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Subtle differences in birds detected between organic and nonorganic farms in Saskatchewan Prairie Parklands by farm pair and bird functional group

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ABSTRACT

Organic farming may be more beneficial to biodiversity than nonorganic farming but the comparison is often confounded by regional within-farm and landscape differences. We compared breeding bird species composition and abundance on 10 farm pairs of each type matched at the site level for land cover in the prairie parklands of Saskatchewan, Canada in 1990. Land cover was measured around bird point counts at two extents; 'site' (6.3 ha area) and 'field' (16.3 ha area). We pooled species into functional groups; linear mixed models showed no significant differences between farm types for species richness but that all birds, migratory birds using crops and aerial insectivores were more abundant on organic farms. A permutational multivariate analysis of variance demonstrated that farm type did not have a significant overall effect on compositional similarity but that pairwise differences existed between about half of the farm pairs (the direction of differences in beta diversity was not consistent between organic and nonorganic farms according to tests for the homogeneity of multivariate dispersions). Farm-pair differences were more pronounced for all birds and for migratory bird species using crops, migratory birds consuming grains and ground feeders, but not grassland birds. *n*MDS ordinations suggested that there was more variation in species composition and abundance on organic farms than nonorganic ones but the difference was not significant. Distance-based redundancy analysis (*db*RDA) was used to examine the main drivers of bird species composition and abundance and to see which extent was most important; land cover at the field extent was more important than land cover at the site extent or the farming practices measured. The most important field-extent land cover was the amount of native grassland, woodland (including shelterbelts) and wetlands. After controlling for significant field-extent land cover, seed treatment, herbicide use, and number of passes were significant. At the site extent, greater non-crop heterogeneity had a significantly positive effect on abundance and species richness of several groups (e.g., grassland birds, migratory granivores, ground feeders, ground nesters) but a negative effect on richness of woodland birds and abundance of aerial insectivores. Relationships with crop heterogeneity were mostly negative and non-significant. Overall land cover heterogeneity at the site level was positively related to the richness of grassland birds. In contrast at the field extent, non-crop heterogeneity did not have any significant effects on the richness and abundance of any functional group. Crop heterogeneity had a significantly negative effect on aerial insectivore richness and abundance. In the early 1990s, differences in birds between organic and nonorganic farms in Saskatchewan were evident but subtle and variable among farms, and apparently most related to land cover-bird assemblage interactions/relationships.

1. Introduction

One way to examine the relative effects of farming practices and land cover on biodiversity is to compare species composition and abundance between farms deploying different management regimes or agri-environment schemes (AESs), such as organic farming, and those that do not. According to reviews (Hole et al., 2005) and meta-analyses (Bengtsson et al., 2005; Tuck et al., 2014), organic farming enhanced biodiversity relative to nonorganic farming in the majority of studies from Europe, North America and New Zealand. Additional, indirect, but compelling evidence for the benefits of organic farming comes from Denmark, where organic farming composes a substantial component (35%) of the farmed landscape and few farmland birds are in decline (Fox, 2004). Here we ask whether organic farming could similarly benefit birds in the Canadian prairies, where grassland species have shown significant, long-term declines in abundance over the last 40

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years (NABCI, 2012) and where the potential benefits of organic farming have not been particularly well studied (but see Beecher et al., 2002; Quinn et al. 2012, 2014 for a similar biome in the United States Great Plains). We also acknowledge the limitations of the benefits of organic farming. For example, it has been argued that any positive biodiversity benefit of organic farming is negated because of lower crop yields, which in turn means that more wild and semi-natural areas must be brought under cultivation to compensate (Seufert et al., 2012). Another issue is that the benefits of organic farming appear to be location-dependent: more benefits accrue from an organic farm located in a more intensively farmed (arable) landscape than in a landscape with lower intensity farming (Brittain et al., 2010; Fischer et al., 2011), and organic farms positioned in landscapes with high heterogeneity may differ from those in landscapes that are homogeneous (Smith et al., 2010). Fourth, whether or not organic farming is beneficial to biodiversity appears to be scale-dependent. For example, Schneider et al. (2014) recently found that the benefit faded from field to farm and regional extents.

Four main explanations have been proposed to account for the benefits to biodiversity of organic farming. First, organic farmers do not use chemical pesticides and inorganic fertilizers, so invertebrate and weed seed food supply for birds is higher than on nonorganic farms (Chamberlain et al., 2010; Winqvist et al., 2012; McKenzie and Whittingham, 2014). In the Canadian Prairies, the widespread adoption of minimum tillage to control soil erosion on nonorganic farms could increase invertebrate food supply for birds but this may be offset by associated increases in herbicide use (Martin and Forsyth, 2003; Awada et al., 2014); by contrast, organic farmers choose to use tillage for weed control, which could increase avian nest mortality (Best, 1986). Second, given their interest in ecologically sustainable agriculture, organic farmers may be more committed to retaining and managing non-crop habitats important to wildlife, such as wetlands and field margins (Fuller et al., 2005; Chamberlain et al., 2010; but see Schneider et al., 2014). This may be partly because there are added economic benefits to retaining non-crop cover as habitat for avian predators of arthropod pests (Kirk et al., 1996). Third, organic farms are more likely to have a mix of livestock and arable farming than nonorganic farms (Fuller et al., 2005; Hole et al., 2005), thus providing a richer diversity of vegetation cover and food sources for birds and leading to higher avian biodiversity (Benton et al., 2003; Billeter et al., 2008). In Europe, organic farms generally have higher land cover heterogeneity than nonorganic ones (Chamberlain et al., 2010) and this can confer benefits to biodiversity, particularly in landscapes with low heterogeneity (i.e. more homogenous landscapes; Smith et al., 2010). Assessing landscape-scale effects, particularly spatial extent (Gabriel et al., 2010; Smith et al., 2010) and also heterogeneity (Benton et al., 2003; Smith et al., 2010; Fahrig et al., 2011; Lindsay et al., 2013) are active areas of research. Fourth, organic and nonorganic farmers generally differ in their choice and rotation of crops. While, nonorganic farmers tend to use simple crop rotations combined with pesticides and inorganic fertilizers, organic farmers deploy complex crop rotations to control weeds and pests and use organic manures instead of synthetic fertilizers (Tuck et al., 2014). Thus organic farms are not only likely to have greater crop landscape heterogeneity, but the temporal variability in crops grown and the use of animal manures may facilitate greater invertebrate diversity and thus increase foraging opportunities for birds. Finally, farm size and shape may influence bird species composition and abundance; small farms generally have higher diversity than large farms (see Belfrage et al., 2005) and this may influence comparisons of organic and nonorganic farming systems. Disentangling these different effects is a major, but necessary, challenge in deciding which management options could best benefit avian biodiversity in farmed landscapes while at the same time minimizing loss of agricultural production.

For this study in the prairie parklands of Saskatchewan, we replicated a paired sampling design we had previously used in Ontario based on matching land cover between organic and nonorganic farms (Freemark and Kirk, 2001; Kirk et al., 2011). Given the findings discussed above, we wished to test whether the effects found on the comparatively small farms in Ontario were the same as in Saskatchewan, where farms were much larger. In Ontario, farms averaged 79 ha in 1991, with mixed management regimes (livestock and arable), and often interspersed with hedgerows and woodlots. By contrast, in Saskatchewan, farms averaged 242 ha in 1991, with much bigger fields, often bordered by shelterbelts.

During the 1970s, ploughing of pastures for grain crops and urban development resulted in extensive destruction of native grassland in the prairies (Samson and Knopf, 1994). As a consequence, only 25% of the original 23 million ha of native grasslands remain (Samson and Knopf, 1994; Hammermeister et al., 2001). While the croplands and managed grasslands that replaced native grassland provide surrogate habitats for many grassland bird species (Davis et al., 1999; Fletcher and Koford, 2002; Davis, 2004), the farming practices carried out in these landscapes may be detrimental (With et al., 2008). These include pesticide applications (Mineau et al., 2005), field operations such as haying (Perlut et al., 2006; Norment et al., 2010), greater reliance on large machinery, and the larger field sizes that are concomitant with the expansion of modern farming (Rodenhouse et al., 1995). Use of certain insecticides has been linked to extensive bird mortality in western Canada (e.g., granular formulations - Mineau et al., 2005, and more recently, neonicotinoids– Mineau and Palmer, 2013) and to grassland bird population declines in the United States (Mineau and Whiteside, 2013), though loss of grassland appears to be a bigger factor (Hill et al., 2014).

Because Saskatchewan supports 11 of the 12 primary and 17 of the 25 secondary endemic grassland birds in North America (Knopf, 1994, 1995), it is important to determine the influence of agricultural management schemes on these species. In this paper, we test various predictions about the relative influence of farming practices versus the composition, heterogeneity and spatial extent of habitat on farmland birds from an historical dataset collected in the early 1990s. We considered effects both for birds overall and for functional groups because effects can vary both in magnitude and direction among subgroups within taxa (Smith et al., 2010; Birkhofer et al., 2014). However, in this study, in contrast to that in Ontario, we used only territorial bird species because of the prevalence of flocking species, and examined land cover at two spatial extents. Spatial extent is important because grassland birds respond to their habitat at multiple scales (Koper and Schmiegelow, 2006; Bakker et al., 2008). Moreover, the larger the area sampled for vegetation, the more vegetation types are included because of the relationship between area and heterogeneity. At the time of our original study the importance of spatial extent was only just being recognized (Wiens, 1989). We included two spatial extents that at the time seemed relevant to us for the area surveyed for birds and for management purposes.

Although based on an historical dataset, our work is still highly relevant and timely to the overall question of the benefits to biodiversity of organic farming. First, whether organic farms are beneficial to biodiversity in North America is still relatively unstudied compared to Europe. The reason for this, at least in Canada, may be because of the low proportion of land in organic production compared to Europe. Second, although the acreage farmed organically in Canada has increased from what it was in the 1990s when it was 0.16% of the farmed acreage, it is still only about 2% currently (Macey, 2000; Frick, 2012; Statistics Canada, 2015). This is unlikely to have any substantial impact on regional bird species distribution and abundance. Third, farmland birds in the prairies are showing widespread, long-term declines (as they are globally) and there is continued interest in testing the efficacy of AESs, such as organic farming, in conserving avian biodiversity and reversing trends in declining species. Fourth, many European studies have used an index approach to diversity (species richness, species diversity; e.g., Schneider et al., 2014; Tuck et al., 2014) without the additional multivariate, multi-species measures of