

# 26 The Role of Grassland Areas within Arable Cropping Systems for the Conservation of Biodiversity at the Regional Level

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## 26.1 Introduction

Farmland is the most common habitat in France as well as in Europe as a whole (56% and 52% of the land surface, respectively). As a likely consequence, farmland habitat harbours a major part of European biodiversity. For example, 50% of European bird species live in rural landscapes (Potts, 1997; Tucker, 1997). In Europe as well as in other parts of the world, the process of agricultural intensification has led to the simplification and specialization of farmed landscapes, increased uses of inputs such as pesticides and fertilizers, and the mechanisation of practices. At the landscape level, agricultural intensification has led to a loss of natural or semi-natural habitats and a decrease in habitat heterogeneity. The effects of agricultural intensification on biodiversity are well demonstrated: many studies and reviews documented negative effects of intensification on plants, insects, birds and mammals in various countries (e.g. Krebs *et al.*, 1999; Robinson & Sutherland, 2002; Benton *et al.*, 2003, Inchausti and Bretagnolle, 2005; Julliard *et al.*, 2004; Fried *et al.*, 2009). Recent empirical evidence strongly supports that plant and animal diversity decreases with increasing crop yield, a good proxy of agricultural intensification (see Geiger *et*

*al.*, 2010 and references therein). However, the evidence that agricultural intensification has led to biodiversity loss is mainly based on correlative studies carried out on large spatial scales (regions or countries), whereas the ecological processes involved are not well identified. Moreover, most studies dealt only with few taxa and there is a lack of studies investigating the effects of biodiversity loss on ecosystem services, e.g. soil conservation, nutrient cycling, groundwater purification, pollination or biological control (but see Geiger *et al.*, 2010). Lastly, it is currently uncertain whether biodiversity loss at the regional scale results more from cropping intensification at the field scale or from the loss of natural elements in the landscape.

In France, mixed farming systems (integrating crop and livestock production) have strongly declined during the past 60 years, which was mainly due to the European Common Agricultural Policy (CAP) and other macro-economic constraints. Some regions specialized in intensive cereal production (e.g. La Beauce), others on intensive livestock production (e.g. Brittany), generating uniform patterns of land use across the landscape on large spatial scales. At a landscape level, cereal agroecosystems are characterized by high spatial (i.e. the fields generate strong spatial discontinuity) and temporal (due to

crop rotations, harvesting, mowing and ploughing) variability. Cereal landscapes, being highly fragmented in space, provide to natural populations a spatial patchwork of habitats of temporally varying quality, depending on species characteristics. Ploughing, introducing temporally asynchronous alterations of habitat quality, is probably the strongest human disturbance in these systems. For many types of organisms, it may lead to extinction of the local population on the patch/field. Hence, the metapopulation dynamics framework appears appropriate to study biodiversity in such agroecosystems. In landscapes dominated by intensive cereal cropping, multi-annual forage crops such as meadows, mown grasslands and forage crops can be considered as ‘perennial habitats’ since they are usually kept for 3–4 years (or even longer). They differ radically from all annual crops in terms of mechanical disturbance (soil tillage, sowing, cutting for harvest) but also often receive fewer pesticide and fertilizer inputs.

Patches of perennial crops, as well as field margins and other non-crop habitats, may act as shelters for wildlife within the ‘matrix’ of less favourable annual crops. In regards to biodiversity and trophic network, the presence, abundance and distribution of these perennial habitats may have strong impacts on metapopulation and meta-community dynamics of various organisms (Hanski, 1999). To investigate the role of a particular habitat for biodiversity, particularly in cereal systems, it is therefore important to address the metapopulation dynamics of the organisms in a spatially explicit way and at large spatial scales, since dispersal and colonization, two major processes of metapopulation dynamics, are obviously spatial phenomena. They mainly depend on the distance between source populations and on the structure of the landscape that affects the movement of individuals between habitat patches (Akçakaya, 2000).

In regions now dominated by cereal crop production, the gradual disappearance

of grasslands and multi-annual forage crops negatively impacted fauna and flora but, more generally, presumably led to the reduction or disappearance of ecosystem services, such as beneficial functions for ground-water quality, sequestration of greenhouse gases, and functional biodiversity. It may be hypothesized that the simultaneous presence at the landscape scale of surfaces with herbaceous perennial habitats and annual crops, may maintain high levels of agricultural production while limiting negative impacts on the environment and on biodiversity. In the following chapter we provide empirical results from our long-term studies on voles, plants, grasshoppers, birds and trophic interactions between these groups carried out in the Chizé study region (Zone Atelier ‘Plaine et Val de Sèvre’) in central western France (see Fig. 26.1 and Bretagnolle *et al.*, 2011, for details on the study site). We show that trophic interactions and biodiversity management, as well as conservation, require the presence of grasslands at the landscape scale.



**Fig. 26.1.** A map showing the study site (light grey) and its location in France.

## 26.2 Metapopulation Dynamics of Voles at the Landscape Level

The common vole *Microtus arvalis* is a small-sized rodent abundant in Western European agroecosystems (Mitchell-Jones *et al.*, 1999; Salamolard *et al.*, 2000) where it shows large cyclic variation in abundance (Lambin *et al.*, 2006). Common voles are not restricted to grasslands, perennial crops and edge habitats (e.g. field margin strips) in intensively cultivated areas since they also show high densities in cereal or rapeseed fields (see Salamolard *et al.*, 2000). Short-term effects of farming practices on common vole population dynamics and demographic parameters have already been investigated (Jacob, 2003; Jacob and Hempel, 2003). Harvesting, mowing and mulching (occurring in both perennial and annual habitats) do not destroy nest sites (subterranean burrows), but potentially eliminate a substantial proportion of the local population by direct killing or increased risk of predation due to reduced vegetation height and cover. No dispersive movement appears to be associated with these activities (Jacob and Hempel, 2003). Ploughing (occurring solely in annual crops), which destroys common vole burrows, seems to be the only agricultural practice to eradicate the common vole (Jacob, 2003).

Although common voles are not restricted to grasslands, the maintenance of perennial surfaces at the landscape level have often been viewed as enhancing the common voles cycles, which in turn is supposed to affect the trophic network, in particular the many carnivores that rely on voles as preys. As support to this idea, Butet and Leroux (2001) found a negative correlation between the amplitude of cycles of common vole in the marshes of western France and the degree of agriculture intensification (conversion of grasslands to cereals). Such a result suggests that common vole metapopulations in agricultural mosaics may follow a source-sink dynamic between permanent and temporary habitats. We addressed this question in a landscape genetic study, and showed that common vole gene flow in our study site (450 km<sup>2</sup>) was not sufficiently

limited to result in a strong genetic structure (Gauffre *et al.*, 2008). Rather, we observed a slight, but significant, isolation by distance pattern shaping the roughly homogeneous genetic structure of the studied metapopulation. This result does not contradict a source-sink dynamic model between permanent and temporary habitats but suggests that if such dynamics exist, they occur in the context of large effective population sizes and high movement rates among the different habitat types constituting the agricultural matrix. In another study we demonstrated that dispersal rates are high and strongly male biased at short distances, whereas long-distance dispersal is not rare and affects males and females in similar proportions (Gauffre *et al.*, 2009). Genders also differ in the timing of dispersal. Males migrate continuously from colonies to colonies, whereas females may disperse just once and thus are involved in the foundation of new colonies.

If gene flow is not affected by habitat fragmentation it may be because the common vole life cycle (they reproduce at few weeks of age and have several generations per year) and metapopulation dynamics (through intense dispersal and colonization) are faster than the perturbation dynamics of the landscape, hence mitigating the short temporary suitability of most habitats (i.e. annual crops). Furthermore, the spatio-temporal variation in habitat quality resulting from agricultural land use could select for increased dispersal propensity (Ronce, 2007). The persistence of the common vole in the agricultural landscape seems to be conditioned by its capacity to exploit perennials habitats (e.g. grasslands, always favourable but representing a minor part of land use) as well as ephemeral habitats (annual crops that are not available all year round).

## 26.3 Plants and Weeds in Cereal Systems: Spatial and Temporal Interdependences between Annual Crops and Grasslands

Plants, including both cultivated crop grassland species as well as wild 'weed' species, are the basis of food webs in

agroecosystems and are important determinants of habitat quality for animals (Badenhausser *et al.*, 2009). Plants also show strong interactions with other plants. The abundance of wild 'weed' species is, for instance, strongly determined by the crop plants due to competition (and facilitation). Each crop may favour some types of weed species while suppressing others. This may be due to characteristics of the crop plants (such as its growth dynamic and competitive ability) as well as crop-specific field management practices (including soil tillage, sowing dates, fertilization, harvesting dates, etc.) (Doucet *et al.*, 1999). Therefore, the succession of crops grown year after year on a field may have strong impacts on weed community dynamics (e.g. see the review of Liebman and Dyck, 1993). Due to the separation of crop and livestock production (see above), today's crop rotations are often only composed of annual crops. The inclusion of temporary grasslands (perennial forage crops) into crop rotations may have particularly strong impacts on weed communities, as these types of perennial crops differ in many biotic and abiotic aspects from annual crops (see Sebillotte, 1980; Viaux *et al.*, 1999; and Meiss *et al.*, 2010a for a review). Recent weed surveys in our study site as well as field and greenhouse experiments carried out in eastern France showed that some plant species will profit from the conditions in these 'perennial crops', including biennial and perennial species and annual species with rosettes. At the same time, other species will be suppressed including annual species, especially with an upright or climbing morphology, that are often dominant (and most problematic) in annual cereal crops (Meiss *et al.*, 2008; Meiss *et al.*, 2010b).

These changes in weed species composition may be due to several mechanisms acting on several stages of the plant life cycle. The absence of soil tillage in temporary grasslands may reduce weed germination. The survival of established plants may be favoured by the absence of soil tillage but will be negatively affected by the competition of the perennial

vegetation cover and by the frequent hay cuttings (Meiss *et al.*, 2009). Finally, weed seed survival may be reduced in perennial crops as they stay on the soil surface where they are more accessible to seed predators compared to tilled annual crops. Moreover, experimental studies suggested that post-dispersal weed seed predation (consumption of seeds) by vertebrates and invertebrates increases with vegetation cover in perennial crops (Meiss *et al.*, 2010c).

By modifying the plant species composition, temporary grasslands devoted to forage (or fibre or energy) production may thus both contribute to the regulation of weed populations that are most harmful in annual crops and favour other plant species that are less problematic for the following annual crops. Moreover, specific periods such as overwinter stubble fields that favour the access of farmland birds to seed resources during winter (Moorcroft *et al.*, 2002) may also be integrated into such long crop rotations at the moment when seed bank densities are highest, thus at the end of the period of annual crops. By diversifying crop rotations dominated by annual cash crops with perennial crops and overwinter stubble fields, the functions of crop production, weed management and biodiversity conservation may thus be wisely combined on the scale of the dynamic landscape mosaic.

#### 26.4 Grasshopper Spatial Dynamics and the Role of Perennial Crops

Grasshoppers (Orthoptera: Acrididae) play a major trophic role, being the primary herbivores in grassland habitats, and also because they are prey for other invertebrates, e.g. spiders and vertebrates, notably farmland birds that use them as food for chicks (Barker, 2004). Like many invertebrates, grasshoppers need perennial habitats due to the fact that their survival from one year to the other is achieved by eggs which are deposited in the soil. As ploughing destroys eggs, annual crops are sinks for these populations. Thus, maintaining grasshopper populations in the

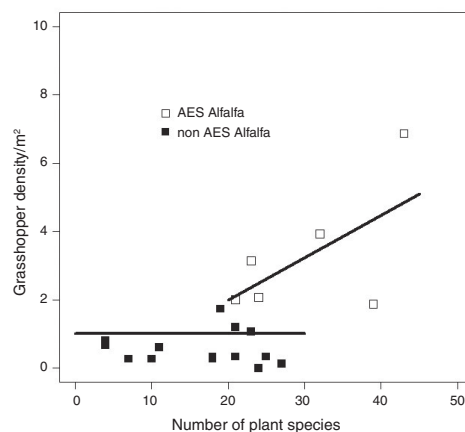
landscape can be achieved only through perennial habitats such as grasslands or field boundaries. However, these areas are rare in intensive agrosystems and temporary grasslands are subject to frequent destruction due to crop rotation. Local extinctions at the field scale can be compensated only if new habitats are available and if species could colonize them, i.e. have sufficient dispersal abilities (Baur *et al.*, 2005). For example, the distance between favourable habitats could be more restrictive for species like the wingless *Pezotettix giornae* than for the winged species *Calliptamus italicus*, which may be more affected by habitat loss than by habitat fragmentation (Tscharrntke and Brandl, 2004).

In that context, grassland availability and distribution at the landscape level has a major impact on the populations. At the field scale, grassland vegetation type and the agricultural practices have strong impacts on grasshopper abundance (Wingerden *et al.*, 1992; Guido and Gianelle, 2001). For example, grasshopper densities in our study site and during the period 2003–2006 were rather low in alfalfa crops (about 0.8 individuals per m<sup>2</sup>) compared to other temporary grasslands (about 3.1 individuals per m<sup>2</sup>). In alfalfa, the lower numbers of grasshoppers could be explained by the agricultural practices on this crop. Surveys that compared extensive alfalfa fields without any input and with no cutting from June to August and conventional fields with at least one herbicide and one insecticide treatment showed that grasshopper densities may be seven to ten times higher in the extensive fields (Badenhausser *et al.*, 2008). This response may also be caused by the number of plant species, which was nearly doubled in the extensive plots (32 plant species; Badenhausser *et al.*, 2008). This is indicated by the positive relationship between grasshopper abundance and plant diversity shown in Fig. 26.2. Increased plant diversity could diversify the offer of different refuges and microclimates to species having different habitat preferences. Moreover, plant diversity may enhance grasshopper diversity as grass-

hopper species could differ in their food preferences (Specht *et al.*, 2008). Thus, management practices such as the amount of inputs and the number of cuttings may be responsible directly or indirectly for the high observed spatial variability in grasshopper abundance at the landscape scale (Badenhausser *et al.*, 2009). Moreover, during the period 1999–2010 in our study site, grasshopper densities exhibited strong temporal variability at the scale of the season but also at the scale of the year (Badenhausser *et al.*, 2009). The range of grasshopper abundances at the peak period of adult stage, i.e. at the beginning of August, during the time period 1999–2010 was from 0.35 grasshopper/m<sup>2</sup> in 2001 to 8.5 grasshoppers/m<sup>2</sup> in 2004 (Badenhausser *et al.*, 2009).

### 26.5 Dependence of Threatened Top Predator Species on their Prey in Cereal Systems

Insects and small mammals make up the bulk of biomass in food supply for higher trophic levels in agroecosystems. For example, the common vole represents a key resource in the trophic chain in agroecosystems (Lambin *et al.*, 2003). In western France, the Montagu's Harrier



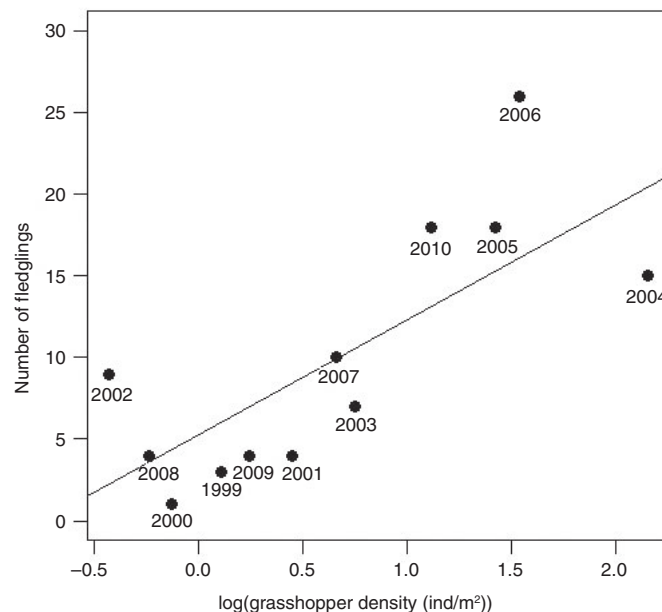
**Fig. 26.2.** The relationship between grasshopper density and plant richness in alfalfa crops. AES, agri-environment scheme.

*Circus pygargus* appears to be highly dependent on common vole abundance since its population density displays a numerical response to the cyclic dynamic of his prey (Salamolard *et al.*, 2000; Millon *et al.*, 2008). Thus, the persistence of this flagship raptor species is conditioned by the maintenance of common vole populations. Similarly, differences in grasshopper availability appear to be critical to the Little Bustard *Tetrax tetrax* productivity. Though populations of Little Bustard in southern France, which are not migratory, are relatively stable (Jolivet, 1997), the population of western France which is wintering in Spain (Villers *et al.*, 2010), has undergone one of the steepest declines ever documented to date for a bird species in Europe: 7800 males in 1978 to 390 in 1996 (a decrease of 95% in 18 years; Inchausti and Bretagnolle, 2005; Bretagnolle *et al.*, 2011), and 300 in 2008. There is a strong positive relationship between yearly average grasshopper abundance (calculated as the mean abundance over the surveyed grasslands for a given year) and total annual productivity of Little

Bustard on our study site (Fig. 26.3), as estimated by the number of fledglings counted in post-nuptial groups (see Bretagnolle *et al.*, 2011 for methods). The case is not unique, as most bird chicks in cereal systems feed primarily on insects (e.g. Rands, 1986; Baines *et al.*, 1996; Panek, 1997) and especially on Orthoptera.

### 26.6 The Conservation of Biodiversity in Cereal-based Cropping Systems

Many species, particularly birds, though being extremely common, have fallen sharply across the agricultural plains in Europe (Fuller *et al.*, 1995; Potts 1997). In Western Europe, about 1% of the avifauna of lowland landscapes disappears annually (Donald *et al.*, 2001, Julliard *et al.*, 2004). In France, between 1989 and 2003, bird populations (all species combined) have declined by 3%, while birds using agricultural habitats declined by 25% (Julliard *et al.*, 2004). Paradoxically however, agroecosystems, though they dominate the land surface of Europe, have been poorly



**Fig. 26.3.** Numerical response of Little Bustard fecundity (chick productivity) and grasshopper density (each point represents a year).

studied until recently in regard to trophic interactions and community ecology. Likewise, almost no conservation effort has yet been undertaken on these areas because of private land ownership and exploitation which forbids the creation of nature reserves, the most-used conservation strategy.

Instead, agri-environment schemes (AESs) and NATURA 2000 are the two main (if not the only) tools available in order to mitigate the devastating effects of intensive agriculture on biodiversity. In intensive cereal systems, AESs should be mainly targeted to the conservation and management of permanent and temporary grasslands due to (i) their key role as habitats for different taxa, (ii) their potential for weed management when inserted into the rotations and (iii) other ecosystem services. However, several studies have shown that AESs (and organic farming, which is often included in AESs, for instance in France) do not always have the expected positive effects on biodiversity (e.g. Kleijn and Sutherland, 2003).

On our study site, we implemented different AESs in order to protect the Little Bustard. Most of these schemes were based on grassland restoration and modification in grassland management. The strong decline in Little Bustard has been linked to the lowering in surfaces of perennial habitats for breeding, but also to strong decreases in insects (particularly grasshoppers) for feeding (Bretagnolle and Inchausti, 2005, Bretagnolle *et al.*, 2011). The latter resulted simultaneously from a decrease in grasslands as the breeding habitat of grasshoppers as well as the intense use of insecticides and herbicides (grasshoppers are herbivorous). Our conservation strategy for the Little Bustard was therefore to counteract the loss of habitat and the low availability of food resources. We developed protection measures providing favourable nesting plots (decrease of agricultural activities to minimize the risk of destruction nests and females) and resources, and more generally to encourage farmers to restore perennial vegetation covers. The Little Bustard population,

which showed an initial decrease by a factor of five in just eight years (about 13% per year since 1996), has now almost completely recovered, in no more than five years (Bretagnolle *et al.*, 2011).

## 26.7 Conclusion

Our results indicate that, in intensive cereal systems, grasslands have a critical role in shaping the distribution and abundance of organisms of different trophic levels including plants, grasshoppers, small mammals and birds. In addition, we show that the population dynamics of top level predators such as raptors (e.g. Montagu's Harrier) or Bustards, which are both of high conservation concern, are driven by the abundances of their prey (insects and small mammals) which ultimately depend to a large extent on grasslands. The management of grassland habitat in such ecosystems is therefore critical for both the maintenance of ecosystem services such as those depending on functional biodiversity, but also for the conservation of threatened species. For the latter, grassland must be managed at the regional rather than the local scale, because these species forage on vast areas and occur at rather low density so that their population dynamic arises at the regional scale. The implementation of the AES, when specifically targeted to mitigate the underlying causes of declining numbers of top predators, can help to maintain or conserve biodiversity and threatened species. In addition, the implementation of AES in our study area has also benefitted other organisms, such as grasshoppers and passerine birds such as the Corn Bunting *Miliaria calandra*. Currently, we are testing whether the AESs dedicated to bird conservation also have positive impacts on other taxa including plants, grasshoppers, beetles and other passerine birds.

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