

Management of agricultural wet grasslands for breeding waders: integrating ecological and livestock system perspectives—a review

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Received: 17 April 2007 / Accepted: 10 December 2007 / Published online: 20 December 2007
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Abstract Although agriculture is pointed to as being one of the major causes of biodiversity loss, it is now recognised that some farming practices, grazing in particular, represent central issues in the on-running debate on wildlife conservation. This paper analyses the relationship between agricultural pasture management and bird preservation, by focusing on the illustrative case study of breeding waders in wet grasslands. After a brief account of the knowledge on research investigating the effect of grazing management on wader distribution or abundance, we reviewed (i) sward structure (i.e. mean sward height and frequency of tussocks) requirements, and (ii) breeding phenologies of five wader species commonly associated with wet grasslands for nesting in Europe. We found differences between species in these two aspects of their biology. Investigating grassland management thus underlines that the question of the timing of grazing should be considered. Moreover, the fragmented characteristic of agricultural landscapes (i.e. a mosaic of fields) in which waders breed emphasises the spatial nature of this management. We examine three spatial scales (i.e. field, set of adjacent fields, landscape) relevant to bird biology and influenced by agricultural activities. Based on these findings, we analyse which livestock system constraints are essential to take into account in order to minimise conflicts between livestock production and conservation aims in marshes. Finally, we highlight possible directions for future research.

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Keywords Birds · Breeding waders · Grazing management · Livestock systems · Sward structure · Wet grasslands

Introduction

Although agriculture is pointed to as being one of the major causes of biodiversity loss (Donald et al. 2001, 2006; Duncan et al. 1999), it is now recognised that some farming practices, grazing in particular, represent central issues in the on-running debate on wildlife conservation (Verdu et al. 2000; Watkinson and Ormerod 2001; Donald et al. 2002). Farmers are increasingly requested to participate, mainly through agri-environment schemes, in the management of pastures that are of special value for animal and plant conservation (Ovenden et al. 1998). This is particularly true in European grasslands where livestock rearing is one of the main economic activities. In these habitats, the creation and the maintenance of grass cover states suitable for both the objectives of production and wildlife conservation are, in a large extent, determined by the timing and frequency of grazing and mowing (Bakker 1989; WallisDeVries et al. 1998) and when the impact of grazing is detrimental, it is not so much due to the presence of livestock per se, but rather a consequence of the adopted intensity of land use. Targeted grazing practices may thus contribute to enhance biodiversity, eliciting increases in the number or density of species.

However, livestock production has its own agenda. Grassland management for livestock feeding is driven by the level of production targeted and the relative importance of grazed grasslands as a unique resource for livestock feeding or as one resource within a larger interdependent set of resources (e.g. hay, grass or maize silage). Several key aspects of grazing regimes (e.g. turnout date, timing, intensity and efficiency of grazing) are inter-related and have strong effects on herbage production and vegetation states. Furthermore, field characteristics, such as wetness, distance to the cowshed or its suitability for hay or grass silage harvesting, are always incorporated into farmers' allocation rules of land use in order to adapt their management to the potentialities of their fields (Joannon et al. 2005). Recent work has emphasised that farm land diversity in terms of vegetation types or field characteristics is an advantage to improve the forage balance in dairy farming systems as it induces higher yields and quality of forage supplies while decreasing the amount of hay fed during the grazing period (Andrieu et al. 2007). On the basis of these elements, we conjecture that it is not possible to design efficient management for conservation without accounting for the interactive nature of farming practices.

This review aims at examining the relationship between farming practices in wet grasslands and wildlife conservation. Previous studies have questioned whether bird biodiversity may, in certain circumstances, benefit from grazing/mowing practices. Many support this view as both activities contribute to the management of wet grasslands for bird conservation (Crofts and Jefferson 1999; Vulink et al. 2001). In order to tackle some aspects of this question, we have, for several reasons, focused this review on breeding waders:

- (i) several species preferentially use wet grasslands for nesting and chick rearing (del Hoyo et al. 1996) and are thus dependent on these habitats throughout their breeding period;
- (ii) these species are ground-nesting birds and are sensitive to sward structure for nesting (Peel et al. 1997; Milsom et al. 2000). Wader species have different sward structure requirements, and thus represent an ideal model group to study whether grazing regimes may have different effects on different bird species;

- (iii) due to their mobility, waders (as many other birds) exhibit a quick response to changes in their habitat (Baines 1988); families move from one field to another during the chick rearing period to access food resources. This implies that supra-field scale is important for their survival.
- (iv) in recent years, severe declines noted in many wader populations throughout Europe (Dubois and Mahéo 1986; Hudson et al. 1994; Rocamora and Yeatman-Berthelot 1999) have led to the formulation and implementation of conservation measures (Trolliet 2000; Sheldon 2002).

Agricultural grasslands form the main breeding areas for many waders (Piersma 1986), and both livestock grazing and mowing are of high importance to their use of grasslands (Shrubb and Lack 1991; Norris et al. 1997; Ottvall and Smith 2006), although such practices are known to have potentially detrimental effects through nest trampling in particular (Green 1986; Beintema and Müskens 1987). Nowadays, there is still a lack of details about the relationships between species richness, breeders abundance, breeding success and the various grazing (and mowing) practices involved in agricultural landscapes (Hart et al. 2002), and this is the main focus of our paper.

In this review, we principally focused on grazing management as a driver of sward structure. Inevitably, other factors than sward structure may also play a role in determining the suitability of grasslands for breeding waders, e.g. field wetness (Caldow et al. 1997; Mason and MacDonald 1999; Milsom et al. 2002). Despite the difficulty to disentangle the influence of grazing from such potential confounding effects, grazing indisputably remains a major factor underlying habitat selection and distribution by waders. Grazing management thus deserves consideration of its own, hence such a review should be useful as it identifies gaps in our way to tackle this issue and offers perspectives for future research.

This paper first focuses on how grassland management, particularly through grazing, has been tackled in various wader studies and what is the current knowledge on this subject. Secondly, we review sward structure (i.e. mean sward height and frequency of tussocks) preferences in five wader species associated with wet grasslands for nesting in Europe, and for which a minimum of information exists: the Lapwing *Vanellus vanellus*, the Redshank *Tringa totanus*, the Black-tailed Godwit *Limosa limosa*, the Curlew *Numenius arquata* and the Snipe *Gallinago gallinago*. We relate this information to differences in their timing of breeding. Thirdly, we analyse implications for suitable grazing management of wet grasslands for waders. Because large herbivores do not graze marshes throughout the year, and due to the fragmented characteristic of agricultural landscapes (i.e. a mosaic of fields), we explore the importance of timing of grazing as well as key spatial scales of investigation. Finally, we discuss our findings in the light of the interactive nature of farming practices, taking into account constraints induced by management prescriptions on livestock systems, and we then highlight future directions and research needs.

Grazing to manage wet grasslands for breeding waders

Grazing (along with mowing in certain circumstances) is a major determinant of the use of wet grasslands by breeding waders. Grazed pastures are generally more used by birds than ungrazed ones (Shrubb and Lack 1991, 1994; Olsen and Schmidt 2004; Vulink et al. 2001). The consequences of the abandonment of grazing are also a proof of the usefulness of grazing for wader settlement, since this leads to changes in vegetation structure that reduce the abundance of waders (LeNeveu and Lecomte 1990). Looking at these examples,

it is clear that the role of grazing for wader preservation has often been tackled simply from the angle of presence/absence of grazing (Hart et al. 2002). Some studies have analysed the relationship between wader densities and stocking density expressed as Livestock Units/ha (Triplet et al. 1997), or through a qualitative 4-point grazing index (e.g. no/light/moderate/heavy grazing; see Norris et al. 1997, 1998 or Ottvall and Smith 2006 for more details). Unfortunately, these studies remain rare and do not shed light precisely on the type of grazing management which can create suitable sward structure for breeding waders. One reason is that much of these studies principally have an ecological approach. There is little tradition in combining ecology and animal production, which is however necessary to perform detailed analysis on grazing practices. Moreover, the success of such interdisciplinary studies depends on an active cooperation with local farmers. Without such cooperation, it is technically difficult to obtain data on grazing practices and stocking densities as movements of herds are often complex (e.g. changing on a daily basis; Hart et al. 2002). Although important factors such as variations in livestock turnout dates or stocking densities among fields have only recently been taken into account (Tichit et al. 2005b; Durant et al. submitted), there is still a lack of knowledge about the relationship between vegetation structure, grazing management and wader density during the different stages of their breeding cycle (Hart et al. 2002). It would however be important, in a bird conservation perspective, to understand how to modify grazing practices to attract breeding waders. Hence the necessity of a good knowledge on i) specific sward structure requirements from the different bird species, and ii) differences in their timing of breeding. These two points are considered in the following part of this paper.

Specific sward structure requirements from breeding waders

Preferred sward structure

In *The Wet Grassland Guide*, Treweek et al. (1997) reported specific sward structure requirements of some waders breeding in Britain. Despite the importance of such a guide for grassland management, it refers to only one study, i.e. Self et al. (1994). Latter, this guide was followed by the work of Wilson et al. (2004), who simply reported bird preferences in terms of 'short grass' or 'taller, more tussocky grassland' without more details, e.g. range of sward heights. Among studies carried out in Europe, we found 14 papers giving indications on sward structure preferences in the five wader species under concern (Tables 1 and 2), most being undertaken on lowland wet grasslands (i.e. pastures and hay meadows periodically flooded or which overlie waterlogged soils, and lying below ca. 200 m altitude; Jefferson and Grice 1998). Some obtained from Uplands (e.g. Baines 1988) were however kept in order to refine this review. Behind the term 'sward structure', two components are considered here: mean sward height and frequency of tussocks.

Mean sward height

Most studies focused on the lapwing, and thus its sward structure requirements are the best documented. Lapwings prefer nesting in short grass generally <10 cm (Table 1), and can abandon the nest if the vegetation becomes too tall (Lister 1964 cited in Hudson et al. 1994). Milsom et al. (2000) relied on a modelling approach to show that the probability for a site to be occupied by breeding lapwings decreased with sward height (i.e. 2–3 cm being

Table 1 Review of the values of preferred sward heights in five species of breeding waders

Species	Preferred sward height (cm)	Method used	Period (nesting/chick rearing)	Habitat/Region	References
Lapwing	≤5	Measurements along transects + visual estimates	Nesting/chick rearing	Grasslands/North Kent	Milsons et al. (2000)
	5.5 ± 6.5	In relation to lapwing height	Nesting	Wet grasslands/France	Boileau et al. (unpubl. data)
	9.2 ± 3.1	Measurements around nests	Nesting	Meadows/Hungary	Hegyí and Sasvari (1997)
	6.0 ± 2.0	Point intercept technique	Chick rearing	Sea shore pastures/Sweden	Johansson and Blomqvist (1996)
	≤10	No indications on measurements	Nesting	Natural grasslands/France	Dubois and Mahéo (1986)
	10–15	?	Nesting	Grasslands/England	Green (1986)
	<15	No indication	Nesting	Wet grasslands/Britain	Treweek et al. (1997)
Redshank	6–14	20 random measurements/field	Nesting	Grasslands/Norfolk coast	Vickery et al. (1997)
	15.8 ± 4.3	Measurements around nests	Nesting	Meadows/Hungary	Hegyí and Sasvari (1997)
	15–20		Nesting		Green (1986)
	10–30	Measurements (no more indications)	Nesting	Wet grasslands/France	Dubois and Mahéo (1986)
	ca. 20	No indication	Nesting	Wet grasslands/Britain	Treweek et al. (1997)
Curlew	10–45	Visual estimates	Nesting	Grasslands/Finland	Valkama et al. (1998)
	<15	?	Chick rearing	Grasslands/Germany	Tüllinghoff and Bergmann (1993)
Black-tailed godwit	12.1 ± 3.6	Measurements around nests	Nesting	Shore meadows/Sweden	Johansson (2001)
	25.5 ± 4.6	Measurements around nests	Nesting	Meadows/Hungary	Hegyí and Sasvari (1997)
	<20 (mid-may)	–	Nesting	–	Green (in Bibby et al. 2000)
	<21 (mid-may) then >21 (early June)	Weekly measurement at five random points	Chick rearing	Grasslands/The Netherlands	Kruk et al. (1997)
Snipe	>25	No indication	Nesting	Wet grasslands/Britain	Treweek et al. (1997)

Values are given as it is indicated in the studies (a range or mean ± S.D.)

Table 2 Review of the preferred frequency of tussocks in five species of breeding waders

Species	Density of tussocks	Method used	Period (nesting/chick rearing)	Habitat/Region	References
Lapwing	Sparse or occasional (5–15%) Rare or absent (<i>Juncus effusus</i>)	Visual estimates	Nesting/chick rearing	Grasslands/North Kent	Milson et al. (2000)
Redshank	Occasional to abundant (5– >35%) 'Rough tussocky sward' 'Tussocky areas'	Visual estimates Visual estimates Visual estimates	Nesting Nesting/chick rearing Nesting	Grasslands/England Grasslands/North Kent Grasslands/Ireland	Baines (1988) Milson et al. (2000) Herbert et al. (1990)
Curllew	'Numerous' (<i>Juncus effusus</i>)	No indication	Nesting	Wet grasslands/Britain	Treweek et al. (1997)
Black-tailed godwit	'Tussocky grass'	Visual estimates	Nesting	Grasslands/England	Baines (1988)
Snipe	'Abundant' (<i>Juncus effusus</i>)	No indication Visual estimates	Nesting Nesting	Wet grasslands/Britain Grasslands/England	Treweek et al. (1997) Baines (1988)

the optimal sward height). Redshanks need generally taller vegetation than lapwings (Vickery et al. 2001). Globally, a sward height of ca. 15–20 cm seems suitable for this species (Table 1), although it has already been reported as being up to 30 cm (Dubois and Mahéo 1986).

Comparison between black-tailed godwits and other species for sward height preferences is more subject to debate. Although Hegyi and Sasvari (1997) showed that black-tailed godwits prefer taller swards (ca. 26 cm) than lapwings or redshanks (ca. 9 and 16 cm, respectively), Johansson (2001) found that this species nests in grass of 12 cm in height. Green (1985) (cited in Bibby et al. 2000) showed that black-tailed godwits nest in grass ≤ 20 cm high. As in redshanks, a mean sward height of ca. 15–20 cm is generally reported for black-tailed godwits.

Sward height preferences for curlews are less documented as a single study (carried out in Uplands) related their preferences during nesting (Valkama et al. 1998). In this study, their nesting habitats were classified as ‘short vegetation’ (i.e. tillage with no or very short vegetation) or ‘tall vegetation’ (i.e. hay: 10–15 cm, stubble: 20–30 cm and fallow or meadow: 25–45 cm). The authors showed that curlews preferred to build their nests in ‘tall vegetation’, but without more precisions on which of the vegetation categories mentioned above was preferred. As Valkama et al. (1999) reported that Curlews preferred ‘unimproved tussocky areas with tall but sparse swards’, we conjecture that this species appreciate medium to tall grass (from 10 to 45 cm as in hay meadows).

Snipes nest in tall vegetation, i.e. >25 cm (Dyrce et al. 1981; O’Brien and Buckingham 1988; Treweek et al. 1997; Vickery et al. 2001). They are mostly encountered in (tall) hay meadows rather than in short pastures (Herbert et al. 1990). The preference of this species for taller grass than other species is confirmed by Vickery et al. (1997) which indicated that fields supporting high breeding densities of lapwings and redshanks in summer did not have high densities of snipes.

Tussock frequency

Grazed swards usually develop a characteristic structure of short and tall areas due to rejection of herbage by livestock, e.g. herbage close to dung or less palatable (Marriott and Carrère 1998). This structure is quantified by estimating tussock frequency, i.e. the proportion of surface area occupied by patches of herbage that are taller than the surrounding sward. This quantification remains quite rare in studies as to our knowledge only Milsom et al. (2000) gave a clear definition and estimations of tussock frequency.

Preferences for tussock frequency in breeding waders are thus less well documented than for sward height. They do, however, seem to match in a way species’ sward height preferences. One of the reasons why breeding birds look for particular sward structures is nest concealment (Götmark et al. 1995). In lapwings for instance, tussock frequency must be rare or occasional (5–15% of the surface area; Milsom et al. 2000). Lapwings do not seem to have a direct need for tussocks to nest since only a small proportion of nests (e.g. 23%, *ibid*) are generally placed near or in tussocks. An irregular vegetation cover may be sufficient to make nests less detectable to predators than in a uniform one (Redfern 1982; Milsom et al. 2000). Finally, lapwings prefer grasslands where tussocks are rather rare, probably because short grass they appreciate is more likely to be found in strongly grazed swards (and thus tussock-poor). Conversely, redshanks accept a larger range of tussock frequencies than lapwings (from 5 to $>35\%$, Milsom et al. 2000). This preference for

‘rough and tussocky’ swards (Herbert et al. 1990; Treweek et al. 1997) is related to their need to build the nest in tussocks.

Curlews, black-tailed godwits and snipes also select fields with ‘a tussocky sward’ (Table 2). For example, Baines (1988) found that the density of breeding curlews was positively correlated with rush (*Juncus effusus*) density. In these species, nests are located near or in tussocks. Tall vegetation is preferred, as higher tussock frequencies are more likely to be found in grasslands with taller vegetation. However, more studies are needed since none estimated optimal tussock frequencies in these species as Milsom et al. (2000) did for lapwings and redshanks.

In conclusion, although waders share a general breeding habitat (i.e. wet grasslands) they differ in their sward structure preferences. There is a kind of continuum in these species, from lapwings nesting in short swards (broadly ≤ 10 cm), to snipes preferring tall ones (> 25 cm) (Fig. 1). Redshanks, black-tailed godwits and curlews show intermediate preferences (ca. 15–20 cm). These differences are likely to be related to two non exclusive explanations. First, species have developed different strategies to minimise the risk of nest predation (Vickery et al. 2001). The most timid species, such as the snipe, relies on vegetation cover and camouflage (cryptic coloration of plumage) to conceal the nest and the incubating bird (Dyrce et al. 1981; Green 1986; Treweek et al. 1997). In other species, such as the lapwing, the black-tailed godwit, or the curlew, and to a lesser extend the redshank (Bertolero 2002), choosing a nest site seems to be a trade-off between concealment of the nest and view of the surroundings, as they rely on an active nest defence against predators (Cramp and Simmons 1983; Berg 1992b). Secondly, preferences in sward height may also be related to adult (and chick) morphological constraints, i.e. leg length, in relation to their movements on the ground or food accessibility (Galbraith 1988; Milsom et al. 1998; Devereux et al. 2004).

Mean sward height preferences reported in a particular wader species are not always consistent from one study to another. The use of different measurement methods (e.g. direct sward height measurements versus visual estimates, Table 1) or whether or not authors only consider the mean sward height in the vicinity of nests or that of the grassland in which nests are found could explain some variability in the results. The measurements of preferred sward heights and tussock frequencies are, therefore, tendencies rather than absolute rules as some individuals may (i) show variations in sward structure preferences according to the range available in their environment (i.e. ecological adaptability to environmental conditions), and (ii) be forced to breed in sub-optimal nesting sites due to intra- or inter-specific competition (Hegyí and Sasvári 1997).

Differences in timing of breeding

The timing of breeding in waders is known to be flexible; it varies within species due to geographical variations in environmental breeding conditions (Holmgren et al. 2001). It also varies among species, which can have important implications for the way in which grazing has to be managed. For instance, in The Netherlands, Kruk et al. (1996) found that the median hatching date (studied over 8 years) was about 10 and 20 days earlier in lapwings than in black-tailed godwits and redshanks, respectively. A review of papers and documents on the timing of breeding of waders in France is summarised in Fig. 2. Despite annual differences related to spring temperatures, there is a general pattern in breeding phenologies (in terms of mean laying date) in the two species of waders under question, which were classified into two groups by Dubois and Mahéo (1986): (1) species with early

Sward height (cm)	]0-5]	]5-10]	]10-15]	]15-20]	]20-25]	]25-30]	]30-35]	]35-40]	]40-45]	]45-50]
Lapwing	•	•	•							
B-t. godwit			•	•	•					
Curlew			•	•	•	•	•	•	•	
Redshank				•	•	•				
Snipe						•	•	•	•	•

Tussock frequency	absent	rare	occasional	abondant
Lapwing	•	•		
B-t. godwit			•	•
Curlew				•
Redshank			•	•
Snipe				•

- consistent between studies
- in debate or uncertain since based on a unique study

Fig. 1 Summary of Tables 1 and 2, about preferred sward heights and tussock frequencies in the five wader species

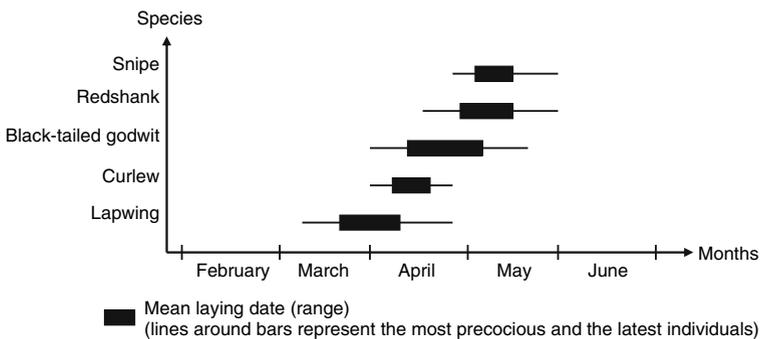


Fig. 2 Differences in timing of breeding in waders (from Dubois and Mahéo 1986; Trollet et al. 1992; Triplet et al. 1997)

breeding dates: lapwings followed by curlews and black-tailed godwits, and (2) species which breed ca. 1 month later: redshanks and snipes. The difference between lapwing and redshank phenologies was confirmed in a study carried out in 2004 in the Marais poitevin (French Atlantic coast) showing that the lapwings nest about 1 month earlier (mean laying date: 16 April ± 9 days, *n* = 71 pairs) than redshanks (21 May ± 10 days, *n* = 42) (D. Durant, unpubl. data).

Grassland management for waders: timing of grazing and key spatial scales

There is a need to understand the nature of dynamic interactions between three closely interlinked components of the farmland ecosystem: the distribution of waders, the grass cover states, and livestock grazing. Grazing management needs to be tackled with careful attention to time since: (i) large herbivores do not graze marshes throughout the year (time is thus important to consider in order to creating swards that are suitable to birds at their

arrival on their breeding sites in spring), and (ii) wader species differ in their timing of breeding. Moreover, the fragmented characteristic of agricultural landscapes (i.e. a mosaic of fields) in which waders breed emphasises the spatial nature of the grassland management. We suggest that it should be implemented taking into account different spatial scales of observation (see Clergeau 1995).

Timing of grazing

Some wader species settle in early spring when grasslands may not yet have been grazed since they have low resistance to the damaging impact of livestock. Short swards suitable for these precocious species, e.g. lapwing, are likely to be largely determined by the grazing regime (or mowing) of the previous autumn (Herbert et al. 1990; Triplet et al. 1997). Therefore, the delayed effects of autumn grazing, and also in certain circumstances winter grazing, could increase field attractiveness. This is in agreement with Tichit et al. (2005b), showing that lapwings occupied fields that were grazed with lower than average intensity of spring grazing and a higher than average autumn stocking rate, from which they inferred that lapwing habitat suitability was improved by autumn grazing. Spring grazing may then also be important for this species as it maintains short swards, e.g. 5 cm in June–July (Galbraith 1988; see also Olsen and Schmidt 2004). On the contrary, species which nest later and prefer taller swards, e.g. the redshank, are likely to be more dependent on light spring grazing that produces swards of taller height and of greater diversity in height (Norris et al. 1997). Different species of waders thus respond differently to grazing and their variable sensitivity to different periods (e.g. autumn versus spring) or to grazing intensities is interpreted in the light of their timing of breeding and their sward structure preferences (Báldi et al. 2005; Tichit et al. 2005b; Durant et al. submitted).

Despite the global benefit of spring grazing for breeding waders, a too early turnout date may be detrimental to nests, leading birds to avoid grazed fields. Indeed, livestock may trample nests, disturb incubating adults or even reduce the sward height so that nests are exposed to predators (Beintema and Müskens 1987). To minimise these risks, many prescriptions include a restriction on livestock densities in April–May, and sometimes the exclusion of livestock (Green 1986; Beintema and Müskens 1987; Hart et al. 2002). Another solution may be to ensure a strong or moderate grazing pressure the previous autumn and to delay the turnout date in spring (late April or even later) (Trolliet et al. 1992), but such solutions are not applicable to all types of farms (see the discussion later). Moreover, this threshold date is not defined a priori and may vary among species, i.e. according to their timing of breeding. Early nesters may benefit from this delayed turnout date, although it may be impossible to avoid trampling for later ones. Conversely, a turnout date delayed for too long will induce changes in sward height due to the rapid rate of grass growth and may thus have more adverse effects on the suitability of sward for breeding waders than nest trampling per se. Managing wet grasslands for breeding waders thus consists in operating a subtle trade-off between the benefits and risks of spring grazing. More studies are needed to explore this trade-off, with perhaps the necessity of accepting a certain level of nest trampling, depending on the conservation status of the species under question.

In conclusion, grazing may have, according to the season, positive or negative side effects on bird breeding success. Grazing management should be considered throughout the year (not only when birds are present on their nesting sites) in order to create the sward

structures desirable at the settlement of wader species under question and in accordance with their timing of breeding.

Spatial scales

Studies that have explained environmental factors involved in habitat use in breeding waders have mainly been conducted at the field scale. However, different ecological factors can influence habitat use of birds at different scales (Luck 2002; Grand and Cushman 2003). A complementary approach would be to consider that nest site choices of waders are the result of a series of hierarchical decisions taken at different spatial scales (i.e. from the landscape to the patch scale). The definition of these scales should be based on relevant ecological traits of breeding birds (e.g. home range size), and on a spatial resolution of their behaviour. This multi-scale approach may help to define appropriate grazing measures according to the scale under consideration.

Field scale

The field is often chosen as the spatial unit of reference (Galbraith 1988; Caldow et al. 1997; Milsom et al. 2000). Its mean sward height and frequency of tussocks are important factors playing a role in the wader choice of a field to breed in. It is even likely that these factors are involved at a finer scale, i.e. the patch scale ($\leq 20 \text{ m}^2$). This scale is defined in relation to the local sward structure where the nest is located. Within grasslands, a variety of patches is available to birds because of varying local features of the field (e.g. micro-topography), or when grazing is concentrated in certain parts of the field. Factors inducing spatial variance in grazing pressure are multiple, e.g. resource quality, distance to water, physical constraints such as slope or field boundaries, and some can be readily manipulated by farmers. These small-scaled grass features are likely to determine whether or not a field will be used by waders for nesting.

The mean sward height and its level of heterogeneity depend on the growth stage of the sward (i.e. the season), as well as the grazing frequency and intensity (Kiehl et al. 1996). When grazing pressure is high, the result is generally a more homogeneous sward structure. Grazing is also a major factor influencing the spatial heterogeneity of swards and large herbivores, through their foraging behaviour, not only respond to heterogeneity but create and sustain it (Adler et al. 2001; Parsons et al. 2000). The livestock type can have an influence through their degree of selectivity (Loucougaray et al. 2004; see also Rook et al. 2004 for a review). Grazing, especially by cattle, promotes structurally diverse swards (Schwinning and Parsons 1999; Parsons et al. 2000). Using a simulation model to assess contrasting spatial ways of resource exploitation by herbivores at the bite scale, these authors showed that different forms of heterogeneity arose. Notably, selective grazing led to a bimodal distribution of patch states: some areas being more frequently grazed than others leading to 'tall' and 'short' areas related to spatial variance in defoliation intervals (ibid). This behaviour is likely to be explained by the feedback between grazing and plant quality (Garcia et al. 2003). Conversely, grasslands heavily grazed by sheep are avoided by waders (Caldow et al. 1997; Treweek et al. 1997; Norris et al. 1998) since more uniform sward heights and less tussocky swards are created. It is however likely that under lower grazing pressure (1.5–3 instead of 10 sheep/ha), vegetation may attract breeding waders since the sward structure can be more diverse (Kiehl et al. 1996).

In the case of horses, whatever their densities, they maintain a mosaic of areas of short grass (lawns) and tall grass in ungrazed areas (latrines) (Ménard et al. 2002). These lawns are thus likely to be advantageous for species looking for short grass, such as lapwings (Zalba and Cozzani 2004).

Scale of a set of adjacent fields

The definition of this larger scale (i.e. a few adjacent fields) is made from the spatial resolution of the distribution of pairs throughout the breeding season, i.e. settlement, incubation and chick rearing, which is usually not restricted to a single field. Territory sizes as large as e.g. 21.8 ± 1.8 ha ($n = 11$; Valkama et al. 1998) or 45.2 ± 28.6 ha ($n = 20$; Berg 1992b) in curlew, have been reported. Moreover, the nesting site being often poor in food resources is not always suitable for chick rearing (Redfern 1982; Galbraith 1989). Thus, soon after hatching, families move from their nest site to other fields, sometimes several hundred metres away (Redfern 1982; Girard and Trolliet 1992; Johansson and Blomqvist 1996; Kruk et al. 1997). These observations thus underline the need to work at a coarser scale than that of the field. However, one difficulty related to this scale is that it cannot be defined a priori. Since home range size varies among wader species (Berg 2002), the choice of the number of adjacent fields to take into account should be based on specific ecological characteristics of the wader species under concern.

A particular point to consider is the importance of the characteristics of adjacent or nearby fields for chick rearing (Redfern 1982), and thus the importance of connectivity between fields (i.e. the degree to which the landscape facilitates or impedes movement of animals among resource patches; Taylor et al. 1993). For instance, pastures are favourable for chick rearing, although meadows are almost never used. If the surrounding fields of an optimal nesting site are mainly made of hay meadows, it is likely that the site will not be used or families may be forced to make very long trips to find good foraging sites (Girard and Trolliet 1992) with a greater risk of chick mortality (Galbraith 1988; Blomqvist and Johansson 1995). This supports the idea that it may be insufficient to simply give recommendations on grazing management (e.g. in terms of stocking rates or turnout date) on specific fields without considering the importance of adjacent or nearby fields for chick rearing and consequently the spatial arrangement of mowing and grazing management.

Landscape scale

The populations of waders considered here are closely associated with lowland farmlands (pastoral farming). We do not consider surrounding uplands (i.e. adjacent pastures and croplands). This spatial scale may thus be considered as the scale of a marsh (a few tens of km²).

Based on the principle that the landscape may provide environmental clues that are used by birds for their habitat selection, some studies have found correlational relationships between bird distribution or abundance and some simple landscape descriptors (Lichstein et al. 2002; Bruun and Smith 2003; Perkins et al. 2003; Virkkala et al. 2004; Batáry et al. 2007). For instance, Atkinson et al. (2002) found that breeding redshanks, snipes and curlews were most abundant in 10×10 km squares with >50% cover of grassland. Valkama et al. (1998) showed that in an intensively cultivated farmland area in Finland, curlews preferred nesting in grasslands (representing 31% of the area). They suggested that the lack of suitable habitats (i.e. grasslands) might be one reason for poor reproductive

success and a decline in curlew populations in this country (see also Berg 1992a; Valkama and Currie 1999) since spring farming practices in arable lands destroyed many nests. Modelling habitat suitability for five wader species in a marsh mainly composed of a mosaic of mowed and grazed grasslands in the French Atlantic wetlands, Renault et al. (2004) showed that birds were not randomly distributed and some sectors of the marsh were more attractive than others. Species preferences were not dependent on the same agro-ecological variables, and notably, breeding lapwings and redshanks were sensitive to land use, especially presence of grazed grasslands.

The composition of the marsh, described by the proportion of grasslands, is thus likely to explain its degree of use by breeding waders. In a marsh, a variety of sward structures are created among fields belonging to several farmers since each of them operates his own grazing practices. However, the effectiveness of the resulting landscape-scale distribution of sward structures remains largely unknown. This assessment may be useful in evaluating whether a marsh is in a position to be frequented by several wader species. It is, however, important to underline that this point cannot be tackled independently from particular landscape features and adjacent habitats that may influence bird distribution (Berg 2002). The configuration of grasslands within the landscape may be as critical as the composition of the landscape itself (Bruun and Smith 2003). For instance, it has been demonstrated that some farmland bird species living in semi-natural dry grasslands show a preference for nesting in pastures situated in open farmland (safer nesting sites and better food conditions) and avoid pastures with a high proportion of forest along their borders (Pärt and Söderström 1999). Since the proximity of trees or forest edges is also known to affect the distribution of open-field birds such as waders (Galbraith 1989; Berg et al. 1992), working at the landscape scale makes it possible to consider these effects which cannot be at a finer scale.

In conclusion, there is not a single scale of investigation for assessing the effect of grazing on grassland suitability for waders. As suggested by Benton et al. (2003) for biodiversity in general, a variety of sward cover-states at a range of spatial scales (from the patch to the landscape) is required by waders. It is therefore necessary to elucidate if grazing and mowing practices can be tailored and targeted to increase heterogeneity. We will tackle this question by analysing the multiple determinants in the livestock systems that play a role on habitat quality for waders at these three spatial scales.

Livestock system constraints at relevant spatial scales and timing for waders

Farming practices have multivariate impacts on waders, mainly indirectly, and these occur at multiple scales. The Fig. 3 provides a simplified schematic diagram to which the reader is invited to refer all over the present section, showing the relationships among farming processes operating at various scales and the effects on bird aspects (previously developed in section 4). It is still unclear whether providing the heterogeneity required by waders conflicts with management for livestock production aims in marshes. Drivers of farming practices thus deserve to be examined, taking into account the particular characteristics of wet grasslands that induce specific constraints on grazing practices.

Field scale: grazing efficiency

The preservation of a variety of grazing regimes is also needed in livestock systems because the feeding system is usually secured by a diversity of resources generated through

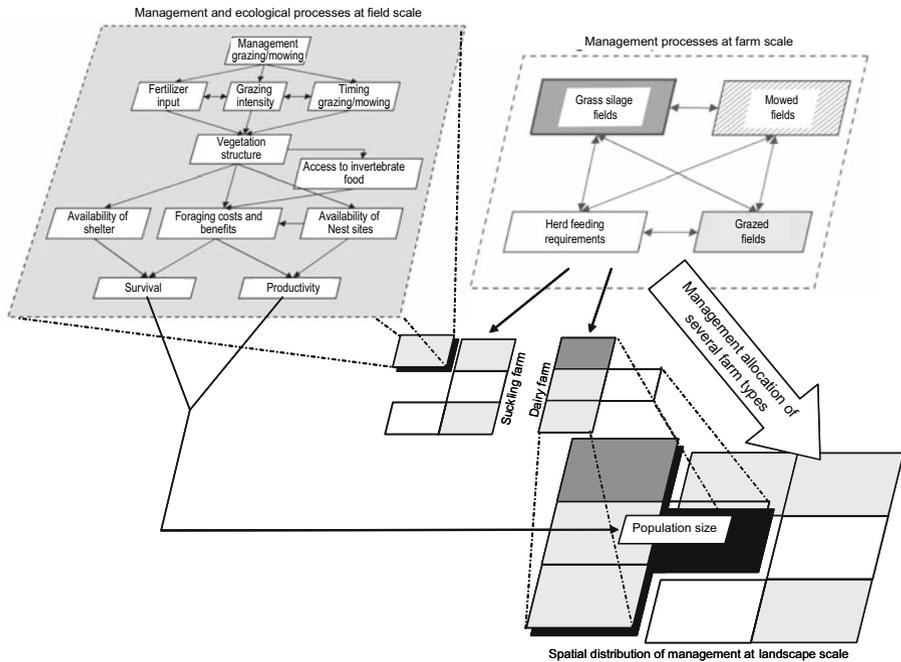


Fig. 3 Multiple scales at which grazing and mowing management impacts on waders. At farm scale, all components of farm territory are interdependent and contribute to herd feeding requirements. At field scale, the timing and intensity of management affects directly vegetation structure which influences food accessibility, nesting and shelter site availability. At landscape scale, several farm types allocate their grazing and mowing regimes according to their own objectives and influence the connectivity among suitable habitats and finally the wader population size

several grazing regimes. These various sets of resources satisfy several animal batches characterised by different feeding requirements and production objectives. In the French wet grasslands, a clustered approach of the timing and intensity of grazing on the 600 fields of 67 farms revealed six main grazing regimes that were related to farm size and intensification of the fodder area. Large extensive farms used two grazing regimes only whereas small intensive farms relied on up to five different grazing regimes (M. Tichit, unpubl. results). These grazing regimes influence mean sward height and its spatial heterogeneity (Tichit et al. 2005a).

Grazing efficiency (also referred as efficiency of herbage utilisation at grazing) is defined as the ratio between herbage consumption and herbage growth (Lemaire and Agnusdei 2000). Stocking density, through the average defoliation interval of plants, is a major variation factor for grazing efficiency (ibid). However, reflecting on what influences stocking density from the livestock system perspective is a complex question which cannot be tackled without taking interdependencies among several components of the forage system (pasture, maize and grass silage) into account. Empirical studies in France have emphasised that area allocation (for maize, grass silage, grazed and mowed pastures) and turnout date need to be combined in order to avoid over or under-production of grazing as well as silage surpluses at the annual scale (Coléno and Duru 1999; Coléno et al. 2002). Using a simulation model, these authors showed that a turnout date based on the available herbage per hectare can be used to calculate grass area allocation for spring grazing in

order to limit the risk of grass shortage or grass under-utilisation (ibid). They also indicated that for a given level of herbage nitrogen status and a given turnout stocking rate, grazing area should be smaller for a late turnout date than for an earlier one. So, the proportions of maize and grass silage in the forage system combined with turnout date are likely to have consequences on the level of grassland utilisation. Notably, they require fine tuning when grazing management aims at herbage use efficiency, i.e. targeting a residual herbage mass that makes it possible to maximise herbivore intake together with herbage re-growth rate after defoliation (Parson and Chapman 1998).

Wet grasslands have low resistance to repeated trampling in early spring and this situation prevents early turnout dates (delayed to early or mid-April). This situation is due to the wetness of fields (variable according to seasonal fluctuations in the rainfall or inundation pattern), which is increased by high soil permeability (hydromorphic clay soils) (Tichit et al. 2003). Due to this major constraint, we conjecture that delayed effects of autumn grazing are essential to create suitable sward structures in the following early spring. Grazing pressure in autumn is allocated according to different strategic (forage stockpiling) as well as contingent (present grass availability) constraints in the livestock system. 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 patterns, wet grasslands are not grazed during this season if it corresponds to the calving period (Tichit et al. 2007a). As a consequence, fields are characterised by a higher and more heterogeneous mean sward height the following early spring than those that were heavily grazed (ibid). This situation is likely to induce constraints in grazing efficiency the following spring and may be a source of increasing sward heterogeneity among the fields of a given farm.

From the production perspective, the question remains whether heterogeneity is an advantage or a drawback. Examining the effect of heterogeneity on yield, Parsons et al. (2000) showed that heterogeneity arising under selective grazing may be negative on yield because some patches are consumed too soon and/or too late in relation to the optimal timing of harvest during re-growth. This result holds true for situations where grazing aims at achieving the maximum sustainable yield. However, as underlined by these authors, recent advances in understanding intake by animals and plant growth at the bite scale draw attention to the constraints that may bind patch harvest to the optimal state, such as time and intake. Going back to the field scale, we argue that the spatial heterogeneity of vegetation needs to be assessed over several seasons. For instance, the warm Atlantic climate, characterised by a large water deficit in summer, reduces the major growth period of the vegetation between the beginning of April and the beginning of July. An under-utilisation of grasslands is frequently observed during spring (Tichit et al. 2007), leading to increased spatial heterogeneity of vegetation. However, this is an essential management option to ensure summer grazing in marshes when growth is severely constrained by climatic conditions.

Supra-field scale: internal farm rules of land allocation and public policies as driving forces of farming systems

Since colony territories are usually not restricted to a single field and soon after hatching families may move from one field to another looking for good foraging sites, the attractiveness of a field will also be determined by the characteristics of adjacent fields. The latter are influenced by the spatial distribution of grazing and mowing regimes

belonging to one or several farms. It is therefore necessary to take into account the determinants of the internal farm rules of spatial allocation of grazing/mowing regimes. Mathieu et al. (2004) showed that the spatial allocation of grazing regimes depends on the functions assigned to a given field, taking its physical and agronomical constraints into account. For instance, early grazing at high stocking density is not possible on fields with a high proportion of low-lying inundated depression. Each farmer allocates different grazing regimes to each field according to both objectives assigned to each animal batch and field constraints. Several sward cover-states may result from periodic moving of the same animal batch to adjacent fields according to rotational grazing. They may also result from several farmers' grazing regimes. Thus, the required connectivity between fields depends on factors that cannot be related to a single farm logic. This situation will be even greater at the next scale, the landscape.

A few studies have reported that land cover, i.e. the proportion of pastures in the landscape, is likely to influence its degree of use by waders (Atkinson et al. 2002). We also conjecture that different land use mosaics, related to grazing and mowing practices, may also influence the potential use of space by birds. The proportion of mowed and grazed pastures depends on farming system characteristics, notably its level of intensification. For this reason, agri-environmental schemes along the French Atlantic coast intended to replace mowed pastures by grazed ones in marshes with wader conservation priority (Steyaert 2002). The general idea was therefore to increase connectivity between grazed pastures, and thus bird habitat quality. Baudry et al. (2003) showed that landscape connectivity varies with the level of intensification of farming systems.

Two points deserve to be stressed. Firstly, as land cover and land use distribution emerge from several farmers acting for their own purposes, it is interesting to note that the emergence of environmental cooperatives in Dutch farming (Renting and Ploeg 2001) may open a new perspective to promoting co-ordination between farmers in order to increase the environmental performance of farming systems at the landscape scale. Secondly, it is evident that Common Agricultural Policy (CAP) is a major driving force in land cover distribution. Great changes in the management of farmland, i.e. increased intensification and specialisation of farms, at large temporal scales (the last four decades) have affected farmed landscapes. This general trend is suspected of having reduced the suitability of grasslands as feeding and breeding habitats for birds through a homogenisation of landscapes (Hudson et al. 1994; Chamberlain and Fuller 2000). In the future, these negative side-effects are expected to be limited by the Rural Development Regulation Programme and the eco-conditionality of subsidies, adopted by the CAP mid-term review.

Conclusion and future research

This review has several implications for future research. First, the fact that most research has focused on lapwings (while other species have received less attention) as well as inconsistent results among studies indicate the need for comparative studies on the role of vegetation cover in breeding site selection in various wader species. There is a need to adopt an experimental approach to really tease apart which grazing practices are most beneficial to these species. In particular, tussock frequency should be studied more deeply since studies on this aspect are quite rare and its role is not always well understood. This question should typically be tackled through such experiments. Secondly, most studies took place at the field scale. A multiple scale analysis (from the patch to the landscape) may improve our knowledge of factors affecting individual site selection along with those

influencing population size. It would allow to know whether it is sufficient or not to simply give recommendations on grazing management without considering the importance of upper-field scales for chick rearing and consequently the spatial arrangement of mowing and grazing management (which mainly appears as a subject for researcher investigation). However, processes at multiple scales cannot be studied through controlled trials. They require new methodological approaches based on modelling in order to integrate spatial and temporal processes (Tichit et al. 2007b). This is a central issue as recent research has emphasised the existence of a delayed response of bird population to grazing management (Tichit et al. 2007a) and to land use changes (Chamberlain et al. 2000). A time lag might be related to a critical threshold of high quality habitat which should be taken into account in order to predict effects of agricultural changes that may be felt several years later. Thirdly, there is a real need to accumulate data in farmlands. The threshold date before which grazing may have too detrimental effects or, conversely a threshold on livestock density, may be useful in mitigating nest trampling. However, we believe that these thresholds should remain flexible according to years in order to adapt to the specific climatic conditions influencing sward growth. This approach would prevent binding farmers' practices, as flexibility in the timing of grassland management is also needed to ensure livestock production aims.

Management effectiveness as well as the question whether providing habitat quality required by birds conflicts with management for agricultural production are still under debate (Kleijn et al. 2001) and more research is necessary to identify the sustainable ways of achieving such habitat quality. So where to next? We believe that the research agenda is to generate an adaptive management (Steyaert et al. 2003) built on the twofold perspective of ensuring cattle feeding and bird habitat conservation. This double goal may require involving farmers in order to make them aware of the relationship between farming practices and nature conservation. Symmetrically, taking into account farm constraints and opportunities will help to design new management practices adaptable to livestock systems. Any adaptive grazing management should be thought about taking into account several spatial scales and paying special attention to delayed effects among critical periods of both the bird and farm cycle. The co-operation between scholars of livestock systems and ecologists is crucial to developing integrative models that contribute to better design links between environmental and agricultural policies for the future.

Acknowledgements This review was supported by a post-doctoral grant to Daphné Durant from the *Institut National de la Recherche Agronomique*. We thank Rodolphe Sabatier for kindly providing the multi-scale figure. Patrick Steyaert and anonymous referees helped to improve earlier versions of the manuscript.

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