Influence of grazing on predation risk in grassland birds

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Abstract

Populations of many grassland bird species have declined in the last decades. Agricultural intensification and particularly higher grazing pressures have been associated with these declines. Herbivore grazing alters habitat structure and how it influences the possibility for birds to optimise their predator avoiding strategy, is reviewed here. In general, due to heavy grazing pressure swards become homogeneous, this leads to "bowling green" swards, with low variation in vegetation structure and composition. Moderate grazing creates structurally diverse swards and low intensity grazing creates an even greater heterogeneity in vegetation structure and composition. No grazing leads to tree sapling establishment and afforestation. Bird species with different anti-predator strategies react differently on changes caused by grazing. For these four categories of birds; 'Grassland birds with aggressive anti-predator behaviour', 'Grassland birds with low anti-predator behaviour', 'Crypsis relying ground feeders' and 'Cover-seeking ground feeders', the effects of grazing on their predation risk is being investigated. Two main differences are being observed, some birds need their view to be unobstructed to notice possible predators, they benefit thus from short vegetation, other birds value the presence of taller vegetation as cover, to go unnoticed by predators. Effects differ per group of species, but generally speaking, habitats with a complex vegetation structure, as a result of low or intermediate herbivore grazing, can support a higher diversity of bird species.

The many articles on this subject this last three decades, have shown that the effects of herbivore grazing on bird populations are omnipresent. Livestock grazing is developing more and more as an important land-use practice both in Europe (Bardgett *et al*. 1995; Bignal & MacCacken 1996) and North America (Fleischner 1994, Brown & McDonald 1995). It is generally agreed that severe grazing pressure, especially by sheep, is deleteriously affecting vegetation and wildlife in many upland regions in Britain (e.g. Woods & Cadbury 1987, Ratcliffe 1990, Thompson *et al*. 1995). Also meadow bird species in the Netherlands have shown a long-term decline in numbers (van der Vliet *et al*. 2010). Agricultural intensification, particularly increasing grazing pressure, is supposed to have similar effects on grassland bird populations worldwide (Fuller & Gough 1999, Vickery *et al*. 1999). In this essay I will answer certain questions about the effect of herbivore grazing on predation risk in particular, in grassland bird populations. The aspect of 'predation' is an interesting indirect factor in bird-herbivore interactions. As Lima & Dill (1990) put it so strikingly: "During any given day an animal may fail to obtain a meal and go hungry, or it may fail to obtain matings and thus realise no reproductive success, but in the long term, the day's shortcomings may have minimal influence on lifetime fitness. Few failures, however, are as unforgiving as the failure to avoid a predator: being killed greatly decreases future fitness. Predation may thus be a strong selective force over evolutionary time, and it has long been recognised as important in the evolution of adaptations." Just these adaptations will be viewed in this essay with respect to the habitat created by grazing.

But to describe the effects of 'grazing' in general is problematic, since grazing can occur in many forms. Therefore in this essay grazing will be specified into categories; low, intermediate and heavy grazing, and no grazing. The effect of different forms of grazing on 'bird

populations' in general, is an effect just as difficult to investigate, since the effect may vary per bird species. In the literature studied for this article I noticed that the differing effects per bird species were explicitly mentioned, but they were never clearly arranged or organised.

To solve this problem I sorted grassland birds into four categories, classified by anti-predator behaviour, so as to be able to describe the effects of grazing on predation risk for the entire group. The type of nest defence is assumed to be an indication of how species cope with predation, so groups of species that cope with predation in a similar way are expected to undergo the same effects of grazing. A note should be made here, no research has been done on whether the effects of grazing on predation risk are the same for species with the same anti-predator strategy.

Birds of prey, just as grassland birds, can be influenced greatly by changes in habitat structure of grassland, since it is for many an important foraging area. They are nonetheless excluded from this essay becasue it is assumed here that their own predation risk is not greatly influenced by changes in grassland habitat structure.

The four categories are 'Grassland birds with aggressive anti-predator behaviour', 'Grassland birds with low anti-predator behaviour', 'Crypsis relying ground feeders' and 'Cover-seeking ground feeders' (See Appendix A; Table 1).

Each category contains some examples of species that show the same behaviour. The list of examples is not in the least exhaustive, it merely illustrates which kinds of birds are associated with certain behaviours. This categorisation will help to make predictions, or increase understanding, when wondering what the influence of grazing on a species will be. One could determine in what category the species would belong by observing or researching the anti-predator strategy, to make a cautious prediction about the consequences of grazing on the predation risk of this species.

Birds with aggressive anti-predator behaviour

This group includes birds that are known to act out aggressive nest-defence, at least during the period of nesting, brooding and hatching.

This aggressive anti-predator behaviour is defined as possessing at least one of the following behaviours: mobbing, crouched or upright run, false-brooding, injury feigning and threat display (Brunton 1990). Eurasian oystercatchers *Haematopus ostralegus* are included in this group since parents show some form of anti-predator aggression, they protect and warn chicks, but even more because chicks of this species are known to be effective in chasing predators away with aggressive behaviours by running towards predators and 'freezing' (Goss-Custard 1996).

Low aggressive anti-predator behaviour

The category of 'Low aggressive anti-predator behaviour', comprises birds that mainly rely on crypsis but sometimes exhibit low aggressive anti-predator behaviour.

The Meadow Pipit *Anthus pratensis* is a well studied example for this group, this small passerine nests in tall grass, where the nests are concealed. Active nest defence is usually avoided because it can draw the attention of predators to the location of the nest (Gill *et al.* 1997; Burhans 2000) but parental nest defence starts at a certain threshold distance from the nest, which varies with the mobility of the predator and danger that the predator presents (Brunton 1990; King 1999).

This group includes some waders, for example the meadow-breeding wader Temminck's stint *Calidris temminckii*, that has anti-predator behaviour including early departure from the nest after detection of a predator or when other birds warn for approaching predators, distraction displays (e.g. injury-feigning), but no aggressive behaviour towards the predator (Koivula & Rönkä 1998). Also the wader Redshank *Tringa totanus* is admitted to this group, because even though it is not known to display (low) aggressive anti-predator behaviour, it does benefit indirectly from aggressive nest defence by nesting close to species with active nest-defence behaviour such as Lapwings *Vanellus vanellus* (Ottval *et al.*, 2005).

Crypsis-relying ground feeders

This category contains ground feeding birds that are well camouflaged, themselves as well as their nests. Their anti-predator strategy is thus to remain still and rely on crypsis not to be discovered.

Cover seeking ground feeders

This group consists of (mainly granivorous) ground feeding species that are alert while foraging so that they can seek cover when a predator arrives.

I will elucidate in this essay that different species do not experience the same consequences from

grazing, but I will show that certain patterns are distinguishable. Illustrating these patterns with help of the aforementioned categories, I will thereby try to answer the question 'How does herbivore grazing influence predation risk in grassland birds?'.

Effect of grazing on grassland

Livestock grazing is becoming an increasingly important land-use issue in Europe (Bardgett *et al.*, 1995; Bignal and McDonald, 1995). Fuller and Gough (1999) have shown that since the 1970s, especially sheep numbers have largely increased in several EU countries.

In Britain livestock numbers have been extensively studied and although a decrease in cattle numbers is seen, a large increase in numbers and density of sheep is seen (Fig 1). Given that grass area is generally decreasing, there is likely to have been an even larger increase in the density of sheep (Chamberlain 2000). There is a widely held view that severe grazing pressure, especially by sheep, has negative consequences on vegetation and wildlife in many upland regions of Britain (Fuller & Gough 1999). The effects of grazing by large herbivores on grassland areas are numerous. For instance, the impact of walking around, trampling of the ground, changes the vegetation structure (Striker *et al.* 2011). Also the dung produced by large grazers has a big influence on grassland insect communities (Helden *et al.* 2010). A grand influence, is the act of grazing itself. For one thing this changes the vegetation composition.

In the case of heavy sheep grazing, the effects of grazing are major, Fuller & Gough (1999) show that vegetation composition as well as vegetation structure are changed by grazing.

Dwarf shrub heaths have a tendency to shift towards grassland composed of unpalatable grasses when grazing is present, especially towards swards with high abundances of *Nardus* and *Molinia* on moist soils and on better drained soils the vegetation changes towards *Agrostis-Festuca* swards (Welch 1986; Miles 1988).

The declines in ground nesting birds in the uplands of Wales have been partially attributed to grazing pressure by sheep (Lovegrove *et al.*, 1994, 1995; Shrubb *et al.*, 1997). The cause of these declines are often proposed to be the loss of vegetation dominated by heather *Calluna vulgaris* due to intensive grazing by sheep, because certain bird species depend on heather. However, it has been shown that the mechanisms by which changes in sheep grazing can affect bird populations are various. Many Brittish upland areas that are subdued to increased grazing pressure actually have rather little heather, yet changes in grazing pressure within such areas are known to have a big influence on bird populations (Fuller & Gough 1999).

Not only vegetation composition is altered as a result of grazing, it fundamentally changes available food resources and the structure of the vegetation. For ground-nesting and ground-feeding bird species, small changes in vegetation structure can be of great consequence to habitat quality (Vickery *et al.* 2001). Some variation in sward structure is probably important for most species by offering hiding places for nests and chicks as well as possible sources of nourishment in

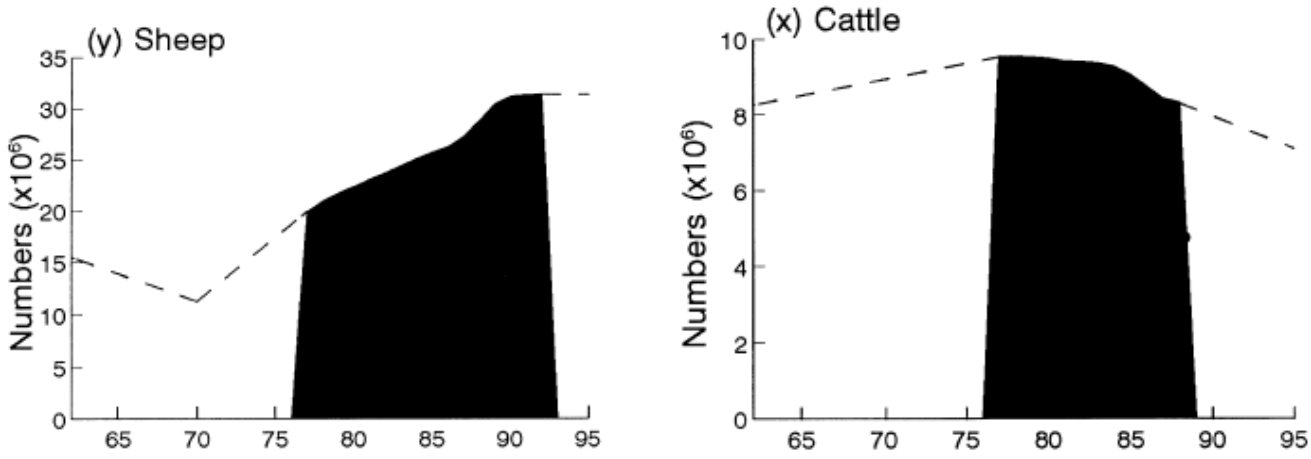

Fig. 1 Chamberlain *et al.*, 2000. Trends in agricultural variables for the whole of England and Wales.
Variables with continuous runs of annual data have been smoothed to reveal underlying trends. Solid black shading indicates annual smoothed data lines joining crosses indicate data from intermittent years. Dashed lines indicate interpolated/extrapolated data.

the form of invertebrates (Fuller & Gough 1999). It is generally recognised that arthropod abundance and species diversity increases when habitat heterogeneity increases as a result of herbivore grazing (Dennis *et al.* 1998). This greater heterogeneity includes presence of patches that are not preferred by grazers, with therefore taller grass, and patches that are heavily grazed, with short grass. The greater invertebrate abundance in areas with greater heterogeneity is due to the fact that these tall patches act as a reservoir of large insects. The boundaries between tall grass, with many large invertebrates, and short grass, where the insects become accessible to birds, are valuable foraging areas for insectivorous grassland birds (Vanhinsbergh 1999).

The general effect of grazing animals on woodland area is that shrubs are removed, establishment of tree seedlings is prevented, saplings are trampled and browsed, and the grass is grazed heterogeneously (McIntyre, Heard & Martin 2003).

But the effect that grazers have on a grassland area differs with grazing species, density and whether the grazing is performed by one or two types of grazers. The general pattern seen is that with heavy grazing pressure (generally interpreted as 2.72 sheep/ha) the sward becomes homogeneous, this leads to low heterogeneity, "bowling green" swards (Fuller & Gough 1999). Moderate grazing (generally interpreted as 0.91 sheep/ha) creates structurally diverse swards (Fuller & Gough 1999). Low intensity grazing (generally interpreted as 0.91-0.6 sheep/ha) creates an even greater heterogeneity in vegetation structure and composition (Evans *et al.* 2006). When no grazing is applied to grasslands, vegetation height is seen to significantly increase and eventually absence of large grazers will lead to tree establishment and forest maturation (Pearce-Higgins *et al.* 2007).

Evans *et al.* (2006) compared low intensity grazing solely by sheep with mixed low intensity grazing (cattle and sheep) and they have shown that low intensity mixed livestock grazing provides a more favourable foraging habitat for certain insectivorous species, by increasing vegetation structure heterogeneity and hence arthropods availability. This is probably due to the addition of a second type of grazer, leading to two different grazing strategies, with different effects on the vegetation that is being grazed, and two different trampling impacts. This results in greater heterogeneity of vegetation structure. There are also indications to assume that cattle grazing has a positive effect on diversity and abundance of arthropods because they are attracted to the dung (Evans *et al.* 2006).

Predation risk

The most obvious effects of predators on their prey are that of eating the prey, predator-prey interactions and population dynamics. But aside from the direct effects, the indirect effects of predators on prey, like influencing where they choose to feed, breed and sleep, are interesting to observe (Whittingham & Evans 2004).

The risk of predation influences animal decision making in many ways. For example, if we consider a cryptic bird, due to its coloration and camouflage it can efficiently avoid visually oriented predators as long as it stays motionless. But it must nonetheless move around to survive, for example to forage, attract mates or maybe migrate (Lima & Dill 1990). There is a clear trade-off between remaining undetected and moving to act out necessary behaviours. But not just cryptic birds endure this dilemma, if we regard birds that feed in open areas but seek cover when detecting a predatory bird, a same kind of trade-off can be found. Here it concerns, amongst other behavioural acts, for example food intake, and vigilance. Simply put, the more time a bird devotes to being vigilant, the less time it has to search and handle food.

Birds with aggressive anti-predator behaviour, show a behaviour that brings along a more complex trade-off. These birds engage in the act of 'mobbing', taking to the air and attacking predatory birds, generally to ensure protection for young or eggs (Lima & Dill 1990). In these situations the risk for the parent to be predated is usually relatively low. It is apparent that mobbing behaviour is relatively low since it is rarely observed

Grazing intensity	sheep/ha
High	2.72
Moderate	0.91
Low	0.91-0.6

Table 2. Grazing intensities in the case of sheep grazing, as used in Brittish studies on effects of grazing intensities (Douglas *et al.* 2008; Evans *et al.* 2006; Vandenberghe *et al.* 2009)

that mobbing animals are captured. Evidence shows that mobbing parents are rather capable of assessing the risk of being predated or hurt, so they adjust their behaviour to that risk (Lima & Dill 1990, Curio & Regelmann 1985). It has been shown for example that mobbing Great Tits *Parus major* approach less dangerous predators closer than very dangerous ones, and that their mobbing behaviour changes with the distance from the predator (Curio & Regelmann 1985). But there is nonetheless an energetic cost to this behaviour and risk of injury is present. Trade-offs can be found in the bird choosing between staying where it is, save the energy and hope that it and its young or eggs will not be predated, or it can take to the air, enhance the risk of being injured but lower the risk of the young being predated upon. Another trade-off: staying on the nest and defending it or to leave the nest and forage.

The efficiency of these anti-predator behaviours, the possibility to maximise the fitness regarding predation, is influenced by habitat characteristics. Since grazing changes elements as habitat structure and vegetation composition, it has a great influence on the efficiency of anti-predator behaviours. The negative effect of habitat degeneration on foraging possibilities, as a result of intensive grazing, makes prey more susceptible to predation (Evans 2004). For example, when invertebrate availability is low, this may leave chicks malnourished and chicks that are hungrier are expected to beg for food more loudly to attract their parents attention and thereby increase the risk of detection by a predator (Evans *et al*. 1997).

Although especially avian predation is reviewed here, predation by mammalian carnivores can be very important for grassland birds. Pita *et al*. (2009) report that the presence of mammalian carnivores in Portugal is influenced by habitat characteristics, such as vegetation structure. They found that the three main generalist ground predators, Domestic Dog *Canis familiaris,* Red Fox *Vulpes vulpes* and Egyptian mongoose *Herpestes ichneumon*, were most abundant in areas of farmland landscapes with small arable fields and many woody patches and corridors. Some ground breeding birds avoid breeding close to woody patches or forest edges, to decrease risk of predation by mammalian carnivores and for these birds continuous arable fields are beneficial (Pita *et al*. 2009). Different types of birds react differently on ground predation (Dion *et al*. 2000), just like they react differently on avian predation.

For 'Crypsis-relying ground feeders' and 'Birds with low aggressive anti-predator behaviour' dense vegetation, where nests can be well concealed, would be preferential when avian predators are the most important threat. But when the primary predators are carnivorous mammals this would not be the case, then more sparsely vegetated habitats, less suitable for small mammals, would be preferred (Dion *et al*. 2000). This conflicting pattern complicates conclusions about the influence of vegetation structure on predation in grassland birds and is a worthwhile area of study for more research. In this article the focus will be on situations where avian predation is the most important threat to grassland birds.

Effects of grazing on grassland birds

The different effects of grazing on grassland birds are reviewed in this section. The habitat characteristics that are selected for their foraging qualities and for their anti-predator qualities, and that are influenced by grazing, will be discussed.

Birds with aggressive anti-predator behaviour

Birds with aggressive anti-predator behaviour are in general found in open field locations, sparsely vegetated (Whittingham & Evans 2004).

Birds with an aggressive nest defence have sought their main anti-predator strategy in actively scaring off any predators. To act out this behaviour, their clear view of the surroundings is essential. That is why these birds are generally found in open field locations, such as meadows, pastures and orchards, mostly located in farmland (e.g. Golawski & Meissner 2007, Whittingham & Evans 2004).

This indicates that this group strongly benefits from grazing, since grazing does not allow grass to grow too tall and obstruct the view. Also, it enhances foraging efficiency by increasing mobility of foraging individuals.

On the other hand, some of these species might require the grass to attain, at least at some places, a greater length. This is because they feed off insects, and insects are generally more abundant in higher grass. Without these patches of high grass their vigilance and foraging efficiency would be high but there would be not enough to forage for. This shows that for this group an intermediate to high

grazing level can be beneficial, although high grazing must be present is the area for breeding locations.

Low aggressive anti-predator behaviour

Skylarks *Alauda arvensis* avoid heather and are associated with grass moorland, so in general skylarks would benefit from grazing (Fuller & Gough 1999). Also Meadow Pipits have been found to be less abundant in areas dominated by heather than in areas with a high grass: heather ratio (Redpath & Thirgood 1997). These species tend to occur more frequently in habitats that include mosaics of grass and small shrubs (Vanhinsbergh & Chamberlain 2001). This means that these species need a certain amount of grazing to create an apt habitat, to diminish the amount of heather, but too heavy grazing pressure will lead to homogeneous swards that are deleterious for these species.

This group of birds has adopted a little bit of both active and passive anti-predator strategies. Most of the birds in this group rely partially on crypsis, nests are well hidden in tufts of grass, but when necessary they can use an aggressive nest-defence strategy. For these birds to be able to hide their nests, tall grass within a field is needed. This would suggest that a strategy of low grazing is required. But a sward that is too heavily grazed is not only negatively effecting nesting, it also hinders foraging. Douglas, Evans and Redpath (2008) have shown that Meadow Pipits increase the distance they travel to forage in intensively grazed areas. This is probably due to the less successful foraging activity and the necessity for increased search time in multiple foraging locations before returning to the nest. For a different insectivorous passerine it was concluded that longer foraging trips were a good indication of poor breeding habitat (Britschgi *et al*. 2006). Increased foraging distances probably result in extra fitness costs and an increased predation risk (Muchai, Lens & Bennum 2002). But a field with too much tall grass would not be suiting either, since tall vegetation is known to reduce the accessibility and detectability of food items (Butler & Gillings 2004) as well as reducing mobility while foraging (Devereux *et al*., 2004). This means that a heterogeneously grazed grassland is important for survival, both to decrease predation and to increase foraging efficiency. As described in the previous section, to obtain a heterogeneous grassland, intermediate to low grazing is thought to be the best management strategy.

Crypsis-relying ground feeders

It has been found that for example Red Grouse *Lapogus lapogus* show a consistent strong association with heather. Because grazing usually increases the grass: heather ratio, heavy grazing will have a negative effect on these species (Fuller & Gough 1999). Since the chicks in this group are in general insectivorous whereas the adults feed off plants, these birds demand a heterogeneous surrounding with taller vegetation that shelters invertebrates as well as the right plant composition for adult foraging (Wegge *et al*. 2010).

Species that have adopted the strategy of remaining still and relying on crypsis when confronted with predation, benefit from longer within field vegetation if not too dense (Whittingham & Evans 2004). They nest in herbaceous cover and rely on concealment from predators (e.g. Rands 1986, Green & Stowe 1993). Black Grouse *Tetrao tetrix* are known to a wide range of habitats, they use mires, heathland, moorland, young and open forests and meadows (Pearce-Higgins *et al*. 2007). Agricultural intensification, conversion to pasture and silage, has lead to decreases in black grouse populations, just as increased levels of grazing by sheep and Red Deer *Cervus elaphus*. This increased grazing pressure has lead to reductions in vegetation height and dwarf shrub cover, which often plays an important role as nourishment, food plants for the adults, but also by providing protection from predators and nesting locations. Also afforestation of moorland is named as a factor in reducing abundances of Black Grouse. The early stages of tree growth may contain suitable habitat, but in the later stages of afforestation are detrimental, because the important dwarf shrub layer is lost when the canopy closes (Mackey *et al*. 1998; Cayford 1990; Baines & Hudson 1995). The maturation of forest is possibly accompanied by increases of some important predators of Black Grouse (e.g. Red Foxes and Goshawks *Accipiter gentilis*) (Pearce-Higgins 2007). To conclude, these species obviously don't benefit from heavy grazing and even intermediate grazing might lead to a deleterious reduction in vegetation height, whereby their anti-predator strategy is hindered. On the other hand, no grazing, which eventually leads to succession towards forest maturation is also detrimental. A low intensity grazing strategy might be of help in conservation of this group of species.

Cover seeking ground feeders

This group of birds is often found in open field situations, stubble field is a preferred foraging habitat for many farmland species that are of conservation concern such as Yellowhammer *Emberiza citronella*, Corn Bunting *Miliaria calandra,* Reed Bunting *Emberiza schoeniclus* and Common Linnet *Carduelis cannabina* (Whittingham & Evans 2004).

The Northern Wheatear *Oenanthe oenanthe* and the Red-Billed Chough *Pyrrhocorax pyrrhocorax* are known to benefit from a "bowling green" sward, since their principal feeding habitat is heavily grazed turf (Whittingham & Evans 2004).

This group of birds species relies on detecting predators by sight, ensuring that a predator is seen quick enough to take protective cover in a suiting hide-away such as hedgerows or trees. To guarantee this timely flight, vigilance is required, which leads to the foraging-vigilance trade-off as described before. When foraging in an area with increased visual obstruction vigilance will have to increase as well to prevent predation. The effectiveness of this increased vigilance is studied by Whittingham *et al.*, (2004) on a farmland bird, Chaffinch *Fringilla coelebs*, foraging on artificially created stubble fields in aviary conditions. As expected, Chaffinches showed increased vigilance levels, they spent 13% more of their time on vigilance when foraging in obstructed patches than when foraging in patches with a clear view of the surroundings. Despite these differences in vigilance, the detection of a moving stuffed Eurasian Sparrowhawk *Accipiter nisus* was approximately 24% slower in obstructed patches than in patches with a clear field of view. Also, birds that foraged on fields with an obstructed view, pecked on average 16.0 $\pm$ 0.80 pecks/ minute compared to 18.3 $\pm$ 0.74 pecks/ minute on fields with a clear view, a difference of 13%. This research shows that foraging in patches with an obstructed view, imposes both the costs of reduced foraging efficiency and increased predation risk. The amount of cover present is another factor that is of influence for the predation risk of this group. Lima and Valone (1991) experimentally manipulated cover of shrubs in open grasslands in winter. They found that the addition of cover caused an increase in abundance of species with cover-dependent escape strategies.

Farmland granivores, such as Yellowhammers are likely to forage close to hedgerows and are not seen often to forage in the central part of fields (Whittingham & Evans 2004). They select foraging areas close to hedges to be able to flee quickly from predator attacks. Canadian studies of granivores with this behaviour suggest that subdominant species are forced to forage further from cover (Lima *et al.* 1987). Although this group benefits from grazing, because it keeps grass short, which facilitates vigilance and therefore optimises foraging efficiency, cover in the form of shrubs or hedgerows is equally important. Stretches of open field are valuable, but if they are too wide these species won't be able to exploit the center parts. This means that grazing in an intermediate manner could be advantageous for this group.

Discussion

As seen in the previous sections of this essay grazing affects different species in various ways. If a species is concerned for conservation it is therefore necessary to research the effects of grazing on this species to determine a suiting grazing regime to help conserve this species. But when concerned to find a way to conserve grassland bird species in general and to promote bird species diversity, it has been proposed that ensuring a heterogeneous landscape is beneficial for many species and thus a goal worth striving for when aiming to meet conservation ends (Martin & Possingham 2005, Fuhlendorf *et al.* 2006). Bird species richness has long been linked already many times to habitat characteristics, in particular the complexity of vegetation structure (MacArthur & MacArthur 1961, MacArthur 1964, Cody 1968, Recher 1969, Willson 1974). Generally, habitats with a complex and variable structure support more species than habitats with a simple architecture because generally they provide more resources and different niches (Bell *et al.* 1991; MacArthur, Recher & Cody 1966; Vickery *et al.* 2001). Thus more species are probable to co-occur per unit area, which leads to a positive correlation between biological biodiversity and structural diversity (MacNally *et al.* 2001).

If we look at this from the perspective of predation risk, a grazing regime that results in a structurally heterogeneous grassland, is beneficial for many species. When a sward contains short grass patches with little view obstruction from surrounding vegetation as well as tall grass patches containing shrubs with hiding places for crypsis relying species, this sward may sustain many grassland bird species. To obtain this structural heterogeneity Evans *et al.* (2006) showed that compared with intensively grazed areas,

low intensity, mixed livestock grazing may provide a more favourable habitat for species many species, by increasing vegetation structure heterogeneity.

On the other hand, this might have positive effects for most of the groups named in this essay, not for 'Birds with aggressive anti-predator behaviour'. This group requires open field breeding situations, a surrounding that would not per se sustain a great number of species. The birds from this group can breed even in surroundings where no hedgerows or other cover is present, which would not be suitable for, for example the 'Cover-seeking ground feeders'.

Although the situation for grassland birds can be optimised with help of a proper grazing management, some aspects of predation risk are not influenced by grazing. Thirgood *et al.* (2002) found that even though heather cover significantly influenced Red Grouse *Lagopus lagopus* density, differences in vegetation structure itself had no significant effect on survival. Neither was there a difference in the success of attacks by Hen Harriers *Circus cyaneus* on Grouse broods in areas of different vegetation heights. One possible explanation for these results is that Hen Herriers hunt using mainly auditory cues (Rice 1982, Simmons 2000) and in this situation vegetation height might be of less importance in avoiding being captured than in situations where visual cues are used to detect prey.

Other effects of the presence of large herbivores in grasslands, like trampling of the nests, are not reviewed in this essay, although it should be kept in mind that they can be of influence.

The declines of many grassland bird species in the last decades show that more research in this field of studies is necessary to help conserve these species. While answering the question of what influence grazing has on the predation risk of grassland birds, I hope to have shown that these influences differ greatly between species. I have tried to demonstrate that there is a general pattern however, birds with the same predator avoidance strategy are deemed to undergo similar effects of grazing. The consequences of certain grazing regimes on bird species can be predicted to a certain degree, but thorough investigation of the species' ecology is always important before acting on predictions and determining on an effective long term conservation strategy.

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Appendix A **Table 1.**

Groups of grassland birds classified by anti-predator behaviour.

Group	Predation avoidance strategy	Nesting location	Foraging location	Species	Source
Aggressive anti-predator behaviour	Taking to the air, mobbing	Ground	Ground	Northern Lapwing *Vanellus vanellus*	Whittingham & Evans 2004
				Stone Curlew *Burhinus oedicnemus*	Whittingham & Evans 2004
				Golden Plover *Pluvialis apricaria*	Whittingham & Evans 2004
				Oystercatcher *Haematopus ostralegus*	Goss-Custard *et al.* 1996
				Killdeer *Charadrius vociferous*	Brunton 1990, Dianne 1990
Low aggressive anti-predator behaviour	Relying on crypsis but when necessary capable of low aggressive anti-predator behaviour	Ground	Ground	Meadow Pipit *Anthus pratensis*	Pavel & Bures 2008
				Temminck's stint *Calidris temminckii*	Koivula & Rönkä 1998
				Redshank *Tringa totanus*	Ottvall *et al* 2005, Valle *et al.* 1999
				Skylark *Alauda arvensis*	Whittingham & Evans 2004
Crypsis-relying ground feeders	Crypsis, keeping still	Ground	Ground	Gray partridge *Perdix perdix*	Whittingham & Evans 2004
				Black Grouse *Tetrao tetrix*	Baines & Hudson 1995
				Red Grouse *Lagopus lagopus*	Thirgood *et al* 2002
				Rock Ptarmigan *Lagopus muta*	Whittingham & Evans 2004
				Cornrake *Crex crex*	Whittingham & Evans 2004
				Gray Partridge *Perdix perdix*	Rands 1986
Cover seeking ground feeders	Seeking cover	Mostly hedgerows, shrubs and trees	Ground	Chaffinch *Fringilla coelebs*	Whittingham & Evans 2004
				Reed Bunting *Emberiza schoeniclus*	Whittingham & Evans 2004
				Corn Bunting *Miliaria calandra*	Whittingham & Evans 2004
				Cirl Bunting *Emberiza cirlus*	Whittingham & Evans 2004
				Yellowhammer *Emberiza citrinella*	Whittingham & Evans 2004
				Common Linnet *Carduelis cannabina*	Whittingham & Evans 2004
				Bullfinch *Pyrrhula pyrrhula*	Whittingham & Evans 2004
				Northern Wheatear *Oenanthe oenanthe*	Whittingham & Evans 2004
				Red-Billed Chough *Pyrrhocorax pyrrhocorax*	Whittingham & Evans 2004