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Concentrating or scattering management in agricultural landscapes: Examining the effectiveness and efficiency of conservation measures

Martijn Hammers[a,b,*], Gerard J.D.M. Müskens[b], Ruud J.M. van Kats[b], Wolf A. Teunissen[c], David Kleijn[a,b,d]

[a] Resource Ecology Group, Wageningen University, P.O. Box 47, 6700 AA, Wageningen, The Netherlands
[b] Animal Ecology Group, Alterra Wageningen UR, P.O. Box 47, 6700 AA, Wageningen, The Netherlands
[c] Sovon Vogelonderzoek Nederland, P.O. Box 6521, 6503 GA, Nijmegen, The Netherlands
[d] Plant Ecology and Nature Conservation Group, Wageningen University, P.O. Box 47, 6700 AA, Wageningen, The Netherlands

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ABSTRACT

A key issue in conservation is where and how much management should be implemented to obtain optimal biodiversity benefits. Cost-effective conservation requires knowledge on whether biodiversity benefits are higher when management is concentrated in a few core areas or scattered across the landscape, and how these effects vary between species. To address these questions, we examined species-specific behavioural responses of over-wintering farmland birds to enhanced seed availability. In a two-year experiment we first examined the relationship between landscape-scale seed availability and farmland bird density. Then we investigated the relative resource delivery (difference in bird densities between landscapes with and without additional management) and the efficiency (number of individuals supported per unit management) of conservation actions, both at the landscape-scale (*ca* 100 ha) and at the scale of the conservation measures (3.6 ha). The conservation actions were targeted towards ten seed-eating farmland bird species, but we also considered the responses of seven non-targeted and more generalist seed-eating species, seven species that are less dependent on seeds and three species of birds of prey. We found a positive relationship between bird density and landscape-scale seed availability for eleven species and, for four of these species, the slope of this relationship changed before and after a threshold seed density. For two seed-eating specialists, the number of individuals using conservation patches declined with landscape-scale seed availability. In addition, we found that the relative resource delivery declined with landscape scale seed availability for three seed-eating specialists and was independent of landscape-scale seed availability in four other species. Our results suggest that farmland specialists may benefit most from winter food additions if conservation actions result in high landscape-scale seed availability. This may be achieved by concentrating conservation measures or by establishing measures in areas with high baseline seed availability. By contrast, species that can utilize a wider range of habitats and resources may benefit more from scattering measures across larger areas. Therefore, optimal management for the full range of farmland birds in wintertime may require a combination of core areas with concentrated management and more widely distributed smaller patches of conservation measures.

1. Introduction

A key issue in conservation is where and how much management should be implemented to obtain optimal biodiversity benefits, for example in terms of the number of different species supported (species richness) and abundance of those species. With respect to *where* conservation should be targeted, studies examining the effectiveness of conservation on farmland generally find that biodiversity increases are more pronounced in low-quality landscapes supporting moderate biodiversity levels

* Corresponding author. Present address: Behavioural & Physiological Ecology, Groningen Institute for Evolutionary Life Sciences, P.O. Box 11103, 9700 CC Groningen, The Netherlands.
E-mail addresses: m.hammers@rug.nl (M. Hammers), gerard.muskens@wur.nl (G.J.D.M. Müskens), ruud.vankats@wur.nl (R.J.M. van Kats), wolf.teunissen@sovon.nl (W.A. Teunissen), david.kleijn@wur.nl (D. Kleijn).

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than in high-quality, high-biodiversity landscapes (Tscharntke et al., 2005; Scheper et al., 2013; but see Kampmann et al., 2008; Batary et al., 2010). The explanation for this is that in high-quality landscapes, biodiversity in intensively managed sites is being subsidised by the continuous colonisation of species from the surrounding landscape, which may mask any biodiversity responses to management. This is not the case in lower-quality landscapes so that conservation-induced differences in biodiversity can be more easily detected, provided that source populations of target species persist that can benefit from conservation. This hypothesis was originally developed by Tscharntke et al. (2005) using landscape structure as an indicator of landscape quality and species richness as an indicator of biodiversity. However, the theory should apply to any indicator of habitat quality or resource availability and to any indicator of biodiversity (*cf.* Kleijn et al., 2011). This hypothesis therefore predicts that it is more effective to target conservation actions at medium- to lower-quality areas than at high-quality areas.

A study by Hammers et al. (2015) on a functional group of seed-eating farmland birds supported this prediction. They used winter food availability as an indicator of habitat quality and provided additional winter food to improve habitat quality. They demonstrated experimentally that the relative increase (in experimental versus control areas) in resource use of a group of over-wintering farmland birds decreased with increasing food availability in the wider area surrounding the food patches. Intriguingly, they also showed that the density of individuals per ha of management was independent of the amount of food that was already available in the landscape. This finding has important implications for conservation as it suggests that the conclusions regarding the effectiveness of conversation management may differ depending on whether the *relative effectiveness* or the *conservation efficiency* (i.e. amount of biodiversity supported per ha or per €) of conservation measures is considered. Often, studies evaluating conservation actions only consider relative effectiveness by comparing responses on sites with management relative to sites without management (but see e.g. Aebischer and Ewald, 2004; Smart et al., 2014). However, when the cost-effectiveness of management is considered, conservation efficiency may be a more important indicator than the relative increase in the number of individuals.

Linked to this is the issue of *how* to implement management to obtain optimal biodiversity benefits. Conservation activities can improve the ecological quality of agricultural landscapes, but it is currently unknown how much landscape quality – measured in terms of availability of key resources – should be raised to elicit a response. Since ecological processes are often density-dependent, the effectiveness of conservation actions is likely related to the quantity or density of management. However, few studies have specifically examined the relationship between the quantity of conservation actions and its effectiveness (but see Heard et al., 2007; Hinsley et al., 2010; Carvell et al., 2011). It is particularly relevant to test whether responses are proportional to the amount of conservation, whether conservation actions only trigger a response when habitat quality is raised above a threshold, or whether additional conservation actions do not have any effect when habitat quality exceeds a threshold. Cost-effective use of limited conservation budgets also requires knowledge on whether biodiversity benefits are higher when habitat quality is improved in high-quality patches scattered in low-quality landscapes, or when clustered in larger-scale core areas, and how this varies between species (Siriwardena et al., 2006).

Seed-eating birds are among the farmland animal groups that have suffered greatest population declines in recent decades (Fuller et al., 1995; Donald et al., 2001). One of the main causes of their decline is reduced over-winter survival due to insufficient seed availability in winter (Newton, 2004). Conservation actions that are regularly implemented to improve winter food availability include set-aside of farmland, stubble fields, managed field margins and wild bird seed mixtures (e.g. Henderson et al., 2004; Vickery et al., 2004; Gillings et al., 2005). Numerous studies have reported positive behavioural (e.g. habitat use) or demographic (e.g. changes in survival, reproduction or population size) responses of farmland bird species in response to such conservation actions (e.g. Newton, 2004; Siriwardena et al., 2007; Baker et al., 2012). However, little is known about how the intensity and spatial configuration of conservation actions affect how farmland birds respond to improved resource availability (but see Siriwardena et al., 2006). Moreover, most conservation programmes are aimed at preventing further declines of rare or target species (Hoffmann et al., 2010), while common or non-target species may show greatest declines in terms of abundance and biomass (Inger et al., 2015). Therefore, investigating the potential side-effects of conservation actions aimed at rare or target species on common or non-target species is important to 'keep the common species common', which is crucial for the continued functioning of ecosystems.

Here, we examine the relationship between landscape-scale winter seed availability and densities of over-wintering farmland birds and test species-specific behavioural responses to experimental increases in winter seed availability in landscapes representing a gradient in food availability. Specifically, we explore where and how much seed additions should be made to obtain optimal biodiversity benefits and how this differs between species. This work extends our previous work on the factors determining the effectiveness of conservation measures. Hammers et al. (2015) have previously used data from this experiment to test one of the key hypotheses explaining conservation effectiveness (ecological contrast hypothesis, see Kleijn et al., 2011), using a 'guild approach' (the pooled number of individuals of a functional group of ten farmland bird species). The current study differs considerably from our previous work. First, Hammers et al. (2015) have not tested whether and how different species respond to management, which we do in the current study. Specifically, here we investigate relationships between seed availability and densities of 27 targeted and non-targeted farmland species. Despite being more complex than the combined responses of a functional group, such species-specific responses are more useful from an applied conservation perspective (e.g. for conservation practitioners). Second, in the current study we investigate whether scattering or clustering conservation measures represents a more effective conservation strategy, a question not considered in our previous work. Finally, we consider how the conclusions may differ depending on whether this question is studied in terms of relative effectiveness or efficiency.

Although behavioural responses (i.e. birds moving to areas with food) cannot be used to establish whether the conservation actions elicit responses at the population level, they can be used as measures of how many birds benefit from the resources provided by conservation actions (e.g. Siriwardena et al., 2008). The gradient in food availability in our study was largely the result of pre-existing conservation practices targeted towards farmland birds or European hamster (*Cricetus cricetus*). This conservation-induced gradient in food availability allowed us to explore how much food needs to be available before species start responding to management and at which food densities species stop responding (i.e. reach saturation densities). This also allowed us to test whether wintering farmland birds show greater increases in resource use when measures are being implemented in areas that already contain much food or in areas with lower initial food availability. In addition, we examine the relative effectiveness (difference in numbers using the resource in areas with versus without enhanced