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Landscape-scale crop diversity interacts with local management to determine ground beetle diversity

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Abstract

Crop diversification and maintenance of semi-natural habitats (grasslands and field boundaries) are suggested to enhance farmland biodiversity, but the relative importance of these factors remains poorly known. We evaluated how crop diversity and availability of semi-natural grasslands at a landscape-scale interacted with local farming management (three management types from low to high intensity: ley < winter wheat < sugar beet) in their effect on ground beetle assemblages in southern Sweden. Ground beetle diversity increased with crop diversity either independently of local management (Simpson species diversity), or only in the less intensively managed habitats (rarefied species richness). While ground beetle diversity in leys tended to increase with field boundary length, no such relationship was observed in winter wheat or sugar beet fields. In contrast, the landscape proportions of leys and semi-natural grasslands did not affect ground beetle species richness and diversity. We conclude that (a) semi-natural grasslands and leys may not function as source habitats at a landscape-scale if they comprise a low proportion of the total land-use, while (b) increasing crop diversity is correlated to ground beetle richness and diversity in agricultural landscapes dominated by arable land. The beneficial effect of landscape-scale crop diversification on farmland biodiversity may depend on the general level of agricultural intensity of a region.

Zusammenfassung

Man nimmt an, dass Anbaudiversifizierung und der Erhalt von halbnatürlichen Habitaten (Grasländer und Feldraine) die Biodiversität im Agrarland steigern, aber die relative Bedeutung der beiden Faktoren ist weitgehend unbekannt. Wir untersuchten in Südschweden, wie die Anbaudiversität und die Verfügbarkeit von halbnatürlichen Grasländern auf der Landschaftsebene mit der lokalen Bewirtschaftung (drei Bewirtschaftungsweisen von geringer bis hoher Intensität: Grasland < Winterweizen < Zuckerrübe) interagierten und die Laufkäfergemeinschaften beeinflussten. Die Laufkäferdiversität stieg mit der Anbaudiversität entweder unabhängig von der lokalen Bewirtschaftung (Simpson-Diversität) oder nur auf den

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weniger intensiv bewirtschafteten Flächen (rarifizierter Artenreichtum). Während die Laufkäferdiversität auf Grasländern tendenziell mit der relativen Feldrandlänge zunahm, konnte für Winterweizen und Zuckerrübe keine solche Beziehung beobachtet werden. Dagegen beeinflussten die Flächenanteile der Grasländer und der halbnatürlichen Habitate Artenreichtum und Diversität der Laufkäfer nicht. Wir schließen, dass (a) halbnatürliche Habitate und Grasländer nicht als Quellhabitate auf der Landschaftsebene fungieren könnten, wenn sie einen geringen Anteil an der genutzten Fläche ausmachen, während (b) zunehmende Anbaudiversität mit dem Artenreichtum und der Diversität der Laufkäfer in von Ackerflächen dominierten Agrarlandschaften korreliert sind. Der günstige Effekt der Anbaudiversifizierung auf Landschaftsebene auf die Diversität von Agrarflächen kann vom generellen Level der Bewirtschaftungsintensität einer Region abhängen.

Keywords: Agricultural landscapes; Agricultural management; Carabidae; Crop diversification; Landscape heterogeneity; Species diversity; Species richness; Trophic groups

Introduction

Loss of landscape heterogeneity at multiple spatial and temporal scales caused by agricultural intensification is a major driver of farmland biodiversity decline (Benton, Vickery, & Wilson 2003). Hence, maintenance of semi-natural habitats and crop diversification can mitigate biodiversity loss and promote sustainable agriculture (Plieninger et al. 2012). Research on landscape-scale effects on biodiversity in farmland have often used proportions of semi-natural habitats as a proxy of landscape heterogeneity, while crop fields have been considered a hostile "matrix" (Fahrig et al. 2011). The relative and interactive effects of semi-natural grasslands and crop diversification has only rarely been simultaneously evaluated empirically; the few studies doing this have focused on crop diversity at the farm scale rather than across entire landscapes (Billeter et al. 2008; Chaplin-Kramer & Kremen 2012).

The activity and diversity of ground beetles is correlated to crop type (Eyre, Luff, Atlihan, & Leifert 2012) and increases with increasing number of crops on farms (Billeter et al. 2008), landscape habitat diversity (Weibull, Östman, & Granqvist 2003; Woodcock et al. 2010) and proportion of grasslands and non-crop area (Purtauf, Dauber, & Wolters 2005). Increasing amounts of field edges, proportions of ley and semi-natural grasslands, and crop diversity may increase beneficial edge effects at crop-crop interfaces (Rand, Tylianakis, & Tscharntke 2006), increase the availability of less intensively managed habitats (Kleijn, Rundlöf, Scheper, Smith, & Tscharntke 2011) and/or provide greater resource availability and beneficial overwintering environments for polyphagous ground beetles (Holland, Birkett, & Southway 2009). Furthermore, local biodiversity can be modulated by both local and regional factors (Tscharntke et al. 2012). A high-quality habitat patch may be species-poor if no source populations are available (Whittingham 2007). Conversely, an intensively managed habitat may be deprived of species even if source populations would be available in the surrounding landscape (Ekroos & Kuussaari 2012). Interactions between local management and landscape factors may also depend on ecological traits, such as trophic rank since predatory ground beetles respond more strongly to landscape-scale complexity than those with more plant based diet (Purtauf, Dauber, et al. 2005).

In this study we evaluated the interactive effects of landscape-scale factors (crop diversity, field boundary length, and proportions of leys and semi-natural grasslands) and local management of focal fields (ley, winter wheat and sugar beet) on ground beetle diversity in southernmost Sweden. The landscape-scale factors measured land-cover composition on the scale of multiple farms, while local management described crop type in the sampling sites. Both winter wheat and sugar beet fields were more intensively managed than ley fields, in particular sugar beet fields, as they had no vegetation during the winter and were tilled before sowing. We expected a positive effect on ground beetle species richness and diversity with decreasing local management intensity and increasing proportions of ley, semi-natural grasslands, field boundary length, and crop diversity at the landscape-scale. We also expected to find an interaction between local management and landscape context, with a disproportionately higher ground beetle diversity with increasing influence of the four landscape factors in ley than in winter wheat and sugar beet fields (cf. Kleijn et al. 2011). Finally, we expected the landscape effects to be stronger for predatory ground beetles than for ground beetles having a more plant based diet, since predatory species are generally more mobile (Woodcock et al. 2010).

Materials and methods

Study design

The field work was carried out during April-July 2011 in an area covering approximately 850 km^2 of the cultivated plains of Scania, the southernmost province of Sweden. The study area was dominated by annual crops ($78.0 \pm 9.9\%$), comparable to intensively managed agricultural regions in northern Germany and Denmark regarding main crop