Estimating relative densities of breeding birds by the line transect method. IV. Geographical constancy of the proportion of main belt observations

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JÄRVINEN, O. & R. A. VÄISÄNEN [Dept. of Genetics, University of Helsinki, P. Rautatiekatu 13, SF-00100 Helsinki 10, Finland] 1976 — *Estimating relative densities of breeding birds by the line transect method. IV. Geographical constancy of the proportion of main belt observations.* Ornis Fennica 53: 87—91.

All observations are recorded in the line transect censuses, but those made within 25 m from the transect are distinguished from the others, being considered to belong to the *main* belt. The proportions of main belt observations *(MB)* are used to estimate species-specific coefficients of detectability. These improve the efficiency of the transect method.

The geographical constancy of total *MB* was investigated in Finland and adjacent areas. Analysis of data from 515 line transect counts, covering a total of 2211 km, revealed considerable heterogeneity in *MB,* which could be explained by the total density of birds (proportion of variance explained 61 %). It is concluded that *MB* increases with the density of birds, because the censusing of pairs outside the main belt becomes more difficult.

A method is suggested for correcting for the density-dependent bias in *MB.* Numbers of pairs in a census are multiplied by a coefficient obtained from a simple regression formula, with pairs per main belt km as the independent variable. The correction will steepen the gradient of bird densities in Finland by increasing the highest densities and decreasing the lowest densities.

Introduction

In line transect censuses of breeding birds, all observations within 25 m from the transect are considered to fall within the so-called *main* belt, while the rest of the observations are said to belong to the *supplementary* belt. These two belts together form the *survey* belt. The ratio of main belt to survey belt observations is termed *MB,* and 100 *MB* is the main belt percentage. This proportion can be used to improve the line transect method, provided that 100 *MB* values need not be estimated separately for each region studied (JÄRVINEN & VÄISÄNEN 1975, JÄRVINEN 1976). The species-specific *MB* is constant throughout the breeding season, if recommendations concerning the census hours are observed (JÄRVINEN et al. 1976).

The purpose of this paper is to investigate the geographical constancy of the main belt percentages of different species in the whole of Finland and adjacent regions (N Norway, Eastern Karelia and surroundings of Leningrad, U.S.S.R.).

Materials and methods

The data used come from 515 line

transect counts, covering a total length of 2211.0 km. We have chosen the biological provinces of Finland and Eastern Fennoscandia as the basis for comparisons (see HEIKINHEIMO & RAATIKAINEN 1971). Division of the material among 24 provinces facilitates analysis, but does not result in too small fractions. The total material (Table 1) comprises all the censuses available, except those in which the census-taker recorded observations from only the main or the survey belt, or in which the two belts were of different lengths.

Results

We have applied a method which is derived from that presented by JÄRVINEN et al. (1976). We checked the constancy of the *MB* values of different species in our extensive geographic area (about 1300 km × 700 km) by trying to predict all observed changes in total *MB* from differences in the species composition between different provinces. In other words, we assumed that the *MB* values of different species are geographically constant, putting MB_i as the fraction of the main belt observations of the *i*th species in the total material. Accordingly, *the expected number of main belt observations in the jth province* $= \sum_i MB_i \, N_{ij}$, where N_{ij} = the number of survey belt observations of the *i*th species in the *j*th province. Comparison of the observed/expected ratios revealed considerable heterogeneity, which could be related to variation in the total densities of birds (Fig. 1). In high densities, the proportion of main belt observations was 1.2—1.4 times as high as could be expected on the basis of the species composition; in low densities it was 0.7—0.9 times as high. The regression of this ratio upon the densities of birds in the main belt was highly significant, and about 61 % of the total variance in the observed/expected ratio could be ascribed to this single factor. The rest, nearly 40 %, can be explained by inter-observer variation and a number of other factors controlling *MB*, e.g. habitat structure and the weather. We propose that line transect data should be corrected by multiplying all the numbers of pairs recorded from the survey belt by *y*, which is obtained from

$$y = 0.0346x + 0.6963,$$

where x = the number of main belt observations per km in a census. This

TABLE 1. The distribution of the line transect counts in the biological provinces of Finland and adjacent countries. We have followed the numbering of HEIKINHEIMO & RAATIKAINEN (1971), with the exception of provinces 22—24. Province 23 = 32 in HEIKINHEIMO & RAATIKAINEN, and the other two have not been numbered by them.

	Biological province	Transect km
1	Åland (Ahvenanmaa)	174.9
2	Varsinais-Suomi	33.6
3	Uusimaa	144.3
4	South Karelia	12.3
5	Satakunta	51.8
6	South Häme	164.4
7	South Savo	109.8
8	Ladoga Karelia	8.0
9	South Ostrobothnia	77.4
10	North Häme	68.7
11	North Savo	68.9
12	North Karelia	232.6
13	Central Ostrobothnia	101.7
14	Kainuu	90.9
15	North Ostrobothnia (S part)	85.9
16	North Ostrobothnia (N part)	84.7
17	Kuusamo	111.4
18	Kemi Lapland (W part)	71.2
19	Kemi Lapland (E part)	113.7
20	Enontekiö Lapland	77.6
21	Inari Lapland	156.2
22	Finnmark (Norway)	113.4
23	Karelian isthmus (U.S.S.R.)	13.0
24	Leningrad and its surroundings (U.S.S.R.)	44.6

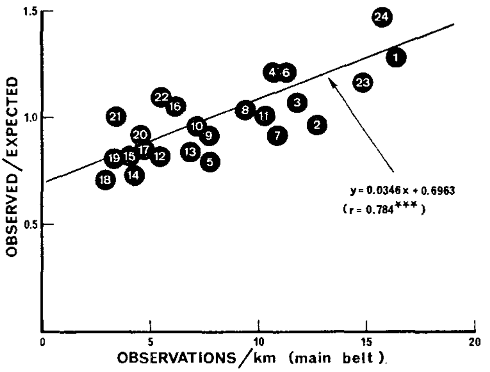

FIG. 1. The relationship between the density of birds and the ratio of the observed to the expected *MB* values in different biological provinces. The methods of calculation are explained in the text.

correction procedure is based on the following interpretation of the above highly significant regression: high densities in the main belt prevent efficient detection of birds in the supplementary belt and low densities make it possible to census the supplementary belt exceptionally well (see Discussion).[1]

The extensive censuses by E. Merikallio made it possible to investigate the same relationship with data free from inter-observer variation. The regression was equally significant, and its slope was slightly steeper. So a correction formula derived from Merikallio's data alone would allow for a slightly stronger effect of density on *MB*.

Discussion

We have suggested that *MB*, the proportion of main belt observations, increases with the density of birds, because the censusing of the supplementary belt is impaired. Another psychological interpretation is possible, though, in our opinion, unlikely: the census-takers make density-dependent errors in the estimation of the width of the main belt, and the actual extent of the zone treated as the main belt thus increases with increasing density. If this were true, not only would the first interpretation be wrong, but the line transect method in general would be worthless in the estimation of density. We have no data with which to refute either of the hypotheses, but the first interpretation is very strongly supported by the fact that the ratio of the observed to the expected *MB* correlates with the number of observations (per km) in the survey belt ($r = 0.471^{*}$). This correlation is not deducible from the second hypothesis, but is perfectly in accordance with the first one, for we can, quite theoretically, expect that the numbers of main belt and survey belt observations per km will correlate well. The correlation would be perfect, if the census results were not affected by such variables as the average habitat structure, or the composition of the avifauna (and, of course, chance); actually, $r = 0.907^{***}$. Field experience also supports our first hypothesis. We have noticed that when the transect runs through a dense community in southern Finland, it is more difficult to observe birds from the supplementary belt than in poor bird communities in Lapland, where only a few birds require attention in the main belt. Of course, these experiences cannot be quantified easily.

1) *Note added in proof.* Censuses made in June 1976 have shown that the correction method suggested is not valid if habitat structure is very mosaic-like. The censusing of the supplementary belt is apparently not impaired in such an area, because the birds of the supplementary belt can be observed from the frequent intervening low-density patches. This exception clearly proves the rule.

We have, so far, not found adequate methods for quantification.

The correction method suggested will steepen the gradient of Finnish bird densities derived from survey belt data. The two extremes in the present material are the provinces 1 and 18 (Fig. 1), for which the numbers of main belt observations per km are 16.3 and 2.9, respectively. So the correction factors would be 1.26 and 0.80. As densities in the linear model are obtained by multiplying the species-specific "detection coefficients" (*k*) by the number of observations and the inverse of the transect length (and a constant, 10^3), the corrected densities are 1.26-fold the original values for the Åland Islands, and 0.80-fold those for province 18. The ratio of these extreme average correction factors is 1.58. This is thus the largest increase in the average ratios of the densities of two provinces after our correction.

However, if *MB* values depend on density, the survey belt data to be corrected should ideally be divided in such a way that no density variation is present in the main belt material of the different fractions. This is not possible with the present Finnish line transect material. Such a procedure would also be very laborious, and it would tend to split the main belt data into a great many fractions, all with high variances in the number of observations per km, because homogeneous biotopes often cover a couple of hundred metres only. Accordingly, in future we shall correct the data of each transect separately. The number of main belt observations per transect is not inconveniently sensitive to chance variation, but it is nevertheless useful to be able to distinguish between different transects, possibly covering areas with quite different densities of birds. In this way we can also avoid the decision whether the survey belt data of a transect should be corrected according to the 100×100 km square, the biological province, the zoogeographical region, etc., to which the transect belongs. In other words, the data will not be manipulated to increase within-region homogeneity in one areal division of Finland, at the cost of increasing heterogeneity in another division.

Acknowledgements

Most of our recent censuses, which cover important marginal areas, have been financed by a grant from the National Research Council of Science, Academy of Finland.

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Selostus: Linja-arviointimenetelmä pesimälinnuston paritiheyksien arvioinnissa. IV. Lajin pääsarkahavaintojen osuuden maantieteellinen vaihtelu

Pääsarkaprosentin maantieteellistä vaihtelua tutkittiin koko Suomesta, Pohjois-Norjasta ja Neuvostoliiton Karjalan—Leningradin alueelta kootusta 515 linjan (2211 km) aineistosta, joka jaettiin 24 luonnontieteelliseen maakuntaan käsittelyä varten. Aineisto jakautui näin sopiviksi osiksi.

Kun oletettiin lajin pääsarkaprosentti vakioksi, voitiin laskea eri maakuntien odotetut pääsarkaprosentit. Odotetun ja havaitun prosentin suhde vaihteli huomattavasti, mikä merkitsee sitä, että saman lajin pääsarkaprosentti vaihtelee eri alueilla.

Vaihtelu voitiin selittää pääosin (61 %) linnuston tiheyden avulla. Kun tiheys on alhainen, havaitaan pääsaralla odotettua pienempi osuus pareista, ja kun tiheys on korkea, todetaan pääsaralla odotettua useampi pari (Kuva 1). Riippuvuuden pääteltiin johtuvan maastossa havaitusta ilmiöstä, että lintutiheyden kasvaessa kaukaisempien lintujen havaitseminen vaikeutuu. Lapissa ja yleensä kun linnusto on harvaa, on helppo laskea etäisetkin parit, koska pääsaran havainnot jäävät vähiin. Eteläsuomalaisessa lehdossa pääsarka taasen tulvii lintuja, ja huomattava osa linjalle asti kuuluvista tai näkyvistä apusaran pareista jää pääsaran lintujen peittoon ja havaitsematta.

Tiheyden vaikutus laskentatulokseen esitetään korjattavaksi kertomalla reitin tutkimussaran parimäärät korjauskertoimella $y = 0.0346x + 0.6963$, missä x = reitin parimäärä pääsaralla kilometriä kohti. Korjauksen vaikutuksesta tutkimussarka-aineistoon perustuvat tiheysarvot suurentuvat siellä missä pareja on paljon pinta-alayksikköä kohti ja pienentyvät harvalinnustoisilla alueilla.