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Are buntings good indicators of agricultural intensity?

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ABSTRACT

Numerous countries in Western Europe have experienced a dramatic decline in their yellowhammer (*Emberiza citrinella*), corn bunting (*E. calandra*) and ortolan bunting (*E. hortulana*) populations. Data from the Common Breeding Bird Survey in Poland were used to examine the response of bunting population densities to agricultural intensification at different spatial scales. The results suggested that buntings preferred habitats that differed from those that are characteristic of Western Europe. Although yellowhammers preferred extensive agricultural areas, corn and ortolan buntings reached maximum densities in intensively managed farmland. In addition, both species preferred different woodlot structures and crop types. All studied bunting species exhibited non-linear responses to agricultural intensification. Under certain conditions, agricultural intensification may increase bunting population densities (especially for corn buntings). More generally, we provided a description of how complex patterns of bunting occurrence in agricultural landscapes may serve as indices of agricultural intensification in Europe.

1. Introduction

Over the past few decades, farmland bird populations have been declining in nearly all European countries (Krebs et al., 1999; Donald et al., 2001; Newton, 2004). The largest reductions were documented in the United Kingdom, where from 1979 to 1999 about ten million breeding individuals of ten different bird species disappeared (Krebs et al., 1999). All of these bird species (e.g., skylark *Alauda arvensis*, linnet *Carduelis cannabina* and tree sparrow *Passer montanus*) were associated with agricultural landscapes. Indices of population changes aggregated for 22 common farmland bird species also suggested a decline in Poland (Chylarecki and Jawińska, 2007). While afforestation of agricultural lands, landscape fragmentation, urbanisation, climate change and increased predation were possible causes for this decline, agricultural intensification has been the most widely accepted explanation for the loss of farmland biodiversity in Europe (Krebs et al., 1999; Donald et al., 2001; Benton et al., 2003; Newton, 2004; Báldi and Faragó, 2007).

Buntings are small, seed-eating passerines, but the diet of nestlings is largely composed of a wide variety of invertebrates (Stoate et al., 1998). Many studies conducted in Western (W) and Northern (N) Europe showed that buntings were commonly associated with extensively managed farmlands (e.g. Fuller et al., 1995; Lilleør, 2007; Fox and Heldbjerg, 2008). However, European regions differ significantly in their agricultural characteristics. Western and North-Western (NW) European countries have been dominated by intensive farming practices, homogeneous landscapes and high levels of productivity (Donald et al., 2001; Reif et al., 2008). The agriculture in Mediterranean region has been characterised by diverse farming practices, extensively managed farmland areas and complex heterogeneous landscapes (Concepción et al., 2008; Morgado et al., 2010). In Central-Eastern (CE) Europe, farming and traditional agriculture have remained unchanged for decades (Tryjanowski et al., 2011), whereas agricultural intensification and abandonment of arable fields nowadays occur simultaneously (Stoate et al., 2009; Tryjanowski et al., 2011).

Most of our knowledge of how farmland birds respond to agricultural intensification was derived from studies conducted in regions other than CE Europe. However, some studies showed that long-term trends of farmland bird populations (e.g., skylark, barn swallow *Hirundo rustica* and white wagtail *Motacilla alba*) differed between W and CE Europe (Voříšek et al., 2007; Klvaňová et al., 2009). After the collapse of socialism, agricultural output crashed in CE European countries, whereas for 15 EU countries, agricultural output levels continued to increase (Donald et al., 2001). Although

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farming intensity has increased since 1991, CE European countries had lower levels of agricultural productivity at that time and have grown more slowly than other countries in W and NW Europe. These different rates of agricultural intensification have generated distinct areas in Europe that differ in the structure and composition of their farmland landscapes. We hypothesised that bunting populations from W and CE Europe may respond in a manner that reflects the historically different rates of agricultural intensification in these regions.

The main goals of this study were: (1) to examine how agricultural intensification affected densities of yellowhammers (*Emberiza citrinella*), corn buntings (*E. calandra*) and ortolan buntings (*E. hortulana*); (2) to evaluate the utility of these species as indicators of agricultural intensification. We studied agricultural intensification at two levels: landscape structure and on agricultural production directly. Furthermore, we discussed reasons for the differential response of buntings to agricultural intensification in W and CE Europe and proposed a hypothesis, consistent with our results that explained these differences.

2. Materials and methods

Data on bird numbers were collected from the Common Breeding Bird Survey (CBBS) in Poland from 2008 to 2010. Study plots were 1 km × 1 km squares distributed randomly throughout the country. Fieldwork was carried out by volunteers on 546, 560 and 593 study plots in 2008, 2009 and 2010, respectively. During the fieldwork, volunteers walked along two parallel 1 km-long transects situated approximately 500 m apart and classified all birds that were seen or heard into three categories of distance from the transect line (<25, 25–100, >100 m). Observers counted birds twice per season each year. The first survey took place between April 10 and May 15; the second survey between May 16 and June 30. Both visits were separated by at least four weeks. Each survey started in the morning hours, usually between 6:00 and 7:00 a.m., and no later than 9:00 a.m. (Chylarecki and Jawińska, 2007).

Only plots where at least one bunting species was observed twice from 2008 to 2010 (i.e. a total of 450) were analysed. Breeding densities of yellowhammer, corn bunting and ortolan bunting (estimated for each year of the study and each survey plot) were calculated using the software DISTANCE 6.0 release 2 (Thomas et al., 2010). A half-normal model with no adjustments was selected. Data outside the range of 100 m contained observations of unknown distance and were excluded from density estimations. Average breeding densities (mean densities from 2008 to 2010) of each species for all study plots were calculated. Breeding densities were not normally distributed and were therefore log transformed prior to data analysis.

2.1. Landscape data

Data on land use in each study plot were derived from the CORINE Land Cover 2006 (CLC) database (European Environment Agency, 2007). Vector layers were re-projected to the PUWG-1992 coordinate system and aggregated to 1-km resolution (which corresponds to the resolution of a single study plot) in QuantumGIS 1.7.1 software (Quantum GIS Development Team, 2011). Seven variables were used to describe land use types (Table 1). Landscape characteristic was calculated using Fragstat ver. 3.3 software (McGarigal and Marks, 1995).

On each study plot, we manually digitised small-scale habitat elements using QuantumGIS 1.7.1 software based on orthophotomaps created from aerial photographs, which were taken in 2009 in Poland and provided by the National Spatial Data Infrastructure (Table 1).

Table 1
Habitat variables used to investigate relationships between buntings densities and the structure and composition of agricultural landscape in Poland.

Variable	Description [units]
Land use	
CLC.1	Urban areas [ha]
CLC.211	Non-irrigated arable lands [ha]
CLC.222	Fruit trees and berry plantations [ha]
CLC.231	Grasslands and pastures [ha]
CLC.242	Complex cultivation patterns [ha]
CLC.243	Land principally occupied by agriculture, with significant areas of natural vegetation [ha]
CLC.31	Deciduous, coniferous and mixed forests [ha]
Landscape characteristic	
SHAPE	Index of agricultural areas shape (mean habitat patch perimeter divided by the minimum perimeter possible for a maximally compact habitat patch)
SHDI	Land cover diversity index (Shannon's diversity index calculated for all habitat patches on each study plot)
Small-scale habitat elements	
Alleys	Length of tree alleys, i.e. Planted trees along straight roads [km]
Forest.roads	Length of roads surrounded by forests [km]
Field.roads	Length of ground roads surrounded by arable lands [km]
Per.forest	Length of forest edges [km]
Tree.clumps	Length of tree clumps, i.e. Small-scale clusters of trees surrounded by fields, measured along the longer axis [km]
Shrubs	Length of shrubs grown wild between fields [km]
Trees	Number of solitary trees

2.2. Agricultural data

Agricultural data came from the National Agricultural Census (NAC) conducted between September 1st and October 31st, 2010, by the Central Statistical Office in Poland. The NAC database included information about land use and sown areas of particular crop types, livestock populations, fertilisers, etc., obtained from approximately 1.7 million farms (Central Statistical Office, 2011). Originally, data sets were aggregated to various territorial units and expressed at various spatial scales. To unify the spatial scale of all of the variables characterising agriculture, only data aggregated to the commune level, the basic unit of administration in Poland, were used. In total, 18 variables describing agriculture characteristics were used (Table 2).

2.3. Statistical analysis

To assess how agricultural intensification affected bunting densities, two separate Canonical Correspondence Analyses (CCA) were performed. First, variation in bunting densities was explained by variables relating to land use, landscape characteristics and small-scale habitat elements (Table 1). In the second CCA, we examined how agricultural intensification gradients, extracted from variables directly describing farming practices (Table 2), explained variation in bunting densities. In addition to ordination analysis, Species Response Curves (SRC) for all species were estimated to examine how buntings responded to intensification gradients.

The CCA was performed in Canoco for Windows 4.5 software (Lepš and Šmilauer, 2003). Significance of canonical axes was tested separately for the first axis and for all axes jointly, based on Monte Carlo permutation tests (1000 permutations for each test) implemented in Canoco. The Species Response Curves were estimated in CanoDraw for Windows 4.1 (ter Braak and Šmilauer, 2002) based