Efficiency of the line transect method in mountain birch forest

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Four line transect censuses (totalling 16 km) were made in rich mountain birch forest in Swedish Lapland, under favourable weather conditions. The results were compared with those of mapping censuses made in an area of 42 ha in the same habitat and altitude, and in the same breeding season. Line transcet density, 266 pairs/km², was 87 % ± 16 % (*S.D.*) of that found in the mapping, 306 territories/km² (only land birds included). The transect densities of *Phylloscopus trochilus, Fringilla montifringilla* and *Emberiza schoeniclus* were more than 87 % of the corresponding mapping densities, and the transect densities of *Luscinia svecica, Turdus* spp. and *Prunella modularis* were less than 87 %. Estimates of diversity, *H′*, were not affected by the census method. The composition of the community, measured with the frequencies of the species, was very similar in the results of the mapping and the line transects. The main factors contributing to the high efficiency of the line transect probably include the optimal census hours (early morning), short census period (middle part of the breeding season) and the narrow strip used (25 m on both sides of the observer). As the mapping census does not include other than stationary birds, the inclusion of non-stationary birds in the transect census may also considerably narrow the gap between the results of the two methods. Similar data from other habitats are necessary to judge the average efficiency of the transect method in Fennoscandian conditions.

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Introduction

The line transect method has been used in Finland for several decades (e.g. MERIKALLIO 1946, JÄRVINEN & VÄISÄNEN 1976c), but no data on its efficiency are available. As noted by PALMGREN (1930), ENEMAR (1959) and later ornithologists studying the efficiency of bird census methods, a full list of breeding (or stationary) birds cannot be obtained during a single visit to a land bird community. A more typical result seems to be 30 to 70 % of the pairs (stationary males) per visit (e.g. BERTHOLD 1976 and references there). It is the purpose of this paper to report the results of an experiment made to elucidate the efficiency of the line transect method.

Material and methods

Four line transects, each 4.0 km, were censused at Ammarnäs, Swedish Lapland (65°58′N, 16° 13′E), between 13 and 26 June 1977. The field method followed the standard rules (JÄRVINEN & VÄISÄNEN 1976c) exactly, except that all the transects ran in rich mountain birch forest. (Normally, all habitats are represented in their true proportions.) The results were compared with mapping results from four census plots (totalling 42 ha) in the same habitat and altitude. The main belt of the transect (covering 80 ha) was often located in the mapping plots, but this was not always possible. The mapping work was performed according to the standard rules for the mapping method (ANON. 1970). Each plot was visited 10 times. The thrush species were censused by counting the nests (see ENEMAR et al. 1976).

The two censuses were made by different persons (mapping by L.-Å. Flodin, I. Lennerstedt and L. Nilsson, transects by A. Enemar), all of whom had considerable experience on bird censuses. Consequently the person making the transect censuses had not learnt the location of the bulk of the territories during previous mapping work in 1977, but as he had been working at Ammarnäs in 1963—76, he was well acquainted with the habitat and its bird community. The census weather was good or fine (little or no wind, no rain, partly or wholly clear sky, temperatures about 10°C or a little more). The census period was also apparently the best possible (cf. JÄRVINEN et al. 1977).

The relationship between the number of nests and the number of territories found in the mapping census has been studied in the same habitat and area by ENEMAR et al. (1973, 1976). They found that the results of the mapping were very close to the actual number of the nests, with few exceptions (e.g. *Fringilla montifringilla* was underestimated by about 25 % in the mapping). So we start from the assumption that, in this habitat, the results of the mapping represent about 100 % of the total land bird community. Moreover, we compare the density of "pairs" on the line transects directly with the density of the "territories" of the mapping census, although the units of the two census procedures are not fully equivalent.

Results

The densities obtained are compared in Table 1. Two columns have been given for the line transect results. One column contains the result of the main belt (the area covering 25 m on each side of the observer), and they can be compared with the results of the mapping without any reservations. The other column gives data for the survey belt. These are all the observations made during the census, including those of the main belt, corrected according to the linear model of JÄRVINEN & VÄISÄNEN (1975; see also JÄRVINEN 1976, JÄRVINEN & VÄISÄNEN 1976b, 1976c, JÄRVINEN et al. 1976), which makes use of correction coefficients calculated for each species from the Finnish line transect material. As the standard line transect censuses were made in heterogeneous habitats, the validity of the coefficients in homogeneous habitats is questionable. The data for the survey belt are thus less reliable than those for the main belt.

The efficiency of the line transects in rich mountain birch forest can now be assessed: the main belt gives 266/306 = 87.0 % of the result of the mapping. The separate values for the four transects ranged from 67 to 103 %, *S.D.* being 15.6 %, so that the efficiency of the different censuses thus varied a good deal (*C.V.* = 17.9 %), party due to variation in habitat. As the density value for the survey belt normally (i.e. in heterogeneous habitats) exceeds that of the main belt by 5—10 % (JÄRVINEN & VÄISÄNEN 1975), the efficiency now found for the survey belt, 225/306 = 74 %, is not representative. The survey belt results varied nearly as much as those for the main belt (*C.V.* = 11.7 % for the number of observations per tıansect). The difference between the densities in the main belt and the survey belt is mainly due to a great difference in the estimates for *Phylloscopus trochilus*, whose density at Ammarnäs is much higher than the average in Finland. As JÄRVINEN & VÄISÄNEN (1976b) found that birds are poorly observed in the supplementary belt (the area outside the main belt) if the density of the main belt is high, the detectability of

TABLE 1. A comparison of the densities of land birds observed in the census experiment in rich mountain birch forest. *MAP* gives the number of territories per km² in the mapping plots (42 ha, 31 ha for *F. hypoleuca*). *MB* and *SB* give the numbers of pairs per km² observed in the line transect census (16.0 km). *MB* is based on the main belt, *SB* on the survey belt. Sample size (*N*) in parentheses.

Species	*MAP*	(*N*)	*MB*	(*N*)	*SB*	(*N*)
Buteo lagopus	—	(—)	—	(—)	0.2	(5)
Falco columbarius	—	(—)	—	(—)	0.2	(1)
Tetrao urogallus	—	(—)	2.5	(2)	2.3	(2)
Lagopus lagopus	2.4	(1)	5.0	(4)	3.3	(4)
Cuculus canorus	—	(—)	—	(—)	0.1	(2)
Surnia ulula	—	(—)	—	(—)	0.5	(1)
Jynx torquilla	—	(—)	1.2	(1)	0.6	(4)
Picoides tridactylus	2.4	(1)	—	(—)	—	(—)
Corvus corax	—	(—)	—	(—)	0.0	(1)
C. corone	2.4	(1)	—	(—)	0.5	(6)
Parus major	—	(—)	1.2	(1)	2.0	(4)
P. montanus	2.4	(1)	1.2	(1)	1.8	(3)
Troglodytes troglodytes	—	(—)	—	(—)	0.4	(1)
Luscinia svecica	14.3	(6)	8.8	(7)	13.2	(34)
Phoenicurus phoenicurus	7.1	(3)	6.2	(5)	2.2	(10)
Saxicola rubetra	2.4	(1)	—	(—)	0.8	(2)
Turdus torquatus	—	(—)	—	(—)	0.2	(1)
T. pilaris	7.1	(3)	1.2	(1)	5.4	(12)
T. iliacus	14.3	(6)	10.0	(8)	15.7	(43)
T. philomelos	4.8	(2)	1.2	(1)	3.7	(13)
Sylvia borin	2.4	(1)	1.2	(1)	1.9	(6)
Phylloscopus trochilus	116.7	(49)	117.5	(94)	68.6	(245)
Muscicapa striata	4.8	(2)	—	(—)	—	(—)
Ficedula hypoleuca	3.2	(1)	8.8	(7)	9.6	(23)
Prunella modularis	31.0	(13)	17.5	(14)	17.2	(53)
Anthus trivialis	14.3	(6)	11.2	(9)	6.7	(24)
Motacilla flava	—	(—)	—	(—)	1.5	(3)
Carduelis spinus	—	(—)	—	(—)	0.8	(3)
C. flammea	28.6	(12)	18.8	(15)	13.3	(74)
Pyrrhula pyrrhula	2.4	(1)	1.2	(1)	0.9	(3)
Loxia sp.	—	(—)	—	(—)	0.1	(1)
Fringilla coelebs	9.5	(4)	2.5	(2)	3.4	(10)
F. montifringilla	14.3	(6)	21.2	(17)	20.5	(82)
Emberiza citrinella	—	(—)	—	(—)	0.3	(1)
E. schoeniclus	19.0	(8)	27.5	(22)	26.9	(69)
Total	306	(128)	266	(213)	225	(746)

Ph. trochilus was probably much reduced in the supplementary belt.

The above result for *Ph. trochilus* thus indicates that the correction coefficients used in the analysis of the survey belt results are valid for heterogeneous habitats only. However, the coefficients do also depend on the behaviour of the species, e.g. the frequency and audibility of the song and the tendency of the birds to evade the observer. (The correction coefficients increase with increasing proportion of main belt observations, and are lowest for species which are easily observed at great distances.) As survey belt data would probably have great potential for elucidating the species composition of homogeneous habitats, if proper correction coefficients were available, we attempted to find relationships between the coefficients and the census result.

For this we chose species which were observed at least 10 times in the survey belt. A comparison of the densities in the main belt (MB) and in the survey belt (SB) revealed three relatively distinct groups of species.

(1) Unexpectedly few observations in the supplementary belt (i.e. the density estimate for the survey belt was unexpectedly low compared with the density for the main belt): *Phoenicurus phoenicurus, Phylloscopus trochilus, Anthus trivialis* and *Carduelis flammea*, or "MB species".

(2) Unexpectedly many observations in the supplementary belt: *Luscinia svecica, Turdus pilaris, T. iliacus, T. philomelos* and *Fringilla coelebs*, or "SB species".

(3) The densities estimated in the two belts agree: *Ficedula hypoleuca, Prunella modularis, Fringilla montifringilla* and *Emberiza schoeniclus*.

The data for these species have been summarized in Table 2, which also includes the species-specific coefficients used in transforming the survey belt data to densities (Järvinen & Väisänen 1977). The coefficients (1000k)

Table 2. The relationship of the main belt (*MB*) and survey belt (*SB*) densities to the species-specific correction coefficients, 1000k. The densities (Table 1) are expressed as percentages of the corresponding mapping densities. For sample sizes, see Table 1.

Species	*MB*	*SB*	1000k
"MB species"			
Phoenicurus phoenicurus	87	31	3.02
Phylloscopus trochilus	101	59	3.77
Anthus trivialis	78	47	3.76
Carduelis flammea	66	46	2.43
"SB species"			
Luscinia svecica	62	92	5.22
Turdus pilaris	17	76	6.09
T. iliacus	70	110	4.93
T. philomelos	25	77	3.86
Fringilla coelebs	26	36	4.63
Others			
Ficedula hypoleuca	275	300	5.63
Prunella modularis	56	55	4.36
Fringilla montifringilla	148	143	3.36
Emberiza schoeniclus	145	142	6.23

average 3.24 ± 0.65 (*S.D.*) in MB species and significantly more, 4.95 ± 0.82, in SB species ($t = 3.39$*). Thus, the correlation coefficient seems to have a certain relationship to the discrepancy observed between the main belt and survey belt estimates. Two questions remain:

(1) Why was the detectability of the MB species considerably reduced in the supplementary belt?

(2) Why was the detectability of the SB species considerably enhanced in the supplementary belt?

It seems that the answer to the first question is provided by the effect already observed in *Phylloscopus trochilus:* a considerable proportion of the line transect observations on these species come from N Finland, where the average density of the birds is quite low compared with that in the rich mountain birch forest at Ammarnäs. This should be reflected in relatively low k values for the MB species and, as found here, underestimates in habitats where bird density is high.

The second question is more difficult to answer, since the differences in the average density of SB species in Finland and Ammarnäs only explain the case of *Fringilla coelebs*. With the other species, the explanation seems to be their singing pattern: they tend to sing vigorously at times (on certain mornings or during a brief period of the season), but are more or less silent at other times. For example, on "good" mornings the thrushes may sing almost without interruption, but on the very next morning they may remain silent. Such species should have higher k values than might be expected from the audibility of their song (note that individual differences in the song, especially of *Turdus iliacus*, certainly improve the result on "good" mornings). We thus suggest that a group of SB species was found because the mornings used for the experiment were favourable; in the standard line transect censuses in Finland the average intensity of the song was presumably less. Further, it should not be assumed that capricious song patterns are typical only of our SB species. Other species may be equally or more capricious, but their behaviour on the experimental mornings may have happened to correspond to the average found previously in Finland. Attempts should certainly be made to quantify the variability of bird song on different mornings.

Species diversity was measured with Shannon's function (corrected *H'*, see JÄRVINEN & VÄISÄNEN 1977). The estimates were as follows:

	$H' \pm S.D.$	N
Mapping	2.38 ± 0.11	128
Main belt	2.12 ± 0.09	213
Survey belt	2.50 ± 0.04	746

The main belt diversity differed highly significantly ($P<0.001$) from that of the survey belt, but the differences between the line transects and the mapping were not significant. Diversity was high in the survey belt mostly because the dominant *Ph. trochilus* had a relatively low frequency, due to its unsuitable correction coefficient.

The estimates of the evenness index $J' = H'/\ln S$, where S = number of species observed, were not greatly affected by the census method, either (J' = 0.75, 0.69 and 0.71 for mapping, main belt and survey belt, respectively).

It is clear from Table 1 that the results of the mapping and the main belt indicate similar frequencies for most species. We used methods described by JÄRVINEN & VÄISÄNEN (1977) for a numerical comparison of the composition of the two sets of data, and found that the difference between the results of the main belt and the mapping was about 1 *rD* unit. This difference is very small (cf. JÄRVINEN & VÄISÄNEN 1976a, 1976d, JÄRVINEN et al. 1977), because *rD* may range from 0 (identity) to 100 (complete dissimilarity).

Discussion

The experiment performed at Ammarnäs thus suggests that the result of the line transect census is, on average, only 13 % lower than that obtained in the mapping census, if conditions are optimal or nearly so. This indicates that "transect efficiency" is higher than might be expected from other studies on the efficiency of bird censuses based on a single visit. This could be partly explained by the fact that the efficiency estimates are not directly comparable. The "transect efficiency" is taken as the ratio of the density of the main belt observations to the density of stationary males or territories as mapped in the study plots, whereas in other investigations efficiency is estimated from the probability that males (or pairs) will be discovered (see MYSTERUD 1968). The stationary birds overlooked during a single visit could be partly compensated for in the main belt by observations which are not accepted in the mapping census ("surplus observations", see ENEMAR 1959:20—23). These observations could be of three main kinds:

(1) Visiting birds from territories just outside the main belt or study plot.

(2) Birds belonging to boundary territories excluded from the study plot by the international rules.

(3) Birds belonging to the "floating population" (non-stationary birds). FREDRIKSSON et al. (1973) and CEDERHOLM et al. (1974) have shown that there is a "floating" component in certain species populations in the same habitat at Ammarnäs, although exact quantitative data are not yet available.

The observations of "floating" birds are often excluded from the study plot censuses.

In addition, differences in the rules for the field work may contribute to the high result obtained in the transect census. Three points seem to deserve special mention.

(1) Estimates of efficiency are usually derived from censuses made (often of necessity) at different times of the day. However, results are, on average, considerably poorer if census work is performed at other times of the day than early morning. For example, afternoon censuses give less than 60 % of the birds observed in early morninig (JÄRVINEN et al. 1977).

(2) The period used for mapping censuses extends over the whole breeding season and thus includes periods which are relatively poor for the census of the majority of the species, though optimal as regards some species.

(3) The main belt of the line transect is relatively narrow, only 25 m on both sides of the observer, while broader strips are sometimes covered in mapping censuses.

These circumstances, together with the "surplus observations" and the fact that the experiment was performed in favourable weather, seem sufficient to explain why the "transect efficiency" was as high as 87 %.

The efficiency estimates obtained for the three abundant species, *Phylloscopus trochilus*, *Fringilla montifringilla* and *Emberiza schoeniclus*, were higher than the average or 87 % of the mapping estimate (Tables 1 and 2). The mapping density of *F. montifringilla* may have been lower than the true density (see ENEMAR et al. 1976), but the high value for *Emberiza schoeniclus* was a surprise, as HAUKIOJA (1968) found a low efficiency for the species. The present censuses were better timed than those of HAUKIOJA, and his study area was probably also more difficult to survey than the mountain birch habitat at Ammarnäs. Some of the birds at Ammarnäs may also have belonged to the floating population (see also JÄRVINEN & VÄISÄNEN 1975).

Luscinia svecica, *Turdus* spp. (censused, in contrast to other species, by searching for nests in the study plots) and *Prunella modularis* seemed to have a lower efficiency than the average in the experiment. Since the sample sizes are small, other comparisons at the species level are hardly of any value. For example, the density of *Fringilla coelebs* was much higher in the mapping than in the line transects, but this was probably due to chance: unpublished data of the LUVRE project indicate that the true proportion of the two *Fringilla* species in the habitat was much closer to 1:10, as found in the line transects, than 2:3, as found in the mapping. Similarly, the pronounced difference in the estimates for *Ficedula hypoleuca* is also probably due to chance.

Finally, we add a word of caution. The present result, which indicates a high efficiency for the transect method in optimal conditions, should not be used for other areas or habitats before more data are available from experiments of this kind. The results may even vary from one year to another — there may be annual differences in the singing activity of the species, and the proportion of the birds belonging to the floating population may vary. It seems likely that the efficiency of the line transect method is lower in more southern parts of Fennoscandia, where the breeding season is longer and the habitats often less easily surveyed than at Ammarnäs. The data collected at Birdsong Valley, southernmost Sweden (ENEMAR 1959, 1966), throw some light on this point. The area studied can, roughly, be regarded as a main belt, since the average breadth of the area populated by birds is about 50 m. The censuses progressed at about the same rate as that recommended for the line transects. The results for 28 May and 21 June 1957 were chosen for analysis, as the weather was fine on both days and the estimates can thus be directly compared with those obtained at Ammarnäs. All the morning censuses (4—10 a.m.) were included and all the observations, regardless of their significance, were considered. The average "transect efficiencies" for the two dates were 67 and 70 %, respectively. Of course, these percentages are based on the population estimate obtained in mapping censuses at Birdsong Valley, which may be too low for certain species (see NILSSON 1977, who gives data on the efficiency of the mapping method in southern Sweden). May we generalize and suggest that the density value obtained in a line transect census made in optimal conditions varies between 2/3 and 5/6 of that of the stationary community, depending on latitude?

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Selostus: **Linjalaskennan tehokkuus tunturikoivikon pesimälinnuston arvioinnissa**

1. Linjalaskentamenetelmää on jo vuosikymmenet käytetty pesimälinnuston tiheyksien arviointiin, mutta saatujen tiheysarvojen ja todellisten paritiheyksien suhdetta ei ole tiedetty. Tämän vuoksi järjestettiin kesäkuussa 1977 Ammarnäsissa Ruotsin Lapissa koe, jossa laskettiin 16 km linjaa rehevässä tunturikoivikossa. Tuloksia verrattiin kartoitusmenetelmällä samasta biotoopista samana pesimäkautena saatuihin tiheysarvioihin (alue 42 ha), jotka vastaavat likimäärin todellista pesimäkantaa (ENEMAR ym. 1976).

2. Koelinjat laski sään puolesta lähes ihanteellisissa olosuhteissa Enemar, joka on 1963—76 erinomaisesti perehtynyt biotooppiin ja sen linnustoon, mutta ei edeltäkäsin tuntenut reviirien sijaintia 1977. Laskennassa noudatettiin tarkoin yleisiä ohjeita.

3. Linjalaskennan tulos vastaa yllättävän hyvin kartoitusta: pääsarka antaa 87 % kartoituksen tiheydestä (taul. 1; kartoituksen *MAP* tiheydet reviirejä/km^2, linjalaskennan tiheydet pareja/km^2, *MB* on 50 m leveän pääsaran tulos, *SB* laskettu kaikista havainnoista eli tutkimussaralta). Koska tutkimussaran tiheydet on laskettu käyttäen suomalaisiin keskiverto-oloihin johdettuja korjauskertoimia, saatu tiheysarvio ei ole edustava. Eri laskennoissa (4 linjaa) pääsaran tulos vaihteli selvästi (67—103 %), ainakin osittain siksi, että lasketut osa-alueet poikkesivat toisistaan.

4. Apusarkahavaintoja kertyi odotettua vähemmän neljästä runsaasta lajista, joiden korjauskerroin on suhteellisen alhainen, kun taas viidestä muusta lajista, joiden korjauskerroin on suurehko, apusarkahavaintoja kertyi odottamattoman paljon (taul. 2). Etäisemmät laulajat peittävä hälyvaikutus selittänee edellisen ilmiön — pajulinnun, urpiaisen, metsäkirvisen ja leppälinnun keskitiheydet Suomessa jäävät selvästi jälkeen Ammarnäsin lehtomaisten koivikkojen arvosta. Jälkimmäisessä ryhmässä peippo on päinvastainen esimerkki: Ammarnäsissa asti lajia esiintyy vähän, joten eri peippokoiraiden laulu erottuu etäältäkin hyvin. Muut ryhmän lajit — sinirinta ja rastaat — laulavat joskus (tiettyinä aamuina tai tiettyyn pesimäkauden aikaan) innokkaasti, joskus taas suuri osa havainnoista kertyy pääsaralla nähdyistä vaisuista linnuista. Ilmeisesti mainio laskentasää vaikutti ratkaisevasti siihen, että näistä lajeista kertyi tavallista enemmän apusarkahavaintoja.

5. Lajidiversiteetti (Shannonin indeksi) ei eronnut merkitsevästi linjalaskennassa ja kartoituksessa. Linjalaskennan pääsaran ja kartoituksen antama kuva eri lajien lukusuhteista oli lähes sama — havaittu ero oli pienempi kuin esim. saman linjan pääsarkatulos pesimäkauden alku- ja loppupuolella.

6. Linjalaskennan tulos, 87 % kartoituksessa todetusta tiheydestä, ylittää selvästi muut yhden kerran laskentoja koskevat tiheysarvot. Tähän lienee useita syitä: olosuhteiden edullisuus, linjalaskennan verraten tiukat säännöt ja kiertelevienkin yksilöiden mukaan ottaminen (jäävät pois kartoitustuloksesta). Lajikohtaisia tehokkuusvertailuja vaikeuttaa aineiston niukkuus; runsaista lajeista pajulinnun, järripeipon ja pajusirkun tulos näyttää keskimääräistä paremmalta, sinirinnan, rastaiden ja rautiaisen tulos taas huonommalta. Tuloksia ei voida yleistää koko Fennoskandiaan ennen lisäkokeita.

Enemarin aineistoa skoonelaisesta lehdosta voitiin kuitenkin käsitellä viitteellisesti: tehtyä koetta vastaavaksi tehokkuudeksi saatiin 67—70 %. Näin ollen kokenut laskija havainnee erinomaisissa olosuhteissa linjalaskennan pääsaralla 2/3—5/6 pesimälinnuston tiheydestä.

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