



## Think twice before using narrow buffers: Attenuating mowing-induced arthropod spillover at forest – grassland edges



Csaba Tölgyesi<sup>a,b,\*</sup>, Péter Császár<sup>a</sup>, Attila Torma<sup>a</sup>, Péter Török<sup>b</sup>, Zoltán Bátori<sup>a</sup>, Róbert Gallé<sup>a</sup>

<sup>a</sup> Department of Ecology, University of Szeged, Közép fasor 52, H-6726 Szeged, Hungary

<sup>b</sup> MTA-DE Lendület Functional and Restoration Ecology Research Group, Egyetem tér 1, H-4032 Debrecen, Hungary

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### ABSTRACT

Spillover between agricultural land and natural habitats is recognised as an important mechanism shaping biodiversity and ecosystem functions. Its spatio-temporal patterns and magnitude are thoroughly described in the literature and it is often stated that spillover should be considered in conservation planning. In fact studies that implement and test active interventions to modulate spillover are scarce. Therefore, we studied the spillover of spiders and carabids between hay meadows and natural forests after mowing and tested whether leaving unmown buffer strips in the edges can mitigate undesirable aspects of mowing-induced spillover. We found that mowing affected the assemblages both in the meadows and forests and, interestingly, changes were more profound in the forests. Mowing reduced the spillover of forest assemblages into meadows. Mowing also led to the retraction of forest assemblages from the peripheral zones of forests but did not trigger an influx of meadow assemblages into the forests. Wide (10 m) unmown buffers attenuated or completely offset most of these effects. Leaving narrow (5 m) buffers had unexpected consequences, as they did not function only as buffers but as facilitators of forest-ward spillover from meadows, potentially compromising ecological interactions such as predation or competition in forests. We conclude that using wide buffers can be recommended as a refinement of standard management practices in hay meadow–forest mosaics. Narrow buffers should be applied with great caution and should generally be avoided if the forest-specific assemblages are of conservation interest.

### 1. Introduction

Semi-natural grasslands are decreasing in area and naturalness across Europe due to management intensification, abandonment and transformation to other land use types (Báldi et al., 2013; Dengler et al., 2014). Best management practices for the preservation of remaining grasslands include extensive grazing with various livestock and/or mowing once or a few times a year (Tälle et al., 2016; Török et al., 2016). Extensive grazing with appropriate livestock may mimic pre-historical disturbance regimes of wild megaherbivores (Vera, 2002; Sutherland, 2002) and can create heterogeneous vegetation (Marty, 2005; Tölgyesi et al., 2015), which supports high arthropod diversity (Lambert et al., 2007; Woodcock et al., 2006). Conversely, mowing, which is nowadays performed by high-power machines, leads to more homogenous habitat structure and arthropod assemblages (Cizek et al., 2012). Mowing machines also mechanically kill a large number of animals from insects (Thorbeck and Bilde, 2004) to birds (Vadász and Lóránt, 2015). The physical environmental conditions on freshly mown meadows may be beyond the limit of tolerance of the survivors and they

are also more visible to predators (Opatovsky and Lubin, 2012). To counteract the negative effects of mowing, several recommendations have been proposed in the frame of agri-environmental schemes (AES). These include the careful timing of mowing, increased cut height, the combined application of mowing and grazing, and leaving unmown strips or patches, where animals can find shelter and plants can set seed (Buri et al., 2013; Cizek et al., 2012; Humbert et al., 2012a,b; Lebeau et al., 2015; van Klink et al., 2017).

All recommendations listed above aimed to mitigate the negative effect of mowing on grassland biodiversity. However, processes in one habitat can affect the peripheral zones of adjacent habitats through edge effects (Murcia, 1995). Accordingly, the mowing of grasslands can affect the biota of the neighbouring habitats. These effects should be taken into account, particularly if these habitats are of high conservation value (such as forest fragments) and/or if the grassland and non-grassland patches form a natural mosaic or a fragmented landscape. In such landscapes the edge to patch interior ratio is high, thus the potentially affected proportion of non-grassland habitats is also high (Cook et al., 2002; Madeira et al., 2016).

\* Corresponding author at: Department of Ecology, University of Szeged, Közép fasor 52, H-6726 Szeged, Hungary.

E-mail addresses: [festuca7@yahoo.com](mailto:festuca7@yahoo.com) (C. Tölgyesi), [csaszzi124@gmail.com](mailto:csaszzi124@gmail.com) (P. Császár), [torma\\_a@yahoo.com](mailto:torma_a@yahoo.com) (A. Torma), [molinia@gmail.com](mailto:molinia@gmail.com) (P. Török), [zbatory@gmail.com](mailto:zbatory@gmail.com) (Z. Bátori), [galle.robert@gmail.com](mailto:galle.robert@gmail.com) (R. Gallé).

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A frequently studied manifestation of edge effects is the spillover of arthropods, i.e. their periodic/annual movement or foraging across habitat edges (Rand et al., 2006, Tschardt et al., 2012). Spillover can be traced back to various ecological reasons. Differences in productivity can lead to the movement of organisms from a productive habitat to a less productive neighbouring habitat in a passive, diffusion-like manner, corresponding to the source-sink dynamics described by Dunning et al. (1992). Conversely, an abrupt decline in habitat quality can trigger active emigration from a patch into a neighbouring one (Holt and Hochberg, 2001; Thorbek and Bilde, 2004). Landscape complementation (i.e. the need of an organism for both neighbouring habitats to complete its life-cycle) and landscape supplementation (i.e. if the neighbouring habitats provide alternatives for certain resources) can also explain spillover (Dunning et al., 1992; Fahrig et al., 2011; Tschardt et al., 2012). Spillover has been detected between various habitat pairs such as adjacent arable fields and natural grasslands (Madeira et al., 2016; Rand and Louda, 2006), natural forests and forest plantations (Lucey and Hill, 2012), grasslands and coniferous forests (Lacasella et al., 2015) and even between fields of different crop types (Duflo et al., 2016; Macfadyen and Muller, 2013), indicating that it is a wide-spread phenomenon. The relevance of spillover for conservation issues is emphasised in most of these studies (e.g. Pryke and Samways, 2012; Schneider et al., 2013), as they claim that the influx of arthropods from the neighbouring habitats can import new ecosystem functions (Blitzer et al., 2012; Rand et al., 2006) but can disrupt some functions by increasing competition or predation (Ries and Sisk, 2004).

In relation to forest-grassland edges it has been found that spillover of forest assemblages into grasslands is more pronounced than spillover of grassland assemblages into forests (Boetzel et al., 2016; Lacasella et al., 2015) as the higher biomass of forests can maintain a higher abundance of arthropods, which then spillover into grasslands according to the source-sink dynamics (Dunning et al., 1992). Mowing, however, causes a rapid deterioration of habitat quality in the grassland, actively driving arthropods out of the affected habitats (Eyre et al., 2013; Opatovsky and Lubin, 2012). Thus, we expect that forest assemblages will show an abrupt decline in their spillover rate into freshly mown grasslands and grassland assemblages will likely be seeking shelter in adjacent forest patches, leading to increased spillover into forests immediately after mowing. Although some seasonal landscape complementation or supplementation can exist between the forests and meadows (Dunning et al., 1992; Fahrig et al., 2011), the effects of modern mowing techniques may cause perturbations in spillover that were unprecedented in earlier times. Thus, there is a need to assess the outlined cross-edge effects of mowing and measures should be taken to offset them if necessary. To date, little effort has been made to address this issue. We therefore designed a field experiment in hay meadow-hardwood grove mosaics in Hungary to study the changes of arthropod assemblages in the peripheral zones of adjacent meadow and forest patches immediately after mowing. We chose spiders and carabid beetles as test organisms because they usually have distinct assemblages in forest and grassland habitats (Noreika and Kotze, 2012), are mobile enough to cross edges, are sensitive to environmental variation at small spatial scales, and occupy an intermediate trophic level, which allocates a key role to them in the maintenance of ecosystem functions (Lacasella et al., 2015; Pearce and Venier, 2006). We focussed only on the peripheral zones of forests and grasslands because spillover is expected to be more pronounced there than farther away from the forest edges (Boetzel et al., 2016). Specifically, we asked the following questions:

- (1) Does mowing alter the species composition of spider and carabid assemblages in the peripheral zones of forests and meadows, and can these effects be prevented by leaving unmown buffer strips?
- (2) Does mowing cut back on the spillover of forest assemblages, and can it be restored by buffer strips?
- (3) Does mowing trigger a quick influx of meadow specific

assemblages, and can this be attenuated by buffer strips?

## 2. Material and methods

### 2.1. Study area

We studied a hay meadow-hardwood grove mosaic in the Kiskunság National Park, central Hungary (N46.725 E19.347, 98 m a.s.l.). The climate is continental with a sub-Mediterranean influence; the annual precipitation is 500–600 mm and the mean annual temperature is 10–11 °C (Tölgyesi et al., 2016). Extra water, supplied by groundwater seeping from the adjacent Danube-Tisza Sandy Ridge maintains a vegetation type with high water demand. Hay meadows are characterised by tall grasses, such as *Molinia caerulea* and *Deschampsia caespitosa* and form a mosaic with forest patches, characterised by *Fraxinus angustifolia* subsp. *danubialis* and *Quercus robur*. Both forests and meadows provide habitat for several plants (e.g. *Gladiolus palustris*), invertebrates (e.g. *Isophya costata* and *Phengaris teleius*) and birds (e.g. *Crex crex* and *Haliaeetus albicilla*) of community interest in the European Union. Both habitats are also listed in the Habitats Directive (European Union 1992). The forest patches are part of a strict forest reserve, in which forestry activities have been banned for 60 years. The meadows are used for extensive hay production and are mown once a year, mostly after mid-July to avoid damage to ground-nesting birds. Some strips or larger blocks (10–15% of the total area) are left unmown every year for wildlife refuge and to allow the seed production of late summer plants. Meadows are usually mown up to the edges of the forests. In some years in winter, shrubs (e.g. *Cornus sanguinea* and *Frangula alnus*) are cut back if they show considerable encroachment towards the meadows. As a result, forest edges are stable in position and have not changed notably since the first military mapping of the region in 1783 (Molnár et al., 1997).

### 2.2. Data collection

In July 2014, we prepared a special mowing plan for the site managers. In four locations, mowing was performed as usual, without leaving any unmown fringe along the forest edges. In other locations, five or ten meters of unmown buffers were left, with four spatial replicates for each width. In four further locations, no mowing was allowed (control). Each of these locations corresponded to an 80–100 m long straight forest edge (Fig. 1A). In each location, we installed eight pitfall traps (128 in total), of which four traps were placed in a line in the peripheral zone of the meadows, approx. 2.5 m from the forest edges, and four traps parallel to them in the peripheral zone of the forests, approx. 2.5 m from the forest edge (Fig. 1B). We used 0.5 l plastic glasses as traps with an upper diameter of 8 cm. The trapping fluid was ethylene glycol diluted with water (1/2, v/v) and a few drops of detergent were also added. The traps were installed immediately after mowing and were open for seven days. We chose this short period because grassland vegetation starts to regenerate from approximately one or two weeks onward, which would have obscured the short-term perturbations of the arthropod assemblages the research was designed to measure.

### 2.3. Data processing

We applied permutational multivariate analysis of variance (perMANOVA) with 1000 permutations to identify the effects of mowing and buffer width on the composition of spider and carabid assemblages. Calculations were performed separately on the untransformed species-abundance matrices of the meadows and forests. Traps were handled separately but their nested arrangement was accounted for in the analysis. If a result was significant, we carried out pair-wise perMANOVAs and adjusted the resulting *P*-values with the FDR method. For a visual representation of compositional patterns, we

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