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Efficiency of the line-transect method in mountain birch forest

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The bird community of a 6 ha study plot in rich mountain birch forest, NW Finnish Lapland, was censused by careful nest searching supplemented by territory mapping during two successive breeding seasons. The close-to-absolute numbers of pairs so obtained (43 in 1986, 31 in 1987) were compared with the results of independent line-transects covering the same plot (five in both years; only the 50 m wide main belt used for comparison). The census efficiency of the single counts varied between 23 and 55% (mean 36%), with considerable interspecific variation (e.g. *Fringilla montifringilla* 56, *Phylloscopus trochilus* 54, *Ficedula hypoleuca* 31, *Luscinia svecica* 25, *Carduelis flammea* 11%, on average). The result is in good agreement with earlier similar tests made in other habitats. The reasons for the low efficiency of the line-transect method and its consequences are discussed.

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1. Introduction

In northern Fennoscandia, the densities and species richness of forest birds are usually lower than in more southern parts of the region (e.g. Järvinen & Väisänen 1980). As the forests in the north are also of relatively simple structure (few tree species and low tree height), birds are relatively easy to census there. Hence, single line-transects in mountain birch forests had been thought to encounter between 2/3 and 5/6 of the birds actually present within the 50 m wide main belt, and differences in density estimates derived from different census methods had been assumed to be small (Järvinen et al. 1978). We present here some results of experiments to measure the efficiency of the line-transect method in northern mountain birch forests.

2. Material and methods

A rectangular study area (300×200 m, 6 ha) was chosen within a relatively homogenous and luxuriant mountain birch forest at Kilpisjärvi, NW Finnish Lapland (about 69°03'N, 20°50'E).

The area was divided into 96 25×25 m quadrats and these were marked with numbered sticks (cf. Fig. 1). Thus the coordinates of the nests and pairs of birds found were easy to mark on maps.

The mapping of birds' nests was performed by the authors and 12 students of the Subarctic animal ecology course of the University of Helsinki between 24 and 27 June 1986 and between 23 and 26 June 1987. The students walked in groups of four and in each group there was at least one competent ornithologist. The groups searched for nests in 200×100 m rectangles for 1.5 hours at a time, and then shifted to another rectangle the next day. The whole study area was searched thoroughly six times in 1986 and three times in 1987 (because only a few new nests were found after the third search in 1986). The authors surveyed the area independently and checked all the nests found.

The breeding bird density of the study area was also estimated by the line-transect method. Five censuses were conducted between 28 June and 1 July 1986, and five between 26 and 29 June 1987. The standard 50 m wide main belt was used. The 300 m long study area was walked through along four parallel transects, 50 m apart, in each census. Thus the total study area was covered and each transect amounted to 1200 m. The counts were made in the morning between 6.00 and 7.00 by OH (6), Pekka J. Nikander (2), Martti Hildén (1) and Markku Mikkola (1). Except for one census, the transect counts lasted about 60 min (Tables 2 and 3), thus corresponding to the speed of walking (45–60 min/km) recommended in the instructions for

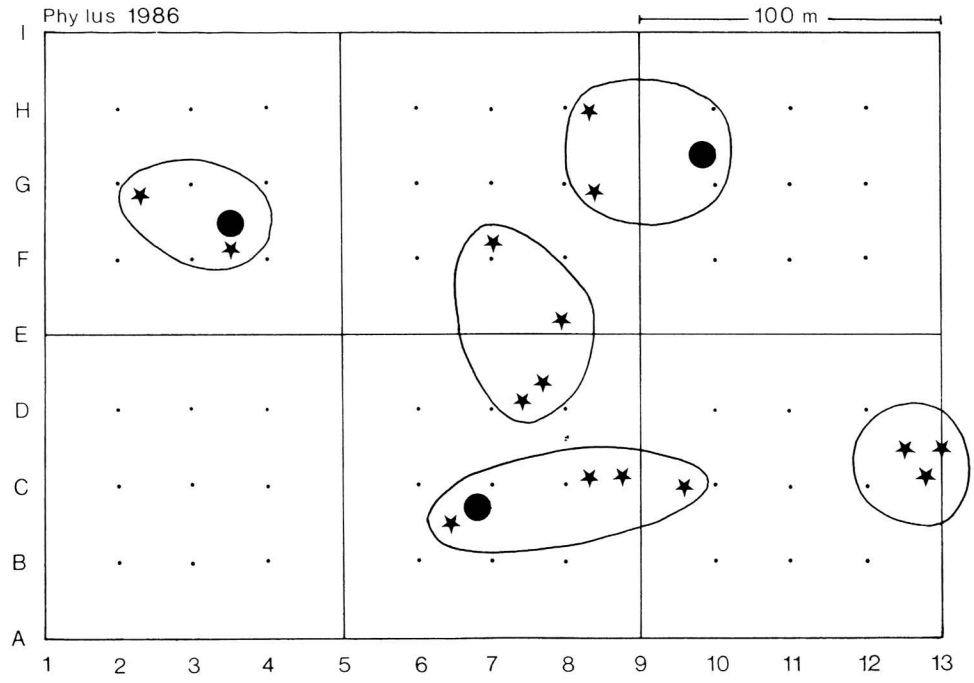

Fig. 1. The six hectare study plot divided into 25×25 m squares. Willow warbler nests found in 1986 are marked with dots and singing willow warbler males in single line-transect counts in 1986 are marked with stars.

line-transects in Finland (e.g. Järvinen & Väisänen 1976a). The weather was moderate to good on each census morning.

The estimates of the probable number of nesting pairs (and of unmated territorial males) of different species in the study area were based on the nest mapping results. For the brambling *Fringilla montifringilla*, the willow warbler *Phylloscopus trochilus* and the bluethroat *Luscinia svecica* these were supplemented by some stationary territories revealed by the line-transect censuses (see e.g. Fig. 1).

The bird community of a certain area can be defined in different ways. We have followed the principle that all pairs and unmated males which have attempted to breed or have established permanent territories within the study plot during the breeding season, have been included. Therefore we have added to the "probable number of pairs" a few destroyed nests (*Turdus iliacus*, *T. pilaris*, *T. philomelos*, *Corvus cornix*; see Discussion), although the birds were no more present at the time of the census. However, to avoid double counting, empty nests were not included if probable replacement nests of the same pairs were found (*Fringilla montifringilla*, *Carduelis flammea*). We find this method the best one, if the purpose of the test is to measure the efficiency of a census method in relation to the true bird numbers of a certain area during the whole breeding season, which is biologically more important than the numbers present during a given, short period. Defined in this way, there were 43 pairs of birds in the area in 1986 and 31 in 1987 (Table 1). The pied flycatcher *Ficedula hypoleuca*, the redstart *Phoenicurus phoenicurus* and the great tit *Parus major* nested only in boxes. At the time of the census work most pairs were incubating or had nestlings.

3. Results

The high bird density on the study plot, corresponding to 500–700 pairs/km^2, was due mainly to the many pairs nesting in boxes (6 in 1986, 9 in 1987; Table 1). In 1986, the high density also resulted from a peak year for redpolls *Carduelis flammea*. Fifteen pairs (Table 1) is most likely a minimum estimate of the probable number of redpolls, since in addition to nine nests found with eggs or young at the time of the survey, 13 fresh but empty nests were found (robbed or under construction). In both 1986 and 1987, redpolls sang and performed display flight actively during the last days of June, so new pairs probably settled to breed in the area in July (cf. Enemar 1969, Hildén 1969).

In 1986, the single line-transect censuses revealed between 23 and 51% (mean 37%) of the probable total number of breeding pairs of birds (Table 2). If the redpoll, the most abundant species and one with an extremely low detectability, is omitted, the efficiency of detection rises to 32–68% (mean 52%). The relative efficiency probably varied between individual censuses in 1986 (χ^2-tests, P=0.07 for all species and P=0.05 without the redpoll). However, when the first census is omitted, the differences between the

Table 1. Number of bird nests found in the 6 ha study area between 24 and 27 June 1986 and between 23 and 26 June 1987, and the estimated probable number of pairs breeding in the same area based on the mapping of nests and stationary territories.

	1986		1987	
	Nests found	Estim. no. of pairs	Nests found	Estim. no. of pairs
Carduelis flammea	22	15	3	3
Fringilla montifringilla	9	10	10	8
Phylloscopus trochilus	3	5	1	5
Ficedula hypoleuca	5	5	6	6
Luscinia svecica	2	3	1	1
Turdus iliacus	2	2	2	2
Parus major	1	1	1	1
Prunella modularis	0	1	0	0
Turdus pilaris	1	1	1	1
Phoen. phoenicurus	0	0	2	2
Corvus cornix	0	0	1	1
Turdus philomelos	0	0	1	1
Parus montanus	0	0	0	0
Turdus torquatus	0	0	0	0
Total	45	43	29	31

relative efficiencies of the remaining censuses are not significant (P=0.27 for all species and P=0.29 without the redpoll). In 1987, the relative efficiency varied from 29 to 55% (mean 35%), but the differences between the five censuses were not significant (χ^2-test, P=0.112; Table 3).

One obvious explanation for varying efficiency amongst individual censuses is that personal differences in efficiency could occur amongst the census takers. The counts conducted by OH gave fairly consistent efficiencies (30, 42 and 40% in 1986, and 29, 26 and 29% in 1987), whereas the two other census takers in 1986 obtained 23 and 51 % respectively, and P. J. Nikander (very experienced with line-transects) in 1987 35 and 55%. In addition, the speed of walking may have affected the census efficiency: the count conducted in the shortest time (37 min) gave the lowest efficiency.

With respect to the individual species, the line-transect method gave reasonably good results for the brambling and the willow warbler, usually the two most abundant bird species in mountain birch forests: between 50 and 60%, on average, of the stationary pairs were recorded in both years. Not in any single count, however, were all pairs registered (the highest efficiency was 75% for the brambling and 67% for the willow warbler). The line-transect method proved to be especially inefficient and unreliable in estimating the numbers of redpolls: in the peak year of 1986, only 1–3 pairs of the minimum estimate of 15 pairs were recorded in the single counts. This poor result was apparently not due to clumping of nests, since according to the nearest-neighbour analysis (with edge-correction, Ripley 1981) the nests were ran-

Table 2. Efficiency of the line-transect censuses in estimating the number of breeding pairs in the 6 ha study area in 1986 as compared with the probable number of pairs given in Table 1.

	Census 1 28 June 37 min	Census 2 28 June 63 min	Census 3 29 June 59 min	Census 4 1 July 59 min	Census 5 1 July 55 min
Carduelis flammea	1	1	1	1	3
Fringilla montifringilla	4	4	8	6	8
Phylloscopus trochilus	3	3	2	3	3
Ficedula hypoleuca	0	3	4	2	2
Luscinia svecica	1	0	1	1	2
Turdus iliacus	0	0	0	0	0
Parus major	0	1	1	1	1
Prunella modularis	0	0	1	1	0
Turdus pilaris	0	0	0	1	1
Parus montanus	1	0	0	0	1
Phoenicurus phoenicurus	0	1	0	0	0
Turdus torquatus	0	0	0	1	1
Total	10	13	18	17	22
Efficiency %	23	30	42	40	51

Table 3. Efficiency of the line-transect censuses in estimating the number of breeding pairs in the 6 ha study area in 1987 as compared with the probable number of pairs given in Table 1.

	Census 1 26 June 58 min	Census 2 26 June 60 min	Census 3 27 June 60 min	Census 4 27 June 66 min	Census 5 29 June 64 min
Fringilla montifringilla	4	5	3	6	2
Phylloscopus trochilus	3	2	2	3	3
Ficedula hypoleuca	1	1	0	3	1
Carduelis flammea	0	1	0	1	1
Turdus iliacus	1	1	1	1	1
Phoenicurus phoenicurus	0	1	1	2	1
Turdus pilaris	0	0	1	0	0
Turdus philomelos	0	0	0	0	0
Parus major	0	0	0	0	0
Luscinia svecica	0	0	0	0	0
Corvus cornix	0	0	0	0	0
Prunella modularis	0	0	0	1	0
Total	9	11	8	17	9
Efficiency %	29	35	26	55	29

domly dispersed in the study area (z=0.73, P>0.4). For the pied flycatcher, the fourth dominant species on the study plot, the mean efficiency was 44% in 1986, but only 20% in 1987.

4. Discussion

According to our results, little more than one third of the birds breeding in mountain birch forests were recorded in single line-transect counts, on average. We believe, however, that our experiment somewhat overestimates the inefficiency of the method, due to the following reasons:

1) At the time of the censuses, the season was rather far advanced and the song activity of some species had already decreased. On the other hand, the area lies in northernmost Finland where the breeding season of birds is much later than in the southern parts of the country (most pairs were either incubating or feeding young).
2) The study plot included luxuriant, in places relatively dense, birch wood, where the bird density was high. In drier and lighter birch woods, with lower bird density, the efficiency of the line-transect method may be higher.
3) More than one third of the breeding birds of the study plot in 1986 were redpolls, which were especially difficult to record on the transects (efficiency only 9%).
4) In 1987, the nesting pied flycatchers were exceptionally silent in late June (very little song and few alarm calls were heard), and most pairs were overlooked.

Hence, the mean efficiency of the line-transect method in mountain birch forest could probably be raised somewhat higher than in our test, but most likely it does not exceed 50%. This result is in good agreement with earlier tests in which single line-transect counts were compared with more absolute, time-consuming censuses in the same study areas (Hildén 1981, Helle & Pulliainen 1983, Hildén & Laine 1985). All these studies, carried out in a variety of habitats and in different parts of Finland, came to the same conclusion that the average efficiency of single line-transects is about 50% or slightly less, with considerable interspecific variation. In the mapping method also, the average registration efficiency of single visits to the study plot seems to be about 50%, but varies greatly from species to species (e.g. Kwak & Meijer 1985). Single censuses in mountain birch forest, by whatever method, thus seem to form no exception to the general rule in terms of their efficiency.

These findings do not agree with the conclusion of Järvinen et al. (1978) that the efficiency of single line-transects in mountain birch forests should be as high as 70–80%. One explanation to this discrepancy could be that in their test line-transects were compared with the mapping method, which itself usually

underestimates the true population densities (e.g. Mysterud 1968, Slagsvold 1973, Jensen 1974, Mannes & Alpers 1975, Berthold 1976, Nilsson 1977, Tomiałojć 1980, Kwak & Meijer 1985). Probably for the same reason, Tiainen et al. (1980), when comparing line-transects with the mapping method in the forests of southern Finland, obtained a mean efficiency of 65%, which is clearly higher than in the studies mentioned above.

Redpolls, for instance, cannot be estimated reliably by mapping the pairs, as the birds constantly fly around over extensive areas. During incubation the female redpoll is almost invisible, only seldom leaving the nest, and the male feeds her infrequently; during the nestling period both parents are mostly away from the nest vicinity (e.g. Peiponen 1962, Hildén 1969). Likewise the thrushes are difficult to map accurately without searching for their nests (e.g. Enemar et al. 1973, 1976). Other factors that may have contributed to the high detection efficiency recorded in the test of Järvinen et al. (1978) were ideal weather and optimal time of the season.

The *poor detectability* of many species (e.g. the female incubates and the male does not sing or is away from the territory) is only one reason for the low efficiency of single line-transects (and all one-visit censuses). In addition, we stress that at the time of the single census, a considerable proportion of the pairs forming the bird community of a certain area *may not be present*: they have not yet arrived (late migrants), or they have already left the area because the young have fledged or the nest has been robbed.

On our study plot, for instance, no less than six of the seven thrush nests recorded in 1986–87 (*Turdus iliacus* 4, *T. pilaris* 2 and *T. philomelos* 1) were destroyed before the censuses. The birds had disappeared, either moved to new territories outside the study plot or given up nesting that year. The only successful pair (redwing with nestlings in 1987) was easily recorded in every count, whereas the six unsuccessful pairs were not seen, except for three observations of solitary fieldfares visiting occasionally the study plot. Similarly, the crow *Corvus cornix* pair, which failed in its nesting attempt in 1987, was never seen in the counts.

In the test conducted by Helle & Pulliainen (1983), all nests that were not in use at the time of the line-transects were omitted from the comparison. Hence, the efficiency of about 50% may, in fact, have been considerably lower if the comparison had been made with the total number of pairs present during the breeding season.

As pointed out earlier by Hildén & Laine (1985), line-transects are a useful method when working with problems in which relative indices will suffice. But results based on this method, or any other single-visit census, should not be used to calculate absolute densities, total numbers of pairs or indices of community composition, as recently stressed also by Tomiałojć (1987). The values obtained in this way are serious underestimates, and the proportions of species in the community may be distorted. This is shown, for instance, by the measures of bird abundance for mountain birch forests presented by Järvinen & Väisänen (1976b): namely a total bird density of 55 pairs/km^2, and densities of willow warbler 15.1, brambling 11.1, redpoll 5.3, redwing 5.0 and bluethroat 0.8 pairs/km^2. Compared with studies carried out with more absolute census methods, these values are, in general, much too low. In the bluethroat, for instance, the difference is fivefold (A. Järvinen & Pietiäinen 1983).

To take one more example, Merikallio (1958) estimated from single line-transect counts that the mean density of the redpoll in Finnish Lapland was 5.2 pairs/km^2 and the total Finnish population 470000 pairs. In peak years, as in 1968 (Hildén 1969) and 1986 (this study), its density in birch forests may reach 250 pairs/km^2, and it breeds abundantly in a wide variety of habitats including bushy peatlands, open mountains with low dwarf birches and junipers, and coniferous forests (e.g. Hildén 1969). Thus in these years its total population in Finland must be several millions of pairs. In average years the population is roughly 25–30% of the peak years' level (Enemar & Nyström 1981, Enemar et al. 1984), which means that even the "normal" Finnish breeding population must be several times higher than that estimated by Merikallio. This conclusion is also supported by the very low census efficiency of the species on line-transects in our test.

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