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Cover estimation *versus* density counting in species-rich pasture under different grazing intensities

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Abstract Two methods for monitoring of grassland vegetation were compared: visual estimation of plant cover (C) and plant densities counting (D). C and D were performed in monthly intervals for three vegetation growing seasons after imposing different grazing regimes on abandoned grassland in 1998. Species scores obtained from paired redundancy analyses (RDA) of C and D data were compared and Spearman's rank correlations were used to show if the two methods give comparable results. Results of C and D were highly correlated in the first two growing seasons only. In the third season, correlation was substantially lower as the sward structure was more heterogeneous due to creation of differently defoliated patches especially under extensive grazing. Presence of the same plant species with different habit in frequently and in infrequently grazed patches, reduced significance of Spearman's rank correlations. Cover estimation can fully substitute plant density counting in grassland with lower proportion of frequently and infrequently grazed patches only, but caution should be used when comparing different management regimes in long term analyses.

Keywords Grassland · Grazing management · Plant counting · Vegetation monitoring · Visual estimation · Czech Republic

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Introduction

There are many features of grassland vegetation that can be measured and different methodologies must be used for attributes. Often, several methodologies are possible when measuring a particular attribute and the choice is affected by the purposes for which the measurements are being made (Whalley and Hardy 2000).

Quantitative description of swards in terms of their floristic and morphological composition provides basic information about the vegetation and allows the effects of management (grazing, cutting, fallow, fertilization) to be studied in manipulative experiments.

Visual cover estimation (canopy or basal cover) in many modifications is a widespread method for sward evaluation. In comparison to other methods, it is less time-consuming. However, the main disadvantage of cover estimation is bias, which can be reduced by several observers working together and adjusting their extreme estimates (Klimeš et al. 2001; Kercher et al. 2003; Klimeš 2003). Regarding multivariate analysis, the error caused by missing species was at least as important as the error in visual estimation of species cover (Lepš and Hadincová 1992).

The problem of cover estimation concerned those species that were either small, had a high abundance or were winding plants (Carlsson et al. 2005). It should be noted that humans visually perceive cover on a geometric scale rather than on a linear scale, because human visualization is attuned to doubling and can more easily discern the difference between values of 1% and 2% than between 31% and 32% (Bonham et al. 2004).

In addition to point-frequency (Brakenhielm and Liu 1995) and subplot-frequency analysis (Carlsson et al. 2005), the counting density of individual plants (Brock et al. 1996) is another widespread quantitative description of sward to provide specific information about grassland. In comparison with cover estimation, this technique reduces bias arising from assumptions of each observer. However changes in the sward structure were mostly of a quantitative not qualitative character, thus the presence-absence data collection is not a suitable method for monitoring the effects of management restoration (Hejcman et al. 2008). In sown grassland, rather than in semi-natural species-rich grassland, number of grass tillers, stolon growing points of white clover and number of other plants were used to analyze changes in sward structure under grazing (Brock et al. 1996; Laidlaw et al. 1995; Silvertown et al. 1994; Matthew et al. 2000; Pavlů and Velich 2001). This is because in semi-natural species-rich grasslands horizontal variability tends to be much greater, both in terms of the range of tiller sizes and densities which may be encountered (Grant 1993).

Plant density counting and cover estimation provide similar information in grass monocultures or simple grass - clover mixtures (Whalley and Hardy 2000), but comparison of results obtained by both methods in seminatural species-rich grassland is still missing. The aim of this paper was, therefore, to answer the following question: Are the results based on cover estimates and plant density counting comparable in semi-natural grassland for different years and grazing regimes?

Materials and methods

The study area

The study was undertaken on an experimental grassland in the Jizerské Mountains in the northern part of the Czech Republic, 10 km north of the city of Liberec (50°50′N, 15°06′E). The altitude of the investigated grassland is 420 m, the average annual precipitation is 803 mm, and the mean annual temperature is 7.2°C (Liberec meteorological station). Experimental plots (0.35 ha in size) were established in spring 1998 and were arranged in two completely randomized blocks. Grazing by heifers consisted of the following treatments: intensive grazing (IG), first cut followed by intensive grazing (ICG), extensive grazing (EG), first cut followed by extensive grazing (ECG). See Pavlů et al. (2006) for a detailed description of the experimental design.

Data collection

The data sets for the analysis were obtained by field sampling of experimental pasture from 1998 to 2000 (Pavlů et al. 2006). The abundance of all vascular species was estimated in 100 cm^2 circles (diameter 11.2 cm) by two sampling methods: percentage visual estimation of plant cover (C) and plant density counting (D). Ten randomized circles were used to collect data in each experimental plot. Data were collected monthly from May to October during each of three experimental seasons. All present plant species were recorded. Grasses that were unidentifiable due to grazing were classified into one group, with the exception of the simply recognizable *Festuca rubra* agg. The group of grasses was composed of the following species: *Agrostis capillaris*, *Alopecurus pratensis, Holcus mollis*, *Poa pratensis*, *P. trivialis* and *Trisetum flavescens*. The term “plant density” refers to the number of individual tillers for grasses, the number of stolon growing-points for *Trifolium repens* (Davies 1993), and the number of single primary stems or rosettes for other forbs in this paper. Nomenclature of vascular plants follows Kubát et al. (2002).

To compare time-consumption of cover estimation and density counting, two experienced observers independently sampled ten random circles in intensively grazed plots.

Data analysis

To evaluate cover estimates and counting of plant number, we compared species scores from redundancy analyses (RDA, CANOCO software, Lepš and Šmilauer 2003) of C and D i) in each of three individual growing seasons (1998, 1999 and 2000), where month was the only explanatory variable and plot identifier and interaction of month with treatments were treated as covariables ii) in each individual treatment (EG, ECG, IG and ICG) and growing season (four treatments × three seasons = 12 analyses), where month was the only explanatory variable. Spearman's rank correlations were used to evaluate species scores relationship of paired analyses (the same analyses for C and D data).

Species recorded in all growing seasons and in all treatments were used only. One-way ANOVA was used to evaluate the time taken for completing each method.

Results

The species scores of C and D data based on RDA analyses are presented in Table 1. In these RDA analyses the month was the explanatory variable and covariables were plot identifier and interac-

Table 1 Species score of plant density and cover estimation based on the RDA analyses regardless of treatments in the study years 1998–2000

Species	1998		1999		2000	
	Density	Cover	Density	Cover	Density	Cover
Grasses (without *Festuca rubra* agg)	0.5319	0.4264	0.1077	0.1471	0.2512	0.2145
Festuca rubra agg.	0.3341	0.3100	−0.0448	−0.0419	−0.1407	−0.072
Achillea millefolium	0.1985	0.1437	0.0189	0.0630	−0.0037	−0.0618
Aegopodium podagraria	−0.0707	−0.2367	−0.0154	−0.0169	−0.0957	−0.2293
Alchemilla spp.	−0.0287	−0.0820	−0.0794	−0.1566	0.1317	−0.0046
Anthriscus sylvestris	−0.0931	−0.0874	0.0532	−0.0211	0.2093	0.1419
Campanula patula	0.1277	0.0971	−0.1711	−0.1699	−0.0962	0.0734
Cerastium holosteoides	0.1348	0.1797	0.0595	0.1735	0.0318	0.0344
Cirsium palustre	0.0089	0.1243	0.0427	0.2019	−0.0157	0.2367
Galium album	−0.2049	−0.2877	−0.0973	−0.1216	0.1495	−0.0281
Glechoma hederacea	−0.0521	−0.0607	−0.1144	−0.0886	−0.0613	−0.0278
Hypericum maculatum	−0.1840	−0.2974	−0.2713	−0.2047	−0.1061	−0.1502
Lathyrus pratensis	0.0887	0.0446	−0.1819	−0.0443	−0.0329	−0.1979
Lotus uliginosus	0.1166	0.1346	0.0126	−0.0283	−0.0569	−0.0686
Plantago major	0.0592	0.0592	−0.0674	−0.0187	0.0899	0.0870
Ranunculus repens	0.4194	0.3918	0.3307	0.3422	0.1866	−0.0197
Rumex acetosa	0.2382	0.3536	−0.0966	−0.1300	−0.1916	0.2063
Rumex obtusifolius	−0.0122	−0.0042	0.3035	0.3346	−0.0415	−0.0547
Stellaria graminea	0.1392	−0.0136	−0.0513	−0.1042	0.0369	0.0531
Taraxacum spp.	0.2972	0.2467	0.5645	0.3557	0.4340	0.2487
Trifolium repens	0.1125	0.1125	−0.0613	−0.0310	0.1421	0.1200
Urtica dioica	0.0955	0.0911	−0.2509	−0.1730	−0.1159	−0.1049
Veronica chamaedrys	0.1456	0.0472	0.0934	0.0915	0.1716	−0.0477
Veronica serpyllifolia	0.2080	0.2159	−0.0037	−0.0238	0.1203	0.1423
Vicia cracca	0.0450	0.0701	−0.0149	0.0504	−0.0766	−0.1467
Vicia sepium	0.1168	0.0768	−0.1307	−0.1243	0.0102	−0.1012

Table 2 Spearman rank correlation coefficients of the score of the RDA analyses—comparison between cover estimation and density of plants under different grazing management

Year	IG	ICG	EG	ECG
1998	0.94 ($p < 0.0001$)	0.96 ($p < 0.0001$)	0.79 ($p = 0.0003$)	0.94 ($p < 0.0001$)
1999	0.89 ($p < 0.0001$)	0.79 ($p = 0.0002$)	0.73 ($p = 0.0013$)	0.91 ($p < 0.0001$)
2000	0.93 ($p < 0.0001$)	0.70 ($p = 0.0025$)	0.56 ($p = 0.0235$)	0.61 ($p = 0.0129$)
Mean	0.92	0.82	0.69	0.82

IG Intensive grazing, *ICG* first cut followed by intensive grazing, *EG* extensive grazing, *ECG* first cut followed by extensive grazing) in the study years 1998–2000

p = p-value of correlation coefficient

tion of month with each treatment. The species scores showed similarity between C and D in main sward dominants - grasses, *Trifolium repens*. However, other dominants such as *Ranunculus repens* and *Taraxacum* spp. had close-fitting relationship in the first two years only. This was well documented in mean cover of *Cirsium palustre* which was 7.4, 15.0 and 22.3 whereas mean number of plant was 1.2, 1.5 and 1.4 in 1998, 1999 and 2000 respectively. Spearman's correlation coefficients between both methods were 0.93 ($p < 0.0001$), 0.91 ($p < 0.0001$), and 0.50 ($p < 0.009$) in 1998, 1999 and 2000 respectively, and all correlations were significant. Both methods gave comparable results in 1998 and 1999 only. However, more different results were detected in 2000.

The second part of the study tested RDA analyses in each treatment and growing season, where the month was the only explanatory variable. The mean Spearman's rank correlation coefficients of C and D methods under IG, ICG, EG and ECG treatments were 0.918, 0.818, 0.694 and 0.818, respectively (Table 2). They were the highest in the first year of study and then a gradual decrease was recorded in all treatments. The lowest coefficients were revealed under both extensive treatments (EG, ECG), whereas the highest under intensive grazing (IG). Similar average Spearman's rank correlation coefficients were revealed under both treatments with cutting management (ECG, ICG). Thus, Spearman's rank correlation coefficients reflected the defoliation intensity (IG>ICG, ECG>EG).

The observer needed less time surveying per 100 cm^2 circle using the C than the D method ($p < 0.001$); average time used was 65 and 156 s, respectively.

Discussion

Cover estimation enables the determination of changes in species richness and relationships among species, but is usually weak in study of morphological plasticity of sward components under grazing (Jewiss 1993). The size–density compensation principle (see Matthew et al. 2000) documented in sown grass monocultures is also applicable to many dicotyledonous species in species-rich grasslands (Pavlů et al. 2006) and it is evident that increases in plant density as a result of defoliation is not restricted to grasses only but also to legumes and forb species in semi-natural grasslands.

Scale of study plot is also important and different methods are used for vegetation measurement on a global scale compared with a small replicated experiment. Smaller areas are more suitable for denser usually agriculturally managed communities (Whalley and Hardy 2000). However coefficient of cover variation of individual species is strongly depended on study area and as was documented by Klimeš (2003) it decreased with increasing plot size. Similarly (Otýpková and Chytrý 2006) revealed that smaller plots tend to produce less stable ordination patterns, especially in data sets with low diversity and species cover-abundances.

Extensive grazing supported the creation of heterogeneous sward which consisted of a mosaic of ungrazed, little-grazed and severely-grazed patches (WallisDe Vries et al. 1998). It should be noted that the majority of vascular plant species present here were present in all types of patches as was reported by Guerovich (2005). However, probably due to diverse conditions in patches (e.g. nutrient status, shade, selective grazing) they differed in their habit. These differences caused the main discrepancy in the comparison between density counting and cover estimation. Under intensive grazing, plants usually produce a high number of relatively small individuals (Matthew et al. 2000) and intensive grazing also reduces areas of ungrazed patches (WallisDe Vries et al. 1998). So, intensively grazed grassland, in comparison with extensively grazed grassland, is relatively more homogeneous and mostly composed of grazing-tolerant species (Correll et al. 2003). That is why we observed the highest correlation between C and D methods under intensive grazing. As well as in ECG treatment, cutting before grazing reduced horizontal heterogeneity and increased comparability of both methods, even though it was followed by the extensive grazing management. Similarly Chiarucci et al. (1999) found that the relation between cover and biomass will not be so strong, when plant communities are structurally richer, and diversified in more than a single vegetation layer.

After the introduction of grazing on abandoned grassland, patchiness was not well formed, so Spearman's rank correlation coefficients were relatively high in 1998 and 1999. However, the patchiness was well developed especially in the EG treatment in the third grazing season in 2000 and that is why correlation between both methods decreased substantially. The relationship between C and D methods is weak when some plants have avoidance mechanisms which reduce the probability and intensity of grazing (Briske 1996). This was well documented in the year 2000, when enhanced coverage of *Cirsium palustre* was recorded predominantly in extensively-grazed plots without substantial change in plant number. Similarly, considerable increase in prostrate forbs (*Ranunculus repens* and *Taraxacum* spp.) with their different habit, in frequently and as well as in infrequently grazed patches, reduced closeness of this positive correlation in the year 2000.

The cover estimation method was less time-consuming than plant counting, as in comparison of cover estimation to other methods (Brakenhielm and Liu 1995; Carlsson et al. 2005). Detailed counting of each grass tiller and stolon growing-point for *Trifolium repens* was the main reason for making the plant counting method more time consuming than cover estimation.

Cover estimation can produce highly correlated results and can substitute relatively time- consuming plant counting in relatively homogeneous grasslands without high occurrence of ungrazed patchiness and/or plants with grazing avoidance mechanisms. Intensity of defoliation management must be taken into account as well, because intensive defoliation reduces horizontal heterogeneity and consequently approximated results of both methods used.

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