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Effects of an agri-environment scheme on bumblebee reproduction at local and landscape scales

Claire Carvell[a,*], Andrew F.G. Bourke[b], Juliet L. Osborne[c], Matthew S. Heard[a]

[a]NERC Centre for Ecology & Hydrology, Maclean Building, Crowmarsh Gifford, Wallingford OX10 8BB, Oxfordshire, UK
[b]School of Biological Sciences, University of East Anglia, Norwich Research Park, Norwich NR4 7TJ, UK
[c]Environment & Sustainability Institute, University of Exeter, Penryn TR10 9FE, Cornwall, UK

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Abstract

Agri-environment schemes (AES) have been implemented across Europe, aiming to mitigate effects of habitat loss in agro-ecosystems for a range of declining species. These include pollinating insects such as bumblebees, for which positive effects of AES on abundance and species richness have been shown. However, there is a lack of evidence for effects of AES on reproduction of target species, at either local or landscape scales. We conducted a large-scale study across landscapes exhibiting a gradient of agricultural intensity to investigate the effects of a targeted flower mixture, sown in patches of three different sizes, on an index of the total biomass of bumblebee sexuals (males and queens) on replicated transects within each landscape. We used this index (MQ) as a measure of bumblebee reproduction. After controlling for floral density on transects, we found that MQ was significantly higher on sown flower patches than on conventionally managed control patches at local scales throughout the three-year study. While sown flower patches did not significantly increase MQ in surrounding landscapes, MQ was higher in landscapes surrounding larger (1 ha) than smaller (0.25 ha) sown patches. Our results suggest that, while responses of different bee species may vary depending on the plant species sown, targeted flower mixtures can enhance bumblebee reproduction by providing locally attractive forage resources to bumblebees of all castes and sexes from nests within foraging distance. If established at large enough scales, sown flower patches may lead to a detectable spill-over of reproductives into surrounding landscapes. Furthermore, effects of sown patches on MQ were moderated by landscape context, the strongest positive responses being detected at sites with high proportions of arable land. This supports previous findings that AES can deliver greater net benefits for pollinators in more intensively farmed landscapes.

Zusammenfassung

Agrar-Umweltprogramme (AES) sind in ganz Europa eingerichtet worden mit dem Ziel, die Auswirkungen von Habitatverlusten in Agrarökosystemen für eine Reihe von zurückgehenden Arten zu mildern. Hierzu gehören Bestäuberinsekten wie z.B. Hummeln, für die positive Effekte durch AES auf Abundanz und Artenreichtum gezeigt werden konnten. Indessen mangelt es an Befunden zum Effekt von AES auf die Reproduktion von Zielarten auf der lokalen oder Landschafts-Skala. Wir führten eine großräumige Untersuchung in Landschaften, die einen Gradienten landwirtschaftlicher Intensität darstellten, durch, um

*Corresponding author. Tel.: +44 0 1491 838800.
E-mail address: ccar@ceh.ac.uk (C. Carvell).

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den Effekt einer gezielt zusammengestellten Saatmischung, die auf Flächen unterschiedlicher Größe ausgesät wurde, auf einen Index der Gesamtbiomasse der Geschlechtstiere von Hummeln (Männchen und Königinnen) zu erkunden, indem wir replizierte Transekte in jeder Landschaft absuchten. Wir benutzten diesen Index (MQ) als ein Maß für die Reproduktion der Hummeln. Nach Kontrolle d er Blütendichte auf den Transekten fanden wir, dass auf der lokalen Skala MQ während der dreijährigen Untersuchungszeit auf den eingesäten Blühflächen signifikant höher war als auf konventionell bewirtschafteten Kontrollflächen. Während eingesäte Blühflächen den MQ-Index in der umgebenden Landschaft nicht signifikant erhöhten, war MQ in Landschaften, die große (1 ha) Blühflächen umgaben, höher als in Landschaften, die kleinere (0.25 ha) Blühflächen umgaben. Unsere Ergebnisse legen nahe, dass, während die Reaktionen unterschiedlicher Bienenarten in Abhängigkeit von den ausgesäten Arten unterschiedlich ausfallen können, zielorientierte Saatmischungen die Reproduktion von Hummeln steigern können, indem allen Kasten und Geschlechtern aus Nestern in Sammelentfernung lokal attraktive Nahrungsressourcen angeboten werden. Wenn sie in ausreichend großem Maßstab eingerichtet werden, können Blühflächen zu einem merklichen spill-over von reproduzierenden Individuen in die um gebende Landschaft führen.

Desweiteren wurden die Effekte der Blühflächen auf MQ durch den Landschaftskontext vermittelt, wobei die am stärksten positiven Reaktionen in Landschaften mit hohem Anteil von Agrarflächen gefunden wurden. Dies unterstützt frühere Befunde, nach denen AES den größeren Netto-Nutzen für Bestäuber in intensiver bewirtschafteten Landschaften erbringen kann.

Keywords: *Bombus*; Seed mixture; Floral density; Pollinators; Sexual biomass; Foraging; Landscape scale

Introduction

Population declines in many native species within agro-ecosystems have been attributed partly to the loss and fragmentation of suitable habitats resulting from agricultural intensification (Tilman et al. 2001; Winfree, Aguilar, Vazquez, LeBuhn, & Aizen 2009). To mitigate these declines, a number of government-funded agri-environment schemes (AES) have been implemented (European Economic Community regulation 2078/92). These compensate farmers for undertaking farming practices considered favourable to biodiversity, including less intensive management within cropped areas and creating new habitats on uncropped land. AES have been shown to benefit birds, bees, butterflies, and plants, leading to increased species richness and abundance of individuals on focal habitat patches (Carvell, Meek, Pywell, Goulson, & Nowakowski 2007; Pywell et al. 2011, 2012). However, there has been much debate as to whether these local-scale benefits translate to effects on long-term declines in farmland biodiversity (Kleijn & Sutherland 2003; Carvalheiro et al. 2013). In particular, there is little evidence for positive effects of AES on reproduction and population persistence of key taxa.

Bumblebees are a group of conservation concern globally, having undergone widespread declines in range and diversity over recent decades (Williams & Osborne 2009; Cameron et al. 2011). They are key pollinators of native plant species and a variety of crops and, together with other wild bees, may provide insurance against honey bee declines (Winfree, Williams, Dushoff, & Kremen 2007; Garibaldi et al. 2013; Garratt et al. 2014). Bumblebees are eusocial insects with (in temperate regions) an annual colony cycle. Queens establish colonies in spring and their ability to produce new sexuals (males and queens) at the end of the cycle is largely dependent on the availability of floral resources to their worker force within foraging distance of the nest. They therefore require an extensive habitat matrix providing undisturbed nesting sites, accessible foraging resources with a temporal succession of nectar and pollen-rich plants, and mating and hibernation sites (Benton 2006).

The importance of food availability for bumblebee reproduction has been inferred from the earlier appearance of queens at flower-rich sites (Bowers 1985). Studies using laboratory-reared colonies placed in the field have shown positive effects of supplementary food (Pelletier & McNeil 2003) or increased floral resources in the landscape on colony growth and numbers of males produced, but mixed effects on queen production, despite positive correlations between worker number and reproductive success (Westphal, Steffan-Dewenter, & Tscharntke 2009; Williams, Regetz, & Kremen 2012). These studies suggested that spatiotemporal variation in floral resources was a key determinant of reproductive success, and availability of later-season resources could be critical for queen production. Furthermore, bumblebee declines across Europe, particularly in late-emerging species, have been linked to the loss of preferred forage resources such as late-season red clover (*Trifolium pratense*), as a result of agricultural intensification (Carvell et al. 2006; Fitzpatrick et al. 2007; Kleijn & Raemakers 2008; Bommarco, Lundin, Smith, & Rundlöf 2012).

Production of sexuals may therefore be increased in many wild bee species by an increase in food resources available to the provisioning adults. However, since the work of Bowers (1985), few field studies of wild bumblebees have reported counts of sexuals, as opposed to workers. Lye, Park, Osborne, Holland, and Goulson (2009) investigated the effects of habitat management under the Scottish agri-environment scheme on nest-site searching queens during the period of