grasses and a large amount of forbs, some very drought-resistant.	*Festuca ovina* L., *Hieracium pilosella* L., *Galium verum* L, *Lychnis viscaria* L. and species of the family *Crassulaceae*.
M	15–46% Median: 32%	Vegetation on moderately wet to moderately dry mesotrophic soils. Both broad- and thin-leaved grasses are common, along with many forbs and clovers.	*Agrostis capillaris* L., *Rumex acetosa* L., *Primula veris* L., and *Alchemilla* and *Trifolium* spp.
W	0–18% Median: 9%	Found in depressions in the ground, along riverbanks and ponds or on any poorly drained soil. Strongly characterised by broad-leaved grasses, larger forbs and very often by rushes and sedges.	*Caltha palustris* L., *Deschampsia cespitosa* L., *Filipendula ulmaria* L., *Geum rivale* L. and many species of *Carex* and *Juncus*.
S	18–48% Median: 30%	Vegetation in shaded or sparsely to moderately forested areas. Patchy growth of some grasses and forbs, but also low shrubs, mosses and lichens.	*Anthriscus sylvestris* (L.) Hoffm., *Calamagrostis arundinacea* (L.) Roth., *Convallaria majalis* L., *Geranium sylvaticum* L., *Pteridium aquilinum* (L.) Kuhn, *Vaccinium myrtillus* L. and *Vaccinium vitis-idaea* L.
NP	16–47% Median: 30%	Found in naturalised cultivated pastures, meadows or pastures on arable land, often previously fertilised. Low biodiversity, mainly broad-leaved grasses and a limited amount of forbs.	*Achillea millefolium* L., *Plantago major* L., *Festuca rubra* L. and *Rumex, Taraxacum* and *Trifolium* spp.

was analysed separately for each year in a MIXED model, for year 1 in a model with the variables vegetation type, month and site and associated interactions. However, interaction between month and vegetation type was not significant and was removed from the model. In a similar manner the analysis of behaviour observations showed no interaction between vegetation type and month for the behaviours grazing, urination and defaecation. These findings for year 1 is why only one observation per site was performed in year 2, making it possible to increase the number of study sites in that year ($n = 9$).

3. Results

There was an overall difference in the RP values for grazing between vegetation types ($P < 0.0001$) in both years (Table 2). In pair-wise comparisons, the RP value for grazing on NP did not differ from M, but was consistently greater than on D and S in both years and differed from W in year 2 (Table 2). Choice of vegetation type for grazing was similar during both years. Across sites and years, the only vegetation type that was clearly preferred was NP (RP ≥ 2.0), while M was grazed in proportion to its area. Both S and D were avoided in both years, while W was grazed in proportion to its area in year 1 and avoided in year 2 (Table 2, Figs. 1 and 2).

The RP values for both urination and defecation differed between vegetation types ($P < 0.0001$) in both years, but were consistently greater on NP than on D, S and W (Table 2). For most vegetation types, RP for urinating or defecating in an area was similar to RP for grazing in

Table 2
Least squares means and standard error (SE) for natural logarithm values of relative preferences for grazing, fouling (urination and defecation) and resting (year 2 only) behaviour on different vegetation types (*D* = dry; *M* = mesic; *W* = wet; *S* = shaded; NP = naturalised pasture) in year 1 and 2. Three focal animals, three periods and two sites ($N = 18$) in year 1; three focal animals, one period and nine sites ($N = 27$) in year 2.

	Vegetation type					
	D	M	W	S	NP	SE[1]
Year 1						
Grazing	-4.15^{a}	-0.15^{c}	-0.12^{c}	-2.45^{b}	0.74^{c}	0.413
Urination	-6.91^{a}	-2.54^{c}	-5.22^{ab}	-4.58^{b}	-1.00^{c}	0.703
Defecation	-6.45^{a}	-0.59^{b}	-5.21^{a}	-5.90^{a}	0.29^{b}	0.571
Year 2						
Grazing	-5.02^{a}	-0.23^{c}	-2.05^{b}	-2.80^{b}	0.65^{c}	0.362–0.591
Resting	-4.91^{a}	-1.84^{b}	-4.46^{a}	-4.55^{a}	-0.62^{b}	0.617–1.00
Urination	-5.58^{a}	-2.59^{b}	-4.97^{a}	-5.15^{a}	0.22^{c}	0.580–0.912
Defecation	-5.53^{a}	-1.24^{b}	-5.62^{a}	-4.91^{a}	-0.09^{b}	0.518–0.845

[a-d] Different superscripts within rows indicate significant difference ($P < 0.05$) between vegetation types. [1] SE range in year 2 is due to unbalanced data.

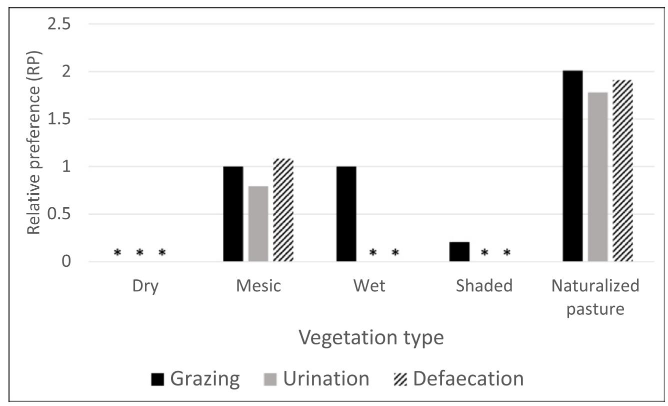

Fig. 1. The relative preference (RP) for grazing, urination and defecation behaviours recorded in year 1 on different vegetation types on semi-natural pasture (*D* = dry; *M* = mesic; *W* = wet; *S* = shaded) and on naturalised pasture (NP). RP for a vegetation type is the ratio between percent activity and percent area where RP values < 0.8, RP = 0.8–1.2 and RP > 1.2 are defined as vegetation being avoided, indifferent or preferred, respectively. Median of three focal animals observed during 24 h, repeated over three periods (June, July and August) and two sites ($N = 18$). The symbol * illustrates the value zero for a behaviour on a vegetation type.

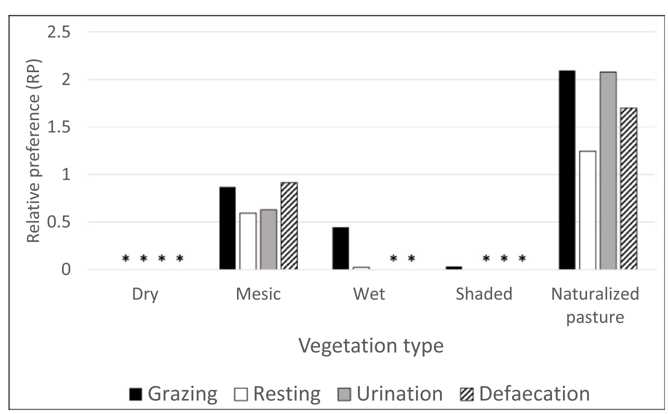

Fig. 2. The relative preference (RP) for grazing, resting urination and defecation behaviours recorded in year 2 on different vegetation types on semi-natural pasture (*D* = dry; *M* = mesic; *W* = wet; *S* = shaded) and on naturalised pasture (NP). RP for a vegetation type is the ratio between percent activity and percent area where RP values < 0.8, RP = 0.8–1.2 and RP > 1.2 are defined as vegetation being avoided, indifferent or preferred, respectively. Median of three focal animals observed during 24 h repeated on nine sites ($N = 27$). The symbol * illustrates the value zero for a behaviour on a vegetation type.

Table 3
Content of metabolisable energy (ME), crude protein (CP), neutral detergent fibre (NDF) in herbage dry matter (DM) and herbage mass (kg DM/ha) in semi-natural vegetation from sampling plots (*D* = dry; *M* = mesic; *W* = wet; *S* = shaded), in naturalised pasture (NP) and in pasture selected by focal animals (selected vegetation) in year 1 and 2. Least squares means (LSM), standard error (SE) for vegetation types and number of observations (N).

	Vegetation type (LSM)					Selected vegetation	SE[1]	N[1]
	D[1]	M	W[1]	S	NP			
ME MJ/kg DM								
Year 1	9.4^{a}	9.6^{ad}	8.3^{b}	9.4^{a}	10.1^{c}	9.9^{cd}	0.14	18
Year 2	9.4^{abd}	9.6^{bd}	8.3^{c}	9.0^{a}	9.8^{d}	9.9^{d}	0.14–0.22	27
CP, g/kg DM								
Year 1	102^{a}	131^{b}	130^{b}	94^{a}	157^{c}	152^{c}	5.0	18
Year 2	116^{a}	122^{ab}	127^{abc}	124^{abc}	131^{bc}	136^{c}	4.5–7.1	27
NDF, g/kg DM								
Year 1	523^{a}	485^{b}	574^{c}	578^{c}	453^{d}	461^{bd}	10.7	18
Year 2	468^{a}	471^{a}	533^{b}	509^{b}	456^{a}	472^{a}	10.5 −16.7	27
Herbage mass kg DM/ha[2]								
Year 1	328^{a}	448^{a}	1304^{b}	178^{c}	365^{a}		74.7	18
Year 2	226^{a}	458^{bd}	1364^{c}	358^{ab}	594^{d}		79.0–127.0	27

a-e Different superscripts in lowercase letters indicate significant difference ($P < 0.05$) between vegetation types within rows.
1 Samples from 2 sites 3 times with three repetitions in year 1. Sampling on 9 sites one time with three repetitions in year 2, with the exception of D (N = 24) and W (N = 12), therefore SE range presented year 2.
2 Herbage mass data only available for cut samples (D, M, W, S, and NP).

that area (Figs. 1 and 2). However, in year 1, cattle avoided urinating and defecating on W, but had an RP for grazing on W of approximately 1.0, indicating neither preference nor avoidance (Fig. 1). In year 1, when observations were performed on only two sites, there was a significant interaction between resting behaviours on different vegetation types and sites. In that year, the animals at one site preferred to rest on D vegetation while the animals at the other site preferred to rest on NP. However, on both sites, animals avoided resting on S vegetation. The interaction in year 1 between vegetation type and site for the variable resting was one of the reasons for increasing the number of sites in year 2. In year 2, the RP values for resting differed between vegetation types ($P<0.0001$), with greater values for resting on NP and M than on D, S and W (Table 2). In general, resting behaviour patterns were variable and largely influenced by where the cattle chose to rest during the night, as this was the longest resting bout, but vegetation type S was clearly avoided both years. Nutrient content and herbage mass differed between the five different vegetation types and the 'selected vegetation' eaten by focal cows (Table 3). The NP vegetation type had the greatest ME content, and was similar to that in the selected vegetation. Compared with the other vegetation types, W had small energy content but considerably more herbage mass than all other vegetation types (Table 3). When results from year 2 were separated into two data sets depending on where water was provided (on NP and M vegetation), the median and mean of RP values for grazing were similar irrespective of water location with overall RP values of around 2 and 1 for grazing on NP and M vegetation types, respectively.

4. Discussion

The results indicated that cattle clearly preferred to graze on NP vegetation (RP ≥2.0 in both years). It had the greatest content of ME (approximately 10 MJ/kg DM)), which has been shown to have a strong influence on the selective behaviour of cattle (Lopez et al., 2019; Pauler et al., 2020). Other factors, such as herbage mass, may also influence the grazing behaviour of cattle (Schultz et al., 2018). The vegetation cut on plots directly after the behaviour observations were completed, gave an estimate of the amount of vegetation available to the animals at the time. However, the comparatively small nutrient content of W vegetation had a larger influence on behaviour than the large amount of herbage available on W areas (Tables 2 and 3), giving intermediate RP values. Minor values for grazing frequencies in wet areas of Swedish semi-natural pastures, probably due to small ME values, have been reported previously (Spörndly and Widén, 2007; Hessle et al., 2008). If left ungrazed, vegetation in W areas tends to grow rapidly and lose its nutritive value (Lifvendahl, 2004). Since cattle generally avoid wet areas when stocking rates are moderate (Spörndly and Widén, 2007), farmers may need to mow pasture to maintain a well-grazed wet sward.

The RP values of approximately 2 seen for NP indicate that grazing behaviour was influenced by the combined effect of large nutrient content and relatively large herbage mass (Table 3). The high productivity of NP, with greater DM yield than all other vegetation types except W, confirms recent findings for Sweden (Spörndly and Glimskär, 2018). Selection differences on pasture at different grazing intensities have been reported previously (Orr et al., 2012), with animals spending more time grazing nutrient-rich short patches when grazing is less intensive (Dumont et al., 2007). It is reasonable to assume that the opportunity for selective grazing is greater when abundant forage is available (Schultz et al., 2018). Stocking rate in the present study was from 0.5 to 1.6 LU/ha, which is well below the estimated recommendation of 2.2 LU/ha on these types of pastures with a pasture utilization of 70% (Spörndly and Glimskär, 2018), allowing the animals to select grazing area and vegetation type. However, the heterogeneity of permanent pasture makes it difficult to interpret stocking rates, as each site has unique proportions of different vegetation types.

This study was conducted on commercial farms and had to fit within the existing conditions. The fact that drinking water was located on NP and M vegetation is a shortcoming, since cattle like to stay in the vicinity of drinking water (Yoshitoshi et al., 2016). However, as mentioned in the results, the RP values for grazing NP vegetation was around 2 irrespective of where drinking water was located, and in a similar manner the RP values for grazing on M vegetation were approximately 1 irrespective of drinking water location. Thus while location of drinking water may have had some effect, this indicates that it did not have a major influence on the RP values for NP and M vegetation in this study.

Grazing, fouling (urination and defecation) and resting behaviour generally had similar RP values for a particular vegetation type. A small RP value for resting and other activities on S vegetation both in year 1 and in year 2 showed that animals did not actively seek shade which suggests that hot weather was not a major problem for the animals in this study. Associations between grazing and fouling behaviour have been reported previously (Jewell et al., 2007; Dubeux et al., 2014). The present study indicated that cattle do not specifically graze nutrient-rich areas and then deposit urine and faeces in nutrient-poor semi-natural areas in connection with resting. Thus, nutrient redistribution to the latter, and associated effects on biodiversity does not seem to be a major issue. However, nutrient transport within pastures is also influenced by sward nutrient composition, sward height and season (Lopez et al., 2019). Furthermore, the amounts and nutrient content of faecal and urinary deposits can vary considerably over the season (Orr et al., 2012) and over the day and night (Hirata et al., 2011). Animal response to fouled vegetation may be another factor in nutrient redistribution, as animals avoid pasture near dung pats, which also affects intake (Spörndly, 1996). Thus while the results presented here indicate that including nutrient-rich areas in semi-natural pastures grazed by cattle does not cause problems with nutrient transport from nutrient-rich naturalised pasture to biodiverse nutrient-poor areas, the effect of other factors needs further research to verify these conclusions.

5. Conclusions

The conclusions of this study is that cattle fouling, to a substantial degree, takes place in connection to grazing. Therefore, areas with vegetation types that animals prefer to graze, are also the same areas where cattle mainly choose to defaecate and urinate. Thus, based on the results from this study, the risk of nutrient transport from one vegetation type to another within continuously grazed heterogeneous semi-natural pastures is not considered a risk to bio-diverse nutrient poor areas.

6. Author statement

The authors to the paper have contributed in the following way

1 First author Maja Pelve: Has collected data and samples, has processed the data statistically, has written an outline of the paper
2 Second author Eva Spörndly (corresponding author): Has written and revised the paper, has been supervisor to the study, is responsible of initiating the study
3 Third author Ingemar Olsson: Has contributed with expertise in the field of statistics, animal rearing, and has contributed substantially to the writing of the final version of the paper
4 Fourth author Anders Glimskär: Has contributed to the layout of the study, the choice of experimental sites, defining vegetation types and mapping them out in the sites, writing the parts of the paper connected to semi-natural grasslands and biodiversity.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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