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The varying impact of agri-environment schemes on birdlife in two regions of Poland

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The implementation of agri-environment schemes (AES) in Poland began in 2004, yet the effects of their implementation were not systematically monitored until 2010. Using monitoring data collected in 2011 from two regions of Poland, the foothills and the lowlands, we examined the impact of environmental variables and the AES on 1) the number of species, 2) the number of territories of all breeding species, 3) the number of territories of target species for bird-oriented AES, and 4) the numbers of territories of the eight most frequent farmland species. More species and a larger number of territories were recorded in the lowland study plots than in the foothill ones. The proportion of land covered by AES on the study plots had no impact on the number of species or the numbers of territories of all species in either region. Furthermore, the relationship between the number of territories of target species and the proportion of land covered by AES in the lowland region was negative. Environmental variables significantly affected the numbers of territories of two numerous farmland species in the foothill region and three species in the lowlands. The implication of these results is that the AES dedicated to bird conservation need further assessment. To be more effective, the AES have to allow for regional variation; they definitely require further, detailed study.

1. Introduction

The agri-environment programme has been implemented in the European Union (EU) since 1993 and has been obligatory since a subsequent reform of the Common Agricultural Policy in 2003. Its aim is to counteract the negative effects of intensive agriculture on the environment by providing financial incentives to farmers for adopting environmentally friendly agricultural practices through agri-environment schemes (AES). The EU budgetary spending on agri-environmental measures has increased rapidly since 1993, exceeding 3 billion in 2010 (European Commission 2012). In 2007–2013, 23 billion of EU funds were spent on agri-environment measures covering 46.9 million hectares (European Commission 2015), the intention being to make AES a major tool for protecting biodiversity in farming areas across Europe.

In spite of their nearly quarter-century-long history of AES, their effectiveness remains contentious, even though they have been the subject of many studies carried out in Western Europe (Kleijn *et al.* 2001, Whittingham 2007, Concepcion *et al.* 2008). AES also falls within the sphere of interest of decision-makers and the general public (Morris *et al.* 2000, Donald & Evans 2006). AES have not always achieved their aims. In the case of birdlife, the effects of AES have been positive, negative or zero (Kleijn *et al.* 2001, Whittingham 2007, Broyer 2011, Princé *et al.* 2012). Quite a number of AES, particularly in the first years of their implementation in various countries, were so poorly monitored that any positive effect could well have gone unnoticed. Others were introduced in areas where biodiversity was already at a relatively high level, so the effect of AES would have been scarcely measurable. Nevertheless, it is AES targeting particular species that have resulted in larger populations of Cirl Bunting (*Emberiza cirlus*; Peach *et al.* 2001), Stone Curlew (*Burhinus oedicnemus*) and Eurasian Skylark (*Alauda arvensis*; Evans & Green 2007) in England, and have reversed the declining trend in populations of several other species in Great Britain (Vickery *et al.* 2004, Perkins *et al.* 2011) and Switzerland (Roth *et al.* 2008).

Few studies have yet assessed the effectiveness of AES in the central-eastern European countries that acceded to the EU in 2004 (Elts & Lõhmus 2012, Marja *et al.* 2014, Żmihorski *et al.* 2016a). There is, therefore, an urgent need for such studies and for comparisons with results achieved by the EU 15 (member states before 2004). This is also because it has become abundantly clear that the management solutions developed mainly in Western Europe should not be used as a blanket prescription for the whole of Europe (Tryjanowski *et al.* 2011, Sutcliffe *et al.* 2015). Tworek (2010) points out that analyses of correlations between species occurrence and characteristics of habitats, landscapes and even farmland management may yield different results, depending on the scale of the research, and that more accurate results are obtained at a regional level than at higher, e.g., nationwide, levels. The fact is, however, that species protection programmes and AES are most often implemented at the nationwide level and assume that their influence on target species is similar across the entire range of influence of a given programme or scheme (Sanderson *et al.* 2016). Relatively little explored in farmland systems (Whittingham 2007), this assumption needs to be addressed in greater detail, especially since Kleijn *et al.* (2004) infer from their research that AES aimed at particular species and limited to a particular region instead of the entire country are more effective.

Implementation of AES in Poland started after the country acceded to the EU in 2004. The programme for 2007–2013 comprised of two AES targeted at endangered bird species and habitat types: one was started at Natura 2000 sites (package 5), the other at non-Natura 2000 sites (package 4). One of the variants of both packages (4.1 and 5.1) involved protecting breeding habitats of birds. The aim of this variant was to protect the nesting habitats of 10 bird species, henceforth referred to as the target species: Dunlin (*Calidris alpina*), Montagu's Harrier (*Circus pygargus*), Northern Lapwing (*Vanellus vanellus*), Corncrake (*Crex crex*), Great Snipe (*Gallinago media*), Common Redshank (*Tringa totanus*), Common Snipe (*Gallinago gallinago*), Black-tailed Godwit (*Limosa limosa*), Eurasian Curlew (*Numenius arquata*) and Aquatic Warbler (*Acrocephalus paludicola*). In Poland, the species on this list are predominantly characteristic of permanent grasslands, fresh and marshy meadows situated mostly in river valleys.

The species supported as part of these variants nest on the ground or in the herb layer, and too early mowing or too extensive cattle grazing can result in the destruction of their clutches. On the other hand, the abandonment of land to permanent grassland leads to the degradation of these birds' nesting sites. Therefore, the requirements involved in variants 4.1 and 5.1 (hereafter referred to as the bird package or the bird AES) aimed to adapt the use of these areas to the needs of species nesting on meadows and pastures. A piece of land covered by the bird package could be used as a meadow, a pasture or a combination of both. The most important requirements of the bird package included late mowing (between August 1st and September 30th), leaving 5–10% of the land unmown and keeping the maximum livestock density under

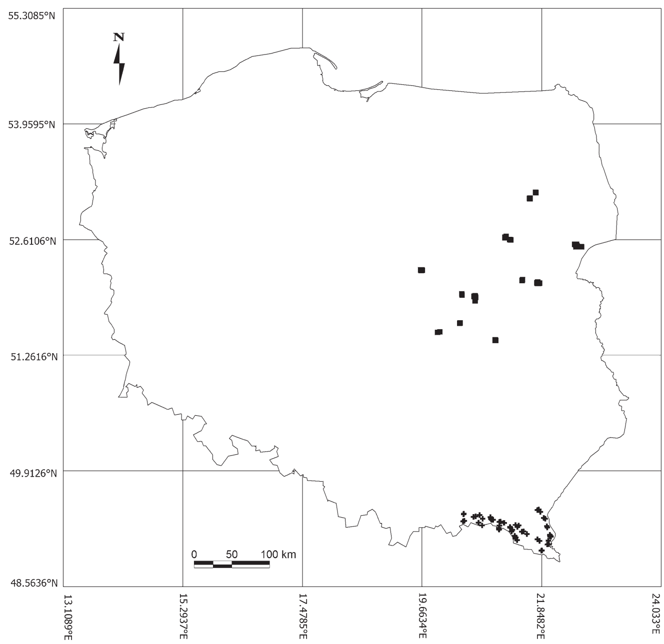

Fig. 1. Distribution of research plots in two regions of Poland: squares–lowland plots, crosses–foothill plots.

control (less than 0.5 livestock units per hectare, where 1 livestock unit is equivalent to one cow) in cases where the land is grazed rather than mown. In addition, such farming practices as tilling, sowing, fertilization and chemical plant protection were prohibited on land subject to AES during the breeding season, nor was the construction or improvement of drainage systems permitted.

In 2011, a programme was initiated at the nationwide level to improve the natural environment and natural resources in Poland. One of the priorities of this programme was to monitor the effects of AES on the environment. The objective of the bird monitoring carried out as part of the programme was to assess the influence of bird-oriented AES on the populations of 10 target bird species and on populations of other farmland species nesting in meadows and pastureland. We used the monitoring data from 2011 to assess 1) the impact of AES on the number of bird species and territories, including the target species (see above), in two regions of Poland that have different physical geographical characteristics; and 2) the impact of different environmental variables on the number of bird species and the number of territories across all birds and particular species. We analysed the occurrence of birdlife in the context of the habitat components existing on the study plots. We considered grassland area, length of drainage ditches, woodlot area and the number of single trees that are the main characteristics of these landscapes and are known to affect bird assemblages (e.g., Marja & Herzon 2012, Wilson *et al*. 2014).

2. Material and methods

2.1. Study area and research plots

Our studies were carried out between April 15th and July 15th, 2011 in two regions of Poland: a lowland region (CE Poland) and a foothill region (SE Poland). Both regions are characterized by a relatively low intensity of farming and by a mosaic-like landscape, so they are important for the occurrence of farmland birds in Poland (Kuczyński & Chylarecki 2012). On the other hand, the regions differ in their topography, soil type, distribution of habitats, and altitude: the lowland plots were situated between 64 and 154 m amsl. whereas the foothill plots lay between 445 and 794 m amsl.

The research plots were randomly selected from a grid of 300 x 300 m squares (area 9 ha), on permanent grasslands. A minimum distance of 300 m was used when selecting the sampling plots. Squares occupied by permanent grasslands to the greatest possible extent (minimum 50% of the area) and covering, at least partly, land included in the bird AES were taken into account in the selection. Altogether, 115 such plots were selected: 58 in the foothills and 57 in the lowlands (Fig. 1).

2.2. Bird counts

Data relating to the occurrence of birds, i.e., the number of species, the total number of breeding territories, and the number of territories of target species, were gathered using spot mapping. Five counts were carried out by 21 experienced ornithologists at fixed time intervals during the season: three daytime and two night-time counts. The daytime counts were carried out in the following periods: April 15th–April 30th, May 15th–May 31st and June 15th–June 30th. They began one hour after sunrise and were continued until 10:00 hrs at the latest. The night-time counts were carried out between May 15th and May 30th and again from July 1st to July 15th. Carried out primarily to find Corncrakes, these nocturnal visits took up to three hours, starting at dusk, in accordance with the census techniques recommended for this species (Bibby *et al.* 2000). During one morning, two study plots were censused. The standard rules for recording birds in the field were applied in accordance with the territory mapping method (Bibby *et al.* 2000). The only difference was at the stage of estimating the number of breeding territories: the highest number of territories occupied by calling males within the borders of a study plot recorded during all counts served as the estimated number of territories in that plot.

2.3. Environmental variables

The study plots included a number of aspects that could have affected the numbers of birds. Even though most of the areas studied were permanent grassland (including AES areas), they also supported woodlots and single trees, which can shape bird assemblages to a significant extent (Tworek 2007, 2010). Drainage ditches can strongly influence numbers and distributions of birds (Marja & Herzon 2012). The analysis of the occurrence of birds thus took these environmental variables into account. All the variables (see the list below) present in the plots were recorded directly in the field on completion of the second daytime count. 1:3,000 scale aerial photographs were used to detail these variables. These data were then digitized and saved as vector files (.shp). Based on them, the environmental variables were calculated as:

– number of single trees (number per plot),
– length of ditches (metres),
– area of grasslands (hectares)
– area of woodlots (hectares).

Data on surface areas and land distributions under the bird AES (hectares) were obtained from the Agency for the Restructuring and Modernization of Agriculture, designated to implement agricultural policy in Poland.

2.4. Statistical analyses

We applied the *t*-test to analyse the number of bird species, the total number of breeding territories, and the number of territories of target species among the 9 ha plots situated in the lowland and foothill areas. The variables were not transformed because their distribution did not deviate markedly from the normal.

Then we applied generalized least squares regression (GLS) using R (R Development Core Team 2015) with the "nlme" library, which enables control of the spatial autocorrelation effect. The number of bird species, the number of breeding territories and the number of territories of target species were treated as response variables, while the number of individual trees, the length of ditches, the area of grasslands, the area of woodlots, and the surface area of the bird AES (Table 1) were used as predictors.

We developed two sets of GLS, separately for the foothill and lowland regions. In each case we considered only full models (without selection methods of models and/or predictors). In the first step, we developed models for each response variable using the linear structure without the spatial autocorrelation effect. Then, the residuals of the models were checked with regard to the residual spatial autocorrelation using Moran's I statistics and the variogram procedure (library: ape for R, Paradis 2016). Moran's index varies between –1 and 1, with non-significant values close to zero (Legendre & Legendre 1998, Rosin *et al*. 2012). The variogram describes the measure of dissimilarity (semivariance) against the distance and di-

Table 1. Habitat characteristics of the study plots (9 ha each). Variables used: Trees – number of single trees, Ditches – length of ditches, Grasslands – area of grasslands, Woodlots – area of woodlots, Birdscheme – area covered by the bird package.

Variable	Foothill plots, *n* = 58				Lowland plots, *n* = 57			
	Mean	SE	Min	Max	Mean	SE	Min	Max
Trees (number per plot)	6.5	1.1	0	42	6.5	1.4	0	56
Ditches (m)	175.3	32.1	0	1,061	597.9	52.9	0	1,358
Grasslands (ha)	7.96	0.11	5.87	9.00	8.17	0.11	4.66	9.00
Woodlots (ha)	0.92	0.11	0	2.99	0.48	0.08	0	2.98
Birdscheme (ha)	4.34	0.35	0.09	8.95	1.94	0.27	0	7.83

rection of separation (lag vector; Webster & Oliver 2007). Spatially uncorrelated data display no observable change in semivariance with increasing lag distance (flat variogram, or more irregular but not increasing), while spatially correlated data are represented by a monotonically increasing semivariance as the lag distance between sites increases (Naura *et al*. 2016). In cases where spatial autocorrelation occurred, we developed a new full GLS model in which we added a spatial autocorrelation structure (correlation = corSpatial) with latitude and longitude to the model framework. With that procedure, part of the variation of a response variable is explained by geographical location, which in turn makes the residuals in the model spatially independent (Żmihorski *et al*. 2016b).

The same procedure (full models) was used to assess the impact of the same five environmental variables on the number of territories of the eight most numerous farmland bird species: Common Whitethroat (*Sylvia communis*), Yellowhammer (*Emberiza citrinella*), Whinchat (*Saxicola rubetra*), Meadow Pipit (*Anthus pratensis*), Marsh Warbler (*Acrocephalus palustris*), Red-backed Shrike (*Lanius collurio*), Common Quail (*Coturnix coturnix*) and Corncrake, the last-mentioned being the only target species.

3. Results

3.1. Comparison of avifauna parameters in two regions of Poland

A total of 101 breeding species were found, with 80 species in the lowlands and 76 in the foothills. On average, 13.6 species per plot were found in the foothills (SD = 5.18, $n = 58$), whereas 16.0 species per plot were found in the lowlands (SD = 5.37, $n = 57$, $t = 2.52$, $df = 113$, $p = 0.013$). The average combined number of breeding territories of all species was 26.2 (SD = 9.67) per plot; 22.2 territories were recorded in the foothill plots (SD = 8.15) and 30.4 territories in the lowland plots (SD = 9.38, $t = 5.02$, $df = 113$, $p < 0.001$). On average, 2.8 breeding territories of target species per plot (SD = 1.85) were recorded in the study areas: 2.0 territories (SD = 1.27) in the foothills and 3.6 territories (SD = 2.03) in the lowlands, a statistically significant difference ($t = 4.90$, $df = 113$, $p < 0.001$).

3.2. Effect of environmental variables and bird package proportion on avifauna parameters

For the foothill models we did not find any residual spatial autocorrelation effect for the number of bird species ($I = –0.01$, $p = 0.920$) or for the number of breeding territories ($I = 0.08$, p = 0.612), but spatial correlation did occur ($I = 0.15$, $p < 0.001$) for the number of territories of target species. For the lowland models, Moran's I and the variogram confirmed autocorrelation in all cases: the number of bird species ($I = 0.20$, $p = 0.006$), the number of breeding territories ($I = 0.18$, $p = 0.010$) and the number of territories of the target species ($I = 0.12$, $p = 0.050$).

The environmental variables under consideration had a statistically significant influence on bird parameters only in the lowlands (Table 2). The number of species in the lowlands increased with the area of woodlots in the plot (Estimate =

Table 2. Results from a GLS analysis examining the effect of different environmental variables on the number of breeding species, the number of territories and the number of breeding territories of the target species in two regions (foothills and lowlands) of Poland. The statistically significant results are in bold. See Table 1 for description of variables.

Parameter / Predictor	Foothill (n = 58)				Lowland (n = 57)			
	Model type	Estimate	SE	P	Model type	Estimate	SE	P
Number of breeding species								
Trees	1)	0.093	0.060	0.128	2)	0.056	0.065	0.391
Ditches	1)	–0.000	0.002	0.831	2)	–0.000	0.002	0.893
Grasslands	1)	–3.200	2.438	0.195	2)	0.861	1.166	0.469
Woodlots	1)	1.103	2.482	0.658	2)	**3.510**	**1.604**	**0.035**
Birdscheme	1)	0.065	0.197	0.743	2)	–0.272	0.326	0.407
Number of breeding territories								
Trees	1)	0.091	0.111	0.417	2)	–0.051	0.118	0.664
Ditches	1)	0.001	0.003	0.665	2)	–0.002	0.003	0.451
Grasslands	1)	–2.906	4.496	0.520	2)	0.900	0.429	0.669
Woodlots	1)	1.858	4.577	0.685	2)	5.062	2.888	0.080
Birdscheme	1)	–0.460	0.364	0.212	2)	–0.630	0.588	0.288
Number of breeding territories of the target species								
Trees	2)	–0.000	0.020	0.967	2)	0.007	0.025	0.764
Ditches	2)	0.001	0.000	0.138	2)	–0.000	0.000	0.273
Grasslands	2)	–0.248	0.825	0.764	2)	0.592	0.432	0.176
Woodlots	2)	–0.484	0.840	0.566	2)	0.452	0.611	0.462
Birdscheme	2)	–0.032	0.066	0.631	2)	**–0.420**	**0.130**	**0.002**

1) No spatial autocorrelation model
2) Spatial autocorrelation model

3.51, t = 2.19, p = 0.035, Fig. 2). On the other hand, the number of target species territories decreased as the land under permanent grass covered by the bird package in the study plot increased (Estimate = –0.42, t = –3.20, p = 0.002, Fig. 3).

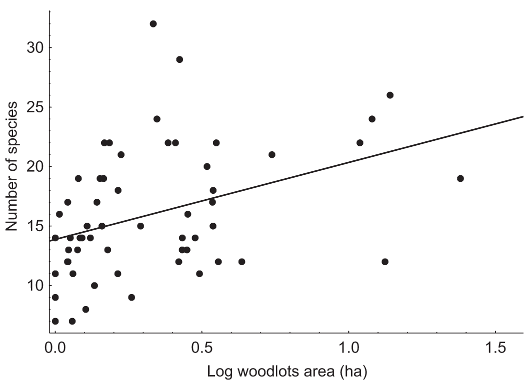

Fig. 2. The relationship between the woodlots area (logarithmically transformed) and the number of species on lowland plots in Poland.

3.3. Effect of environmental variables and bird package proportion on individual bird species

We found spatial autocorrelation in the foothill and in the lowland regions for the number of territories of Common Whitethroat (I = 0.12, p = 0.006, and I = 0.27, p < 0.001, respectively), Corncrake (I = 0.13, p = 0.003, and I = 0.14, p = 0.040 respectively), Red-backed Shrike (I = 0.28, p = 0.001, and I = 0.16, p = 0.002, respectively) and Marsh Warbler (I = 0.08, p = 0.020, and I = 0.19, p = 0.005, respectively). In the cases of Whinchat (I = –0.04, p = 0.640, and I = 0.13, p = 0.050) and Yellowhammer (I = 0.07, p = 0.080, and I = 0.28, p < 0.001) autocorrelation occurred for the lowland region only, while Common Quail (I = 0.15, p = 0.007, I = 0.11, p = 0.100) and Meadow Pipit (I = 0.11, p = 0.008, I = 0.10, p = 0.130) were spatially autocorrelated in the foothills.

The number of territories of particular species showed contrasting relationships to the environ-

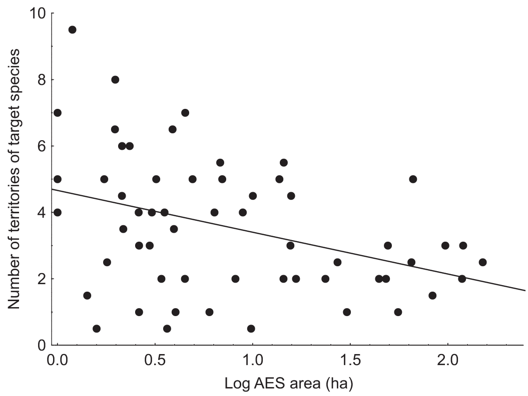

Fig. 3. Dependence between the area covered by the AES (logarithmically transformed) and the number of breeding territories of the target species on lowland plots in Poland. Target species include Dunlin, Montagu's Harrier, Northern Lapwing, Corncrake, Great Snipe, Common Redshank, Common Snipe, Black-tailed Godwit, Eurasian Curlew and Aquatic Warbler.

mental variables between the foothills and the lowlands, certain environmental variables being significant in one region only (Table 3). The numbers of Red-backed Shrike and Yellowhammer territories increased with the proportion of tree coverage in the lowland plots (Table 3). The number of Yellowhammer territories in the lowland plots also increased with the size of meadows covered by the bird package (Table 3). In addition, the number of territories of Marsh Warbler in the foothill plots and those of Whinchat and Common Quail in the lowland plots increased with drainage ditch length (Table 3). None of the environmental variables had an effect on the Common Whitethroat, the Corncrake or the Meadow Pipit in the foothill region or the lowlands.

4. Discussion

4.1. The effect of AES areas on bird assemblages and species

We expected that the target species, to which AES are aimed at, would be positively correlated with the grassland areas covered by the AES. The present study did not confirm this. Moreover, the relationship between target species and the covered by the AES was negative in the lowland region. It should be remembered that 2011 was the first year when AES were implemented. Thus, birds might simply not have had sufficient time to respond to the changes in the usage of these areas. Be that as it may, studies done in Poland in 2013–2014 (3–4 years after the initial implementation of AES) did not demonstrate any effects of AES on the occurrence of target species either; indeed, species richness actually decreased with increasing proportions of AES grassland (Żmihorski *et al*. 2016a). It is very likely, then, that the reason for the absence of any effect of AES grassland or even a negative relationship with the occurrence of target species should be sought in the populations of species inhabiting the farming landscape in Poland, which are in any case relatively numerous as a consequence of its extensive management and the mosaic-like diversity of habitats (Tryjanowski *et al.* 2011). The study plots, as well as their immediate surroundings, included a wide diversity of meadows and pastures, where the more intensively used plots were adjacent to extensively used and unused plots, making up a mosaic of habitats of diverse plant density and height. Such a spatial arrangement of habitats gives birds an opportunity to nest on extensively used or irregularly mown meadows, whilst they may use the intensively farmed areas as feeding grounds (Schifferli 2001, Żmihorski *et al*. 2016a).

We assume that, at the scale of our studies, a mosaic of grassland habitats differing in quality and management adjacent to the study plots may have been of greater importance for birds than the AES as such. This has not been demonstrated in the literature directly, although some authors have pointed out the importance of meadow quality diversification (e.g., Báldi *et al.* 2005, Sanderson *et al.* 2009, Berg *et al.* 2015) and sward structure (Devereux *et al.* 2006, Elts *et al.* 2015) to breeding birds. On the other hand, the differences between the two regions, i.e., the negative influence of AES on the target species in the lowlands and its zero effect in the foothills could have been due to the differences in the numbers of these species between the regions: there were 1.8 times as many species in the lowlands as in the foothills. The minimal variability in numbers of the bird assemblage in the foothills may have been insufficient to show up any effect whatsoever of AES.

Table 3. Results from a GLS analysis examining the effect of different environmental variables on the number of breeding territories (*n* = bp.) of selected bird species in two regions (foothills and lowlands) of Poland. Statistically significant results are in bold. See Table 1 for description of variables.

Species /Predictor	Foothill (*n* = 58)				Lowland (*n* = 57)			
	Model type	Estimate	SE	*P*	Model type	Estimate	SE	*P*
Red-backed Shrike								
Trees	2a)	–0.005	0.019	0.758	2c)	0.018	0.010	0.082
Ditches	2a)	–0.001	0.000	0.105	2c)	–0.000	0.000	0.525
Grasslands	2a)	–0.147	0.774	0.849	2c)	0.298	0.178	0.099
Woodlots	2a)	0.070	0.784	0.920	2c)	**0.587**	**0.249**	**0.022**
Birdscheme	2a)	–0.005	0.060	0.923	2c)	–0.052	0.052	0.327
Marsh Warbler								
Trees	1a)	–0.019	0.023	0.410	2d)	–0.005	0.018	0.773
Ditches	1a)	0.000	0.000	0.925	2d)	**0.001**	**0.000**	**0.014**
Grasslands	1a)	–0.411	0.952	0.667	2d)	0.410	0.315	0.199
Woodlots	1a)	–0.519	0.965	0.592	2d)	0.004	0.443	0.992
Birdscheme	1a)	–0.024	0.075	0.752	2d)	0.070	0.094	0.457
Whinchat								
Trees	1b)	–0.017	0.016	0.312	1d)	–0.002	0.022	0.893
Ditches	1b)	**0.001**	**0.000**	**0.004**	1d)	–0.000	0.000	0.587
Grasslands	1b)	0.562	0.673	0.407	1d)	–0.264	0.327	0.422
Woodlots	1b)	–0.010	0.685	0.988	1d)	–0.747	0.467	0.115
Birdscheme	1b)	–0.052	0.054	0.339	1d)	0.039	0.104	0.709
Common Quail								
Trees	2b)	–0.006	0.001	0.545	2e)	–0.002	0.006	0.749
Ditches	2b)	**0.001**	**0.000**	**0.009**	2e)	0.000	0.000	0.285
Grasslands	2b)	0.148	0.444	0.740	2e)	0.077	0.094	0.417
Woodlots	2b)	0.070	0.451	0.876	2e)	–0.112	0.134	0.407
Birdscheme	2b)	0.014	0.035	0.694	2e)	0.013	0.030	0.645
Yellowhammer								
Trees	1c)	0.010	0.014	0.465	1e)	–0.014	0.011	0.186
Ditches	1c)	0.000	0.000	0.597	1e)	–0.000	0.000	0.424
Grasslands	1c)	–0.309	0.571	0.590	1e)	–0.019	0.201	0.923
Woodlots	1c)	–0.120	0.581	0.836	1e)	**0.655**	**0.275**	**0.020**
Birdscheme	1c)	–0.078	0.046	0.096	1e)	**0.141**	**0.057**	**0.017**

1) No spatial autocorrelation model: a) *n* = 43 bp., b) *n* = 114 bp., c) *n* = 76 bp., d) *n* = 98 bp., e) *n* = 51 bp.
2) Spatial autocorrelation model: a) *n* = 74 bp., b) *n* = 28 bp., c) *n* = 45 bp., d) *n* = 77 bp., e) *n* = 12 bp.

Among the species analysed only numbers of Yellowhammer were positively correlated with the AES area, as with the area of woodlots. The Yellowhammer is an ecotonal species living on the border between forests or other wooded areas and open country. The additional dependence on woodlot area is therefore unsurprising; the positive effect of AES could have emerged from this species' general preference for the woodland-meadow ecotone (Golawski & Dombrowski 2002).

4.2. The effect of habitats on the occurrence of bird assemblages

A relationship between the numbers of species or of birds overall and the habitats in question was demonstrated only in one case: the number of all species increased with the proportion of tree coverage in the lowlands. Such a relationship is an expected result when all species are considered, because it is related to the increase in habitat heterogeneity, which, in turn, enhances species richness, especially if this heightened heterogeneity is due to the presence of woodlots in the open landscape (Benton *et al.* 2003, Tworek 2007, Wretenberg *et al.* 2010). In addition, the increase in numbers of all birds with respect to the area of woodlots was close to being statistically significant, a result to be expected in the light of the greater habitat heterogeneity and the larger number of species present there.

Importantly, the area of grasslands and drainage ditch length are parameters that ought to increase species diversity and the number of breeding pairs. The most important aspect, however, is that the influence of habitats important to the whole bird assemblage were not significant, especially not for target species. The presence of drainage ditches may only weakly affect grassland bird assemblages as demonstrated by Marja and Herzon (2012). These authors are of the opinion that ditches modified breeding performance and population stability, but did not influence the number of breeding individuals. While it is understandable that grassland areas have no effect on species diversity or the numbers of the entire bird assemblage because of the importance of woodlots in this respect (Wretenberg *et al.* 2010), it is difficult to draw meaningful inferences with regard to the numbers of target species. In this case, it may well be possible that the absence of a relationship with grassland area is due to the increasingly common colonization of crop fields by some of the most numerous target species, e.g., Northern Lapwing, particularly those with wetter soils situated close to grasslands (Kotowska & Żmihorski 2015).

4.3. The effect of habitats on the occurrence of particular species

A habitat effect on the numbers of breeding pairs was demonstrated for five species, whereby in no case was the influence of a particular habitat on a bird species the same in both the foothills and the lowlands. Generally speaking, the effect of these habitats on numbers of particular species was as expected. Numbers of Red-backed Shrike depended on the areas of woodlots, in which they usually nest and the edges of which they use as look-out posts for prey (Kotowska & Żmihorski 2015, Morelli *et al*. 2016). The positive effect of woodlots and the AES area on Yellowhammer numbers was mentioned earlier. Drainage ditches, and especially the taller vegetation growing along them, were a suitable habitat for Marsh Warbler and Whinchat, which nest in such vegetation and use it as song- and look-out posts (Surmacki 2005, Pearce-Higgins & Grant 2006). The only surprise is the positive effect of ditches on numbers of Common Quail, although it is hard to find convincing arguments for why this species should prefer areas with larger numbers of ditches. Perhaps it is due to the tall, dense vegetation growing along them, as such plant cover is favourable to colonization by the Common Quail (Sarda-Palomera *et al*. 2012).

Importantly, our species-specific analysis of the foothill and lowland plots did not reveal similar relationships for any species. There are several possible explanations for these regional differences. The occurrence of a species in many different places within its range may be limited by slightly different factors and the connections between them, including species interactions, food resources, habitat features, etc. (Tworek 2010). It is also possible that even if a particular species does display a preference for a given habitat e.g., Whinchats along drainage ditches, a superabundance of such a habitat may mask any relationship between a species and that habitat. In contrast, if such a habitat is not so common, the relationship may turn out to be statistically significant. Such a dependence would explain the regional differences for Red-backed Shrike and Yellowhammer with respect to woodlots, of which there were fewer on the lowland plots, and the significant effect of ditch length on numbers of Whinchat, of which there were fewer on the foothill plots. Only Marsh Warbler does not fit these relationships: its numbers were significantly dependent on ditch length, as demonstrated on the lowland plots, where there were far more drainage ditches than on the foothill plots.

The choice of nesting site also depends on the spatial structure and arrangement of habitats in the landscape, which vary between regions, not only on account of topography, soil and climate differences, but sometimes even in relation to historical causes (Concepcion *et al.* 2008, Tworek 2010). Taken together, it is these factors that determine the quality of a habitat. Clearly, more work is needed to characterize habitat variables that are suitable for explaining abundances within and across species.

The result that the influence of a given variable on the occurrence of a species may differ at the regional scale is potentially important for bird conservation. AES in Poland and in many other countries are implemented at the nationwide scale, on the assumption that the package requirements will have the same influence on a species across its entire distribution. Some studies have already suggested that the nationwide approach may be unsuitable. Tworek (2010) pointed out that arguments substantiating the occurrence of birds in agricultural areas should be sought on a smaller scale, preferably regional, and if a region's physical geography is diverse, within even smaller units. Moreover, the results of Kleijn *et al.* (2006) indicate that a substantial number of AES benefit primarily common species, and have limited usefulness for the conservation of endangered and often even uncommon species. AES that have been successful in promoting populations of endangered species, however, were either tailored to the needs of single species or were implemented in specific, high-biodiversity areas.

Large amounts of money have been spent every year on AES, although their positive outcomes vis-à-vis the target avifauna has been relatively poorly examined in European farmland systems (Whittingham *et al.* 2007). This is borne out by the results of our study, in which AES were shown to be of neutral or even negative significance for target species. Like Żmihorski *et al.* (2016a), we suggest that the concept of and approaches to bird conservation in farmland should be better adjusted to local patterns and peculiarities. We suggest that the AES intended for bird conservation in Poland should be reassessed, because if the package requirements are formulated in too general a manner, are aimed at a large number of species and are "averaged out" for over the entire country, their effectiveness will be minimal in the case of rare species and/or those most threatened by extinction.

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Ympäristötukiohjelmien vaikutus peltolinnustoon Puolassa

Euroopan Unionin maatalouden ympäristö- ja erityistukiohjelmat aloitettiin Puolassa vuonna 2004, mutta ohjelmien vaikutuksia ei seurattu systemaattisesti ennen vuotta 2010. Me suoritimme peltolinnuston kartoituslaskentoja kaakkois-Puolan ylänköalueella ja itä-Puolan alankoalueella. Suoritimme laskennat satunnaisesti valituissa yhdeksän hehtaarin kokoisissa ruuduissa (yhteensä 115 ruutua).

Tutkimme eri ympäristömuuttujien ja maatalouden erityistukiohjelmien vaikutuksia lintujen laji- ja reviirimäärään sekä erikseen maatalouden erityistukien kohdelajien sekä kahdeksan yleisimmän peltoympäristössä pesivän lintulajin reviirimääriin. Alankoalueella havaittiin enemmän lajeja ja reviirejä kuin ylänköalueella. Erityistukien hoitotoimien vaikutuksen alla olevan alueen osuus ei vaikuttanut lajien tai reviirien määriin. Yllättäen alankoalueella kohdelajien reviirimäärä jopa väheni erityistukien alla olevan pinta-alan lisääntyessä. Ympäristömuuttujien (esim. ojien tai puuston määrä) havaittiin vaikuttavan vain kahden yleisen peltolinnun reviirimäärään ylänköalueella sekä kolmen lajin reviirimäärään alankoalueella.

Tulostemme perusteella lintujen suojeluun tähtääviä maatalouden erityistukitoimia tulee kehittää sekä niiden vaikutuksien arviointia tulee jatkaa. Jotta tukitoimet olisivat tehokkaita niiden tulisi huomioida ympäristön ja lajiston vaihtelu, ja toimet tulisi soveltaa paikallisiin oloihin.

References

Báldi, A., Batáry, P. & Erdős, S. 2005: Effects of grazing intensity on bird assemblages and populations of Hungarian grasslands. — Agriculture Ecosystems & Environment 108: 251–263.

Benton, T.G., Vickery, J.A. & Wilson, J.D. 2003: Farmland biodiversity: is habitat heterogeneity the key? — Trends in Ecology & Evolution 18: 182–188.

Berg, Å., Wretenberg, J., Żmihorski, M., Hiron, M. & Pärt, T. 2015: Linking occurrence and changes in local abundance of farmland bird species to landscape composition and land-use changes. — Agriculture Ecosystems and Environment 204: 1–7.

Bibby, C.J., Burgess, N.D., Hill, D.A. & Mustoe, S.H. 2000: Bird census techniques. Second Edition. — Academic Press, London.

Broyer, J. 2011: Long-term effects of agri-environment schemes on breeding passerine populations in a lowland hay-meadow system. — Bird Study 58: 141–150.

Concepcion, E.D., Diaz, M. & Baquero, R.A. 2008: Effects of landscape complexity on the ecological effectiveness of agri-environment schemes. — Landscape Ecology 23: 135–148.

Devereux, C.L., Vickery, J.A., Fernandez-Juricic, E., Krebs, J.R. & Whittingham, M.J. 2006: Does sward density affect prey availability for grassland birds? — Agriculture, Ecosystems and Environment 117: 57–62.

Donald, P.F. & Evans, D. 2006: Habitat connectivity and matrix restoration: the wider implications of agri-environment schemes. — Journal of Applied Ecology 43: 209–218.

Elts, J. & Lõhmus, A. 2012: What do we lack in agri-environment schemes? The case of farmland birds in Estonia. — Agriculture, Ecosystems and Environment 146: 89–93.

Elts, J., Tätte, K. & Marja, R. 2015: What are the important landscape components for habitat selection of the ortolan bunting *Emberiza hortulana* in northern limit of range? — European Journal of Ecology 1: 13–25.

European Commission 2012: Agri-environmental indicator – commitments. http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_commitments (last accessed on 11 January 2016).

European Commission 2015: EU agriculture spending focused on results. http://ec.europa.eu/agriculture/cap-funding/pdf/cap-spending-09-2015_en.pdf (last accessed on 15 June 2016).

Evans, A.D. & Green, R.E. 2007: An example of a two-tiered agri-environment scheme designed to deliver effectively the ecological requirements of both localised and widespread bird species in England. — Journal of Ornithology 148: 279–286.

Golawski, A. & Dombrowski, A. 2002: Habitat use of Yellowhammers *Emberiza citrinella*, Ortolan buntings *E. hortulana* and Corn Buntings *Miliaria calandra* in farmland of east-central Poland. — Ornis Fennica 79: 164–172.

Kleijn, D., Baquero, R.A., Clough, Y., Diaz, M., De Esteban, J., Fernandez, F., Gabriel, D., Herzog, F., Holzschuh, A., Johl, R., Knop, E., Kruess, A. & Marshall, E.J.P. 2006: Mixed biodiversity benefits of agri-environment schemes in five European countries. — Ecology Letters 9: 243–254.

Kleijn, D., Berendse, F., Smit, R. & Gilissen, N. 2001: Agri-environment schemes do not effectively protect biodiversity in Dutch agricultural landscapes. — Nature 413: 723–725.

Kleijn, D., Berendse, F., Smit, R., Gilissen, N., Smit, J., Brak, B. & Groeneveld, R. 2004: Ecological effectiveness of agri-environment schemes in different agricultural landscapes in the Netherlands. — Conservation Biology 18: 775–786.

Kotowska, D. & Żmihorski, M. 2015: Wyniki monitoringu ornitologicznego w 2015 roku. Zakres prac zrealizowanych w 2015 roku oraz wstępne wyniki monitoringu efektów programu rolnośrodowiskowego w zakresie ornitofauny. — Falenty. ITP. ISBN 978-83-65426-09-3 ss. 66. (In Polish)

Kuczyński, L. & Chylarecki, P. 2012: Atlas Pospolitych Ptaków Lęgowych Polski. Rozmieszczenie, Wybiórczość Siedliskowa, Trendy. — GIOŚ, Warszawa. (In Polish)

Legendre, P. & Legendre, L. 1998: Numerical Ecology. — Elsevier, New York.

Marja, R. & Herzon I. 2012: The importance of drainage ditches for farmland birds in agricultural landscape in the Baltic countries: does field type matter? — Ornis Fennica 89: 170–181.

Marja, R., Herzon, I., Viik, E., Elts, J., Mänd, M., Tscharntke, T. & Batáry, P. 2014: Environmentally friendly management as an intermediate strategy between organic and conventional agriculture to support biodiversity. — Biological Conservation 178: 146–154.

Morelli, F., Mroz, E., Pruscini, F., Santolini, R., Golawski, A. & Tryjanowski, P. 2016: Habitat structure, breeding stage and sex affect hunting success of breeding Red-backed Shrike (*Lanius collurio*). — Ethology, Ecology & Evolution 28: 136–147.

Morris, J., Mills, J. & Crawford, I.M. 2000: Promoting farmer uptake of agri-environment schemes: the Countryside Stewardship Arable Options Scheme. — Land Use Policy 17: 241–254.

Naura, M., Clark, M.J., Sear, D.A., Atkinson, P.M., Hornby, D.D., Kemp, P., England, G., Peirson, G., Bromley, C. & Carter, M.G. 2016: Mapping habitat indices across river networks using spatial statistical modelling of River Habitat Survey data. — Ecological Indicators 66: 20–29.

Paradis, E. 2016: Ape library for R: Analyses of Phylogenetics and Evolution ver: 3.5. https://cran.r-project.org/web/packages/ape/index.html (last accessed on 27 June 2016).

Pearce-Higgins, J.W. & Grant, M.C. 2006: Relationships between bird abundance and the composition and structure of moorland vegetation. — Bird Study 53: 112–125.

Peach, W.J., Lovett, L.J., Wotton, S.R. & Jeffs, C. 2001: Countryside stewardship delivers cirl buntings *(Emberiza cirlus)* in Devon, UK. — Biological Conservation 101: 361–373.

Perkins, A.J., Maggs, H.E., Watson, A. & Wilson, J.D. 2011: Adaptive management and targeting of agri-environment schemes does benefit biodiversity: a case study of the corn bunting *Emberiza calandra.* — Journal of Applied Ecology 48: 514–522.

Princé, K., Moussus, J.P. & Jiguet, F. 2012: Mixed effectiveness of French agri-environment schemes for nationwide farmland bird conservation. — Agriculture, Ecosystems & Environment 149: 74–79.

R Development Core Team, 2016: A Language and Environment for Statistical Computing. — R Foundation for Statistical Computing, Vienna, Austria.

Rosin, M.R., Skórka, P., Wylegała, P., Krakowski, B., Tobólka, M., Myczko, Ł., Sparks, T.H. & Tryjanowski, P. 2012: Landscape structure, human disturbance and crop management affect foraging ground selection by migrating geese. — Journal of Ornithology 153: 747–759.

Roth, T., Amrhein, V., Peter, B. & Weber, D. 2008: A Swiss agri-environment scheme effectively enhances species richness for some taxa over time. — Agriculture, Ecosystems & Environment 125: 167–172.

Sanderson, F.J., Kloch, A., Sachanowicz, K. & Donald, P.F. 2009: Predicting the effects of agricultural change on farmland bird populations in Poland. — Agriculture, Ecosystems & Environment 129: 37–42.

Sanderson, F.J., Pople, R.G., Ieronymidou, C., Burfield, I.J., Gregory, R.D., Willis, S.G., Howard, C., Stephens, P.A., Beresford, A.E. & Donald, P.F. 2016: Assessing the performance of EU nature legislation in protecting target bird species in an era of climate change. — Conservation Letters 9: 172–180.

Sarda-Palomera, F., Puigcerver, M., Brotons, L. & Rodriguez-Teijeiro, J.D. 2012: Modelling seasonal changes in the distribution of Common Quail *Coturnix coturnix* in farmland landscapes using remote sensing. — Ibis: 154: 703–713.

Schifferli, L. 2001: Birds breeding in changing farmland. — Acta Ornithologica 36: 35–51.

Surmacki, A. 2005: Habitat use by three Acrocephalus warblers in an intensively used farmland area: the influence of breeding patch and its surroundings. — Journal of Ornithology 146: 160–166.

Sutcliffe, L.M.E., Batary, P., Kormann, U., Baldi, A., Dicks, L.V., Herzon, I., Kleijn, D., Tryjanowski, P., Apostolova, I., Arlettaz, R., Aunins, A., Aviron, S., Balezentiene, L., Fischer, Ch., Halada, L., Hartel, T., Helm, A., Hristov, I., Jelaska, S.D., Kaligaric, M., Kamp, J., Klimek, S., Koorberg, P., Kostiukova, J., Kovacs-Hostyanszki, A., Kuemmerle, T., Leuschner, Ch., Lindborg, R., Loos, J., Maccherini, S., Marja, R., Mathe, O., Paulini, I., Proenca, V., Rey-Benayas, J., Sans, F.X., Seifert, Ch., Stalenga, J., Timaeus, J., Torok, P., van Swaay, Ch., Viik, E. & Tscharntke, T. 2015: Harnessing the biodiversity value of Central and Eastern European farmland. — Diversity and Distribution 21: 722–730.

Tryjanowski, P., Hartel, T., Baldi, A., Szymański, P., Tobolka, M., Herzon, I., Golawski, A., Konvicka, M., Hromada, M., Jerzak, L., Kujawa, K., Lenda, M., Orlowski, G., Panek, M., Skorka, P., Sparks, T.H., Tworek, S., Wuczynski, A. & Żmihorski, M. 2011: Conservation of farmland birds faces different challenges in Western and Central-Eastern Europe. — Acta Ornithologica 46: 1–12.

Tworek, S. 2007: Factors affecting bird species diversity on a local scale: A case study of a mosaic landscape in southern Poland. — Polish Journal of Ecology 55: 771–782.

Tworek, S. 2010: Factors affecting the occurrence of breeding bird species in the agricultural landscape of southern Poland. — Studia Naturae 58: 1–180. (In Polish with English summary)

Vickery, J.A., Bradbury, R.B., Henderson, I.G., Eaton, M.A. & Grice, P.V. 2004: The role of agri-environment schemes and farm management practices in reversing the decline of farmland birds in England. — Biological Conservation 119: 19–39.

Webster, R. & Oliver, M.A. 2007: Geostatistics for Environmental Scientists, 2nd ed. — John Wiley & Sons Ltd., Chichester.

Whittingham, M.J. 2007: Will agri-environment schemes deliver substantial biodiversity gain, and if not why not? — Journal of Applied Ecology 44: 1–5.

Whittingham, M.J., Krebs, J.R., Swetnam, R.D., Vickery, J.A., Wilson, J.D. & Freckleton, R.P. 2007: Should conservation strategies consider spatial generality? Farmland birds show regional not national patterns of habitat association. — Ecology Letters 10: 25–35.

Wilson, J.D., Anderson, R., Bailey, S., Chetcuti, J., Cowie, N.R., Hancock, M.H., Quine, C.P., Russell, N., Stephen, L. & Thompson, D.B.A. 2014. Modelling edge effects of mature forest plantations on peatland waders informs landscape-scale conservation. — Journal of Applied Ecology 51: 204–213.

Wretenberg, J., Pärt T. & Berg, Å. 2010: Changes in local species richness of farmland birds in relation to land-use changes and landscape structure. — Biological Conservation 143: 375–381.

Żmihorski, M., Kotowska, D., Berg, Å. & Pärt, T. 2016a: Evaluating conservation tools in Polish grasslands: the occurrence of birds in relation to agri-environment schemes and Natura 2000 areas. — Biological Conservation 194: 150–157.

Żmihorski, M., Pärt, T., Gustafson, T. & Berg, Å. 2016b: Effects of water level and grassland management on alpha and beta diversity of birds in restored wetlands. — Journal of Applied Ecology 53: 587–595.