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Review

Meadow harvesting techniques and their impacts on field fauna

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ABSTRACT

Meadows require regular harvesting (cutting) to avoid vegetation succession, and this is well known to promote high plant diversity. The impacts of the harvesting process on animal, and particularly invertebrate, abundance and diversity is not, however, well known, but is expected to be largely negative. This study reviews the available information on the direct mortality caused by the meadow harvesting process on vertebrate and invertebrate populations with the intention of raising the profile of this neglected area of research which is nevertheless important in the context of declining field fauna diversity. Collectively, the studies show a direct and often substantial impact of the harvesting process on the fauna, especially from the mowing stages, and that this impact depends on the techniques and equipment used, as well as the settings, the habitat and the ecology of each species. The post-mowing harvesting stages also have considerable relevance, especially grass removal (baling), which may first concentrate organisms in windrows before removing them from the field, but have been rarely studied. Differences among mowing techniques and equipment can amount to a threefold change in the scale of impact on field fauna, and therefore there is a potential to reduce direct harvesting impacts. According to the reviewed studies, the use of cutter bar mowers is recommended over rotary and flail mowers, as they cause half as much mortality. If a rotary mower is used, then an add-on conditioner should be avoided. However, for less mobile species, it is still unclear if the benefit gain from friendly mowing techniques might be cancelled by subsequent harvesting stages, and this important point needs further investigation. Because no practicable harvesting processes are damage free, leaving uncut grass strips is a simple and good practice that will benefit many organisms.

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1. Introduction

Meadow and pasture agricultural systems are widespread throughout Europe, and the general impact of the intensification of such systems on biodiversity in agricultural landscapes is relatively well known (Krebs et al., 1999; Robinson and Sutherland, 2002). Grassland intensification interventions include increased fertilizer input, the application of pesticides (although

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often less than in arable fields) and reseeding, which results in increased grass production, allowing earlier and more frequent cuts or higher grazing intensity. These changes are, in general, detrimental to grassland biodiversity, with declining plant, bird and invertebrate populations attributed to grassland intensification (e.g. Wilson et al., 1999; Vickery et al., 2001; Benton et al., 2002; Donald et al., 2006; Marini et al., 2008), and this trend is likely to continue if no land-use changes are made (Tilman et al., 2001; Reidsma et al., 2006). In view of this, initiatives in several European countries aim to restore the biodiversity of agricultural landscapes by promoting practices that are more favourable to biodiversity (Kleijn and Sutherland, 2003). Within agricultural landscapes, emphasis on the high biodiversity value of grassland (Bignal and McCracken, 1996; Vickery et al., 2001), has promoted more extensive forms of management and efforts to restore degraded meadow systems. However, scientific knowledge of the impacts on field fauna diversity of various agricultural techniques associated with cutting in more extensive systems is very limited. 'Cutting' or 'mowing' are terms referring often to the full meadow harvesting process and encompass several stages applied under different environmental conditions with different machines, and the response of organisms is likely to vary in response to these harvesting regimes. Therefore, to be able to advise farmers and land managers about appropriate harvesting techniques requires some knowledge of the impact of these on field fauna diversity as a whole, and on specific taxa of particular conservation or ecosystem function concern.

Meadows require regular harvesting (cutting) to avoid vegetation succession, and this is well known to promote high plant diversity (Grime, 2001). However, the impacts of the harvesting process on animal, and particularly invertebrate, abundance and diversity is not well known, although is expected to be largely negative (Morris, 2000). The increasing recognition of the value of invertebrates in ecosystem function, notably their role in key ecosystem processes such as herbivory, nutrient cycling and pollination belies the limited knowledge on their persistence in managed meadows, habitats that dominate agricultural landscapes in Europe (e.g. New, 2005; Brussaard et al., 2007). Additionally, there has been much recent concern regarding invertebrate population declines, associated with a transformation and intensification of landscapes (Hendrickx et al., 2007). In the context of a metapopulation model of invertebrate persistence, it is not clear whether managed meadows represent source or sink populations. Understanding this will contribute to our understanding of the long-term viability of invertebrate populations across anthropogenic landscapes. Further relevance of this topic relates to the incentives for low impact meadow management for the purpose of promoting biodiversity. Yet these biodiversity-rich extensively managed meadows are harvested using mechanised technology, the impact of which on invertebrate biodiversity is largely unknown. Here the available information on impacts of meadow harvesting on vertebrate and invertebrate biodiversity is reviewed with the intention of raising the profile of this neglected area of research which is nevertheless important in the context of declining field fauna populations.

This review will start with a brief section about the global effects of grassland management by cutting on meadow biodiversity. It will proceed with the main section, which reviews and synthesizes our current knowledge of the direct impact of different grassland harvesting techniques on the fauna of meadows. Finally, we will provide (i) recommendations about harvesting practices and techniques to minimize impacts on field fauna, and (ii) a foundation for effective targeted research to address areas of scientific uncertainty relevant to this field.

2. Meadow management by cutting

Grassland ecosystems depend on regular disturbances to prevent vegetation succession (Huston, 1994; Grime, 2001). Grassland disturbances include the grazing regime as well as management interventions and activities such as cutting and/or burning. Cutting is the most relevant and regular intervention for meadows that are managed for hay or silage production. The main objective of cutting is to provide winter cattle feed, but in recognition of high plant diversity on extensive meadows the cutting regime is also used to maintain natural habitats of conservation importance (e.g. Cattin et al., 2003). The objective of maintaining plant biodiversity is realised at the scale of the meadow itself, but it is not known whether plant diversity correlates with invertebrate diversity and abundance at the same scale and under the same management regime. Harvesting has also undergone changes in recent decades with a dramatic increase in mechanisation and the introduction of harvesting-associated activities such as conditioning. Invertebrate field organisms that were adapted to previously implemented 'traditional' hay systems may have become additionally vulnerable to current cutting techniques.

One or two cuts per year are beneficial to meadow plant diversity (Huston, 1994; Antonsen and Olsson, 2005). However, for grassland invertebrates, investigations have confirmed the usual responses to cutting: reduction in diversity and in abundance of most groups and species, with positive benefits to a few (Gerstmeier and Lang, 1996; Morris, 2000). For example, Coleoptera seems to be a robust group in its response to cutting treatments when compared to other more sensitive arthropods, such as Heteroptera (Morris, 1987; Gerstmeier and Lang, 1996). Butterflies and spiders are also sensitive taxa, and it has been shown that cutting has a drastic impact on their abundances and richness (e.g. Baines et al., 1998; Bell et al., 2001; Cattin et al., 2003; Johst et al., 2006).

The time and frequency at which meadows are cut are among the most important factors affecting field biodiversity, although appropriate timing for cutting regimes vary according to the taxon concerned (Morris, 2000). For example grassland-nesting birds are mostly favoured by a summer cut to allow clutches to hatch (Tyler et al., 1998; Müller et al., 2005; Walter et al., 2007), while for spiders (Baines et al., 1998) and Hemiptera (Morris and Lakhani, 1979) summer cuts are more detrimental than spring and/or autumn cuts. For butterflies, Feber et al. (1996) and Johst et al. (2006) recommended a spring and autumn cut over a summer cut, while Walter et al. (2007) argued that a spring cut should be avoided because it would affect the less mobile developmental-stages such as caterpillars. The type of the meadow is also an important feature dictating the time and frequency of the cut, as in wetlands, late mowing on a supra-annual cycle is recommended for the conservation of arthropods (Wettstein and Schmid, 1999; Cattin et al., 2003).

It is not planned to review in detail the effect of timing here, but to emphasise that there is no ideal cutting time for all taxa, and therefore cutting will always occur at a critical period for some organisms. In addition, there is a wide literature on the subject, including reviews (e.g. Gerstmeier and Lang, 1996; Morris, 2000), and restriction on the first cutting date have already been implemented in some agri-environmental schemes. For instance, in Switzerland extensive meadows classified as Ecological Compensation Area (ECA) cannot be mown before 15th June in lowland and 1st or 15th July at higher elevations, and ECA wet meadows cannot be mown before 1st of September (Swiss Federal Council, 1998).

While the general negative impact of grass cutting on field invertebrates is relatively well known, few studies have investi-