

The influence of intersections and dead-ends of line-corridor networks on the breeding bird distribution

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Abstract. The breeding bird communities in four networks of line corridors were studied during the period 1993–1996 with the aim to characterise the influence of intersections and dead-ends of corridors on the breeding bird distribution. The results of this study show that species richness and number of territories in line-corridors depend on the vegetation volume, width and distance of the section from the nearest intersection or dead-end. Moreover, the abundance of corridor-dependent species is influenced not only by the distance of the section from the nearest intersection or dead-end, but also by the section type. Sections adjacent to intersections support more territories of corridor-dependent species. In our study we recorded increasing number of territories of nightingale, blackcap, whitethroat, lesser whitethroat along with the decreasing distance of sections from dead-ends or intersections. Territories of great tit and icterine warbler were more common in sections adjacent to intersections. Only one species (tree sparrow) was associated with sections adjacent to dead-ends.

Key words: windbreaks, spatial structure, bird species richness, bird density, GLM

Introduction

Networks of line-corridors are typical features of agricultural landscapes in Central Europe. In many cases they are the only semi-natural habitats in many thousand-hectare wide areas. Windbreaks, hedgerows and tree-lines along streams, ditches, railways and roads serve not only as corridors for flora and fauna, but also as breeding habitats for many bird species in Slovakia (Krištín 1987, Tirinda 1994, Mošanský 1996), as well as in neighbouring countries (Balát 1986, Jánoska 1993, Gromadzki 1970, Górski 1988, Kujawa 1997). In British farmland, hedgerows are the typical landscape features and valuable habitat for breeding birds (e. g. Osborne 1984, Lack 1988, Green et al. 1994, Parish et al. 1994, 1995, Hinsley & Bellamy 2000). Similarly, shelterbelts and windbreaks provide good nesting condition for birds in overseas countries (e.g. Yahner 1983, Best 1983, Hino 1985, Johnson & Beck 1988).

Many studies have shown that bird species richness and overall abundance depends on corridor width and area (Cable et al. 1992, Parish et al. 1994, Kujawa 1997, Hinsley & Bellamy 2000, Sykes & Hannon 2001) as well as on vegetation structure (Osborne 1984, Hino 1985, Kujawa 1997, Hinsley & Bellamy 2000, Sykes & Hannon 2001). The influence of surrounding land-use and the wider landscape on bird species richness and bird abundance were also confirmed (Osborne 1984, Parish et al. 1994). However, there was only one study examining

the relationship between bird distribution and corridor intersections (L a c k 1988). The influence of windbreak intersections on bird density was also examined in our previous study (T i r i n d a 1994). The theory that nodes (crossings – intersections) in hedgerow networks are preferred by bird species due to their specific microhabitat requirements has been generally accepted (W i l l i a m s o n 1969, B e n s o n & W i l l i a m s o n 1972, H o f f m a n n & K r e t s c h m e r 1994), however, it is not supported by experimental data. On the other hand, corridor dead-ends and breaks are considered as barriers (F o r m a n & G o d r o n 1986, F o r m a n 1983).

The aim of our study was to examine the distribution and abundance of breeding birds in line-corridors in relation to the vegetation structure, width and proximity to dead-ends or to intersections. Three hypotheses have been proposed in this study: (1) the species richness increases with decreasing section distance from the dead-end or intersection; (2) the total number of breeding territories in corridor sections adjacent to dead-ends and intersections is higher than in sections farther from them; (3) territories of corridor-dependent species are accumulated in sections adjacent to or in the vicinity of dead-ends or intersections, whereas territories of other species are distributed randomly along the corridor.

Study Area

Four networks of line-corridors situated in the agricultural landscape near the city of Bratislava, South-Western Slovakia, were studied to determine the bird distribution in the line corridor networks (Fig. 1).

The first network of corridors is situated in the northeast periphery of Bratislava, near the suburban village Vajnory – Čierna Voda. The second locality (about 20 km east of Bratislava, between Dunajská Lužná and Šamorín) is a part of the greatest wheat region of Slovakia – the Podunajská nížina lowland. The third network of corridors is located about 30 km north-east of Bratislava near Šenkvice and Báhoň in the Trnavská pahorkatina upland. The last locality is situated in the north-west periphery of Bratislava, near the village Devínska Nová Ves.

The localities differed from each other in type and origin of line corridors, which were ditch-bank vegetation, stream-bank vegetation, hedgerows and windbreaks.

Locality 1 (Vajnory – Čierna Voda)

The studied ditch network was established in the late decades of the 19th century to ameliorate the frequently swamped arable lands of the area. Originally, cherry-, walnut-, plum- and pear-trees had been planted along the banks, but recently this generation of trees has almost completely disappeared being naturally replaced by such tree species as *Acer campestre*, *Cerasus avium*, *Crataegus monogyna*, *Prunus spinosa*, *Quercus robur*, *Salix fragilis*, *Ulmus laevis* and *U. minor*. The shrub layer is extremely dense. The most abundant species are *Crataegus monogyna*, *Evonymus europaea*, *Prunus spinosa*, *Rosa canina*, *Rubus caesius*, *Sambucus nigra*, *Cornus sanguinea* and *Ulmus minor*. The bottoms of ditches are submerged only in spring.

The total length of the 16 studied corridors is 4.9 km, their total area is 6.8 ha, and the average corridor width is 13.8 m (Table 1). The nearest forest is in contact with the studied network, but considering the rather short-distance effect of forests (F o r m a n & G o d r o n 1986), only 3 out of 16 corridors could be affected by the forest.

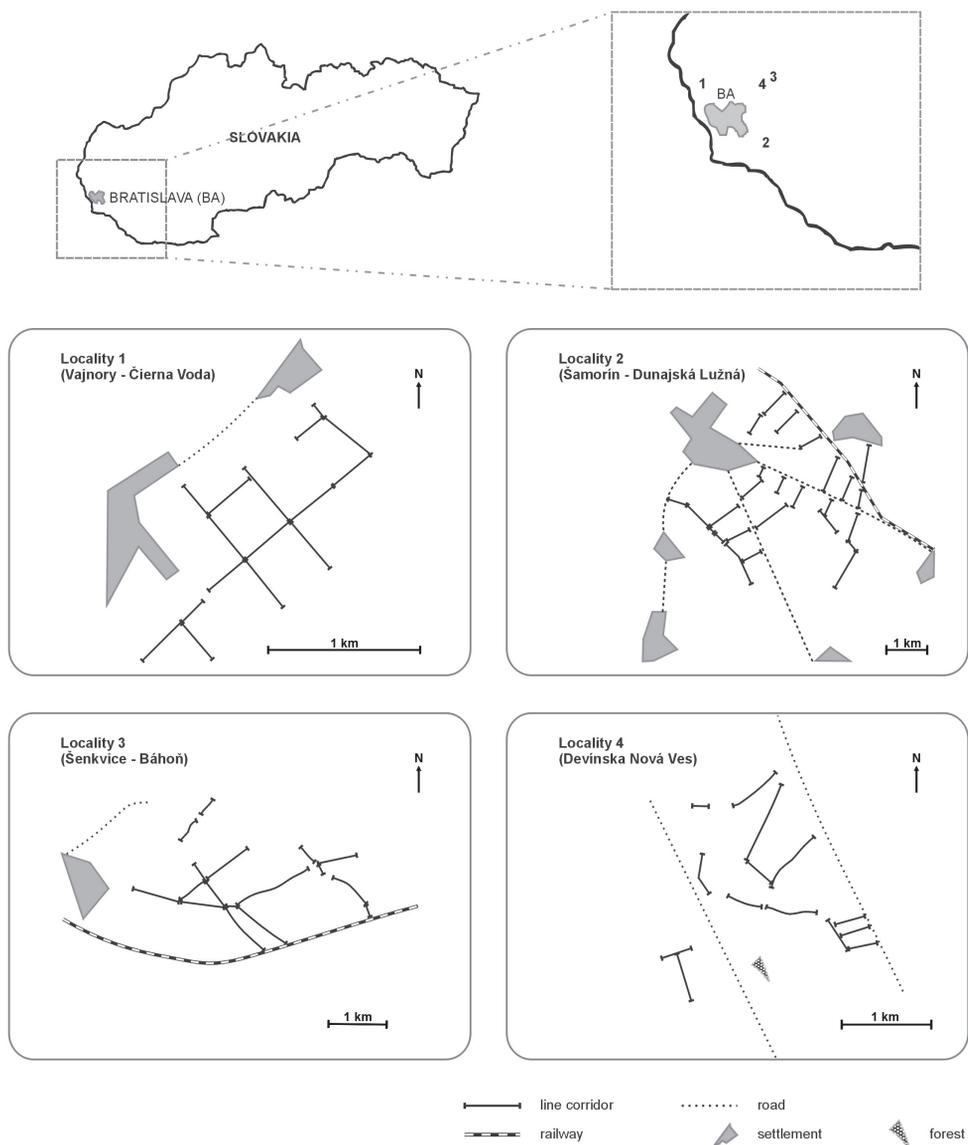


Fig. 1. Location of study sites and spatial arrangement of corridors.

Locality 2 (Šamorín – Dunajská Lužná)

The second network consists of windbreaks established in the 1950's to alleviate wind erosion and drought, and to improve the water balance of the area. The dominant tree species in the locality are *Acer campestre*, *A. negundo*, *A. pseudoplatanus*, *A. tatarica*, *Fraxinus excelsior*, *Morus alba*, *M. nigra*, *Populus canadensis*, *Quercus robur*, *Robinia pseudoacacia*, *Tilia cordata* and *Ulmus laevis*. The shrub layer is composed of *Crataegus monogyna*, *Ligustrum*

vulgare, *Prunus spinosa*, *Rosa canina*, *Rubus caesius*, *Sambucus nigra*, *Cornus sanguinea*. The nearest forest is about 2 km away from the studied network.

The total length of the 26 studied windbreaks is 17.4 km, their total area is 28.7 ha, and the average width of windbreaks is 16.5 m (Table 1).

Table 1. Basic characteristics of four networks.

	Locality 1	Locality 2	Locality 3	Locality 4
number of corridors	16	26	16	14
total length of corridors (m)	4900	17400	10600	6300
min. length of corridors (m)	170	318	150	150
max. length of corridors (m)	386	1250	1567	920
average corridor width (m)	13.8	16.5	15.5	13.8
min. corridor width (m)	8.5	6.3	6.2	6.0
max. corridor width (m)	26.5	25.6	30.3	21.0
total area of corridors (ha)	6.8	28.7	16.2	9.3
distance to the nearest forest (m)	30	2000	400	500
average tree height (m)	9.3	10.9	10.1	9.9

Locality 3 (Šenkvice – Báhoň)

This floristically and structurally very heterogeneous network of windbreaks and hedgerows was established in the 1950's to moderate wind and water erosion in undulating agricultural landscape. The dominant tree species in the corridors are *Aesculus hippocastanum*, *Ailanthus altissima*, *Fraxinus excelsior*, *Juglans regia*, *Populus nigra*, *Prunus spinosa*, *Robinia pseudoacacia* and *Salix fragilis*. The dominant shrub species are *Crataegus monogyna*, *Prunus spinosa*, *Rosa canina*, *Rubus caesius*, *Sambucus nigra*. The nearest forest is in contact with one end of the longest hedgerow. This hedgerow is structurally very different from the forest, so it could be only slightly affected by the vicinity of the forest.

The total area of the 16 studied corridors is 16.2 ha, their total length is 10.6 km, and the average width is 15.5 m (Table 1).

Locality 4 (Bratislava – Devínska Nová Ves)

This network consists of windbreaks, ditch-bank vegetation corridors and stream-bank vegetation corridors. The ditches sometimes contain water only temporarily, but the streams are permanent. The dominant tree species along stream-banks were pear, plum and apple. Because of the neglected bank management a dense shrub layer (*Prunus spinosa*, *Rosa canina*) grows along the banks. The tree canopy layer in the windbreaks and ditch-banks is composed of such species as *Alnus glutinosa*, *Cerasus avium*, *Crataegus monogyna*, *Evonymus europaea*, *Fraxinus excelsior*, *Populus alba*, *P. canadensis*, *P. nigra*, *Prunus spinosa*, *Salix alba*, *S. cinerea*, *S. fragilis* and *Sambucus nigra*. The most abundant shrub species are *Crataegus monogyna*, *Evonymus europaea*, *Prunus spinosa*, *Rosa canina*, *Rubus caesius*, *R. fruticosus*, *Salix cinerea*, *Sambucus nigra* and *Cornus sanguinea*.

The total area of the 14 studied corridors is 9.3 ha and the total length is 6.3 km (4 km of windbreaks and ditch-bank vegetation, and 2.3 km of stream-bank vegetation). The average width of the corridors is 13.8 m (Table 1).

Material and Methods

Bird censuses

The distribution of breeding territories of passerines and the distribution of nest sites of falcons and pigeons was estimated by means of a combined version of mapping method (Tomiałojć 1980). The field observations were carried out in Locality 1 during the breeding season in 1995, in Locality 2 in 1993 and 1994, in Locality 3 in 1996, and in Locality 4 in 1994 and 1995. Locality 1 was mapped 11 times, Locality 2 nine times in 1993 and eight times in 1994. Eight bird censuses were made also on Locality 3 as well as in both breeding seasons on Locality 4.

Individual registrations were transferred onto the species maps, and territories were identified according to the recommendations of Tomiałojć (1980).

All species maps were superimposed and subsequently one map for each corridor per year was elaborated. These maps were divided into about 100 m long sections which matched the division and marking of corridors in the field. The number of breeding species and the number of breeding territories were determined for each of the 100 m long sections. In case the breeding territory of a pair extended on two or more 100 m long sections, the part of the territory occurring in a given corridor section was determined as a proportion of the total area of territory. In case the locality was observed during two breeding seasons, the average number of breeding species and the average number of breeding territories were used. Similarly, the numbers of territories of the 17 most commonly breeding species (kestrel *Falco tinnunculus*, wood pigeon *Columba palumbus*, goldfinch *Carduelis carduelis*, greenfinch *Carduelis chloris*, chaffinch *Fringilla coelebs*, magpie *Pica pica*, starling *Sturnus vulgaris*, tree sparrow *Passer montanus*, red-backed shrike *Lanius collurio*, blackbird *Turdus merula*, great tit *Parus major*, icterine warbler *Hippolais icterina*, nightingale *Luscinia megarhynchos*, blackcap *Sylvia atricapilla*, whitethroat *Sylvia communis*, lesser whitethroat *Sylvia curruca*, golden oriole *Oriolus oriolus*) were obtained for each of the 100 m long sections.

Habitat sampling

Habitat surveys were carried out in late summer after the bird censuses were completed. The width of the corridor, tree height and total vegetation strata coverage were measured at 1–3 sample sites per 100 m long section. The profile of a line corridor sample was divided into four strata: 0–1 m, 1–3 m, 3–7 m and 7–9 m. The total vegetation strata coverage was estimated as percentages from black-and-white slides of vegetation samples taken from a distance of 25 m. Each of the 100 m long sections was characterised by their average width, average tree height and total vegetation strata coverage.

Data analysis

The species richness, number of territories and habitat characteristics of 380 corridor sections were available. It could not have been assumed that each 100 m long section represented an independent observation, because some territories spanned section boundaries. Moreover, the presence of some species in the corridor section could influence the presence of other species in neighbouring sections. To ensure the independence of observations, we reduced the data

matrix in this way: all sections adjacent to intersections or to dead-ends were preserved; every second straight section was excluded. The data matrix used in the next analysis included 248 sections (81 sections adjacent to intersections, 41 sections adjacent to dead-ends and 126 straight sections).

Principal component analysis (PCA) was used to reduce the number of habitat variables. By this method the section width, tree height, vegetation cover and locality 1 – 4 were substituted with two independent PCA factors (Appendix 1). The first PCA factor correlated indirectly with tree height (-0.541) and vegetation cover (-0.639; Appendix 1, Fig. 2) and was therefore associated with decreasing vegetation volume mostly in the tree layer. The second PCA factor was associated with Locality 2 and correlated indirectly with the section width (-0.425; Appendix 1, Fig. 2).

To test the relationship between the species richness and section type, distance to the dead-end or intersection and habitat characteristics represented by the first two PCA factors, the generalized linear model (GLM) with Poisson distribution and log link function was used. The total number of territories, number of territories of individual species as well as the number of territories of corridor-dependent species and corridor-independent species were also subjected to GLM. In all GLM, the categorical predictor was the section type, the continuous predictors were the distance of the section from the nearest dead-end or intersection, the first PCA factor and the second PCA factor. For each response variable the

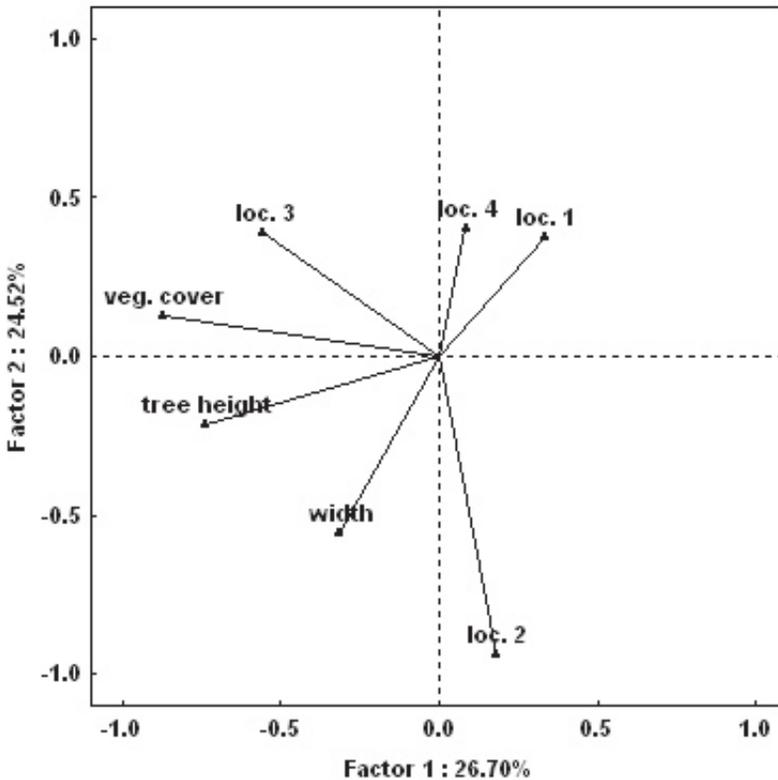


Fig. 2. Correlation of habitat variables with the first two PCA factors. Veg. cover = total vegetation strata coverage; loc. 1 – loc. 4 = Locality 1 – Locality 4.

best subset of predictors were selected by excluding the non-significant variables from the original model.

The statistical analyses in this study were carried out by STATISTICA 7.0 software. (StatSoft 2004).

Results

Species richness

The species richness in corridor sections was dependent on the distance of the section from the nearest dead-end or intersection, as well as on vegetation volume (factor 1) and width of the section (factor 2; Table 2). The distance of the section from the nearest dead-end or intersection was negatively related to the species richness: species richness significantly increased with decreasing of the section distance from the nearest dead-end and intersection, respectively (Table 2). The species richness increased with increasing vegetation volume in 100 m long sections (for negative correlations of vegetation cover and tree height with the first PCA factor see Appendix 1, for negative coefficient of factor 1 in GLM see Table 2). The last predictor statistically related to species richness was the width factor, which influenced species richness positively; it means, wider sections supported more bird species (for negative correlation of width with the second PCA factor see Appendix 1, for negative coefficient of factor 2 in GLM see Table 2).

The number of territories

The number of territories was dependent on the same predictors as species richness – distance of the section from the nearest dead-end or intersection, vegetation volume and width of the section (Table 2). The first two predictors were related to the number of territories in the same way as it was by species richness. The number of territories increased with decreasing section distance from the dead-end or intersection and increasing vegetation volume. Contrary to expectation, the width factor influenced the number of territories negatively (Appendix 1, Table 2).

Table 2. Generalized linear models (logit link function, Poisson distribution) for species richness and total number of territories. Distance = distance of the section from the nearest dead-end or intersection; factor 1, factor 2 = the first two factors of PCA (see Appendix 1).

	intercept	distance	factor 1	factor 2	intersection	dead-end
species richness						
Estimate	1.779 ***	-0.001 ***	-0.069 ***	-0.065 **	-	-
Wald statistic	1780.398	15.788	11.118	9.338		
number of territories						
Estimate	1.248 ***	-0.002 ***	-0.120 ***	0.070 *	-	-
Wald statistic	468.830	27.875	18.503	5.261		

* P < 0.05; ** P < 0.01; *** P < 0.001

The number of territories of the most common bird species breeding in line-corridor networks

The blackcap (*Sylvia atricapilla*), whitethroat (*Sylvia communis*) and lesser whitethroat (*Sylvia curruca*) were more common in sections adjacent to the dead-end or intersection. Indeed, only one variable – the distance of the section from the nearest dead-end or intersection – statistically predicted the number of territories of the mentioned species (Table 3). The distance of the section from the nearest dead-end or intersection together with vegetation volume significantly influenced the number of nightingale (*Luscinia megarhynchos*) territories. The number of nightingale territories increased with proximity to the dead-end or intersection and with increasing vegetation volume (Table 3). The number of icterine warbler (*Hippolais icterina*) territories increased with increasing vegetation volume and section width. Moreover, icterine warbler territories were located more commonly in sections adjacent to intersections (Table 3). The same holds true for the great tit (*Parus major*), whose territories were also more common in sections adjacent to intersections, although the significance of the predictor was only marginal (Table 3).

The total number of territories of corridor-dependent species was related to the distance of the section from the nearest dead-end or intersection and to the section type “intersection”.

Table 3. Generalized linear models (logit link function, Poisson distribution) for the number of territories of corridor-dependent species. Distance = distance of the section from the nearest dead-end or intersection; factor 1, factor 2 = the first two factors of PCA (see Appendix 1).

	intercept	distance	factor 1	factor 2	intersection	dead-end
icterine warbler <i>Hippolais icterina</i>						
Estimate	-4.390 ***	-	-0.910***	-0.627 *	0.962 *	-
Wald statistic	50.874		10.423	5.521	6.145	
nightingale <i>Luscinia megarhynchos</i>						
Estimate	-0.116 ns	-0.003 ***	-0.216***	-	-	-
Wald statistic	0.927	16.461	13.244			
golden oriole <i>Oriolus oriolus</i>						
Estimate	-3.497 ***	-	-0.423+	-0.487 +	-	-
Wald statistic	73.556		3.313	3.719		
great tit <i>Parus major</i>						
Estimate	-2.720 ***	-	-	-	0.428 +	-
Wald statistic	113.109				2.795	
blackcap <i>Sylvia atricapilla</i>						
Estimate	-0.606 ***	-0.002 **	-	-	-	-
Wald statistic	16.294	6.752				
whitethroat <i>Sylvia communis</i>						
Estimate	-1.344 ***	-0.003 *	-	-	-	-
Wald statistic	36.755	3.884				
lesser whitethroat <i>Sylvia curruca</i>						
Estimate	-1.955 ***	-0.008 *	-	-	-	-
Wald statistic	22.013	4.274				
number of territories of corridor-dependent species						
Estimate	0.615 ***	-0.002 ***	-	-	0.135 *	-
Wald statistic	50.589	10.849			4.084	

ns P > 0.1; + P < 0.1; * P < 0.05; ** P < 0.01; *** P < 0.001

The number of territories of corridor-dependent species increased with decreasing section distance from the nearest dead-end or intersection, moreover, the number of territories was higher in sections adjacent to intersections (Table 3).

The number of territories of goldfinch (*Carduelis carduelis*), starling (*Sturnus vulgaris*) and tree sparrow (*Passer montanus*) increased significantly with increasing vegetation volume (Table 4). The last mentioned species occurred more often in sections adjacent to dead-ends (Table 4). The number of territories of greenfinch (*Carduelis chloris*), wood pigeon (*Columba palumbus*), kestrel (*Falco tinnunculus*), red-backed shrike (*Lanius collurio*) and blackbird (*Turdus merula*) was influenced by the width factor, although not

Table 4. Generalized linear models (logit link function, Poisson distribution) for the number of territories of corridor-independent species. Distance = distance of the section from the nearest dead-end or intersection; factor 1, factor 2 = the first two factors of PCA (see Appendix 1).

	intercept	distance	factor 1	factor 2	intersection	dead-end
<i>goldfinch Carduelis carduelis</i>						
Estimate	-3.079 ***	-	-0.628 ***	-	-	-
Wald statistic	87.452		11.576			
<i>greenfinch Carduelis chloris</i>						
Estimate	-2.544 ***	-	-	0.394 *	-	-
Wald statistic	110.953			4.117		
<i>wood pigeon Columba palumbus</i>						
Estimate	-2.965 ***	-	-	-0.700 ***	-	-
Wald statistic	83.149			11.146		
<i>kestrel Falco tinnunculus</i>						
Estimate	-3.212 ***	-	-	-0.475 *	-	-
Wald statistic	87.701			4.133		
<i>chaffinch Fringilla coelebs</i>						
Estimate	-3.039 ***	-	-0.652 ***	0.595 *	-	-
Wald statistic	73.370		15.528	5.212		
<i>red-backed shrike Lanius collurio</i>						
Estimate	-2.540 ***	-	-	0.629 **	-	-
Wald statistic	93.832			8.891		
<i>tree sparrow Passer montanus</i>						
Estimate	-0.739 ***	-	-0.185 *	-	-	0.282 *
Wald statistic	40.288		6.509	-		5.665
<i>magpie Pica pica</i>						
Estimate	-2.946 ***	-	-	-0.281 ns	-	-
Wald statistic	106.239			1.892		
<i>starling Sturnus vulgaris</i>						
Estimate	-3.275 ***	-	-0.442 *	-	-	-
Wald statistic	87.875		4.187			
<i>blackbird Turdus merula</i>						
Estimate	-3.146 ***	-	-	0.619 *	-	-
Wald statistic	79.158			4.731		
number of territories of corridor-independent species						
Estimate	0.029 ns	-	-0.150 ***	-	-	-
Wald statistic	0.212		11.344			

ns P > 0.1; * P < 0.05; ** P < 0.01; *** P < 0.001

always in the same direction. The number of territories of wood pigeon and kestrel increased with the width of the section, the number of territories of such species as greenfinch, red-backed shrike and blackbird increased with decreasing width of the section (Table 4). The number of chaffinch (*Fringilla coelebs*) territories increased with the vegetation volume and decreasing section width. The number of territories of any corridor-independent species was not related to the distance of the section to the nearest dead-end or intersection or to the section type.

The total number of territories of corridor-independent species was significantly related just to the vegetation volume. The number of territories increased with increasing vegetation volume (Table 4). Neither the distance of the section to the nearest dead-end or intersection nor the section type influenced the number of territories of this species group significantly.

Discussion

It is apparent from our study that species richness in 100 m long sections increased with decreasing section distance from the nearest dead-end or intersection, with increasing vegetation volume and increasing section width. The total number of territories increased with decreasing section distance from the dead-end or intersection and increasing vegetation volume and, contrary to expectation, with decreasing section width. The number of territories of species typical in corridors was influenced not only by the distance of the section from the dead-end or intersection but also by the section type, which was intersection.

The importance of intersections and dead-ends for breeding birds was emphasized in our previous study (Tirinda 1994), although the influence of vegetation structure was not considered in the interpretation. The same situation was recorded in a British farmland environment (Lack 1988). There were significantly more bird species recorded at hedge intersections than at straight sections and the total number of birds recorded near the intersections of hedges was 1.7 times higher than the number recorded along the same total length of straight hedge (Lack 1988). Similarly, in an arable landscape in Germany Hoffmann & Kretschmer (1994) noticed that birds were concentrated in hedge intersections. Unfortunately, their conclusion was not supported by experimental data.

In our study we recorded increasing numbers of territories of great tit (*Parus major*), icterine warbler (*Hippolais icterina*), nightingale (*Luscinia megarhynchos*), blackcap (*Sylvia atricapilla*), whitethroat (*Sylvia communis*) and lesser whitethroat (*Sylvia curruca*) in corridor sections closer to intersections and dead-ends. In British farmland, five species showed a significant preference for hedge intersections (wren *Troglodytes troglodytes*, robin *Erithacus rubecula*, blackbird *Turdus merula*, blue tit *Parus caeruleus*, great tit *Parus major*) and most of the others species were also more common at intersections, however not significantly (Lack 1988). Another observations from British farmland detected a concentration of wren's song-points at hedgerow intersections, where the cover was relatively more dense (Williamson 1969). The hedgerows in British farmland were attractive also to the chaffinch (*Fringilla coelebs*), moreover, the hedgerow intersections were preferred by this species (Benson & Williamson 1972).

As density could be a misleading indicator of habitat quality (van Horne 1983), it could also be misleading to infer from increasing values of species richness or the number of territories near intersections or dead-ends that these types of habitat are "preferred" by birds. The increasing species richness and number of territories near dead-ends or intersections

could be partly explained by the longitudinal edge effect. It could be assumed, that individuals tend to accumulate near dead-ends because their movement is stopped by a barrier (edge) effect of the end of the habitat. Similarly, the movement of individuals is inhibited by encountering other individuals coming from the opposite direction at the intersections. To prove our assumptions further research focused on bird movement and habitat selection is needed.

Appendix 1. Eigenvalues and percentages explained with the first two PCA factors and principal component loadings for the seven original habitat characteristics.

	Factor 1	Factor 2
eigenvalue	1.869	1.716
explained percentage of total variance	26.7	24.5
locality 1	0.245	0.289
locality 2	0.131	-0.718
locality 3	-0.406	0.295
locality 4	0.061	0.310
width	-0.231	-0.425
tree height	-0.541	-0.165
vegetation cover	-0.639	0.099

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