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The importance of edge effect in line transect censuses applied in marshland habitats

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We estimated relative densities of the 8 most abundant passerine bird species using the Finnish line transect method, and compared them with the results of territory mapping in an extensive Hungarian marshland. Along the transect route on the dikes we found a high positive edge effect for several passerine species. For density estimation in the edge zone, main belt data (0–25m) proved to be useful, but densities for the whole area were overestimated when calculated directly from main belt data for the Bearded Tit (*Panurus biarmicus*), the Moustached Warbler (*Acrocephalus melanopogon*), the Sedge Warbler (*Acrocephalus schoenobaenus*), and the Marsh Warbler (*Acrocephalus palustris*). The Finnish line transect method, especially when the linear model is applied, proved to be useful for estimation of densities of these species using observations from the whole survey area. Species showing little or no edge effect (Savi's Warbler *Locustella luscinioides*, the Great Reed Warbler *Acrocephalus arundinaceus*, and the Reed Bunting *Emberiza schoeniclus*) indicated a tendency for underestimation of density. For these species and for the Reed Warbler *Acrocephalus scirpaceus* the negative exponential model gave better results than the linear model. We also discuss factors affecting line transect censuses in marshland habitats (edge effect, territory size, singing activity pattern vs. detectability). Of these factors, the edge effect along the observer's route may be more important than is generally the case in woodland habitats. The optimal date for a census is mid-May, but a separate census in late April would also be helpful when a passerine bird community in central European marshland habitat is surveyed.

1. Introduction

The Finnish line transect method (Järvinen & Väisänen 1975) has become a well-known technique for density estimation of breeding birds over the last two decades (Järvinen et al. 1991, Bibby et al. 1992). The main advantage of this technique is its efficiency in time. Its major drawback is that density estimation is based on a single census; therefore, incomplete detectability is a serious source of error (Rinne 1985). For this reason, single line transect censuses usually underestimate densities; moreover, the accuracy of the technique varies from species to species (e.g. from 33% to 67%, Hildén 1981). For the seven most abundant species in Hungarian woodlands, Moskát (1987) found a good (75%) estimation in relation to the mapping method. Järvinen and Väisänen (1983) summarised the results of several studies so that true (mapping) densities were about 1.3 to 1.6 times higher than those found along transects. In spite of this, relative density values obtained by this method are acceptable for several purposes, including bird population monitoring (Järvinen et al. 1991). Although the estimation of species' density is species specific, its accuracy is more or less stable for a species; therefore, census results from different years or sites can be compared with each other. In some cases, only observations within the 25 m distance limit (main belt data) are used to estimate density, although main belt data are not necessarily more reliable than the estimation based on all data (survey belt) (Tiainen et al. 1979). Correction coefficients of the Finnish line transect method make it possible to convert the survey belt data to values corresponding to the main belt data (Järvinen & Väisänen 1983).

The application of standard bird census techniques in marshlands is problematic (Bell et al. 1973), and needs further investigation. Most of the methodological tests have been carried out in woodland habitats and only a few studies were conducted in marshland habitats. Haukioja (1968) detected only 40% of the Reed Bunting (*Emberiza schoeniclus*) population by using Merikallio's (1946) line survey method, and estimated only a third of the real population of Sedge Warblers (*Acrocephalus schoenobaenus*). Applying the mapping method, Bell et al. (1968) reported only 37% detection for the Sedge Warbler, while they obtained better estimates for Reed Warblers (*Acrocephalus scirpaceus*) (75%), and Reed Buntings (78%).

An additional point of interest is the question of applicability of the technique for biomonitoring or inventory projects. In the present paper we evaluate whether the Finnish line transect technique can be applied in marshland areas, where strong edge effect may occur along the census route. We also examine how observations from the supplementary belt could be applied in addition to main belt data.

2. Study area and methods

Our study was conducted in the Kis-Balaton marshland area, a nature reserve in western Hungary. The marshland lies around the River Zala inlet into Lake Balaton (46°42'N, 17°21'E). Its vegetation is mainly composed of *Phragmites australis* and *Typha angustifolia*. Bushes and trees of *Salix alba, S. fragilis*, and *Alnus glutinosa* are scarce in the area (for more details of the habitat see Lőrincz et al. 1990).

Bird censuses were carried out by the Finnish line transect method (Järvinen & Väisänen 1975, 1976, Järvinen et al. 1991). In the Kis-Balaton marshes the only possibility to mark out the transect route was to follow the dikes crossing the marshland. Only one side of the 8.8 km long transect line was counted because marshland habitats on the other side occasionally varied with small woodlands and ruderal habitats, which are not typical of the marshland. The dikes were ca. 3 m higher than the neighbouring ground level, so we could observe the entire census area. Censuses were carried out in the early mornings (ca. 6:00–9:00) when the wheather was fine. Each of us counted half of the survey line, exactly the same sections on every census date. Both hearings and sightings of birds were recorded, following the standard rules for the line transect technique (Järvinen & Väisänen 1976, IBCC 1977). We conducted censuses of passerine birds 8 times during the breeding season in 1991, from early April to late May (census dates: 4, 16, and 26 April, 7, 9, 21, 23, and 29 May). For each bird detected we noted the distance from the starting point and the lateral perpendicular distance from the observer's route. The latter was assigned to either main belt data (< 25 m) or supplementary belt data (> 25 m) for the analyses. Raw data were plotted on maps following the guidelines of the standard territory mapping method: in our case, when 8 visits were carried out, a cluster of at least three records is necessary to identify a territory on the species maps (Anon 1969, see also Svensson 1979a). Territory maps were evaluated by one of us (C. M.). The territory mapping data were used as a reference for testing the line transect results. This procedure is generally applied in bird census methodology, although studies based on nest locations also showed some bias of the mapping technique, e.g. when territories are large, or when all species are counted, including superabundant and rare species (Svensson 1979a, 1979b, Tomialojc 1979). We displayed a 75 m wide census area on the territory maps, so the survey belt of the line transect censuses which had no distance limit almost exactly overlapped with the area of territory mapping. Only 9 observations in the survey belt fell outside of the mapping census area (less than 1% of the records for the 8 species). Density estimates, based on the survey belt data of the line transect method, were calculated based on the linear and negative exponential models proposed by Järvinen and Väisänen (1975). In the linear case, density (D; measured in pairs/10 ha) is calculated by the following equation:

$$D = 100*k*SB/T, \qquad (1)$$

where k = species-specific correction coefficient, SB = number of survey belt observations for a given species, and T = length of the transect (km). For the negative exponential model:

$$D = 100*l*SB/T, \qquad (2)$$

where l = species-specific correction coefficient.

As the species-specific correction coefficients published by Järvinen and Väisänen (1983) are recommended for use in Fennoscandia, we calculated new coefficients for the Kis-Balaton marshland habitat by the formulas suggested by Järvinen and Väisänen (1975). For the linear model:

$$k = (1 - \sqrt{1-MB/SB})/25, \qquad (3)$$

where MB = number of main belt observations for a given species. For the negative exponential model:

$$l = -\log_e(1-MB/SB)/25. \qquad (4)$$

Correction coefficients were calculated from all of the censuses.

Agglomerative hierarchical cluster analysis was applied for comparison of the similarities among the 8 line transect censuses, based on observations of the main belt. The computer program SYN-TAX (Podani 1993) was applied using the options percentage difference for measuring similarities and average linkage for fusion of clusters.

3. Results

Eight bird species, the most dominant of the reedbed passerines in the area, were selected from the 37 species detected during the 8 line transect censuses. A total of 973 observations of these species were gathered during the censuses.

Most of the early censuses in April resulted in low densities (Fig. 1). As the Bearded Tit (*Panurus biarmicus*) and the Reed Bunting are resident species, they were detected in relatively high numbers in these early censuses. Detectability of the Moustached Warbler (*Acrocephalus melanopogon*) also showed a similar pattern over time, because it arrives earlier (beginning of April) than the other marshland warblers. However, the Sedge Warbler, and the Marsh Warbler (*Acrocephalus palustris*) were not observed until the second census date, and the Great Reed Warbler (*Acrocephalus arundinaceus*) was not recorded until the fourth census.

The dendrogram of a hierarchical cluster analysis demonstrated that the first census in early April showed the highest separation from all of the censuses (Fig. 2). At that time, most of the migrants were represented only in low numbers, and three species, namely the Sedge, Marsh, and Great Reed Warblers had not arrived yet. The second and third censuses, carried out in mid- and late April, showed higher similarity. At that time, all of the species except the Great Reed Warbler were present in the area. All of the remaining 5 censuses from early May to late May showed high similarity and were grouped into one cluster.

Main belt observations accounted for a high proportion of the survey belt data, although they varied among species (41–100%) (Table 1). The Marsh Warbler was the only species where all of the observations fell in the main belt. The most likely reason is the high preference of this species for little *Salix* bushes, which were scattered along the dikes. We believe that the concentration of observations in the main belt is due to the edge

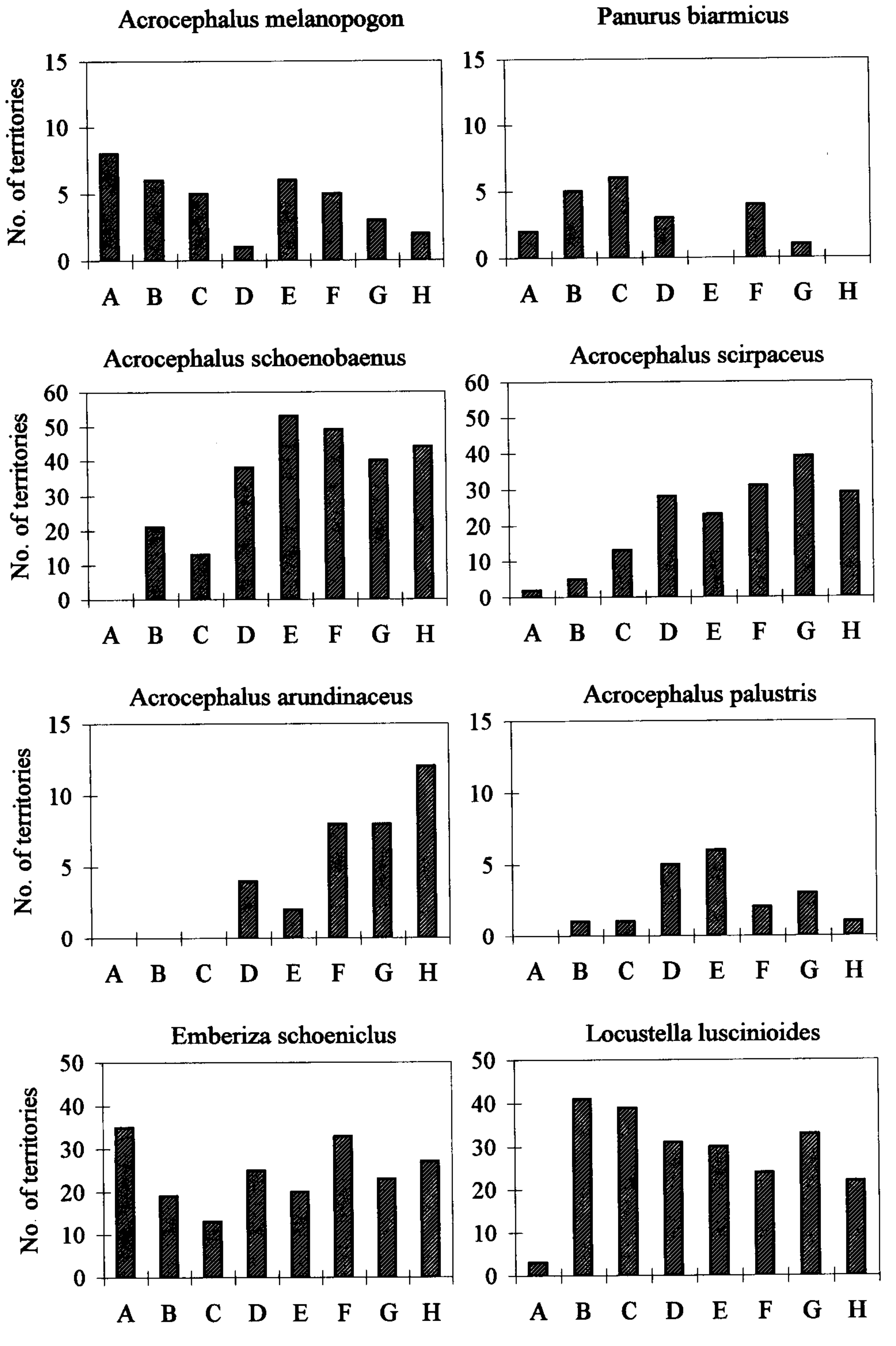

Fig. 1 Number of territories of 8 passerine species obtained from 8 consecutive line transect censuses (denoted by letters from A to H) in the Kis-Balaton Nature Reserve, Hungary, between 4 April and 29 May, 1991.

effect. Báldi and Kisbenedek (1999) described that this type of edge effect is caused by the dikes being used as census routes.

Main belt and supplementary belt frequencies differed significantly when our results were compared with those published by Järvinen and Väisänen (1983). For comparison, data collected between 1973 and 1983 in Finland were selected. Chi-square tests for each of the available four species (Sedge, Marsh, Reed Warblers, and Reed Bunting) showed highly significant differences ($P < 0.001$). This showed that calculation of the species-specific correction coefficients from our sample insted of using those published for Fennoscandia was correct.

Except for the Marsh Warbler, where all observations occurred in the main belt, census efficiency in relation to the results of the mapping method showed three tendencies (Table 2): (i) Density estimation based on the main belt observations overestimated densities by 4–102%, and only one species, the Reed Bunting showed an underestimation by 8%. (ii) When density estimation was based on all of the observations (survey belt data), the linear model showed better estimation than the negative exponential model in the case of the Bearded Tit, and the Moustached and Sedge Warblers (overestimations by 21–49% and 61–120%, respectively, when calculated by the linear or negative exponential models). In these species, main belt observations represented a high proportion of the survey belt data (> 69%). (iii) In species which showed lower abundances in the main belt (< 69%), like Savi's Warbler *Locustella luscinioides*, the Reed Warbler, Great Reed Warbler, and Reed Bunting, the linear model underestimated densities by 21–44%. The negative exponential model showed the same tendency (underestimation by 19–31%), except for the Reed Warbler, which was slightly overestimated by 6%.

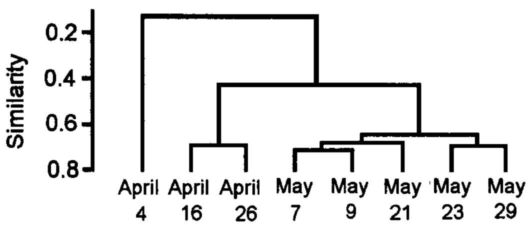

Fig. 2. Dendrogram of cluster analysis representing the similarities of 8 line transect censuses based on the 8 most abundant bird species in the Kis-Balaton marshes (for list of species see Table 1).

4. Discussion

In marshlands, marking out a census route is generally difficult. The observer often moves along artificial trajectories, e.g. dikes (Lőrincz et al. 1990), or counts from a boat (Báldi & Kisbenedek 1999). Large territories may cause problems in line transect censuses, because a bird moving within the territory may be observed in the sur-

Table 1. Main belt (0–25 m) observations expressed as percentage of the survey belt (> 0 m) observations, number of observations in the main belt (MB), number of observations in the survey belt (SB) and calculated species-specific correction factors both for the linear (K = 1000**k*) and the negative exponential model (L = 1000*l).

Bird species	%	MB	SB	K	L
Panurus biarmicus	81	17	21	22.54	66.33
Locustella luscinioides	55	122	223	13.08	31.68
Acrocephalus melanopogon	69	25	36	17.89	47.42
*Acrocephalus schoenobaenus**	86	221	258	24.85	77.68
*Acrocephalus palustris**	100	19	19	nc	nc
Acrocephalus scirpaceus	72	122	170	18.75	50.58
*Acrocephalus arundinaceus***	41	21	51	9.32	21.23
Emberiza schoeniclus	58	113	195	14.06	34.65

nc = not computed because all of the observations fall in the main belt
* = based on 7 censuses
** = based on 5 censuses

veyed area more than once, even if most of its territory lies outside the sampling area. Since territory size is relatively small among the reedbed passerine species (van der Hut 1986), we can expect a good estimation of bird densities if main belt data are used for calculation. The only problem that territories lying close to the census route are likely to be affected by the edge effect, even if the census route is narrow. The distribution of the Bearded Tits and the Reed Warblers showed a positive edge effect. A similar pattern was also detected in other Hungarian marshes (Csörgő 1995), even along narrow, 2 m wide boat pathways through the reedbed (Báldi & Kisbenedek 1999). In this study we demonstrated that a positive edge effect may cause significant overestimation of densities if only the main belt (< 25 m) observations are used for density calculation in a larger area. When observations from the supplementary belt were added to the main belt, the Finnish line transect method using species-specific corrections following the linear model gave a useful estimation for larger areas.

Three important factors influence the results of the line transect technique in marshland habitats, although these types of effects may also occur in other habitats: (i) The type of the edge (reed/open water surface, reed/bare ground, etc.) is important if edge effect occurs, depending on the habitat preference of species. For example, the Great Reed Warbler showed only little edge effect in our study area, where mainly the reed/ground edge occurred along the census route. However, Báldi and Kisbenedek (1999) reported a high edge preference for the reed/water edge in this species on Lake Velence, Hungary. (ii) The width of the observer's route may also affect the results significantly. Even narrow routes may cause some edge effect in marshlands. (iii) Different vocalisations of species affect detectability, so a species with a well-heard song (e.g. Great Reed Warbler, Savi's Warbler) may be recorded

Table 2. Species densities (pairs/10 ha) calculated from main belt data (0–25 m) of 8 single line transect surveys along the 8.8 km observation route between April 4 and May 29 in 1991, in the Kis-Balaton marshland area, Hungary. Data given are mean ± S.D. Density estimation for the survey belt (> 0 m) was calculated by the linear and the negative exponential models (Järvinen & Väisänen 1975). The results of territory mapping over the truncated survey belt (0–75 m) are shown for comparison. Mean estimations by the main belt observations, the linear and the negative exponential models are also shown in parentheses as percentage of the mapping result. (The number of censuses was reduced for late-arriving species; see footnote.)

Bird species	Mapping	Main belt	Survey belt	
			Linear model	Neg. exp. model
Panurus biarmicus	0.45	0.97 ± 0.99 (202%)	0.67 ± 0.58 (149%)	0.99 ± 0.85 (220%)
Locustella luscinioides	6.67	6.93 ± 3.43 (104%)	4.15 ± 1.78 (62%)	5.02 ± 2.16 (75%)
Acrocephalus melanopogon	0.76	1.42 ± 0.78 (187%)	0.92 ± 0.47 (121%)	1.22 ± 0.63 (161%)
*Acrocephalus schoenobaenus**	7.42	14.35 ± 4.92 (193%)	10.83 ± 4.40 (146%)	16.27 ± 6.48 (219%)
*Acrocephalus palustris**	0.30	1.23 ± 0.94 (410%)	nc	nc
Acrocephalus scirpaceus	5.76	6.93 ± 4.83 (120%)	4.53 ± 2.81 (79%)	6.11 ± 3.80 (106%)
*Acrocephalus arundinaceus***	1.52	1.91 ± 1.26 (126%)	1.08 ± 0.47 (71%)	1.23 ± 0.54 (81%)
Emberiza schoeniclus	6.97	6.42 ± 1.18 (92%)	3.89 ± 1.17 (56%)	4.80 ± 1.44 (69%)

nc = not computed because all of the observations fall in the main belt
* = based on 7 censuses
** = based on 5 censuses

more frequently in the supplementary belt than a species without a loud song.

The determination of the best census date for single line transect censuses should be based on the predictions of singing activity curves of territory holders, which predefines detectability, but the effect of floaters also could be relevant in avian censuses (Moskát & Báldi 1995). The best census date is difficult to predict as a result of the high variation in species' detectability maxima, but mid-May appears to be suitable for most species in central Europe.

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Selostus: **Linjalaskennan soveltamisesta kosteikkolintujen runsauden arviointiin Unkarissa.**

Kirjoittajat arvioivat suomalaisen linjalaskentamenetelmän soveltuvuutta kosteikkolintujen runsauden määrittämiseen Unkarissa vertaamalla linjalaskennalla saatuja tuloksia reviirikartoituksen tuloksiin. Kirjoittajien laskentalinjat noudattelivat pääasiassa ruovikkoalueella esiintyviä ojan penkkoja, jotka olivat ainoita mahdollisia kulkuväyliä. Ojanpenkat kuitenkin aiheuttivat monien lajien tiheyksiin reunavaikutusta siten, että näiden lajien reviirit pyrkivät sijaitsemaan lähellä ojan penkkaa. Tällaisille lajeille (viiksitimali, tamariskikerttunen, ruokokerttunen ja rytikerttunen) tiheysarvio perustuen pääsarkahavaintoihin yliarvioi todellista tiheyttä. Tutkimussarkahavaintoihin perustuva tiheysarvio sitä vastoin osoittautui melko hyväksi, varsinkin jos se laskettiin olettaen havaintotodennäköisyyden laskevan suoraviivaisesti etäisyyden laskentalinjasta kasvaessa (Taulukko 2). Niille lajeille, joilla vastaavaa reunavaikutusta ei havaittu (ruokosirkkalintu, rastaskerttunen ja pajusirkku), pääsarkatiheys oli puolestaan aliarvio todellisesta tiheydestä. Näille lajeille sekä rytikerttuselle tutkimussarkatiheys laskettuna olettaen havaintotodennäköisyyden laskevan negatiivisen eksponentiaalisesti etäisyyden laskentalinjasta kasvaessa osoittautui lineaariseen malliin perustuvaa tiheysarviota tarkemmaksi. Kirjoittajat toteavat, että kuvatunlainen reunavaikutus on huomattavasti tärkeämpi tiheysarvioiden tarkkuuteen vaikuttava tekijä kosteikoilla kuin metsäympäristöissä, missä linjalaskentaa enemmän sovelletaan. Kirjoittajat pitävät kuitenkin linjalaskentaa sopivana menetelmänä myös keskieurooppalaisten kosteikkolintujen runsauden arvioimisessa. He suosittelevat, että laskennat tehtäisiin kuitenkin kahteen kertaan. Optimaalisin laskenta-ajankohta on toukokuun puoliväli, mutta tätä laskentaa on hyvä täydentää huhtikuun lopulla tehdyllä laskennalla varhain pesivien lajien runsauden tarkemmaksi määrittämiseksi.

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