

## Effects of habitat area on breeding bird communities in Northeastern Finland

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Breeding bird communities were studied in different stages of secondary forest succession during three years' period in Kuusamo, Northeastern Finland. The data consist of 36 plots (size range 3-100 hectares), the birds of which were censused by single visits. The plots of young forest stages were surrounded by mature forests and the plots of older forest stages by clearcut areas.

No correlation was found between bird density and habitat area in plots of 2-10 years of age. In areas appr. 25 years old and in the moist mature forest plots the correlation was negative. The relationship between habitat area and number of species was described best with the logarithmic function. The older stages ( $\geq 75$  ys) support roughly twice as many species per unit area as do the younger stages ( $\leq 25$  ys). Part of the difference in the number of species is due to the larger samples of the older stages. *Cuculus canorus*, *Turdus iliacus*, *Sylvia borin* and *Carduelis flammea* preferred small habitat areas while *Certhia familiaris* and *Carduelis spinus* show an opposite trend.

The relationship between habitat area and bird density is discussed in the light of the edge effect theory. Three aspects are pointed out which affect the bird density at forest edges: 1) the structure of vegetation, 2) forest edges as singing places of some species, 3) in spite of 'extra' territories in edges between forest and open habitat foraging may take place in open areas.

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### 1. Introduction

The size of a study plot is an important variable in quantitative bird studies (e.g. Engström 1981). Even if the density of birds per unit area remains the same in plots of different size, the number of species will increase with increasing plot size. The situation is more complicated if the density increases with decreasing plot size, which is the case when the edge effect is marked (Oelke 1966). The effects of the size of a habitat patch are also of practical interest: e.g. the fragmentation of habitats has been shown to cause considerable changes in bird communities (Haila et al. 1980, Whitcomb et al. 1981).

During the breeding seasons of 1980-82 I collected material for studying bird density and community structure in different stages of secondary forest succession in Northeastern Finland. In order to avoid the edge effect I tried to select the study plots so that the variation in plot size would be negligible, but this was not possible. In this paper I analyze the effects of

the habitat patch size (or study plot) on breeding bird density and community structure as well as on densities of individual bird species.

### 2. Study area and methods

The study area is in Kuusamo, Northeastern Finland, appr. 66° N, 29° E. The bird data originate from forest areas of different ages in dry and moist sites. The age of the five successional stages are approximately (I) 2, (II) 10, (III) 25, (IV) 75 and (V) 150 years; the stages are later referred to by their Roman numerals. A total of 36 plots were examined; their size distribution was as follows (in ha, dry and moist sites combined):

	<20	20-50	>50	Total
Number of plots	13	16	7	36
Total area	183	514	470	1167

The climax stage of the dry series is pine dominated *CCIT* or barren *EMT* forest and that of the moist series usually spruce dominated *HMT* forest (for Finnish classification of forest types, see Kalela 1961). The first three stages originated through clearcutting and stages IV and V have grown after forest fires or slash-and-burn cultivation. The study area resembles an archipelago, in which

the young stage areas are "islands" in a forest "sea" in one subarea, and the proper forest patches "islands" in a "sea" of open habitat in the other.

Birds were censused in the summers of 1980-82 between June 5 and July 6 with a method based on single visits. The line transect method with main belt breadth of 50 m (Merikallio 1946) was employed in stages IV and V while stages I-III were studied by covering the total area with parallel lines 50-100 m apart from each other. The censuses were started at 4 a.m. and lasted until no later than 9 a.m. Censuses were made only in mornings with no rain and no or only moderate wind; if the temperature had been below 0 C in the previous night, censuses were not made. A more thorough description of the study area and methods will be published elsewhere.

### 3. Habitat size and bird density

One-visit censuses typically record 60-70% of the total breeding community (see e.g. Järvinen 1978). We must assume that the census efficiency remains approximately the same in all the stages studied when comparing the densities. This assumption is not entirely valid, but we do not have field data to test it. When plotting the observed bird densities against habitat sizes the dry and moist sites have been pooled for stages I-III, because the difference in bird density between the series was not large there.

No correlation can be found between bird density and habitat size in stages I and II: the variation is considerable and the coefficient of correlation is as low as 0.08 (Fig. 1). In stage III the negative correlation is quite clear, but not significant and in moist forests (IV-V) the same trend is nearly significant ( $P < 0.1$ ). In dry forest plots the relationship seems to be different, but no equation has been fitted, because the size variation of the plots is relatively small and these plots were not very clearly limited by open habitats (unlike the moist forest plots).

### 4. Habitat size and number of species

Regression lines between the habitat size and the number of species were calculated first separately for dry and moist sites and also for each successional stage. Several combinations were tried and, after a comparison between the percentages of variances explained, the regressions are presented for young (I-III) and old (IV-V) stages (Fig. 2). The best fits were obtained with the combination  $\log(\text{area})$  vs. number of species. The older stages support roughly twice as many species per unit area as

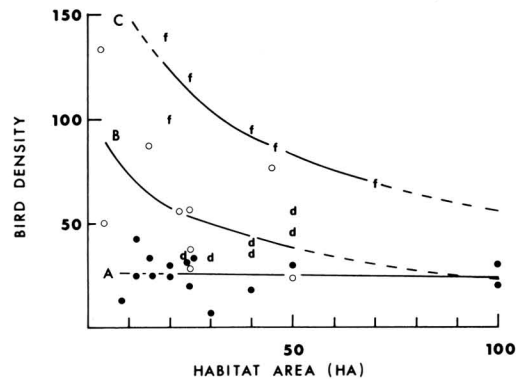


Fig. 1. Relationship between the habitat size and the observed bird density (territories/km<sup>2</sup>) in areas of different forest age in Northeastern Finland. Fitted equations:

A — Stages I-II (dots):

$$y = -0.59 \log(A) + 21.60, r = 0.08$$

B — Stage III (open circles):

$$y = 21.12 \log(A) + 120.59, r = 0.61$$

C — Stages IV-V fresh sites (f):

$$y = -40.97 \log(A) + 244.12, r = 0.77$$

Dry sites of stages IV-V are shown by 'd'.

do the younger stages. Because the bird density per unit area is higher in the older than in younger stages, it is justified to ask whether the difference in the number of species is merely due to larger samples in older stages or not. The question can be solved using the rarefaction method (Heck et al. 1975). The expected number of species in random samples of different size drawn from young and old stage data are as follows:

	Stages I-III	Stages IV-V
50 pairs	15.9	18.9
100 pairs	21.2	25.3
220 pairs	28.8	33.7

The above figures show that the older stages support about 20% more species than young ones in samples of equal size; thus most of the difference in the number of species between young and old stages is not due to sampling effects. The fact that the bird communities are more heterogeneous in forests (stages IV-V) than in young stages can also be seen from species diversity values ( $H'$ , Shannon index, corrected for sample size) of 2.97 for the former and 2.56 for the latter (difference significant at 0.1% level).

It has been customary to describe area/species number relation by the power function ( $S = CA^z$ ) although in many cases alternative functions would have been more exact (see Gil-

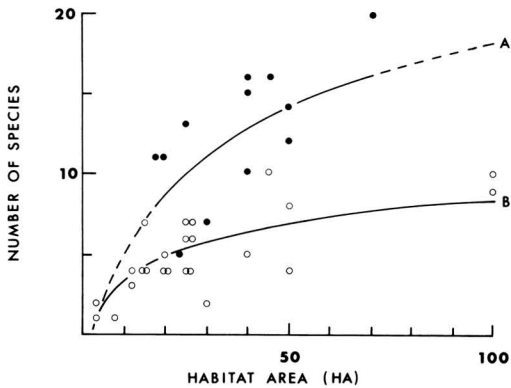


Fig. 2. Relationship between the habitat size and the number of species in the census plots of different age studied in Northeastern Finland.

A — Forests (stages IV-V, dots):

$$y = 5.92 \log(A) - 9.16, r = 0.62^*$$

B — Open habitats (stages I-III, open circles):

$$y = 2.21 \log(A) - 1.74, r = 0.74^{***}.$$

bert 1980). In this case the percentages of variance explained remain somewhat lower when using the power function (see below) than using the logarithmic function (see Fig. 2):

$$\begin{array}{lll} \text{Stages I-III} & S = 0.97 A^{0.49}, & R^2 = 53\% \\ \text{Stages IV-V} & S = 1.94 A^{0.50}, & R^2 = 31\% \end{array}$$

On oceanic islands the value of  $z$  usually falls between 0.20 and 0.35 (MacArthur & Wilson 1967). The value of  $z$  of this study is on average slightly higher than those obtained in studies dealing with northern archipelagoes (Martin 1983, Haila 1983a) and habitat islands (Järvinen & Sammalisto 1976). I am not going to discuss  $z$  thoroughly, because the ecological significance of the slope itself is doubtful (May 1975, Haila 1983b), but will list reasons which may have affected the result or should be taken into consideration. 1) The bird density is not independent of the size of habitat, 2) A high value of  $z$  is often due to the incompleteness of the census (MacArthur & Wilson 1967), 3) The species-abundance distributions, which have an important influence on species number, may be different between the small and large plots (see Haila 1983b), 4) The value of  $z$  is higher the smaller the islands from which the slope is calculated (May 1975; see also Schoener 1976).

In order to assess the fourth point here I calculated the power functions excluding the

Table 1. Pair densities (pairs/km<sup>2</sup>) of the most abundant species in habitat 'islands' of different size. The figures in brackets indicate the area (in hectares) from which the densities are calculated (see text).  $N$  shows the total number of pairs observed.

	<20 ha	20-50 ha	>50 ha	$N$
<i>Numenius phaeopus</i>	- (103)	1.7 (115)	1.5 (200)	5
<i>Cuculus canorus</i>	2.5 (80)	0.3 (399)	0.7 (270)	5
<i>Certhia familiaris</i>	- (20)	0.9 (116)	3.3 (120)	5
<i>Turdus philomelos</i>	5.0 (20)	2.6 (116)	4.2 (120)	9
<i>T. iliacus</i>	3.3 (183)	3.7 (514)	1.3 (470)	31
<i>Oenanthe oenanthe</i>	2.9 (103)	3.5 (115)	2.0 (200)	11
<i>Saxiola rubetra</i>	2.8 (145)	1.3 (235)	1.6 (250)	11
<i>Phoenicurus phoenicurus</i>	10.0 (20)	2.6 (116)	2.5 (129)	8
<i>Erithacus rubecula</i>	5.3 (38)	2.5 (279)	1.4 (220)	12
<i>Sylvia borin</i>	3.8 (80)	0.5 (399)	0.4 (270)	6
<i>Phylloscopus trochilus</i>	14.2 (183)	11.3 (514)	8.5 (470)	124
<i>Ph. collybita</i>	- (38)	2.9 (279)	0.9 (220)	10
<i>Muscicapa striata</i>	2.5 (80)	1.8 (399)	3.0 (270)	17
<i>Ficedula hypoleuca</i>	- (38)	1.8 (279)	0.9 (220)	7
<i>Anthus trivialis</i>	6.0 (183)	4.5 (514)	2.8 (470)	47
<i>Motacilla alba</i>	5.5 (145)	2.1 (235)	2.4 (250)	19
<i>M. flava</i>	1.4 (145)	2.6 (235)	2.4 (250)	14
<i>Carduelis spinus</i>	- (38)	3.6 (279)	1.4 (220)	13
<i>C. flammea</i>	3.3 (183)	2.3 (514)	0.4 (470)	20
<i>Carpodacus erythrinus</i>	3.5 (85)	1.0 (195)	0.5 (200)	6
<i>Fringilla coelebs</i>	5.0 (80)	4.5 (399)	4.1 (270)	33
<i>F. montifringilla</i>	6.5 (123)	5.7 (474)	5.7 (370)	56
Total	83.0	63.7	51.9	

smallest plots (<25 ha). The values of  $z$  are 0.62 for old and 0.58 for young stages, which are higher than those obtained from the whole data. This is an unexpected result, which is probably due to the fact that dry and moist plots are pooled in the two equations (old and young stages). The size distributions of the dry and moist plots are not exactly the same and because the moist plots support marginally more species than the dry ones because of their higher bird density, a biased result may arise.

##### 5. Effects of habitat size at the species level

The population densities (pairs/km<sup>2</sup>) for individual bird species were calculated for the following habitat size classes: <20, 20-50 and >50 hectares. For the successional stages in which a species occurred, the observed number of pairs in plots of each size class was divided by the total area of plots of that size.

The results are given in Table 1. For most species the data are not extensive enough for

statistical testing, or the deviations from equal density are so small that they can be attributed to chance. However, total density tends to decrease with area (Table 1), as many of the abundant species tended to be more abundant in small areas than in large ones (e.g. *Turdus iliacus*, *Phylloscopus trochilus*, *Anthus trivialis*, *Motacilla alba* and *Carduelis flammea*). The differences were not significant in any of these species separately, however, with the exception of *C. flammea* which is significantly more abundant in small (below 50 ha) than in larger areas. One would expect that density maxima have a relatively even distribution among the size classes, but this is not so. The distribution of density maxima is significantly biased in favour of the smallest size class ( $P < 0.025$ ), for as many as 13 species had their density maxima there, but only two species had the maximum in the largest size class (*Certhia familiaris* and *Muscicapa striata*).

## 6. Concluding remarks

One of the simplest ways to study the edge effect — the higher density and number of species at a transition of two (or more) habitats than in homogeneous habitats — is to compare bird communities in habitat patches of different sizes. A negative correlation between habitat size and bird density can be considered as evidence for the edge effect because the smaller the area the bigger the edge length per unit area (e.g. Oelke 1966). The predictions of the theory, however, do not always hold true (for references see Kroodsmá 1982) but this is at least partly due to the relatively loosely defined concepts involved.

Without discussing the edge effect more deeply, I wish to stress three points here. First, the results of this study show that the edge effect is not constant even in ecotones which seem structurally quite similar. In another study (Helle 1983) I censused various open habitat/mature forest ecotones and also estimated several features of the vegetation. A multiple regression analysis showed the density of the bush layer at the forest edge to be most important factor determining the bird density there. The strength of the invading bush layer depends on the age of the clearcut. This variable may thus be important in explaining the habitat size/bird density relationship of the present study. Second, especially in one-visit censuses a bird (pair) is counted for that habi-

tat where it is observed for the first time. In some species, the males quite frequently use forest edge trees as singing places, even if the nest is located at some distance in the forest or in the clearcut. *Anthus trivialis*, *Emberiza citrinella*, *E. rustica*, *Prunella modularis* and *Turdus iliacus* often behaved like this in my study area. This may bias the results as regards the above species in causing some 'extra' edge effect. Third, there may be aggregations of territories near edges between forest and open habitat, and yet the searching for food may take place in open areas. This can easily be seen as 'traffic' between open habitats and forest, but apparently nobody has tried to assess this in detail.

Finally, I present some examples of interesting species with respect to habitat or island size. Haila et al. (1983) have found *Phylloscopus trochilus* preferring relatively large islands in the Åland archipelago in the Baltic, and the same holds true in an archipelago off the Finnish south coast (Martin 1983). In Southern Finland (M. Vickholm, pers. comm.), in the present data and in the archipelago of Lake Inari in Finnish Lapland (Haila 1983a) the species strongly prefers small terrestrial forest islands. *Anthus trivialis* avoids small islands in the above mentioned South coast and Inari studies and also edge forests of islands in the northern Gulf of Bothnia (Helle & Helle 1982) as well as forest edges bordering to fields in southern Finland (M. Vickholm, pers. comm.), while in the present material it shows a marked edge preference (here the open habitats are clearcuts of afforestations). These two examples show that the surrounding habitats of a forest island or patch are very important when discussing the reasons for 'edge reactions' of individual bird species; however, I do not exclude possible geographical differences in colonization patterns of these species (see Haila 1983a).

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