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The importance of drainage ditches for farmland birds in agricultural landscapes in the Baltic countries: does field type matter?

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Land drainage exhibits a considerable impact on biodiversity. Drainage ditches – a regionally common landscape element – carry a number of benefits for birds associated with farmland. The aim of this study was to quantify a relative value of ditches for farmland birds depending on the type of surrounding fields. Survey data on farmland bird communities and farmland landscape structure across Estonia, Latvia and Lithuania were used. Count plots were situated within either arable fields or grasslands, or their combination and contained two types of ditches, with grassy margins or with tall vegetation such as bushes and trees. Focal species were selected based on their plausible use of ditches. Species richness and abundance of farmland birds were positively associated with the presence of ditches with tall vegetation, but the plausible role of ditches with only grassy margins remained unclear. For some species, the relationship was more pronounced in arable land than in grassland. Regional agricultural policy should support the retention of ditches, especially those with complex structure, in farmland. This action is crucial in landscapes dominated by crop production, as they face the most intense utilisation.

1. Introduction

Farmland birds have been declining in Europe with the onset of industrial agriculture (Donald *et al*. 2001, Robinson & Sutherland 2002). One of the reasons for the loss of avifauna in farmland is related to land drainage (Wilson *et al*. 2004, Stoate *et al*. 2009). Effective drainage is a prerequisite for cultivation, especially in the rain-fed regions, which is a considerable part of Europe. For example, in Finland 67% of all agricultural lands have to be drained for production (Lübbe 2008). The impact of drainage on agro-ecosystems results, on one hand, from conversion of natural wet and humid meadows into grass or arable fields and a changed water regime of the fields and, on the other, from changes in the extent of the network of drainage ditches. While the former process leads to the loss of natural habitats and deteriorates foraging possibilities for ground-probing birds (Donald *et al*. 2001, Robinson & Sutherland 2002), the latter introduces a new habitat feature into the landscape. In most countries of Europe, the network of ditches has been created during initial drainage operations. The extent of such network can be extensive: for example, it sums up to 65,000 km in Estonia (Anon. 2011), 78,000 km in Latvia (Viesturs Jansons, pers. comm.) and 62,000 km in Lithuania (Kudakas & Kinčius 2005). With further mechanisation of agriculture, drainage ditches within fields, and those dividing the fields, have been widely replaced by sub-surface pipes (Herzon & Helenius 2008), leading to a secondary homogenisation of the agricultural landscape. However, in some countries, such as Finland, Baltic countries, Poland and the Netherlands, drainage ditches are still a ubiquitous feature of the agricultural landscape.

In Northern Europe, drainage ditches constitute one of the commonest landscape elements and considerably contribute to the landscape heterogeneity of agricultural and, in some places, forestry lands. The ditch, with its margins of grassy vegetation and often bushes and trees, can be a complex ecosystem structured by several zones such as that of open water, wet soil, aquatic and semi-aquatic vegetation, slope and the margin with vegetation of several layers (Dajdok & Wuczyński 2005). Ditches in farmland may harbour a diversity of aquatic macrophyte and macroinvertebrate species characteristic of small fresh waters (Davies *et al*. 2008) and provide resources for species occupying other habitats: for example, overwintering sites for invertebrates and dispersal routs for amphibians or birds (Herzon & Helenius 2008).

For birds utilising agricultural landscapes, a network of ditches is an important determinant of their occurrence and/or abundance (Hinsley & Bellamy 2000, Herzon & Helenius 2008). The decline in the extent of ditches results in the associated loss of margins (that is, foraging and nesting habitats, singing posts, and shelter), impoverishment of invertebrate communities as food resources (especially aquatic species and those of wet soil), and a loss of water source (Butler *et al.* 2010, Eglington *et al*. 2010). Wetness of soil within fields also depends on the presence of ditches to a larger extent compared to the sub-surface drainage by pipes. On peat soils, the lateral movement of water into the fields can be considerable, while the hydraulic conductivity of clay soils is low; therefore, wet soil as a resource is limited to the ditches themselves. Humid and soft soil is critically important for breeding waders (Eglington *et al*. 2009).

A relative value of ditches in resource provisioning to birds may be mediated by ditch characteristics, such as ditch size and presence of bushes (Davey *et al*. 2010), composition of the field area (crop type and the associated management regime) and the structure of the surrounding landscape (Arnold 1983). There are several reasons why the habitat value of a ditch can differ depending on the field type into which it is embedded.

Arable fields and grasslands appear different types of habitat for birds in terms of their structure, resources and disturbance regime. Benefits of arable fields include abundant grain food for granivorous birds and relatively infrequent disturbance during breeding season (Robinson *et al*. 2001). However, they provide poorer shelter in the onset of breeding and after crop harvesting, and possess impoverished invertebrate communities, including those of soil. Ditches and the permanent, tall vegetation on such fields offer shelter on spring arrival or for juveniles of, for instance, the threatened Ortolan Bunting *Emberiza hortulana* (Vepsäläinen *et al*. 2007) or the Corncrake *Crex crex* (Donaghy 2007). Resources within semi-natural margins provide different food (invertebrates and seeds of native plants) from that of the crop (Bradbury & Kirby 2006, Herzon & Helenius 2008), which is also sustained over a longer time.

On arable fields, the application of herbicides and insecticides considerably reduces invertebrates that are the most important food source for farmland birds (Wilson *et al*. 1999, Vickery *et al*. 2009). Finally, undisturbed ditch margins by arable fields are unique breeding sites for edge-associated bird species, i.e., those that breed and/or feed on field edges, thereby increasing bird diversity and abundance over the landscape. Communities of this ecological group are generally poorer on arable land than on grasslands (Batáry *et al*. 2010). Therefore, the presence of grassy strips (such as margins), soft and wet ditches and banks within arable fields is likely to provide an important supplementary habitat especially for invertebrate-feeding birds and waders (Dunning *et al*. 1992).

Grasslands, especially under a relatively extensive management typical for East Europe, provide many of the resources present also in ditch margins. However, the vegetation of ditches is more diverse in terms of structure and species

Fig. 1. Map of the study areas in the Baltic countries.

composition. Within production grasslands mowed frequently, ditches may also provide an important supplementary habitat. The supplementary function is likely to grow with an increase in production intensity of a grassland field due to the increased homogeneity of the grass sward, frequent removal of biomass, and destruction of nests on the ground. Because grasslands in the region, at the time of the present study, were generally under extensive management, ditches with grassy but not bushy or tree-covered margins were not expected to contribute significantly to the bird diversity and abundance. On the other hand, the presence of bush and tree lines as well as water in the ditches was expected to provide supplementary resources regardless of field type.

Understanding the ecological role of ditches within fields of different types is relevant for the agricultural policy. In most countries in the European Union, cross-compliance rules and agri-environment programmes contain measures directed at ditches and their margins (Davey *et al*. 2010, Vepsäläinen *et al*. 2010). Targeting the measures according to the landscape structure and production types has been advocated as a way to improve a generally low efficiency of the current agri-environment programmes in biodiversity support (Rundlöf & Smith 2006, Whittingham 2007). The present study aimed at quantifying the relative importance of drainage ditches for farmland birds depending on surrounding fields of contrasting vegetation types and management. The diversity and abundance of farmland bird species, and especially those dependent on edges, were predicted to be more associated with ditches in arable than in grassland fields.

2. Material and methods

2.1. Study areas and fieldwork

The study was done in Estonia, Latvia and Lithuania, which all are located in the European hemiboreal zone. These countries occupy about 175,000 km^2, stretching about 700 km in a North–

South direction and 600 km in a West–East direction and representing a biogeographical continuum from forest-dominated Estonia (19.7% of land area is under agricultural use) to agriculture-dominated Lithuania (53.4%) with Latvia being in-between (38.3%) (Anon. 2003). The selection of study areas and sampling methods are described in Herzon and O'Hara (2007). Four research areas in Lithuania and Latvia, and three research areas in Estonia, 100 km^2 each, were surveyed (Fig. 1). In these areas, 10–20, 1-km^2 squares were randomly chosen. Two (in Latvia) or four bird-count plots (in Estonia and Lithuania) were systematically placed in each investigated 1-km^2 square at approximately equal distances from the corners and a minimum distance of 300 m between them.

Field work was conducted in spring–summer in 2002. A point-count method with an unlimited distance consisting of two belts, i.e., within an inner 100 m radius and beyond, was used with two visits to each point during central dates in mid-May and in mid-June (Bibby *et al*. 1992). This distance was chosen because the majority of observed foraging flights of small passerines are made within 100 m, especially under conditions of extensive land use (Morris *et al.* 2001, Schifferli 2001). No counts were conducted on days with poor visibility, or in windy or rainy conditions. The duration of the count at each point was 5 minutes. All observers underwent training in the method. The observers mapped bird observations on field maps using commonly-utilized symbols of bird activity (Bibby *et al*. 1992) and placing them in relation to the circle with a radius of 100 m.

2.2. Land-use data

Landscape and habitat variables (crop types and non-cropped areas, and other elements) were mapped during the field work. Proportions of forest, lengths of drainage ditches, and other landscape variables were calculated with LUPA software from topographic maps (LUPA 2002, Herzon & O'Hara 2007) for a 100-m buffer zone around each count plot (3.14 hectare). The distance to the nearest field edge (i.e., forest, orchard, bog or settlement) and major road was estimated in the field and validated from the topographic maps for up to 200 m.

Table 1. The number of count plots for each habitat type (totals given in parentheses) for three ditch types.

Ditch type	Arable (30)	Grass-land (48)	Mixed (50)
Tall vegetation	17	25	22
Completely grassy	11	9	14
Both vegetation types	2	14	14

Out of a total of 544 count plots, 128 containing ditches were used here (Table 1). Arable plots were represented by winter and spring cereals, bare ground, and other crops (rapeseed and root vegetables). Grassland plots contained dry, wet, improved, permanent and abandoned grasslands. Pure arable or grassland plots were classified as such if a respective area of arable or grassland fields exceeded 85% of the area of a plot. The rest of the plots were regarded as mixed (Table 1). The ditches were grouped by the presence of tall vegetation along the margins. Ditches classified as tall vegetation had bushes (up to 4 m tall) and trees (up to 8 m tall) along the margins; here, bushes and/or trees formed single groups or were evenly scattered. Grassy ditches had grassy margins only, i.e., had no bushes or trees. Other characteristics of ditches (e.g., width, depth, presence of water) were not taken into account in this analysis.

2.3. Ornithological data

For each count plot, the maximum count of individuals from two visits was used for analysis. The abundance was interpreted as the number of individuals, which means, for example, a singing male (i.e. a potentially breeding pair) was interpreted as two individuals (Koskimies & Väisänen 1991, Bibby *et al*., 1992). In the case of two birds (male and female) seen together, they were also interpreted as two individuals. A bird not displaying breeding behaviour was counted as a single individual. This interpretation was done in a consistent way by the same person based on the original field maps. All migrating birds and birds passing high overhead were excluded from the analysis. Only data within the 100-m circle were used in this analysis to reflect possible associations with ditches.

Table 2. Descriptive statistics for explanatory variables, bird-community indices and bird-species abundances. Birds, length of ditches and proportion of forest are within 100 m of the count plots, and distances to the nearest field edge and road are within 200 m.

Explanatory variables	No. individuals	Mean	SD
Plot characteristics			
Length of ditches with tall vegetation, D_{VEG}		113.4	98.69
Length of grassy ditches, D_{GRASSY}		84.34	113.33
Scrub-forest%, SCRUB-FOREST		28.01	36.66
Distance to the field edge, EDGE		176.84	67.91
Distance to the nearest road, ROAD		123.04	90.12
Community indices			
SR_{ALL}		8.99	4.39
SR_{OPEN}		1.88	0.79
SR_{EDGE}		1.93	1.27
SUM_{OPEN}		10.33	4.29
SUM_{EDGE}		5.79	4.70
Bird species			
True field species			
Corncrake (CRECRE)	54	0.42	0.96
Meadow Pipit (ANTPRA)	72	0.56	1.00
Northern Lapwing (VANVAN)	38	0.29	0.78
Skylark (ALAARV)	876	6.84	2.71
Edge species			
Common Whitethroat (SYLCOM)	188	1.46	1.35
Whinchat (SAXRUB)	221	1.72	2.01
Yellowhammer (EMBCIT)	128	1.00	1.35
Marsh Warbler (ACRRIS)	94	0.73	1.48
Common Grasshopper Warbler (LOCNAE)	47	0.37	0.92

Farmland birds were divided into ecological groups of all true field species and all edge specialist species after Tiainen and Pakkala (2001). For the characterization of bird fauna, overall species richness (i.e., number of all registered species, SR_{ALL}), overall species richness of true field (SR_{OPEN}) and edge species (SR_{EDGE}), number of individuals of true field (SUM_{OPEN}), and edge species (SUM_{EDGE}) were calculated. For analysis, nine most numerous farmland bird species that breed on fields or on field edges were chosen: Skylark (*Alauda arvensis*), Common Whitethroat (*Sylvia communis*), Whinchat (*Saxicola rubetra*), Yellowhammer (*Emberiza citrinella*), Marsh Warbler (*Acrocephalus palustris*), Meadow Pipit (*Anthus pratensis*), Corncrake, Northern Lapwing (*Vanellus vanellus*), and Common Grasshopper Warbler (*Locustella naevia*). All of them utilise ditches at least to some degree during the breeding season.

2.4. Statistical analysis

Generalised Linear Modelling (GLM) was carried out in R (R Development Core Team 2010) with Poisson log-linear distribution (analysis type III). Mixed modelling was not used because only plots with ditches were selected here and therefore the number of plots grouped by a square varied from one to four. Also, the landscape in the region is mostly highly fragmented and farm sizes were small to preclude high similarity level by the landscape character or farm management. The sampling design of this study might be impacted by spatial autocorrelation, but this risk was considered low, as studies on farmland birds in Finland suggest that an impact of spatial autocorrelation on bird assemblages is not considerable (Piha *et al,* 2007, Vepsäläinen *et al.* 2010).

For each response variable, one multivariate model was carried out, containing all explanatory variables. The explanatory variables are described in Table 2: land-use type (fixed at three classes,

Table 3. Overall GLM results relating farmland bird metrics with landscape characteristics and land use. + = positive and – = negative effect; one + or – symbol indicates $p < 0.05$, two indicate < 0.01 and three indicate <0.001. For variable abbreviations, see text and Table 2.

	SR_{ALL}	SR_{OPEN}	SUM_{OPEN}	SR_{EDGE}	SUM_{EDGE}
Model AICc	705.9	359.9	764.6	404.1	759.9
Value/df	1.5	0.3	1.9	0.8	2.8
Land use					
Arable plots	– – –			– – –	– – –
Mixed plots					– – –
Grassland plots	+ + +		+ + +	+ + +	+ + +
D_{VEG}					
D_{GRASSY}	+ +				
SCRUB-FOREST					+
ROAD	– – –		– –		– –
EDGE	–	+	+ +		
Ditch × land use					
D_{VEG} on arable plots	+			+	+ + +
D_{VEG} on mixed plots					
D_{VEG} on grassland plots					
D_{GRASSY} on arable plots					
D_{GRASSY} on mixed plots					+ +
D_{GRASSY} on grassland plots	+ +				

i.e., arable, grassland or mixed), length of ditches with tall vegetation, length of grassy ditches, scrub-forest proportion within the 100-m radius, distance from a given plot to the nearest field edge, and distance from a given plot to the nearest road of 6–10 m in width (Table 2). No sampling was done near larger roads. Explanatory variables did not significantly vary between land-use types (except for the proportions of scrub and forest area which were lower in arable and mixed than in grassland plots; one-way ANOVA with p <0.0001). The above-listed variables were chosen due to evidence of their importance in determining bird distribution in the region (Prins 2005, Herzon & O'Hara 2007). Moreover, two interactions were considered: length of ditches with tall vegetation by land use, and length of grassy ditches by land use.

The only significant correlation among the explanatory variables was between ditches with tall vegetation and grassy ditches ($r_S = -0.39, p < 0.05$), indicating that in most plots there was only one type of ditch. All variance-inflation factor values were between 1.0 and 1.1, indicating low multicollinearity among these variables (Zuur *et al.* 2009).

Variables retained in the final models were selected in a stepwise selection algorithm based on Akaike's information criteria (AICc) corrected for small sample size (Burnham & Anderson 2002). Working with models containing interactions, a rule of marginality was used, so that non-significant main-effect variables were only removed if their interactions were not significant. Confidence level was accepted at 95%.

Because of many zero cells (more than 40% of data) in the occurrence of scarce species (Marsh Warbler, Meadow Pipit, Corncrake, Northern Lapwing, and Common Grasshopper Warbler), analysis for these species was repeated by using zero-inflated models in R with pscl package (Jackman *et al.* 2011). An excessive number of zeroes in a dataset may cause severe overdispersion and lead to erroneous conclusions about the significance of parameters. The estimated parameters and standard errors may also be biased (Zuur *et al.* 2009). Zero-inflated models treat zeroes differently (Zuur *et al.* 2009) and accommodate several distributions. Two zero-inflated models were created: zero-inflated Poisson (ZIP) and zero-inflated negative binomial (ZINB). Zero inflated models provide results as count-model coefficients, and zero-inflation model coefficients. Comparisons were carried out between different zero-inflated models based on AICc's (Burnham & Anderson 2002). ZIP models were chosen because the AICc values were lower than in ZINB models (results not shown).

3. Results

On the arable plots, overall species richness (SR_{ALL}), species richness of edge species (SR_{EDGE}), and the abundance of edge species (SUM_{EDGE}) were significantly and positively related with the length of ditches with tall vegetation (Table 3). The abundance of Common Whitethroat was significantly and positively associated with the length of ditches with tall vegetation on the arable plots and with grassy ditches on grassland plots. The abundance of Common Grasshopper Warbler was positively associatated with the length of ditches with tall vegetation on arable and mixed plots (Table 4). The abundance of Skylark was negatively associated with ditches with tall vegetation on grassland plots. The occurrence of Meadow Pipit was negatively associated with ditches with tall vegetation on mixed plots.

For grassy ditches, there was no statistically significant difference in the relationship between ditch length and bird communities on arable plots as compared to grassland plots, except for the weak relationship detected for the Marsh Warbler (Table 4). The length of grassy ditches related to the abundance of edge species (SUM_{EDGE}), Whinchat and Marsh Warbler was stronger in mixed than in grassland plots.

Landscape and land-use characteristics also related to bird occurrence in their own right (Tables 3–4). Most of the bird-community attributes had higher values on the grassland than on the arable plots. Only one of the true field species – Northern Lapwing – was more abundant on arable plots. Fewer individuals of the edge species combined, as well as of Common Whitethroat, were registered on the mixed than on the grassland plots. Open-farmland specialists (SR_{OPEN} and SUM_{OPEN}) related positively to the distance to the field-area edge, but the overall species richness (SR_{ALL}) had a negative association with the edge measure. Numbers of all species (SR_{ALL}), the abundance of both groups (SUM_{OPEN} and SUM_{EDGE}) and that of Common Whitethroat and Common Grasshopper Warbler were significantly and negatively related to the proximity of the road from the count plots.

The AICc values of the zero-inflated models were consistently lower than those of the GLMs

Table 4. Bird species-specific results of GLMs relating farmland bird metrics with landscape characteristics and land use. + = positive and – = negative effect; one + or – indicates $p < 0.05$, two indicate < 0.01 and three indicate < 0.001. For variable and species abbreviations, see text and Table 2.

Bird species	ALAARV	SYLCOM	SAXRUB	EMBCIT	ACRRIS	ANTPTRA	CRECRE	VANVAN	LOCNAE
Model AICc	614.9	515.3	481.4	368.9	353.4	273.9	229.7	179.4	214.9
Value/df	1.1	2	2.1	1.7	2	1.3	1.3	0.9	1.2
Land use									
Arable plots		– – –	– –	–		–	– –	+ +	– –
Mixed plots		–	–		– –		– – –		– –
Grassland plots	+ + +	+ + +						– – –	
D_{VEG}	– – –							+	
D_{GRASSY}		+ +		+ + +	+ +				
SCRUB-FOREST			+ +	– –					
ROAD		– –							– –
EDGE			+ + +	+ +				+ +	
Ditch × land use									
D_{VEG} on arable plots		+							+ +
D_{VEG} on mixed plots						–			+
D_{VEG} on grassland plots	– – –							+	
D_{GRASSY} on arable plots					–				
D_{GRASSY} on mixed plots			+		+ +				
D_{GRASSY} on grassland plots		+ +		+ + +					

Table 5. Results of the zero-inflated models relating bird species with landscape characteristics and land use. Count-model coefficients (based on Poisson models with log link) show the abundance if a given species is present. Zero-inflation model coefficients (based on binomial models with logit link) show whether the species was present. NA denotes cases where the estimation of occurrence probability approached infinity, i.e., the species was not registered in a given field type. + = positive and – = negative effect; one + or – symbol indicates p < 0.05, two indicate < 0.01 and three indicate < 0.001. CMC = count-model coefficients, ZIMC = zero-inflation model coefficients. For variable and species abbreviations, see text and Table 2.

Bird species	ACRRIS		ANTPRA		CRECRE		VANVAN		LOCNAE	
Model AICc	258.7		235.5		188.6		155.3		168.3	
Coefficient type	CMC	ZIMC	CMC	ZIMC	CMC	ZIMC	CMC	ZIMC	CMC	ZIMC
Land use										
Arable plots	–				NA		– –		+ +	+
Mixed plots			– – –		– – –				+ + +	+ +
Grassland plots	+ + +	+	+ + +		+ +				– –	–
D_{VEG}									– –	– –
D_{GRASSY}	+		–				+ + +			
SCRUB-FOREST					– – –				+ + +	+
ROAD										+
EDGE			– – –						+ + +	+ +
Ditch × land use										
D_{VEG} on arable plots							+ + +			
D_{VEG} on mixed plots			+		+ + +					
D_{VEG} on grassland plots										
D_{GASSY} on arable plots										
D_{GRASSY} on mixed plots			+ + +		+ + +					
D_{GRASSY} on grassland plots			–				+ + +			

(Table 5). In ZIP models for Marsh Warbler and Common Grasshopper Warbler, interactions between land use and ditches were not significant. On the other hand, the length of ditches with tall vegetation and grassy ditches was significantly positively related to the abundance of Meadow Pipits, Corncrakes and Northern Lapwings on the arable and/or mixed plots in the count models (Table 5). The second part of the ZIP models did not contain significant relationships between the species, land use and ditch interactions for any cases.

The ZIP models confirmed that the GLM with Poisson distribution should be applied with caution for species with many zeroes: Marsh Warbler, Meadow Pipit, Corncrake, Northern Lapwing and Common Grasshopper Warbler. For Skylark, Common Whitethroat, Whinchat and Yellowhammer, GLM with Poisson distribution resulted in better models because the specific frequencies had less than 40% zero values in the data (Zuur *et al*. 2009).

4. Discussion

4.1. The role of ditches depends on farmland type and ditch quality

The hypothesis of higher importance of ditches in arable than in grassland plots for farmland birds seemed to hold only for ditches with tall vegetation, that is, ditches with bushes or trees. Ditches with tall vegetation in arable plots appeared especially attractive for edge species. The presence of ditches boosts the abundance and slightly also species richness of edge-associated birds, and therefore also the overall diversity of the bird community. Grassland fields support higher biodiversity than arable fields do (Andow 1991), which holds also for birds of the study region (Auninš *et al*. 2001, Herzon *et al*. 2008). Importantly, in the Baltic countries during the present study, many grasslands are under utmost extensive management of occasional mowing or grazing. This supports species-rich, structurally heterogeneous vegetation on grassland and subsequently a minor supplementary resource functioning by the ditches. This situation could be different, however, in silage grasslands with homogeneous, dense and frequently-mown swards.

It is plausible that the lack of a notable relationship between grassy ditches and bird community, reported here, stems from a small ecological effect of such ditches in terms of breeding individuals, which cannot be detected with small samples. The effect could locally be more subtle and work through a modified breeding performance and population stability rather than through the number of breeding individuals. More detailed autoecological studies would be needed for determining the true significance of grassy ditches in agricultural landscapes.

4.2. Responses to ditches are species specific

The Skylark was the only species avoiding ditches with tall vegetation on grassland plots, though potentially benefiting from grassy ditches, especially on arable plots. Its territory density is often higher and nesting success is better in set-aside fields than in grass or cereal fields (Poulsen *et al*. 1998, Wrbka *et al.* 2008). Grassy ditches can be considered habitat similar to set-aside strips. Recent studies from Finland demonstrate that the presence of open ditches is among the most important factors in explaining Skylark density (Piha *et al*. 2003, Vepsäläinen *et al*. 2010). The avoidance of ditches with tall vegetation by Skylark is probably largely caused by the avoidance of nest predation (Chamberlain *et al*. 1999, Mason & MacDonald 2000, Piha *et al*. 2003).

Northern Lapwing avoids hedgerows due to the predation risk (MacDonald & Bolton 2008). For this reason, bushes on reserve areas are removed in Northern Lapwing habitats in the UK (MacDonald & Bolton 2008). Contrary to investigations in the Baltic countries (Auninš *et al*. 2001), the study reported a weak indication of an association with ditches with tall vegetation on arable plots.

One explanation might be due to a trade-off associated with habitat selection: despite the predation risk, the species prefers arable fields but also utilises areas around ditches for foraging because of suitable foraging plots, such as wet mud or bare ground (Eglington *et al.* 2008). Also, the agricultural landscapes in the Baltic countries are more fragmented than those in many West European countries and, therefore, Northern Lapwing also utilises fairly small field parcels, tolerating the avian predation risk.

The small passerine species modelled here, including their young during breeding season, are key prey for several raptors, such as the Merlin (*Falco columbarius*), Eurasian Sparrowhawk (*Accipiter nisus*) and Montagu's Harrier (*Circus pygargus*) (del Hoyo *et al*. 1994). Moreover, some of these passerines, such as the Meadow Pipit, Marsh Warbler, Common Whitethroat, Whinchat and Yellowhammer, are important host species for the Common Cuckoo (*Cuculus canorus*) (Moksnes & Røskaft 1995, Soler & Møller 1996, Honza *et al.* 2001). This indicates that ditches have a wider ecological importance in agricultural landscapes, supporting also higher trophic levels of the bird community.

The importance of grassy ditches for the abundance of Whinchats and Marsh Warblers, and that of edge species on mixed plots, is likely to be indirect because in the studied landscapes ditches divide fields of different type, such as arable or grassland. This combination of contrasting field types increases the overall habitat heterogeneity and complementarity of resources at the landscape level (Dunning *et al*. 1992, Andrén *et al*. 1997).

Although the creation of uncropped margins along ditches is already part of the cross-compliance regime and of many agri-environmental schemes in the European Union, the requirements for a minimum width of margins vary widely among the member states. For instance, in England the minimum obligatory margin width is two meters (http://www.crosscompliance.org.uk/), while in Estonia it is only 0.5 m. Also, while in some member states (e.g., Sweden) ditches are regarded as a characteristic landscape element that is preserved, in some, the removal of ditches with sub-surface pipes is a continuing process (Wrbka *et al.* 2008), which is even subsidised by the government in Finland and Estonia. Ditch removal has s strong impact on the landscape (Hietala-Koivu 2002). This study suggests that the adverse impact on farmland birds is the gravest in crop-dominated landscapes.

4.3. Conclusions

This study focused on a specific aspect related to the ecological value of ditches in agricultural landscapes, i.e., the relative importance of ditches for farmland bird species in contrasting settings of arable and grassland fields. Ditches with tall vegetation, containing bushes and trees in their margins, considerably enhance the diversity of farmland birds, especially so in crop-dominated landscapes. The role of ditches with grassy margins only remains undetermined here. It is plausible that the beneficial effect might be determined only through measuring breeding performance (see above). The present results are highly relevant for many Central and East European countries with a similar structure and levels of production intensity as in the Baltic countries. However, despite differences in land-use intensity, the results could be applicable also for North European landscapes with abundant ditches in farmland, such as in Finland, but this aspect should be evaluated separately. It is of pressing importance that the continuing intensification of production across Europe does not lead to the dismantling of the remaining ditch networks, especially in crop-dominated landscapes. All member states of the European Union should ensure that agri-environmental schemes contain a requirement for sufficiently wide, input-free grassy margins and some tree and bush vegetation along the ditches.

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Kuivatusojat ja peltolinnusto Baltian maissa: peltotyypin vaikutus

Maan kuivatus vaikuttaa merkittävästi luonnon monimuotoisuuteen. Kuivatusojat – alueellisesti yleinen maisemaelementti – vaikuttavat positiivisesti maaseutuympäristöihin sopeutuneisiin lintuihin. Tämän tutkimuksen tarkoitus oli määritellä ojien suhteellinen merkitys peltolinnustolle peltotyypin vaihdellessa. Tutkimuksessa käytettiin peltolinnusto- ja viljelymaiseman rakenneaineistoja Virosta, Latviasta ja Liettuasta. Laskentapisteet oli sijoiteltu joko viljellylle tai ruohomaalle tai näiden yhdistelmälle, ja ne käsittivät kahta ojatyyppiä: sellaisia, joita reunusti pelkkä ruohokaistale ja sellaisia, joiden reunoilla kasvoi korkeaa kasvillisuutta (pensaikkoa tai puustoa). Tutkittavat lajit olivat kaikki mahdollisia ojaympäristöjen hyödyntäjiä. Peltolinnuston lajirikkauteen ja yleiseen runsauteen vaikuttivat positiivisesti korkean kasvillisuuden ojat, mutta ruohoreunaisten ojien merkitys jäi hämäräksi. Joillakin lajeilla tämä ero oli selkeämpi viljely- kuin ruohomailla. Alueellisessa maatalouspolitiikassa täytyisi tukea (erityisesti rakenteeltaan monimuotoisten) avo-ojien säilyttämistä viljelymaisemassa. Tämä on erityisen tärkeää viljanviljelyalueilla, koska niillä maankäyttö on kaikkein intensiivisintä.

References

Andow, D. A. 1991: Vegetational diversity and arthropod population response. — Annual Review of Entomology 36: 561–586.

Andrén, H., Delin, A. & Seiler, A. 1997: Population response to landscape changes depends on specialization to different landscape elements. — Oikos 80: 193–196.

Anon. 2003: Estonia, Latvia, Lithuania in figures 2003. — Statistical Office of Estonia. Tallinn.

Anon. 2011: Register of soil improvement. — Estonian Agricultural Board. URL msr.agri.ee/Aruanne_main.aspx?fail=Aruanne_kraav.aspx&liik=1

Arnold, G. W. 1983: The influence of ditch and hedgerow structure, length of hedgerows, and area of woodland and garden on bird numbers on farmland. — Journal of Applied Ecology 20: 731–750.

Auninš, A., Petersen, B. S., Priednieks, J. & Prins, E. 2001: Relationship between birds and habitats in Latvian farmland. — Acta Ornithologica 36: 55–64.

Batáry, P., Báldy, A., Kleijn, D. & Tscharntke, T. 2010:

Landscape–moderated biodiversity effects of agri–environmental management: a meta–analysis. — Proceedings of the Royal Society 1713: 1894–1902.
Bibby, C. J., Burgess, N. D., Hill, D. A. & Mustoe, S. H. 1992: Bird census techniques. — Academic Press, London.
Bradbury, R. B. & Kirby, W. B. 2006: Farmland birds and resource protection in the UK: Cross–cutting solutions for multi–functional farming? — Biological Conservation 129: 530–542.
Burnham, K. P. & Anderson, D. R. 2002: Model selection and multimodel inference. A practical information-theoretic approach. Second edition. — Springer, New York.
Butler, S. J., Boccaccio, L., Gregory, R. D., Voříšek, P. & Norris, K. 2010: Quantifying the impact of land-use change to European farmland bird populations. — Agriculture, Ecosystems and Environment 137: 348–357.
Chamberlain, D. E., Wilson, A. M., Browne, S. J. & Vickery, J. A. 1999: Effects of habitat type and management on the abundance of Skylarks in the breeding season. — Journal of Applied Ecology 36: 856–870.
Dajdok, Z. & Wuczyński, A. 2005: Biocenotic differentiation, functions and protection problems of the small mid-field ditches. — In Środowiskowe aspekty gospodarki wodnej. (eds. Tomialojć, L & Drabiński, A.): 227–252. Wroclaw. (In Polish with English summary)
Davey, C. M., Vickery, J. A., Boatman, N. D., Chamberlain, D. E., Parry, H. R. & Siriwardena, G. M. 2010: Assessing impact of Entry Level Stewardship on lowland farmland birds in England. — Ibis 152: 459–474.
Davies, B., Biggs, J., Williams, P., Whitfield, M., Nicolet, P., Sear, D., Bray, S. & Maund, S. 2008: Comparative biodiversity of aquatic habitats in the European agricultural landscape. — Agriculture, Ecosystems & Environment 125: 1–8.
del Hoyo, J., Elliott, A. & Sargatal, J. (eds.) 1994: Handbook of the birds of the world. Vol. 2. New World vultures to guineafowl. — Lynx Edicions, Barcelona.
Donaghy, A.M. 2007: Management of habitats on the Shannon Callows with special reference to their suitability for corncrake *Crex crex*. — Ph.D. thesis, National University of Ireland, Cork.
Donald, P. F, Green, R. E. & Heath, M. F. 2001: Agricultural intensification and the collapse of Europe's farmland bird populations. — Proceedings of the Royal Society of London Ser. B 1462: 25–29.
Dunning, J. B., Danielson, J. B. & Pulliam, H. R. 1992: Ecological processes that affect populations in complex landscapes. — Oikos 65: 169–175.
Eglington, S. M., Bolton, M., Smart, M. A., Sutherland, W. J., Watkinson, A. R. & Gill, J. A. 2010: Managing water levels on wet grasslands to improve foraging conditions for breeding northern lapwing *Vanellus vanellus*. — Journal of Applied Ecology 47: 451–458.
Eglington, S. M., Gill, J. A., Bolton, M. & Smart, M. A. 2009: Reversion of arable land to wet grassland for breeding waders. — Conservation Land Management 7: 5–9.
Eglington, S. M., Gill, J. A., Bolton, M., Smart, M. A., Sutherland, W. J. & Watkinson, A. R. 2008: Restoration of wet features for breeding waders on lowland grassland. — Journal of Applied Ecology 45: 305–314.
Herzon, I., Auninš, A., Elts, J. & Preikša, Ž. 2008: Intensity of agricultural land-use and farmland birds in the Baltic States. — Agriculture, Ecosystems and Environment 125: 93–100.
Herzon, I. & Helenius, J. 2008: Agricultural drainage ditches, their biological importance and functioning. — Biological Conservation 141: 1171–1183.
Herzon, I. & O'Hara, R. B. 2007: Effects of landscape complexity on farmland birds in the Baltic States. — Agriculture, Ecosystems and Environment 118: 297–306.
Hietala–Koivu, R. 2002: Landscape and modernizing agriculture: a case study of three areas in Finland in 1954–1998. — Agriculture, Ecosystems & Environment 91: 273–281.
Hinsley, S. A. & Bellamy, P. E. 2000: The influence of hedge structure, management and landscape context on the value of hedgerows to birds: a review. — Journal of Environmental Management 60: 33–49.
Honza, M., Moksnes, A., Rřskaft, E. & Stokke, B. G. 2001: How are different common cuckoo *Cuculus canorus* egg morphs maintained? An evaluation of different hypotheses. — Ardea 89: 341–352.
Jackman, S., Tahk, A., Zeiles, A., Maimone, C. & Fearon, J. 2011: Package 'pscl' (October 21, 2011). — URL http://cran.r–project.org/web/packages/pscl/pscl.pdf
Koskimies, P. & Väisänen, R. A. 1991: Monitoring bird populations. — Zoological Museum, Finnish Museum of Natural History, Helsinki.
Kudakas, V. & Kinčius, L. 2005: Actual questions on the supervision of land reclamation ditches. — Rural landscape management: 175–177.
Lübbe, E. 2008: Agricultural Drainage and Environment in different Farming Policies. Proceedings of the 10th international drainage workshop of ICID working group on drainage. Helsinki/Tallinn 6–11 July 2008. — Water Resources Publication 16, Helsinki University of Technology.
LUPA 2.0 2002: Uslugi Informatyczne Desmodus. — Poland.
MacDonald, M. A. & Bolton, M. 2008: Predation of lapwing *Vanellus vanellus* nests on lowland wet grassland in England and Wales: effects of nest density, habitat and predator abundance. — Journal of Ornithology 149: 555–563.
Mason, C. F. & Macdonald, S. M. 2000: Influence of landscape and land-use on the distribution of breeding birds in farmland in eastern England. — Journal of Zoology 251: 339–348.
Moksnes, A. & Røskaft, E. 1995: Egg–morphs and host preference in the common cuckoo (*Cuculus canorus*): an analysis of cuckoo and host eggs from European

museum collections. — Journal of Zoology 236: 625–648.

Morris, A. J., Whittingham, M. J., Bradbury, R. B., Wilson, J. D., Kyrkos, A., Buckingham, D. L. & Evans, A. D. 2001: Foraging habitat selection by yellowhammers (*Emberiza citrinella*) nesting in agriculturally contrasting regions in lowland England. — Biological Conservation 101: 197–210.

Piha, M., Pakkala, T. & Tiainen, J. 2003: Habitat preferences of the skylark *Alauda arvensis* in southern Finland. — Ornis Fennica 80: 97–110.

Piha, M., J. Tiainen, J., Holopainen, J. & V. Vepsäläinen 2007: Effects of land-use and landscape characteristics on avian diversity and abundance in a boreal agricultural landscape with organic and conventional farms. — Biological Conservation 140: 50–61.

Poulsen, J. G., Sotherton, N. W. & Aebischer, N. J. 1998: Comparative nesting and feeding ecology of skylarks *Alauda arvensis* on arable farmland in southern England with special reference to set–aside. — Journal of Applied Ecology 35: 131–147.

Prins, E., Petersen, B. S., Auninš, A. & Priednieks, J. 2005: Using Landsat TM and field data to produce maps of predicted bird densities in Latvian farmland. — International Journal of Remote Sensing 26: 1881–1891.

R Development Core Team 2010: R: a language and environment for statistical computing. — R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R–project.org/

Robinson, R. A. & Sutherland, W. J. 2002: Post–war changes in arable farming and biodiversity in Great Britain. — Journal of Applied Ecology 39: 157–176.

Robinson, R. A., Wilson, J. D. & Crick, H. Q. P. 2001: The importance of arable habitat for farmland birds in grassland landscapes. — Journal of Applied Ecology 38: 1059–1069.

Rundlöf, M. & Smith, H. G. 2006: The effect of organic farming on butterfly diversity depends on landscape context. — Journal of Applied Ecology 43: 1121–1127.

Schifferli, L. 2001: Birds breeding in a changing farmland. — Acta Ornithologica 36: 37–51.

Soler, J. J. & Møller, A. P. 1996: A comparative analysis of the evolution of variation in appearance of eggs of European passerines in relation to brood parasitism. — Behavioral Ecology 7: 89–94.

Stoate, C., Báldi, A., Beja, P., Boatman, N. D., Herzon, I., van Doorn, A., de Snoo, G. R., Rakosy, L. & Ramwell, C. 2009: Ecological impacts of early 21st century agricultural change in Europe – a review. — Journal of Environmental Management 91: 22–46.

Tiainen, J. & Pakkala, T. 2001: Birds. — In Biodiversity of agricultural landscapes in Finland (eds. Pitkänen, M. & Tiainen, J.): 33–50. BirdLife Finland Conservation Series Nr. 3, Helsinki.

Vepsäläinen, V., Pakkala, T., Piha, M. & Tiainen, J. 2007: The importance of breeding groups for territory occupancy in a declining population of a farmland passerine bird. — Annales Zoologici Fennici 44: 8–19.

Vepsäläinen, V., Tiainen, J., Holopainen, J., Piha, M. & Seimola, T. 2010: Improvements in the Finnish agri-environment scheme are needed in order to support rich farmland avifauna. — Annales Zoologici Fennici 47: 287–305.

Vickery, J., Feber, R. E. & Fuller, R. J. 2009: Arable field margins managed for biodiversity conservation: A review of food resource provision for farmland birds. — Agriculture, Ecosystems and Environment 133: 1–13.

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

Wilson, J. D., Morris, A. J., Arroyo, B. E., Clark, S. C. & Bradbury, R. B. 1999: A review of the abundance and diversity of invertebrate and plant foods of granivorous birds in northern Europe in relation to agricultural change. — Agriculture, Ecosystems and Environment 75: 13–30.

Wilson, A. M., Ausden, M. & Milsom, T. P. 2004: Changes in breeding wader populations on lowland wet grasslands in England and Wales: causes and potential solutions. — Ibis 146: 32–40.

Wrbka, T., Schindler, S., Pollheimer, M., Schmitzberger, I. & Peterseil, J. 2008: Impact of the Austrian Agri–Environmental Scheme on diversity of landscapes, plants and birds. — Community Ecology 9: 217–227.

Zuur. A. F., Ieno, E. N., Walker, N. J., Saveliev, A. A. & Smith, G. M. 2009: Mixed effects models and extensions in ecology with R. — Springer.