Ornis Fennica 75:105–118. 1998

The distribution of Danish farmland birds in relation to habitat characteristics

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Received 27 February 1998, accepted 17 July 1998

Decreasing populations of farmland birds have been reported throughout NW Europe. This study aims at identifying habitat elements of importance for the maintenance of a rich avifauna in agricultural areas. Using data from the Danish breeding birds monitoring programme, based on point counts, 706 census points situated in farmland and censused during the years 1990–1993 were selected. The landscape around each point was described quantitatively with respect to general habitat composition, area and structure of habitat islands, and length and structure of linear habitat elements. Bird-habitat relationships were analysed by means of canonical correlation analysis and multiple regression. The number of species was negatively correlated with distance to permanent grassland, wetland and wood, and positively correlated with area of buildings and gardens, dry habitat islands (coverts) and wet habitat islands with woody plants. A number of associations between individual species and habitat elements were found and are described in the paper. Two major species groups may be distinguished: species connected with open countryside and species connected with woody vegetation in gardens, hedgerows and/or habitat islands. A review of the population trends indicates that the declines have mainly occurred within the former group.

1. Introduction

During recent decades, many bird species associated with farmland have been decreasing in numbers in Denmark (Petersen & Jacobsen 1997), as well as in other parts of northwestern Europe (Tucker & Heath 1994, Hagemeijer & Blair 1997). Generally, these population declines are ascribed to environmental changes associated with the intensification of agriculture. Deleterious changes include the loss of habitat due to conversion of uncropped areas to arable land as well as the deterioration of habitat quality from changes in cropping patterns, increased use of pesticides etc. (O'Connor & Shrubb 1986, Fuller et al. 1991, Tucker & Evans 1997). In Denmark, some effects of habitat loss on farmland avifauna have been described by Møller (1980, 1983), but later research on farmland bird populations has mainly focused on the effects of pesticides (e.g., Braae et al. 1988, Petersen 1994).

Large-scale removal of residual habitats in Danish farmland took place until about 1980 (Agger et al. 1986). Since then habitat loss has been much smaller, largely being confined to draining or filling of ponds and marl-pits and uniting of fields (with consequent loss of rough boundary vegetation) on soils of high productivity in the eastern part of the country (Agger & Brandt 1992); however, permanent grassland was still converted to arable fields at an annual rate of approximately two percent until 1993 (Petersen & Jacobsen 1997).

The amount of coverts, small plantations and other 'dry' habitat islands has been increasing, currently at a rate of 2.6% per year (Agger & Brandt 1992), and the planting of hedgerows now probably more than offsets the current removal. Furthermore, the European Union's regulations under the Common Agricultural Policy may, together with national governmental incentives, also increase habitat diversity in farmland through afforestation and the creation of new grasslands and other areas of semi-natural vegetation.

In this paper, I use data from the Danish breeding birds monitoring programme to analyse, on a national scale, the distribution of birds in the agricultural landscape in relation to a number of habitat characteristics. The chief objective has been to identify habitat elements of prime importance for the existence of a rich avifauna in intensively farmed areas and thus improve the possibilities of predicting which species will benefit from different kinds of habitat improvement initiatives. The influence of factors related to field management were not included in the present study, but the effects of cropping pattern and pesticide use on population densities of Danish farmland birds have been described elsewhere (Petersen 1996).

2. Methods

2.1. Field data

In the Danish breeding birds monitoring programme, birds are censused once a year between 15 May and 15 June. Five minute point counts with unlimited distance (Blondel et al. 1970) are used, implying that all birds seen or heard from the census point are recorded. Counts are carried out during the morning hours, and adverse weather conditions (precipitation, visibility < 1 km, wind speed > 9 m/sec) are avoided. Census points are chosen by the individual observers and local co-ordinators, the sole restriction being that the points must be at least 300 metres apart. Once selected, a census point is used year after year. The points are indicated on a map and a crude description of the surroundings is given in the form of a four-figure code indicating which habitats occur and dominate within the area surveyed from the point. Since 1987 about 6000 census points have been used each year.

Based upon the four-figure habitat codes, all census points that were surrounded by at least 75% farmland and where counts had been performed in all of the four years 1990–1993 were selected for habitat analysis. A total of 1022 census points met these criteria. These points were visited during autumn 1993, and a habitat description form was completed. To improve consistency, just two field biologists who received some preliminary training carried out the habitat description work.

The area within a 12.5 ha circle (radius 200 m) around each point was described using a combination of field studies and measurements from topographic maps (1:25,000). The distance to the nearest occurrence of some major habitats, other than arable land, was also measured (if within 500 m). Habitat characteristics quantified within the 12.5 ha circle were: (1) proportion of area covered by each major habitat (arable, permanent grassland, wetland, wood, urban area); (2) length of broad untilled borders along field margins; (3) length and composition of hedgerows; (4) area and composition of 'dry' habitat islands (coverts etc.); (5) area and composition of 'wet' habitat islands (marl-pits, ponds etc.); (6) area and composition of 'human' habitat islands (buildings, gardens). Non-linear habitat elements smaller than 1 ha were classified as 'islands', while larger elements were classified as 'major habitats'. A total of 51 habitat variables were measured in the field, but for analysis they had to be combined to yield a smaller set of variables; the habitat variables used in the analyses are presented in Table 1. All lengths and areas were measured in 10-m and 100-m^2 units, respectively.

2.2. Data analysis

To improve homogeneity, only census points where the total proportion of 'major habitats' (cf. above) other than arable land and permanent grassland did not exceed 10% within the 12.5 ha circle were used for analysis; 706 points met this criterion. A total of 126 bird species were recorded at these points during the four study years. The total number of species recorded at each point was used as a simple measure of species diversity. In the analyses of species-habitat relationships, only species encountered at 20 or more census points were considered, limiting the number of species to 61.

For each of these species, the mean number of individuals 1990–1993 was used as an index of population density at each point. To improve approximation to a normal distribution, all mean densities were $\log_e(x + 1)$ transformed. Habitat variables recorded as percentages in the field were converted to areas or lengths, and the areas were square root transformed, so that all habitat variables entered the analysis on an equal footing.

As an introductory step, the relationship between species diversity and the habitat variables was analysed using stepwise multiple regression analysis. Next, a more species-orientated analysis of species-habitat relationships was carried out by means of canonical correlation analysis (e.g., Gittins 1985, SAS Institute 1990); by this method, axes (canonical variables) are constructed so that the correlation between species variables and habitat variables is maximized. Biplots visualizing the correlations were constructed according to Jongman et al. (1987). As a supplement to the canonical analyses, multiple regression analyses of the population density of each species in relation to habitat variables were performed; because the chief purpose of these analyses was to aid interpretation of the canonical analyses, no attempts at variable selection were made.

The analysis of species-habitat relationships was carried out in two steps. Firstly, the distribution of birds was analysed in relation to gross habitat structure; nine habitat variables were selected or compounded from the original set such that each variable described one of the main habitat features included in the study (Table 1a). Secondly, the importance of 'minor' habitat elements, i.e. linear elements and habitat islands, the effects of which may be disguised by predominant effects of major habitats, was studied in more detail by entering variables describing the composition of the minor habitat elements (Table 1b) into the analyses while eliminating (partialling out, cf. Jongman et al. (1987)) the effects of major habitats (> 1 ha) and buildings/gardens by entering them into the analysis as covariables.

In all analyses, additional factors that might affect the bird densities recorded were included as covariables: (1) Mean census date 1990–1993. This varied by as much as 30 days between points

Table 1. Habitat variables used for analysis. With the exception of 'D'-variables, all variables refer to the area within the 12.5 ha circle around each census point. The variables in (a) were used in the first analysis. In the second analysis, variables HEDGE, COV and PIT were replaced by the variables in (b).

Abbreviation	Description	Range
(a)		
D.GRS	Distance to nearest occurrence of permanent grassland > 1 ha	0–500 m[1)]
D.WET	Distance to nearest occurrence of wetland (marsh, lake, coast) > 1 ha	0–500 m[1)]
D.WOOD	Distance to nearest occurrence of wood > 1 ha	0–500 m[1)]
D.URB	Distance to nearest occurrence of urban area > 1 ha	0–500 m[1)]
BUILD	Total area of buildings, gardens etc. (outside urban areas)	0–5.10 ha
BORD	Total length of broad (≥ 2 m) untilled borders	0–1400 m
HEDGE	Total length of hedgerows	0–2000 m
COV	Total area of dry habitat islands (coverts, groves etc.)	0–1.20 ha
PIT	Total area of wet habitat islands (marl-pits, ponds etc.)	0–1.60 ha
(b)		
DEHE1	Length of deciduous hedgerows lower than 8 m	0–2000 m
DEHE2	Length of deciduous hedgerows higher than 8 m	0–680 m
CONHE	Length of coniferous hedgerows	0–1490 m
DEDRY	Dry habitat island area with deciduous trees	0–0.90 ha
CODRY	Dry habitat island area with coniferous trees	0–0.86 ha
HERB	Dry or wet habitat island area with herbs and grasses	0–0.80 ha
WATER	Wet habitat island area with open water or reeds	0–1.35 ha
WOODY	Wet habitat island area with woody plants (trees or bushes)	0–0.56 ha

[1)] Distances longer than 500 m were coded as 999 m and had to be included as the census period encompassed the main arrival period of many tropical migrants. (2) Observer. A total of 46 different ornithologists participated, entered as 46 dummy variables. As each observer worked within a limited geographical area, this factor may include some locational effects as well, but a survey of the material indicated that differences in observer skill predominated. (3) Longitude (measured to nearest hundredth degree). This factor was included as a simple measure of the census point's location on the major gradient in climate and soil characteristics in Denmark: from comparatively Atlantic areas and sandy soils in the west towards more continental areas and brown earths in the east.

Given the scale of the study, the analyses were used in an explorative way, and no predictions in mathematical terms have been made. Significance levels in the multiple regression analyses are only approximate due to deviations from normality, especially in the less common species. Further, due to the large number of tests performed, some of the correlations found to be significant — especially at the 5% level — may well be spurious.

3. Results

The mean number of species per point, accumulated over four years, was 18.0 (SD = 4.92, range 5–39). The multiple regression analysis (Table 2) showed that the number of species was negatively related to distance to permanent grassland, wetland and wood, and positively related to area of buildings and gardens, dry habitat islands and wet habitat islands with woody plants (all $p < 0.01$). All other habitat variables had p values > 0.05. Variation between observers was highly significant ($p < 0.001$) while date and longitude did not significantly affect species diversity.

Table 2. Results of the stepwise regression analysis of species diversity. Only habitat variables with p values < 0.1 have been included. Variable abbreviations are explained in Table 1.

Variable	Regression coefficient	P value
D.GRS	– 0.0230	< 0.0001
D.WET	– 0.0167	< 0.0001
D.WOOD	– 0.0170	< 0.0001
BUILD	0.0230	< 0.0001
BORD	0.0117	0.0566
COV	0.0194	0.0054
WOODY	0.0405	< 0.0001

The results of the canonical correlation analysis relating species occurrence to gross habitat structure are presented in Fig. 1, while results of the complementary multiple regression analyses are summarized in Table 3. In Fig. 1a, species to the left occur in open arable land whereas species to the right are associated with areas where other habitats occur. Species in the bottom of the figure appear quite strongly connected with buildings and/or the surrounding gardens (notice the affiliation of Collared Dove with urban areas). Upwards through the bottom right quadrant in the figure, species affiliation with human dwellings decreases, and the top right quadrant holds species that are associated with various habitats which break up the uniform farmland, but not with houses or gardens. In Fig. 1b, species to the left of the vertical axis are connected with human dwellings while the opposite is true for species to the right. Species in the lower half of the figure are associated with trees or bushes whereas species above the horizontal axis are birds of the open countryside, including grassland and wetlands. Directed counterclockwise from the BUILD vector, a gradient from garden species to species occurring in hedgerows, coverts and woodland edges is displayed. Clockwise a gradient of decreasing linkage with farmland buildings is followed until the species associated with meadows and wetlands are reached.

The distribution of species revealed in Fig. 1 is heavily influenced by the distance to major habitats and the extent of buildings/gardens. Partialling out the effects of these variables allowed the effects of linear elements and habitat islands to be studied in more detail when variables HEDGE, COV and PIT were replaced by the eight variables in Table 1b. The numerous Skylark — which shows highly significant avoidance of all of the vertical habitat structures (cf. Table 3) — was omitted from the analysis as this made the affinities of the other species appear more clearly. The results of this second canonical correlation analysis are shown in Fig. 2 with the results of the corresponding multiple regression analyses being

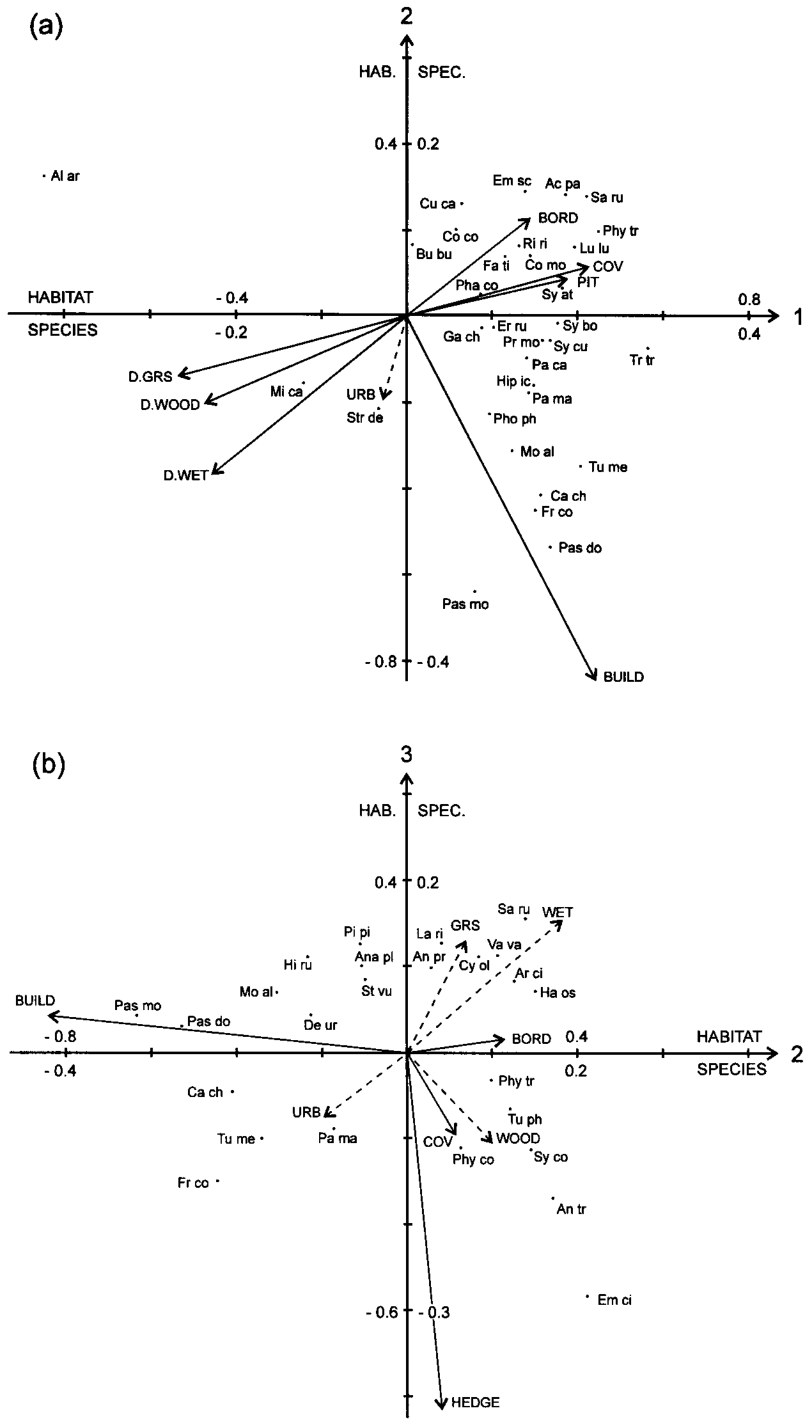

Fig. 1. Correlation biplots visualizing the results of the canonical correlation analysis of 61 farmland bird species vs. 9 habitat variables describing gross habitat structure. Axes are (a) first and second canonical variables of the habitat variables, (b) second and third. The three canonical variables explain 30.5%, 23.6% and 13.7% of the total variance, respectively. Habitat vectors represent correlations between habitat variables and the axes; very short habitat vectors (correlation less than 0.1 with each axis) are not shown. Habitat vector D.URB in (a) and all 'D'-variable vectors in (b) (indicating distance to habitat) have been reflected through the origin to ease interpretation; new vectors URB, GRS, WET and WOOD (indicating proximity of habitat) are shown as broken lines. Species vectors, representing correlations between species variables and the axes, are shown by their end points only. The length of a species vector indicates how well the occurrence of the species in question is explained by the canonical variables of the habitat variables, while the cosine of the angle between a species vector and a certain habitat vector is a measure of their mutual correlation. Species where none of the correlations with the axes exceeded 0.08 (roughly equivalent to p = 0.05) have been omitted. See Tables 1 and 3 for explanation of habitat variables and species abbreviations, respectively.

summarized in Table 4. A number of species groups have been delimited in the figures; this has been done subjectively with the purpose of facilitating interpretation and discussion.

In Fig. 2a, the species in group I are not linked with any of the habitat variables; they are birds of

Table 3. Summary of the results of multiple regression analyses relating population densities of 61 farmland bird species to 9 habitat variables describing gross habitat structure (Table 1a). Only significant relationships are reported. Signs indicate directions of relationships, and number of signs indicate degree of significance ($p < 0.05$, $p < 0.01$ and $p < 0.001$ for 1, 2 and 3 signs, respectively). Notice that a negative relationship (a negative partial regression coefficient) between a species and a 'D'-variable indicates a positive association between the species and the habitat in question. Also shown are abbreviations used in Figs. 1 and 2 and the number of points with records of the species (n).

Abbrev.	Species	n	D.GRS	D.WET	D.WOOD	D.URB	BUILD	BORD	HEDGE	COV	PIT
Ph car	Cormorant *Phalacrocorax carbo*	41									
Ar ci	Grey Heron *Ardea cinerea*	140		–				+ +	–	+	
Cy ol	Mute Swan *Cygnus olor*	33		–							
Ta ta	Shelduck *Tadorna tadorna*	120									
Ana pl	Mallard *Anas platyrhynchos*	105				– –			– –		+ +
Ci ae	Marsh Harrier *Circus aeruginosus*	23						– –			
Bu bu	Buzzard *Buteo buteo*	110									
Fa ti	Kestrel *Falco tinnunculus*	64		– –							
Pe pe	Grey Partridge *Perdix perdix*	96									
Pha co	Pheasant *Phasianus colchicus*	544									
Ga ch	Moorhen *Gallinula chloropus*	20		–		– – –					+ +
Fu at	Coot *Fulica atra*	47		– –							+
Ha os	Oystercatcher *Haematopus ostralegus*	72	–				– – –				+ +
Va va	Lapwing *Vanellus vanellus*	322	– –				–				+
La ri	Black-headed Gull *Larus ridibundus*	477							– –		
La ca	Common Gull *Larus canus*	184									
La ar	Herring Gull *Larus argentatus*	209									
Col pa	Woodpigeon *Columba palumbus*	608									
Str de	Collared Dove *Streptopelia decaocto*	100				– – –					
Cu ca	Cuckoo *Cuculus canorus*	382		– –			–				
Ap ap	Swift *Apus apus*	80									
Al ar	Skylark *Alauda arvensis*	699			+ + +	+ + +	– – –		– – –	– – –	– – –
Ri ri	Sand Martin *Riparia riparia*	33		–	– –						
Hi ru	Swallow *Hirundo rustica*	509	–				+ + +				
De ur	House Martin *Delichon urbica*	182					+ + +				
An tr	Tree Pipit *Anthus trivialis*	57			– –		– –		+ + +	+	
An pr	Meadow Pipit *Anthus palustris*	22		–							
Mo al	White Wagtail *Motacilla alba*	203					+ + +				
Tr tr	Wren *Troglodytes troglodytes*	151			– – –	– –	+ +			+ + +	+
Pr mo	Dunnock *Prunella modularis*	96			–		+			+	
Er ru	Robin *Erithacus rubecula*	23								+	
Lu lu	Thrush Nightingale *Luscinia luscinia*	189		– –							+ +
Pho ph	Redstart *Phoenicurus phoenicurus*	28					+ + +				+
Sa ru	Whinchat *Saxicola rubetra*	38	– – –	– –				+	– –		
Tu me	Blackbird *Turdus merula*	624			– –	– –	+ + +		+		
Tu ph	Song Thrush *Turdus philomelos*	115			– – –		–			+ +	
Tu vi	Mistle Thrush *Turdus viscivorus*	21									
Ac pa	Marsh Warbler *Acrocephalus palustris*	62		–		+ +		+ + +			+ +
Hip ic	Icterine Warbler *Hippolais icterina*	138					+ + +				
Sy cu	Lesser Whitethroat *Sylvia curruca*	119		– –			+ +				
Sy co	Whitethroat *Sylvia communis*	537	–		– –			+ +	+ + +		
Sy bo	Garden Warbler *Sylvia borin*	150			– – –					+ +	
Sy at	Blackcap *Sylvia atricapilla*	159			– – –					+ + +	
Phy co	Chiffchaff *Phylloscopus collybita*	28								+ +	+
Phy tr	Willow Warbler *Phylloscopus trochilus*	175		–	– – –					+ + +	
Pa ca	Blue Tit *Parus caeruleus*	58					+	+			
Pa ma	Great Tit *Parus major*	262	–				+ + +		+ +		
Pi pi	Magpie *Pica pica*	277	– –				+		–		

Table 3. Continued.

Abbrev.	Species	n	D.GRS	D.WET	D.WOOD	D.URB	BUILD	BORD	HEDGE	COV	PIT
Co mo	Jackdaw *Corvus monedula*	144		– –		–		+ +			
Co fr	Rook *Corvus frugilegus*	189									
Co co	Hooded Crow *Corvus corone*	572									
St vu	Starling *Sturnus vulgaris*	516	– –		+		+ +				+
Pas do	House Sparrow *Passer domesticus*	221					+ + +				
Pas mo	Tree Sparrow *Passer montanus*	252					+ + +				
Fr co	Chaffinch *Fringilla coelebs*	520	+ +		– – –		+ + +		+	+	
Ca ch	Greenfinch *Carduelis chloris*	216			–	– –	+ + +				
Ca car	Goldfinch *Carduelis carduelis*	43									
Ca can	Linnet *Carduelis cannabina*	288									
Em ci	Yellowhammer *Emberiza citrinella*	524			– – –		– –	+ +	+ + +	+ + +	+ + +
Em sc	Reed Bunting *Emberiza schoeniclus*	30		– – –							+
Mi ca	Corn Bunting *Miliaria calandra*	160			+ + +	+				–	

the open countryside or are connected with buildings. (If the Skylark had been included, it would have been placed far to the left in the figure.) The species in group II appear associated with untilled borders along ditches and field margins, while species in group III occur in dry habitat islands or in trees and bushes around water holes. Group IV mainly comprises species occurring in hedgerows. In Fig. 2b, species in group I are connected with water. Group II consists of species associated with deciduous dry habitat islands and woody plants around water holes or with untilled borders and other areas with herbs and grasses. Clockwise from the BORD vector (species group III), a gradient of decreasing affiliation with untilled borders and increasing affiliation with low deciduous hedgerows and further with coniferous hedgerows is followed. In this analysis, the fourth axis (not shown) was a water axis, with species like Mallard, Oystercatcher, Lapwing and Moorhen being associated with it.

4. Discussion

4.1. Point counts

The point count method has two major assets: it is easily standardized, and it yields a great amount of data per unit effort. These assets make it ideal for a monitoring programme based on voluntary work. Since a standard area in which to describe habitat characteristics may readily be defined around each census point, the method also offers a straightforward access to analysis of bird-habitat relationships (Bibby et al. 1992). However, when such an analysis is based upon a large, but rather heterogeneous material collected by volunteer ornithologists, problems may arise with observer variability and site representativeness.

The analysis of species diversity showed differences between observers to be a highly significant source of variation. In all analyses, observer effects were estimated and controlled statistically. The 706 census points were selected from the total sample by means of an objective criterion (percentage of farmland within a radius of 200 m), but did not constitute a random sample of Danish farmland. The points were usually placed on roads or field lanes, causing areas near farms and houses to be overrepresented in the sample. A corollary of this is that buildings and gardens made up a larger part of the habitat description circles than of the agricultural landscape in general; this may have led to an overestimation of the effects (positive or negative) of these habitats on farmland avifauna. With respect to other habitat elements, biases were probably small.

No attempts to estimate absolute population densities were made. Absolute densities may be required if comparisons between species are needed, but for the within-species comparisons used in the present context, relative density estimates suffice. A bias may arise if detectability of a species is influenced by habitat. Within the range of habitats covered in the present study, this is a mi-

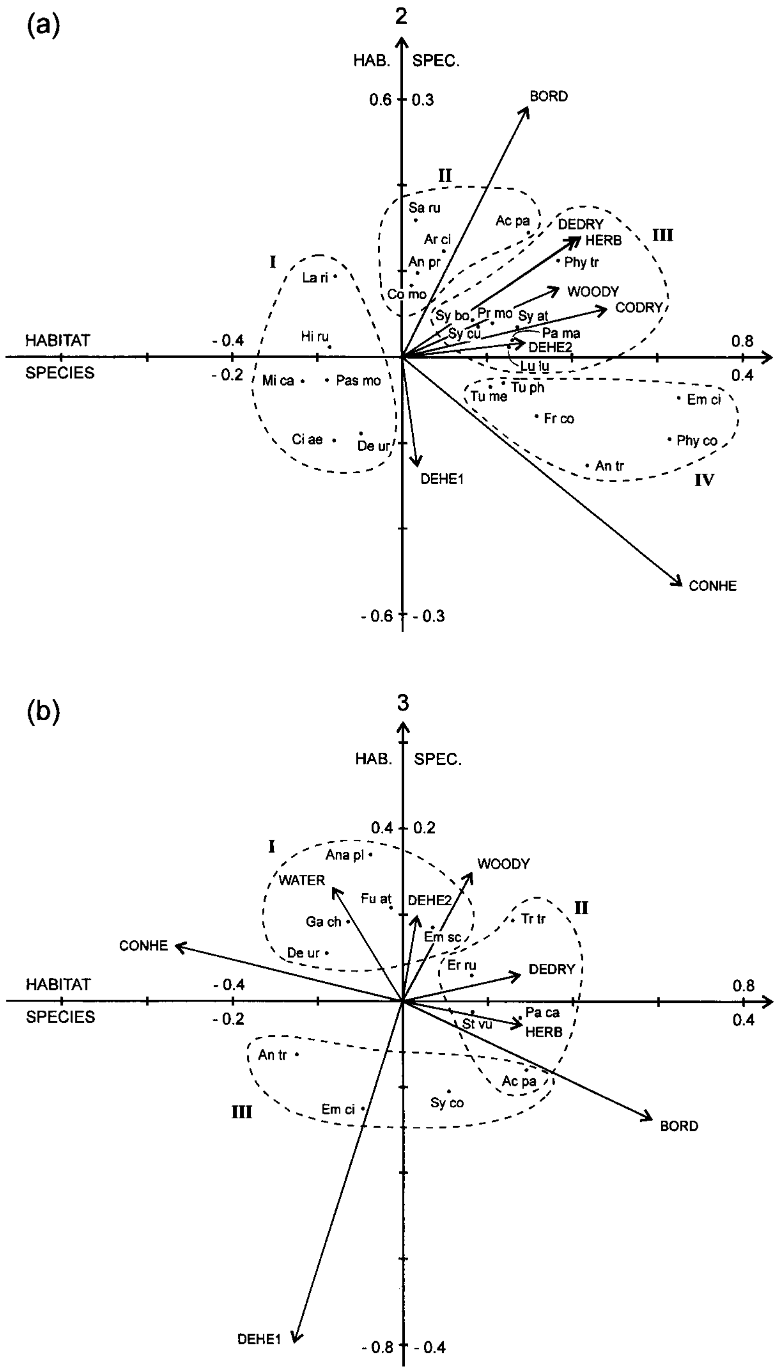

Fig. 2. Correlation biplots showing the results of the second canonical correlation analysis; 60 farmland bird species vs. 9 habitat variables describing extent and structure of habitat islands and linear elements. Effects of major habitats and buildings/gardens have been partialled out. Axes are (a) first and second canonical variables of the habitat variables, (b) second and third. The three canonical variables explain 27.1%, 16.9% and 13.3% of the total variance, respectively. As in Fig. 1, species showing no significant correlations with the axes have been omitted. See Fig. 1 for further explanation and Tables 1 and 3 for habitat variables and species codes, respectively.

nor problem although hedgerows may reduce detectability of species that are primarily recorded by sight (e.g., gulls, corvids). In some of these species, it is not clear whether an apparent avoidance of areas with hedgerows is real or an artifact.

4.2. Effects of habitat

Proximity of other major habitats than arable land (wood, wetland, permanent grassland) has pronounced, positive effects on species diversity as well as on the population densities of many species. In the multiple regression analyses, 15 species increased significantly in numbers with decreasing distance to wetland, 13 with decreasing distance to wood, and 8 with decreasing distance to grassland, whereas only 0, 3 and 1 species, respectively, showed the opposite trend. Distance to urban areas had less distinctive effects.

Equally important, judged by the present data, is the presence of houses and other farmland buildings with adjoining gardens (due to a close correlation between building area and garden area, data

Table 4. Summary of the results of multiple regression analyses relating population densities of 60 farmland bird species to 9 variables describing the extent and structure of habitat islands and linear habitat elements. See Table 1 for an explanation of habitat variables and Table 3 for scientific bird names. Signs indicate directions of significant relationships ($p < 0.05$), and number of signs indicate degree of significance, as in Table 3. Only species in which one or more significant relationships were found have been included.

	BORD	DEHE1	DEHE2	CONHE	DEDRY	CODRY	HERB	WATER	WOODY
Grey Heron	+ +	–							
Shelduck								+	–
Mallard		– –					–	+ + +	
Marsh Harrier	– –		–						
Kestrel							+		– –
Moorhen							– –	+ + +	
Coot									+
Oystercatcher								+	
Lapwing								+	
Black-headed Gull				– –					
Herring Gull							+		
Swift	–								
Sand Martin						+ +			
Swallow						– –			
House Martin								+	
Tree Pipit		+ +		+ + +					
Wren					+ + +				+
Dunnock									+ +
Robin			+ + +						
Thrush Nightingale									+ +
Whinchat	+	–		–					
Blackbird									+
Song Thrush				+ +	+ +				
Marsh Warbler	+ + +						+		
Icterine Warbler			+						
Lesser Whitethroat									+
Whitethroat	+ +	+ + +							
Garden Warbler					+ + +				+
Blackcap					+	+ +			+ +
Chiffchaff			+	+ + +		+ +	+		+
Willow Warbler						+	+	–	+ + +
Blue Tit	+							–	+
Great Tit		+							+
Magpie		–							
Jackdaw	+ +	–						+	–
Rook								+ +	
House Sparrow							+		
Tree Sparrow									–
Chaffinch			+ + +	+ +					+
Goldfinch			+ +						
Yellowhammer	+ +	+ + +		+ + +	+				

did not allow any separation of building and garden effects). In 13 species, all of them passerines, proportion of circle area covered by buildings/gardens was the strongest (positive) predictor of population density in the regression analysis. The species affiliated with human dwellings may be divided into three groups (cf. Fig. 1): species closely connected with buildings and their immediate surroundings (House Sparrow, Tree Sparrow), species associated with buildings for breeding but mostly foraging at grasslands and other open areas (Swallow, House Martin, White Wagtail, Starling), and garden species reaching their highest densities at human dwellings, but also occurring elsewhere in farmland associated with various kinds of woody vegetation (Redstart, Blackbird, Icterine Warbler, Lesser Whitethroat, Blue Tit, Great Tit, Chaffinch and Greenfinch).

As to the linear habitat elements, neither total length of untilled borders nor total length of hedgerows has any significant effect on species diversity, although densities of a number of species increase with increasing length of these habitat structures. The occurrence of broad, untilled borders with herbaceous vegetation between fields and along roads and ditches has a positive effect on densities of Grey Heron, Meadow Pipit, Whinchat, Marsh Warbler and Jackdaw, i.e. species also showing affiliation with meadows and wetlands. A few species mainly connected with trees and bushes (Blue Tit, Whitethroat, Yellowhammer) also increase in numbers where untilled borders occur. However, population densities of the last two species are more strongly affected by hedgerow length, and together with Tree Pipit these species constitute a group which is primarily associated with hedgerows, at least within the range of habitats studied (cf. Table 3). Whitethroats clearly prefer deciduous hedges, especially those lower than 8 m, whereas Tree Pipits favour coniferous hedgerows and Yellowhammers show no obvious preferences (Fig. 2, Table 4). Robin and Icterine Warbler are connected with high deciduous hedgerows. While many arboreal species increase in numbers where hedgerows occur, densities of other species seem to decline with increasing hedgerow length. In some species, this negative correlation may be an artifact as discussed above, but some open-land species, e.g., Skylark, certainly decrease in numbers where the agricultural plains are interspersed with hedges or other vertical structures (Oelke 1968, Christen 1984, Petersen 1996). Lack (1992), summarizing evidence on bird-hedgerow relationships, concluded that species diversity peaks when the amount of hedgerows is equivalent to 60–80 m/ha. This hedgerow density is rarely exceeded in Danish farmland; only five percent of the habitat description circles in the present study held 1000 metres of hedgerow (80 m/ha) or more.

Dry habitat islands with trees and bushes attract a number of passerine species that also occur in woods and gardens, e.g., Wren, Garden Warbler, Blackcap, Chiffchaff and Willow Warbler. The first two species show particular preferences for deciduous stands while Chiffchaff mainly is associated with conifers. Notably, both *Phylloscopus* species increase in numbers where areas with herbs and grasses occur in connection with the woody plants. Trees and bushes around water holes are the haunt of Thrush Nightingales but also attract a number of species that occur in gardens (e.g., Redstart, Blackbird, Blue Tit), dry habitat islands with woody vegetation (e.g., Dunnock, Blackcap, Willow Warbler) and hedgerows (e.g., Yellowhammer). Also Mallards, Moorhens, Coots and Reed Buntings chiefly occur in water holes that are surrounded by woody plants (typically old marl-pits), whereas ponds that are surrounded by herbaceous vegetation attract species like Shelduck, Oystercatcher, Lapwing, Jackdaw and Rook. The densities of Kestrel, Marsh Warbler and Starling appear positively related to the size of the area with herbs and grasses around the pond but not to the area of open water.

In a number of species, variations in population density do not seem to be related to the habitat variables dealt with here, or the correlations between densities and habitat variables are negative. One of these species, the Grey Partridge, is probably not well censused by point counts, and most of the other species that are not associated with any of the habitat features (e.g., Buzzard, Pheasant, gulls, Woodpigeon) are often recorded at some distance, thus having little connection with the habitats quantified within the 12.5 ha circle. Skylarks and Corn Buntings are birds of 'pure' agricultural land, avoiding areas adjacent to woods, urban areas, coverts etc. Within the arable land, their densities are primarily determined by factors that are not considered here, first of all farming regime and crop type (Schläpfer 1988, Jenny 1990, Donald & Forrest 1995). The distribution of some of the 'unexplained' species (Grey Partridge, Linnet, Goldfinch) may also be affected by factors related to cropping pattern and other aspects of agricultural practice; for instance, these species are known to favour unsprayed headlands and fallow (Potts 1986, Berg & Pärt 1994, Petersen 1996). Inquiring into the habitat relationships of these species requires rather detailed information about the cultivated areas; such information has not been collected in the present context.

4.3. Implications for conservation

As demonstrated in the analysis of species diversity and visualized by a comparison of the right and left halves of Fig. 1a, increasing the habitat diversity of farmland generally has a positive effect on species diversity as well as on population densities of many species (numerous examples in Lack 1992). The data presented in this paper indicate which species may benefit from different kinds of habitat enrichment under the conditions prevailing in Danish agricultural areas. Because different species benefit from different habitat features, a mixture of habitats should be created in order to maximize species diversity. The commonest way of increasing habitat diversity is by laying out hedgerows, coverts or small plantations; several studies have dealt with management of these landscape elements and their importance for birds (e.g., Ford 1987, Green et al. 1994, Parish et al. 1994, 1995, Macdonald & Johnson 1995, Sparks et al. 1996). However, it is at least equally important that wetlands and grasslands are preserved or created. It should also be borne in mind that whereas hedgerows benefit a number of arboreal species, a too dense grid of hedges makes the area less suitable for Skylark and other open-plain species.

In Table 5a, I have listed the species which according to the present study will probably benefit from increased amounts of woody vegetation in farmland (as habitat islands or linear elements), together with an indication of the species' recent population trends in Denmark and neighbouring countries. Table 5b gives population trends of farmland species that do not show any affiliations with woody vegetation and thus presumably will not benefit from planting trees and shrubs. A comparison reveals that while population densities of the majority of species associated with open countryside are decreasing, most species connected with woody vegetation have stable or increasing populations. The three species mainly associated with hedgerows tend to differ from most of the other arboreal species by having suffered some recent declines.

The majority of species listed in Table 5b search for most of their food in fields or meadows (Christensen et al. 1996), and reduced amounts of food here may be the major cause of their population declines (Fuller et al. 1991, Petersen 1994). On the contrary, species associated with coverts and other woody habitat islands forage mainly within the island (finches may be an exception) and thus are less affected by impaired feeding possibilities in the fields. The species preferring hedgerows to habitat islands may differ by being more dependent on the fields for foraging, as demonstrated in the Yellowhammer (Biber 1993); this may explain their recent negative population trends. Changes in agricultural practice which increase the quantities of birds' food items in fields and grasslands are probably required if the negative population trends of species relying on these areas for feeding are to be reversed. Habitat improvements that involve further planting of trees and bushes in farmland, on the other hand, may largely benefit species whose populations are either stable or increasing and thus should be of little conservation concern.

Acknowledgements. All the volunteer ornithologists who contributed data to the study are warmly acknowledged. Jörn Eskildsen and Jan Bolding Kristensen did the huge job of describing the 1022 sites. Steffen Brøgger-Jensen is thanked for constructive discussions and advice and Juha Tiainen for valuable comments on the manuscript. The study was supported by the Centre for Agricultural Biodiversity of the Danish Environmental Research Programme.

Selostus: **Peltolinnuston rakenteeseen vaikuttavat tekijät tanskalaisessa maanviljelymaisemassa**

Monien peltolintulajien populaatioiden on todettu taantuneen eri puolilla Luoteis-Eurooppaa. Syynä populaatioiden alamäelle on pidetty maanviljelysmenetelmien tehostumista, joka on johtanut joi-

Table 5. Population trends 1976–1996 of 38 farmland species, half of which connected with woody vegetation (a), the other half occurring in open countryside (b). The three species marked with an asterisk (*) mainly occur in hedgerows rather than in habitat islands. Besides the Danish trends, trends from other North European countries are mentioned if they are known to differ from the Danish trends. Codes are: + 2: large increase (> 50%), + 1: small increase (20–49%), 0: stable (< 20% change), – 1: small decrease, – 2: large decrease, F: fluctuating (changes ≥ 20%, no trend). See Table 3 for scientific names. Based upon Marchant et al. (1990), Hustings (1992), Saris et al. (1994), Tucker and Heath (1994), Asbirk et al. (1997), Jacobsen (1997), and Väisänen et al. (1998).

	Population trend in Denmark 1976–96	Trends elsewhere in N Europe (if different from Danish trend)
(a)		
Wren	F	
Dunnock	– 2	Decrease in UK, stable or increasing elsewhere
Robin	F/+ 1	Stable elsewhere in Fenno-Scandia
Redstart	– 1	Recent increase in UK, decreasing elsewhere
Blackbird	+ 1	Decrease in UK
Song Thrush	0	Decrease in UK and Netherlands
Icterine Warbler	– 1[1)]	Increase in Sweden and Finland, largely stable elsewhere
Lesser Whitethroat	F/– 1	Largely stable elsewhere
Garden Warbler	0[2)]	Increase in UK and Sweden
Blackcap	+ 2	Stable in Norway and Finland
Chiffchaff	+ 2	Decrease in Finland, largely stable elsewhere
Willow Warbler	0	
Blue Tit	F	Increase in UK, Netherlands and Finland, stable elsewhere
Great Tit	0	
Chaffinch	+ 1	Largely stable elsewhere
Greenfinch	+ 2	Mostly stable outside Fenno-Scandia
* Tree Pipit	+ 1[3)]	Mostly stable elsewhere
* Whitethroat	– 1	Decrease in Netherlands and Germany, largely stable elsewhere
* Yellowhammer	0/– 1	Decrease in Netherlands, Germany and Norway, stable elsewhere
(b)		
Kestrel	0[4)]	Decrease in NE Europe
Grey Partridge	– 1	
Oystercatcher	0/+ 1	
Lapwing	– 2	Stable in Netherlands, decreasing elsewhere
Skylark	– 1	
Swallow	– 1	
House Martin	– 1	
Meadow Pipit	– 1	Decrease in some lowland regions; stable or increasing elsewhere
White Wagtail	+ 2	Largely stable elsewhere
Whinchat	– 1	Stable in Norway, Sweden and Finland
Marsh Warbler	0[5)]	Expanding northwards in Fenno-Scandia
Magpie	+1	
Rook	+ 1	Widespread decline c. 1950–75, some recovery since then
Starling	– 1	
House Sparrow	– 1	
Tree Sparrow	F/+ 1	Decrease in UK, Netherlands and Germany
Goldfinch	+ 1	Decrease in UK and Finland
Linnet	– 1[6)]	Decrease throughout NW Europe 1970–90
Corn Bunting	– 2	

[1)] Increase 1976–83 followed by large decrease
[2)] Increase 1976–87 followed by decrease
[3)] Large increase 1976–87 followed by decrease
[4)] Decrease 1976—85 followed by increase
[5)] Range expansion towards N and W, population size stable
[6)] Large decrease 1976–82 followed by slow increase

denkin peltoelinympäristöjen vähenemiseen, elinympäristöjen laadun heikkenemiseen muuttuneiden viljelysmenetelmien ja maatalouskemikaalien käytön seurauksena. Kirjoittaja tutki Tanskan peltolinnuston rakennetta (lajien levinneisyyttä ja runsautta) suhteessa peltomaiseman rakenteeseen. Tutkimuksen päämääränä oli löytää peltolinnuston monimuotoisuuden kannalta keskeiset tekijät, joiden avulla maataloudessa tapahtuvien muutosten vaikutusta linnustoon voitaisiin ymmärtää ja ennustaa. Kirjoittaja käytti aineistona Tanskan pesimälinnuston seurantaohjelman pistelaskentatuloksia vuosilta 1990–1993. Yhteensä 706 laskentapisteen ympäristöstä kirjoittaja kvantifioi peltomaiseman rakennetta mittaamalla eri peltoelinympäristötyyppien ja niiden välisten reunojen määrää ja sijoittumista maisemassa. Tulokset osoittivat, että peltolinnuston lajimäärä oli sitä korkeampi mitä lähempänä laskentapiste oli laidunmaita, kosteikkoja ja metsälaikkuja. Myös monien yksittäisten lajien runsaus kasvoi kohti näitä maisemaelementtejä. Toisaalta lajimäärä sekä monien lajien tiheys korreloi positiivisesti rakennetun maan, puutarhojen, kuivien habitaattilaikkujen (tiheikköjen) ja puustoisten kosteikkolaikkujen määrän kanssa. Maisemassa esiintyvien reunojen määrällä ei tulosten mukaan ollut yhteyttä lajimäärään, vaikka useiden lajien runsaus oli selkeästi yhteydessä reunojen esiintymiseen. Tulosten perusteella peltolinnusto voidaan jakaa kahteen luokkaan: toisaalta tyypillisiin avomaalajeihin ja toisaalta lajeihin, joiden esiintyminen on sidoksissa puuvartisen kasvillisuuden esiintymiseen puutarhoissa, pensasaidoissa ja puustoisissa laikuissa. Viimeaikaisten populaatiotrendien analysointi paljasti, että vähentyneet peltolinnut kuuluvat etupäässä tyypillisiin avomaalajeihin.

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