THE ROLE OF GRAZING IN CREATING SUITABLE SWARD STRUCTURES FOR BREEDING BIRDS IN AGRICULTURAL LANDSCAPES

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Abstract

French wet grasslands support important populations of lapwings *Vanellus vanellus* and other waders. Grazing management is a key issue since these birds are very sensitive to sward structure (grass height, heterogeneity). During two years, repeated measurements of sward height were conducted in a coastal marsh in order to assess the impact of different grazing regimes on sward during spring. Sward structure was characterised by variables related to height classes and an index of heterogeneity. Grazing regimes were described by stocking rates per period and N fertilisation level. A co-inertia analysis showed a strong relationship between grazing regimes and sward structure. Fields showing a sward structure suitable for lapwings were heavily grazed during previous autumn and winter. Wader habitat management calls for more attention to the postponed effects of autumn and winter grazing regimes. Thus, heterogeneity emerges as a new characteristic to steer. Its level depends on selective grazing by cattle and influences the sward growth: thresholds thus are to be investigated.

Introduction

In response to the sharp decline of many species, in particular farmland birds, agri-environment schemes (AES) have been implemented all over Europe (Beintema et al., 1997). In the wet grasslands of the French Atlantic coast, AES were implemented during the early 90's in order to arrest their destruction and fragmentation through drainage and conversion to arable. For the remaining wet grasslands, management prescriptions aimed at decreasing fertilisation and imposing upper limits on average stocking rates at critical periods (Steyaert, 2001). Recent literature has approached grazing from the perspective of managing it to a desired effect in terms of biodiversity conservation (WallisDeVries et al., 1998). For instance, grazing is a major process directly affecting sward heterogeneity, i.e. spatial variance in sward heights within grasslands. Large herbivores such as cattle not only respond to heterogeneity but also create and sustain it (Hirata, 2000; Parsons et al., 2000). Mechanisms by which grazing animals create sward heterogeneity are multiple. Among the most documented are selective defoliation, treading and nutrient cycling (Rook et al., 2004).

In wet grasslands, grazing is likely to be a 'tool' to create and maintain foraging and nesting habitats for waders (Tichit et al., 2002; Tichit et al., 2003). As these species are sensitive to sward height and heterogeneity (Milsom et al., 2000), positive effects of grazing are related to the importance of sward conditions for these species in choosing a nest site. But grazing may also have negative effects. These latter are related to nest trampling by cattle (Beintema and Müskens, 1987). Indirectly, grazing may also induce secondary effects on invertebrate abundance and availability. It may therefore create unsuitable foraging habitats for birds (Benton et al., 2002). Moreover, since species such as lapwing (*Vanellus vanellus*), redshank (*Tringa totanus*) and black tailed godwit (*Limosa limosa*) do not prefer the same sward structure (i.e. grass height, frequency of tussocks) and because their timing of breeding varies, a diversity of sward structures at different critical stages of their breeding season is needed.

In a recent review, Benton et al. (2003) contend that habitat heterogeneity, at a range of spatial scales, is a key issue in maintaining biodiversity within agricultural landscapes by providing resources throughout the year for species-rich communities of organisms. They conclude that all agricultural practices can, in principle, be tailored and targeted to increase rather than eliminate heterogeneity. Indeed, it is evident that preservation of a variety of grazing regimes and not a single one is required if species conservation is to be achieved at the community level. However, in agricultural landscapes, it is critical to know if providing the architectural heterogeneity required by waders conflicts with management for livestock production aims. The objective of this paper is to

examine how sward heterogeneity is created through grazing in order to identify which trade-off are needed to use grazing as a management 'tool' to create multipurpose resources: ensuring both cattle feeding and preservation and management of bird habitats.

Methods

Study area

The study was undertaken on the Rochefort marsh, a wetland area (2000 ha) on the Atlantic coast of France in the department of the Charente Maritime. Land cover is mainly dominated by wet grasslands (2/3 of total area), crops occur less frequently in the landscape. The study was restricted to permanent grasslands which are grazed throughout spring, summer and autumn exclusively by cattle (suckling and dairy herds). The climate is warm Atlantic with a mean annual temperature of 12.2°C, total annual rainfall of 780 mm and a summer deficit of 331 mm. These grasslands are criss-crossed by a complex network of freshwater ditches. The clay soils of high humidity and salinity ensure a distinctive assemblage of hygrophilous, meso-hygrophilous and mesophilous vegetation along a topographical gradient consisting of low-lying depressions and high level flats (Loucougaray et al., 2004). Such habitat is classed as "*community of interest whose conservation requires the designation of special area of conservation*" (Habitats Directive 92/43/EEC, Annex I).

Data collection and analysis

To assess the impact of grazing on sward height dynamics during spring, a protocol was set up in 2002 and 2003 on respectively 19 and 28 fields. The selection of fields for inclusion within the study was determined by the following criteria: (i) the need to sample a low range of soil/wetness conditions, and (ii) a large range of grazing regimes. Between 1st of April and 1st of June, the sward height was measured every twenty days using a swardstick (Duru and Bossuet, 1992). Measurements were carried out in each field, walking representative transects. Sufficient readings were taken to give an accuracy of +/- 3 cm based on 95% confidence limits. This usually required 60-80 height measures / ha. On each field-date, sward structure was described by 9 variables: percentage of bare ground, percentage of tussocks, 6 height classes in cm (]0-5] [5 – 10[[10 – 15[[15 – 24[[24 – 35[and >= 35) and an index measuring height heterogeneity along the transect. This index developed by Burel and Baudry (1999) was calculated by $H = -\sum p(i, j) * \log(p(i, j))$.

Where i and j are two height classes and $p(i, j)$ is the probability to find these classes adjacent along the transect. With such an index, heterogeneity depends on the number of height classes and their spatial distribution. In order to describe grazing regimes, an accurate recording of the following variables was done for each field: number of livestock units, time spent by animals, field size, N fertilisation. Stocking rates (Days Livestock Units DLU) were calculated for five periods: autumn [year(n-1)] (DLU_A), winter [year(n-1)] (DLU_W), early spring (DLU_{ES}), mid spring (DLU_{MS}) and late spring (DLU_{LS})[year (n)].
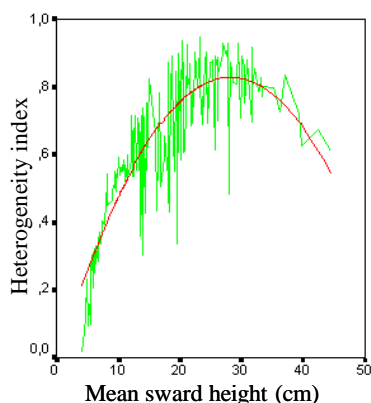
Relation between mean sward height and heterogeneity index was investigated through regression models. To characterise the diversity of sward structure during spring a Principal Component Analysis (PCA) followed by Ascendant Classification (AC) were conducted. Relationship between sward structure and grazing regimes was analysed through co-inertia analysis (Dolédec and Chessel, 1997). This analysis made it possible to investigate the presence of a co-structure between both data sets (sward, grazing regimes) by running a Monte-Carlo test in which the rows of both tables were randomly permuted.

Results

Heterogeneity index varies with mean sward height

Heterogeneity index was quadratically related to the mean sward height (figure 1). On both years, equations were highly significant (2002: $R^2=0.76$, $P<0.001$. 2003: $R^2=0.67$, $P<0.001$). Heterogeneity index reached its maximum value for a mean sward height around 30 cm, then decreased indicating that the sward became homogeneously tall. For mean sward height between 15 and 25 cm, variability of heterogeneity index was highest indicating a complex relation that may be linked with the existence of spatial pattern within the sward. Factors of variation of heterogeneity index are twofold: first is the number of height classes present along transect, second is their spatial distribution. It is likely that the number of height classes is smaller in short than medium and tall swards. Therefore, spatial distribution may not have a strong effect on heterogeneity variability. Conversely, in medium and tall swards, the class number is higher and its effect on heterogeneity may be amplified by the spatial distribution of height classes (fragmentation). Consequently, this may promote heterogeneity by increasing the proportion of the different couples of height classes which would not appear in short swards. It

was therefore relevant to characterise sward structure by taking into account height classes rather than mean sward height.

Figure 1. Relationship between heterogeneity index and mean sward height (2002)
$R^2=0.76$, F=324, p=0.000, n=202.

Diversity of sward structures

PCA analysis was run on both data sets (2002-2003). In both years, the first two PCA axes accounted for 64% of total variance and the structure of variables was quite similar. Short height classes - <10 cm - were negatively and tall height classes – >=24 cm - as well as heterogeneity were positively correlated to the first PCA axis. Medium height classes –   [10-24 cm[- were positively correlated to the second PCA axis.   In both years, the percentages of bare soil and tussocks were badly represented.

Three groups of fields were identified in 2002 and four in 2003 (table 1). In the first group, fields were characterised by an extremely high proportion of short and a low proportion of medium height classes. Classes taller than 24 cm were nearly not existent. The percentage of bare ground was notably higher than in other groups. Heterogeneity was low and the characteristics of this group were very similar on both years. The second group was dominated by medium height classes and a varying proportion of short and tall height classes according to year. It was notably more heterogeneous than the first one and tussocks were more abundant in 2002 than in 2003. The third group showed a high proportion of medium and tall height classes associated to a low proportion of short ones. It was by far reaching the group with the highest level of heterogeneity. The last group was only observed in 2003, its structure was intermediate between groups 2 & 3 with a high proportion of medium height classes and a

nearly equal proportion of short and tall ones. Its heterogeneity was close to that of group 2.
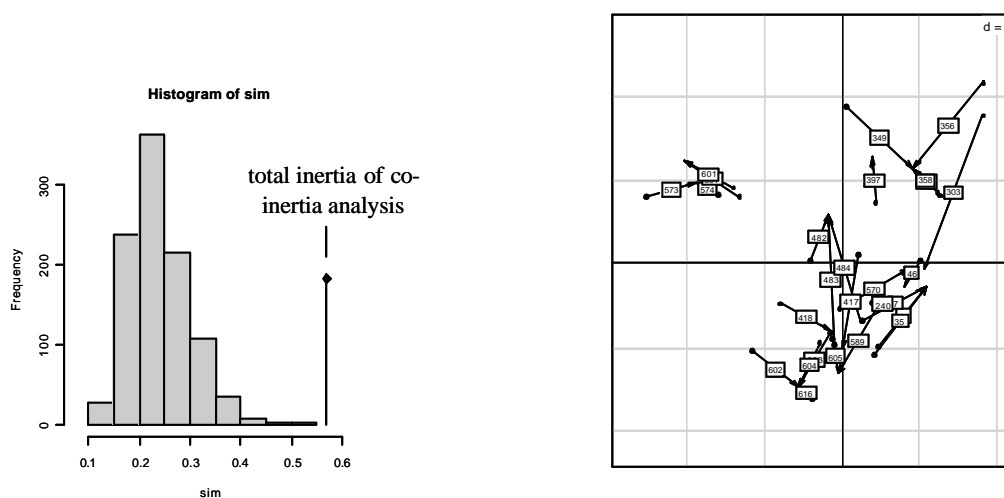
Relation between grazing regimes and sward structure

To investigate relationship between sward structure and grazing regimes two sets of variables were processed through a co-inertia analysis. The first one accounted for sward structure variables at the end of three periods (early spring, mid spring, and late spring). Sward height classes were reduced to three (]0-10[, [10-24[, >=24), respectively referred as short, medium and tall. The second set was represented by N fertilisation level and stocking rate variables during five periods (DLU_A, DLU_W, DLU_{ES}, DLU_{MS} and DLU_{LS}).

Results indicated that 81% (2002) and 95% (2003) of total variance was explained by the first two axes. A total of 1000 co-inertia analysis was processed using a random matching of the two tables. Monte Carlo permutation test gave a probability p=0.0009 to have a random co-structure (observed value was always greatly higher than any simulated one). This indicated that the two tables were significantly related and that a co-structure existed. Stocking rates in autumn and winter were positively correlated to short height classes and bare ground in the following early spring as well as negatively correlated to tall height classes of this same period. Autumn stocking rate (rather than winter) was negatively correlated to the percentage of tussocks and heterogeneity index. Fertilisation was weakly negatively correlated to tall height classes and heterogeneity of mid spring. During spring, relationship between both sets of variables differed between years. In 2002, stocking rate in mid spring was positively correlated to short height classes and percentage of bare ground. Stocking rates during early spring and late spring were badly represented and could not be related to any particular sward structure. In 2003, stocking rate in early spring was strongly correlated to short height classes of mid spring as well as negatively correlated to tall height classes and heterogeneity index. Stocking rate in mid spring was positively correlated to short height classes as well as negatively correlated to tall ones and heterogeneity index in late spring. Figure 2 presents the projection of the two new standardized sets of field scores. The two structures were globally found similar. However, quite long arrows for some fields (349, 356, 303) demonstrated low relationship between sward structure and grazing regimes.

Table 1. Four types of sward structures

| Sward structure	Year	Heteroge-neity	Proportion of height classes[1] (cm) % of total points			Percentage of bare ground[1]	Percentage of tussocks[1]
			]0 – 10[	[10 – 24[	>= 24		
1- Short homogeneous sward	2002 n=13	0.3 (36)	83.9 (16)	15.5 (31)	0.6 (50)	3.0 (84)	0.8 (91)
	2003 n=21	0.4 (18)	71.8 (8)	26.7 (15)	1.5 (53)	2.9 (79)	0.7 (164)
2- Medium homogeneous sward	2002 n=44	0.6 (17)	22.0 (28)	62.4 (20)	14.4 (32)	1.2 (149)	3.5 (84)
	2003 n=37	0.6 (13)	40 (13)	54.4 (14)	5.6 (37)	1.8 (148)	0.7 (123)
3- Tall heterogeneous sward	2002 n=57	0.8 (11)	7.2 (32)	35.4 (23)	57.3 (25)	1.0 (124)	2.9 (91)
	2003 n=70	0.8 (8)	15.5 (29)	37.2 (19)	47.3 (24)	1.4 (108)	2.0 (109)
4- Intermediary between 2 & 3	2003 n=42	0.6 (20)	13.5 (20)	70.1 (12)	16.4 (30)	1.2 (126)	1.2 (135)

[1] mean (coefficient of variation %).

Figure 2. Results from co-inertia analysis in 2003.
Left: histogram of total co-inertia after random permutation of both table rows. **Right**: Projection of the new standardized set of field scores. Each field is defined by an arrow; arrow head marks the scores of the field according to sward structure and the end of the arrow indicates its position according to grazing regime. Variance along each axis is equal to 1.

From these results, it was inferred that delayed effects of grazing regimes during autumn and winter could contribute to create short homogeneous swards in the next early spring. During spring, the relation between stocking rate at a given period and the sward structure of the next one differed according to year. In particular, as shown by 2003 data, when herbage growth was limited by climatic conditions, relationship between stocking rate and sward structure was clearer suggesting an increased impact of grazing. However, for a given climatic year, impact of grazing of sward is not independent from herbage N status (N_i). This is illustrated by figure 3 showing the dynamics of mean grass height (i.e. change over time) in spring 2003. Some fields had a relatively stable mean sward height during spring (21-27 cm), whereas other showed an increasing

mean sward height (12-34 cm). Differences in initial mean sward height seemed to be related to autumn and winter stocking rate. The different evolutions of mean grass height during spring seemed to be related to stocking rate and N_i. Swards with an increasing mean height during spring were more heavily grazed, however stocking rates appeared to be insufficient to control herbage growth (Ni=77% ±15). Conversely, fields with a stable mean grass height were grazed at much lower stocking rates, but grass height remained stable probably due to a lower herbage growth (Ni=58% ±10).
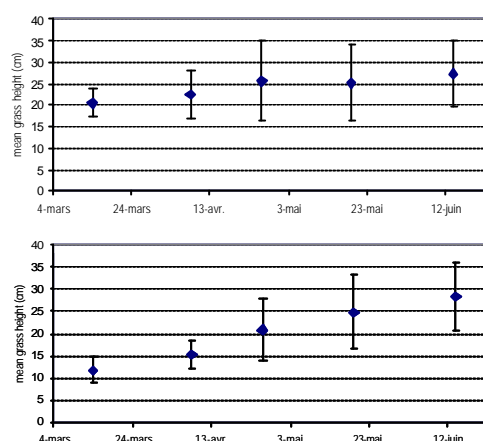
Figure 3. Change of mean grass height over spring (2003).
Top (n=5 fields): Stable mean sward height. Herbage N index= 58% +/- 10. Autumn and winter stocking rate=0 LU/ha. Mean stocking rate in spring=0.9 LU/ha +/- 0.1. **Bottom** (n=13 fields): increasing mean grass height. Herbage N index=77% +/- 15. Autumn and winter stocking rate=0.8 LU/ha. Mean stocking rate in spring=1.4 LU/ha +/- 0.4.

Discussion

Are sward structures suitable for breeding waders?

On the basis of several works in conservation biology, it is possible to reflect on the suitability of sward structures observed in this study in relation to the potential they could offer as wader habitats. We focus on lapwing and redshank habitat requirements as they are more frequently encountered in our study area. Although waders share a general breeding habitat (wet grasslands), all fields are not equally attractive because different species prefer different sward heights. Short swards (= 10 cm) attract lapwings and medium sward (15-20 cm, and even up to 30 cm) are more suitable for redshanks (see review by Durant, 2004). Both species are also sensitive to the abundance of tussocks. The first one prefers grasslands where tussocks are rather rare (about 5-

15 % of field area), whereas the second one needs more tussocky swards since it locates its nest near or in tussocks (Milsom et al., 2000).

From these elements, it is inferred that both species are also likely to be sensitive to sward heterogeneity. Therefore, swards of group 1, with a high proportion of short grass heights and a nearly non existent percentage of tussocks are likely to match lapwing sward structure preferences. Swards of group 2 and 4, in which medium grass heights are largely dominant could correspond to redshank vegetation requirements. However, according to year, the percentage of tussocks may be insufficient. The timing of breeding in both species is another important aspect of their biology to take into account, mainly because their breeding success is influenced by nest trampling by livestock (Hart et al., 2002). A difference between lapwing and redshank phenologies was confirmed by a study carried out in 2004 in the Marais Poitevin (western coast of France), which showed that the lapwing nests about one month earlier (mean date of settlement: 24 March ± 14 days, n = 37 pairs; mean laying date: 16 April ± 9 days, n = 71) than the redshank (21 April ± 17 days, n = 6; 21 May ± 10 days, n= 42, respectively) (Durant unpubl. data). A subtle trade-off may be required to mitigate those negative effects related to livestock density. We conjecture that there may be a 'threshold date' before which grazing may have important detrimental effects. From this perspective, it is interesting to note that delayed effects of autumn or winter grazing are interesting to create the short sward needed for lapwing settlement. As it nests latter, the redshank is more likely to be sensitive to spring grazing. Despite the global benefice of spring grazing for breeding waders, a too early turnout date may be detrimental for nests and birds may avoid heavily grazed fields.

Effects of grazing regimes on sward structure and processes involved

The importance of sward heterogeneity in the choice of a nesting site in waders brings us to reflect on processes involved in the creation and maintenance of sward heterogeneity under grazing. Here, we concentrate on one of them: selective defoliation. Plant-herbivores interactions are dynamical: the structure and the quality of the vegetation affect the diet of the herbivore, and, in turn, defoliation alters sward structure and species composition (Marriott and Carrère, 1998). As we have seen in this study, the level of heterogeneity of the sward depends on grazing pressure but also

on the growth stage of the sward (i.e. the season). However, in some fields, a low relationship between sward structure and grazing regime was observed. As underlined in recent research (see for instance Hirata et al., 2002; Garcia et al., 2003; Garcia et al., 2003), it is possible that spatial patterns in the height of vegetation, may have influence livestock behaviour. These authors show that on swards grazed at low stocking rate, best quality patches (i.e. locations with lower grass height) are more frequently defoliated allowing herbivore to maximize their diet quality. This mechanism induces sward variability and heterogeneity at several spatial scales that has feed-back effects on herbivore behaviour. We conjecture that lightly grazed fields, high levels of sward heterogeneity may create noise in the relation between grazing regime and sward characteristics. In particular on large fields (up to 8 ha in our study) where other factors related to field configuration may also influence spatial and temporal variability of grazing pressure (Dumont et al., 2001). From this perspective, our results confirm the need to explore, from the twofold perspective of herbivore and vegetation, spatial processes involved in grazing and notably the processes and variances in the processes involved in structuring sward heterogeneity (Parsons et al., 2000).

Conclusions and perspectives

We have seen that particular grazing regimes provide suitable nesting sites for lapwings and redshanks, both in terms of sward height and heterogeneity. These results provide important elements for grassland management by grazing in the context of wader conservation. As many other studies in bird habitat selection (Milsom et al., 2000; Hart et al., 2002), our work was conducted at the field scale. However, since agricultural landscapes are organised as a mosaic of fields with variable characteristics, this emphasises the spatial nature of grassland management. Because species-environment relationships are likely to operate at field and coarser scales such as the landscape scale (Grand and Cushman, 2003), we contend that the management of grasslands should be implemented taking into account the various spatial scales at which livestock systems operate. This should be conducted by reflecting on potential links that may exist between these scales and those that are relevant from the spatial resolution of bird behaviour (for instance colony territory during incubation, and home range size during chick rearing). Therefore, it is necessary for future research to integrate at least three spatial scales:

· *Field scale* – Timing and intensity of grazing are critical factors influencing bird habitat selection (see Tichit et al in this congress). Livestock feeding systems usually secure their feeding system by a diversity of resources generated through several field utilisation patterns (Bellon et al., 1999). For a given sward cover, different utilisation patterns will thus create different sets of resources for different animal batches. These utilisation patterns combine various level of grazing intensity at different periods. Grazing pressure in autumn is allocated according to different strategic (forage stockpiling) as well as contingent (present grass availability) constraints in the livestock system. For instance, intensive dairy farmers who feed cows mainly with grass silage in the summer, usually limit grazing intensity in the autumn on some fields to secure grass silage in the following May. Autumn grazing also depends on constraints related to calving date and labour availability. On farms characterised by a highly fragmented field pattern, wet grasslands are not grazed during this season when it match with the calving period. During spring, the level of intensification of the forage system, also has consequences on the level of use of grasslands in spring (Coleno and Duru, 1999). Under-utilization of grasslands is usually linked with the proportion of maize or grass silage in the feeding system. This may be a source of increasing sward heterogeneity. Notably in wet grasslands where low soil carrying capacity and plant phenologies create severe constraints to grazing.

· *Scale of a block of a few adjacent fields* - The definition of this scale can be made from the spatial resolution of the distribution of birds throughout the breeding season, i.e. settlement, incubation and chick rearing. Indeed, colony territories are usually not restricted to a single field, and soon after hatching families move from one field to another, looking for good foraging sites. Attractiveness of a field will thus be also determined by characteristics of adjacent fields. Since it is unlikely that all the fields of a given sector are managed by the same farm, colony territory will be influenced by spatial distribution of sward covers resulting from several batches that graze according to the global configuration of the livestock system they belong to.

· *Landscape scale* - Landscape may provide environmental clues used by birds for habitat selection. Modelling habitat suitability for five wader species, we showed that habitat preferences are not built on the same ecogeographical variables for all species (see Renault et al. in this congress) and species are more or less sensitive to land use (in particular grazing). At the landscape scale, we

showed that birds are not randomly distributed and some sectors of the marsh are more attractive than others. Consequently, the proportion of grazed pastures in the landscape is likely to influence its degree of use by waders. Therefore, different land use mosaics depend on farming systems characteristics. According to their level of intensification, landscape heterogeneity can be highly variable (Baudry et al., 2003). At this scale, the main point that deserves to be stressed is that heterogeneity will emerge from several farmers acting in their own purpose.

Acknowledgements

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