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Local, neighbor and landscape effects on the abundance of weed seed-eating carabids in arable fields: A nationwide analysis

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Abstract

Recent studies suggest that weed seed predation by carabid beetles may partly substitute for chemical weed control in agriculture. Promoting this weed regulation service would require enhancement of the in-field abundance of seed-eating carabids, yet, the diversity of the habitat, trophic requirements and spatial scales of response of different species are complex and our understanding of how management at different spatial scales affects the abundance of seed-eating carabids is limited. Using data collected in 161 arable fields and four crop types across the UK, the factors affecting the abundance of nine common seed-feeding carabid species at three spatial scales (local, neighboring, landscape) were investigated using GLMMs. Locally, crop type strongly affected the abundance of individual species, in a species-specific manner and the intensity of field management had a negative effect on the abundance of several species, irrespective of their trophic guild. The occurrence of oilseed rape and grasslands in the neighborhood was found to decrease the abundance of generalist seed-eating carabids but was the main factor positively affecting the abundance of the mainly granivorous *Amara aenea*, which occur almost exclusively in our sampled oilseed rape fields. At the landscape scale, a generally positive effect of the cover of grassland and oilseed rape demonstrated that in-field carabid abundance responds to the spatial distribution of agricultural land-use in the wider landscape. These findings suggest that management options could be implemented at multiple spatial scales to promote weed seed predation in arable fields.

Zusammenfassung

Neue Studien legen nahe, dass die Prädation von Unkrautsamen durch Carabiden teilweise die chemische Unkrautbekämpfung in der Landwirtschaft ersetzen könnte. Die Förderung dieser Unkrautbekämpfungsdienstleistung würde eine erhöhte Siedlungsdichte der samenfressenden Carbiden auf dem Acker erfordern. Aber die Diversität des Lebensraumes, trophische Ansprüche und räumliche Skalen der Reaktion einzelner Arten sind komplex und unsere Kenntnisse davon, wie Management auf verschiedenen Skalen die Abundanz der samenfressenden Carabiden beeinflusst, sind begrenzt. Basierend auf Daten, die auf 161 Feldern im Vereinigten Königreich für vier Feldfrüchte gesammelt worden waren, untersuchten wir mit GLMM die Faktoren, die die Abundanz von neun häufigen samenfressenden Carabidenarten auf drei räumlichen Skalen (lokal, benachbart, Landschaft) beeinflussten. Lokal beeinflusste die Feldfrucht die Abundanz einzelner Arten stark in artspezifischer Weise, und die Intensität der Bewirtschaftung hatte einen negativen Effekt auf die Abundanz etlicher Arten unabhängig von deren trophischer Gruppe. Das

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Vorhandensein von Raps und Grasland in der Nachbarschaft reduzierte die Abundanz von generalistischen samenfressenden Carabiden, war aber der Hauptfaktor, der die Abundanz der samenfressenden Art *Amara aenea*, die fast ausschließlich auf Rapsfeldern auftrat, positiv beeinflusste. Auf der Landschaftsebene zeigte ein generell positiver Effekt der Flächenanteile von Raps und Grasland, dass die Carabidensiedlungsdichte auf den Feldern auf die räumliche Verteilung der landwirtschaftlichen Nutzung in der weiteren Umgebung reagiert. Diese Befunde legen nahe, dass Bewirtschaftungsformen auf mehreren räumlichen Ebenen festgelegt werden könnten, um den Räuberdruck auf Unkrautsamen auf landwirtschaftlichen Nutzflächen zu erhöhen.

Keywords: Agroecology; Seed predation; Weed control; Response scale; Landscape composition; Trophic guild

Introduction

Weed control is a major issue in arable agriculture worldwide. Arable weeds are a major constraint to crop production (Marshall et al., 2003; Oerke, 2006) and the reliance on chemical control remains high despite recognized detrimental effects on the environment and biodiversity (Paoletti & Pimentel, 2000; Geiger et al. 2010). The regulation of pests by naturally occurring enemies is frequently cited as an important ecosystem service in agroecosystems (Altieri, 1999; Losey & Vaughan, 2006). Among these natural enemies, carabid beetles are known to consume substantial amounts of weed seeds in arable fields (Westerman, Hofman, Vet, & Van Der Werf, 2003; Trichard, Alignier, Biju-Duval, & Petit, 2013). A recent large-scale study provided evidence of a positive relationship between the abundance of seed-eating carabids and the amount of weed seed bank regulation, suggesting that weed seed predation might partly substitute for chemical weed control in agriculture (Bohan, Boursault, Brooks, & Petit, 2011). Enhancing weed seed regulation thus requires management to increase the number of seed-eating carabids in arable fields.

Carabid abundance in arable fields is driven by a number of factors acting at different spatial scales. Locally, microclimate, soil characteristics, vegetation cover and the intensity of agricultural management can have significant impacts on the relative abundances of individual species within carabid communities (Kromp, 1999; Holland & Luff, 2000; Bengtsson, Ahnström, & Weibull, 2005; Menalled, Smith, Dauer, & Fox, 2007). In addition, because most carabids use crops as transient habitats, their abundance in arable fields is also often governed by the habitat composition and configuration of the landscape surrounding the field (Maisonhaute, Peres-Neto, & Lucas, 2010; Woodcock et al. 2010). To date, most landscape ecological studies on carabids have only focused on the contribution of semi-natural habitats to the in-field abundance of carabids. However, non-crop habitats surrounding arable fields have been found to be overwintering sites and thus a source of carabids for recolonization of fields during the crop growing season (i.e. cyclic colonization *sensu* Wissinger, 1997). For example, adjacent grassy field margins, wildflower strips or beetle banks can enhance carabid abundance in the crop (Lys & Nentwig, 1992; Hof & Bright, 2010). At broader spatial scales, semi-natural habitats may enhance carabid populations of arable fields through the provision of shelter and/or corridors for dispersal between habitats across the agricultural landscape (Weibull & Östman, 2003; Vanbergen et al. 2010).

Although this body of research has established the importance of processes acting at neighboring and/or landscape scale for carabids, it has limited use for designing land management strategies aimed at enhancing weed regulation services for two main reasons. First, most studies have focused on the community-level response of carabids, i.e. richness and diversity of communities, whereas our ability to design crop protection strategies is currently limited by equivocal information on the basic ecology of individual carabid species (Thomas, Parkinson, Griffiths, Fernandez Garcia, & Marshall, 2001; Diekötter, Wamser, Wolters, & Birkhofer, 2010). Individual carabid species differ in their habitat and trophic requirements during their life cycle as well as in their ability to withstand perturbations. For example, polyphagous carabids are considered to be resilient to frequent reductions in the availability of resources (Schweiger et al. 2005), while phytophagous carabids are associated with specific habitats such as grasslands (Vanbergen et al. 2010), possibly as a result of their relative dependency on seeds from ruderal plants (Thiele, 1977). Individual carabid species may also differ with respect to the spatial scales at which they respond, suggesting that a community-level approach may not be the most appropriate for detecting neighboring and landscape effects on carabids. Recent studies would suggest that phytophagous species respond at finer spatial scales than carabid species belonging to higher trophic guilds (Purtauf, Dauber, & Wolters, 2005a; Vanbergen et al. 2010) but currently these scales of response of individual species remain poorly documented. Second, a crop vs. non-crop representation of the landscape is usually adopted, a binary categorization that is unlikely to reflect how the different carabid species perceive the environmental heterogeneity of the agricultural landscape. Indeed, the range of crop types that occur simultaneously in the agricultural landscape provides markedly different environmental conditions and food availability – two of the most important factors influencing the distribution of carabid abundances (Luff, 1987; Holland, 2002; Thomas, Holland, & Brown, 2002). Some species are specifically associated with particular crop types and some crop types, such oilseed rape, support many carabid species