

Edge effect on forest bird densities on offshore islands in the northern Gulf of Bothnia

Eero Helle & Pekka Helle

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The structure and numbers of the forest bird populations at different distances from the forest edge were studied on the three main islands of the Krunnit group in the northern Gulf of Bothnia (approx. 65°N) in 1975 and 1977. The birds were observed on transect lines and divided into three categories: outermost edge zone 0—50 m, inner edge zone 50—100 m, and central forest over 100 m from the forest edge.

The following trends were observed from the forest edge towards the centre: 1) an increase in the number of species, 2) an increase in species diversity, and 3) a decrease in bird density. The most typical species favouring the edge was *Emberiza schoeniclus*, but most of the species reached their maximum densities in the inner edge zone, e.g. *Phylloscopus trochilus*, *Turdus philomelos*, *T. iliacus*, *Erithacus rubecula*, *Phoenicurus phoenicurus* and *Acanthis flammea*. The relative abundances of *Muscicapa striata* and *Sylvia borin* were highest in the central forests. The great variety of compressed biotopes within a narrow belt adjacent to the forest edge may be one of the basic reasons for the concentration of nesting birds in the edge zones. This compression creates more diverse resources, e.g. with respect to food and shelter, than in the central forest; other possibilities are also discussed.

The authors stress the importance of paying attention to the edge effect when assessing quantitative bird studies, especially when dealing with fragmented areas.

Eero Helle, Department of Biology, University of Joensuu, P.O.Box 111, SF-80101 Joensuu 10, Finland.

Pekka Helle, Oulanka Biological Station, University of Oulu, Torikatu 7, SF-90100 Oulu 10, Finland.

1. Introduction

Ecotones — the transition zones between vegetation types or plant communities — are much more diverse in their flora and fauna than the homogeneous biotopes which make up the ecotone (for a general review of edge concepts, see Pianka 1974, Burgess & Sharpe 1981). The edge effect works most pronouncedly at the junction between open and forested habitats. Although the edge effect, or edge heterogeneity in its structural sense, is an ecological principle that was discovered long ago, our knowledge of it with regard to birds remains poor (see, however, Schierman 1930, Lay 1938, Sammalisto 1957, Hogstad 1967, Hansson 1979, Whitcomb et al. 1981). Edge heterogeneity plays an especially significant role in forest ecosystems, however, and it is assumed to be one of the factors which have led to the strong increase in land bird populations breeding in Finland in recent decades (e.g. Järvinen et al. 1977).

Since small islands serve as good examples of

the edge effect on bird densities (see Lehtonen 1979), the purpose of this paper is to study the structure and numbers of the forest bird communities at different distances from the forest edge on the three main islands of the Krunnit group in the northern Gulf of Bothnia.

2. Material and methods

2.1. Study area and vegetation

Our study area — the Krunnit sanctuary — lies in the northern Gulf of Bothnia (approx. 65°N), 10—20 km off the Finnish coast. The highest points of the three main islands — Maakrunni, Ristikari and Ulkokrunni — reach 6.4—7.0 m above sea level (Vartiainen 1967), which, when calculated according to the local rate of land uplift of approx. 80 cm per 100 years (Hela 1953), implies an age of 850—930 years. The forested

areas of the islands amount to 84.5, 30.6 and 89.4 ha, respectively. The central forests are mainly of the *Cornus-Deschampsia* type, the most common trees being *Betula pubescens* and *Sorbus aucuparia*. *Avenella flexuosa*, *Cornus suecica* and *Deschampsia cespitosa* predominate in the field layer. The central forests are surrounded by a belt of *Melandrium-Milium* type forest. Moist *Filipendula* type forests dominate the vegetation nearest to the shore. *Alnus incana* is overwhelmingly the most common tree species here. The coverages of the trees in these forest types, reading outwards from the centre, are 30, 30–50 and 40–60 % (see Havas 1967). The edge zone division described later roughly corresponds to the distribution of the above forest types.

The forests are limited to shore meadows 10–100 m in breadth. The most common plant species on the meadows are *Agrostis stolonifera*, *Calamagrostis stricta*, *Juncus gerardii*, *Phragmites australis* and several *Carex* species. In some places the forests are bounded directly by the stony shore. For a more detailed description of the vegetation, see Vartiainen (1980).

The following vegetational features are used for the purpose of studying the bird densities: height of dominant trees (m), dominant tree species (relative abundance > 10 %), foliage height diversity (according to MacArthur & MacArthur 1961 and Røv 1975) based on the proportions of the field, shrub and tree layers, and the coverage of trees (%).

The Krunnit sanctuary was established in 1936, and from that time on the natural succession of the vegetation has proceeded undisturbed. The only human activities on the islands are some slight control of the crow and fox populations and the placing of 230 nesting boxes on Ulkokrunni in 1977. However since only two nestboxes were occupied in 1977, this 'manipulation' has had no effect on the breeding bird community of the island during the study years.

The edge effect studied here is taken to apply specifically to the transition zone between the shore and the forest. It is obvious, when studied in sufficient detail, that the interior parts of the islands consist of numerous "micro edges", which have smaller effects again on the structure of the forest avifauna.

2.2. Census method

The forest bird populations of the Krunnit sanctuary have been censused using the same census routes several times during the last four decades (Merikallio 1950, Salkio 1952, Helle & Helle 1979). The horizontal distribution of the

breeding birds was studied on these routes with respect to the forest edge in 1975 and 1977. The surveys were carried out on days with little wind and relatively clear skies on June 13–16, 1975 and June 16–19, 1977. The birds observed within a belt of 25 m on either side of the transect were divided into three categories: 'outermost edge zone' 0–50 m, 'inner edge zone' 50–100 m and 'central forest' over 100 m from the forest edge. The distribution of the transect lines in relation to these zones and the proportions of the forest areas covered by the zones are presented in Table 1. The authors are well aware of the problem of reliability involved in the line transect method (e.g. Berthold 1976, Enemar et al. 1978, Järvinen et al. 1978, Hildén 1981). However, it is worth stressing that the bird densities given in this paper are only relative, but well comparable with each other (see also Helle & Helle 1979), e.g. because all the censuses were carried out by the same people.

The bird densities are mostly calculated from the main belt observations, the auxiliary belt (beyond 25 m) being used only in the case of *Corvus cornix*, *Turdus* species, *Lynx torquilla*, *Dendrocopus* species and *Cuculus canorus*. The material of 386 pairs representing 27 species originates from 25.6 km of line transect (main belt area 128 ha).

3. Results

The breeding bird densities were about twice as high in the edge zones as in the central forests, the highest density being observed at 50–100 m from the forest edge (Table 1). The bird densities in both the outermost zone and the centres were similar on the different islands, but variability was much higher in the inner edge zone.

The following trends in the bird community structure were observed from the forest edge towards the centre: 1) an increase in the number of species, 2) an increase in species diversity, and 3) a decrease in mean bird density (Table 1).

Almost all the species occurring abundantly on the islands were more common near the forest

Table 1. Areas of line transects, forested areas, forest bird densities, number of species and species diversities in the different edge zones on the Krunnit islands.

	Distance from the forest edge		
	0–50 m	50–100 m	over 100 m
Line transects (ha)	17.0	11.9	35.2
Forested areas (ha)	105.4	57.9	41.2
Pairs/km ²	455	523	240
No. of species	16	16	23
Species diversity (Shannon function)	2.04	2.14	2.36

Table 2. The percentage proportion of the most abundant forest birds in the different edge zones on the Krunnit islands. Significance of the differences of the pair densities tested using the Chi square test.

	Distance from the forest edge			P
	0—50 m	50—100 m	over 100 m	
<i>Phylloscopus trochilus</i>	30.5	37.8	35.0	<0.001
<i>Fringilla coelebs</i>	13.2	10.8	12.9	<0.1
<i>Emberiza schoeniclus</i>	19.2	5.4	3.8	<0.01
<i>Fringilla montifringilla</i>	8.0	10.8	5.8	<0.001
<i>Turdus iliacus</i>	6.0	8.6	7.0	<0.01
<i>Anthus trivialis</i>	6.6	8.6	7.4	<0.01
<i>Muscicapa striata</i>	3.3	2.2	5.9	>0.10
<i>Sylvia borin</i>	3.3	2.2	5.2	>0.10
<i>Acanthis flammea</i>	1.3	4.3	1.9	<0.001
<i>Turdus pilaris</i>	0.7	2.2	2.6	>0.1

edge than in the centres (Table 2), this being most pronounced in the case of *Emberiza schoeniclus*. *Phylloscopus trochilus*, *Turdus philomelos*, *T. iliacus*, *Erethacus rubecula*, *Phoenicurus phoenicurus* and *Acanthis flammea* favoured the inner edge zone, while *T. pilaris*, *Sylvia borin* and *Muscicapa striata* were distributed evenly over the islands (Table 2). The effect of the forest edge on the occurrence of the other species cannot be discussed because of the small numbers recorded.

Phylloscopus trochilus accounts for 30.5.—37.8 % of the total numbers in the communities, with no clear differences between inner or outer parts of the forests (Table 2). The preference of *E. schoeniclus* for the forest edge is very striking, as judged from its frequencies. It is interesting to note that the frequencies of *Fringilla coelebs* are very stable throughout, whereas the proportion of *F. montifringilla* is highest in the forest near the shores. The relative abundances of *Muscicapa striata* and *Sylvia borin* are highest in the centres of the islands.

4. Discussion

Lay (1938) reported that the bird densities near woodland clearings were almost twice as high as in the inner parts of forests, while Hogstad (1967) found in Central Norway that various ecotones will increase bird densities by 1.5—3.3 times over the figures for a uniform conifer habitat. Oelke (1966) showed the bird density to be an inverse function of the size of forest islands, which clearly confirms the outstanding effect of an edge. Haila et al. (1980) report that the edge effect at 50 m increases bird densities by about 20 % in southwestern Finland: they regard this as a minimum figure, since they classify only the marginal 50 m of a habitat as its edge even though some transects followed an edge for a longer distance. It is natural, however, that the effect of a forest edge on the bird population density ought not to remain constant, but should vary for

numerous reasons. The forest edges are also difficult to classify, not only because of their very high variability. The 'breadth' of the edge effect for a specific forest bird species depends both on the habitat and the bird species, the latter being based e.g. on different minimal area requirements of different species (Forman et al. 1976). Thus the use of edge breadths other than 50 and 100 m may have led to different results in the present surveys. When the size of a forest is 0.2 hectares or less, the whole forest should be considered an edge habitat (Galli et al. 1976).

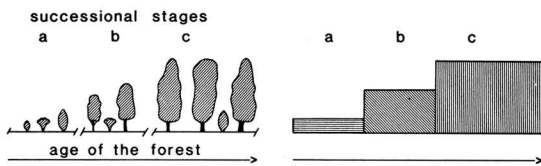
Several bird species are known to prefer edges between open ground and forest with young vegetation (see Haapanen 1965, Gromadski 1970, Odum 1971, Järvinen et al. 1977, Whitcomb et al. 1981), and this seems to be characteristic of passerines in general (Galli et al. 1976).

The strength of any edge effect depends on the heterogeneity of the ecotone, the number of bird species increasing markedly with increasing horizontal structural complexity in the vegetation (see Pianka 1974 and references therein). The vertical complexity of the vegetation (measured in terms of 'foliage height diversity') has the same effect (MacArthur & MacArthur 1961). According to Hohtola (1978) the edge heterogeneity in urban habitats increases bird species diversity, but has no influence on density, although Haila et al. (1980) did not find any clear differences in species diversity between edge and central forest habitats.

One important reason for the differences in bird density and community structure in the various edge zones on the Krunnit islands is our edge zone division, which roughly corresponds to the successional forest types *Cornus-Deschampsia*, *Melandrium-Milium* and *Filipendula*. We are thus dealing not only with a 'pure' edge effect, but also with three distinct habitats. The highest density in the edge may therefore be due to high densities in young successional stages (see e.g. Haapanen 1965); for the analogy between vegetational succession and ecotone in general, see Glowacinski (1979) and Fig. 1. Compared with a normally advancing edge (see Ranney et al. 1981), the successional stages in the Krunnit islands are far more compressed, since the edge can not move outwards because of the shore. This compression may be of great importance when explaining the high breeding bird density in the edges.

The features of the forest types presented in Table 3 suggest that the coverage of the trees may be the main factor causing the high densities near edges. The foliage height diversities do not differ very much but the decreasing trend from the shore to the centre is constant.

A. VEGETATION SUCCESSION



B. ADVANCING EDGE

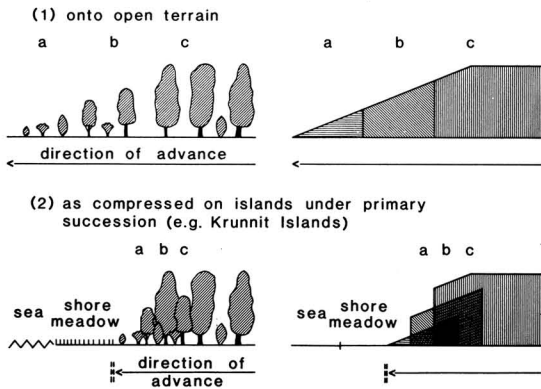


Fig. 1. A schematic picture of the spatio-temporal analogy between vegetational succession and ecotone, and the compression of the successional forest stages (a, b, c) on the Krunnit compared with those in a normally advancing edge (see also text).

It appears to be typical of the Krunnit islands that the highest forest bird density is not reached at the very edge of the forest, but at some distance further in (50–100 m), although it should be remembered, of course, that the census method does not permit one to locate the centre of the territory of a given pair in exactly the correct zone, even if the location is accurate in the majority of cases. The distribution may be explained to a great extent by the fact that the establishment of its territory some distance away

Table 3. Main features of the three forest types occurring on the Krunnit islands.

	<i>Filipendula</i>	<i>Melandrium-Milium</i>	<i>Cornus-Deschampsia</i>
Height of dominant trees (m)	8	12	14
Dominant tree species (frequency > 10 %)	<i>Alnus</i> <i>Betula</i>	<i>Betula</i> <i>Sorbus</i> <i>Alnus</i>	<i>Betula</i>
Foliage height diversity ^a	0.90	0.83	0.85
Coverage of trees (%)	50	40	30

^a Calculated according to MacArthur & MacArthur (1961) and Røv (1975) from the proportions of the field, shrub and tree layers.

from the edge of the forest ensures a bird access to a variety of forest habitats in the edge zones and central zone. It would not seem desirable for true forests species to settle at the very edge and thus have 'unnecessary' areas of open ground close to their nests. An explanation such as this would seem valid for forest birds in general, even though quite distinct attitudes towards an adjacent forest edge are found at the species level (see Table 2). It is also possible that the birds may avoid the extreme edge of the forest on account of the greater severity of the colder spring climate in that zone. This microclimatic phenomenon is probably responsible for the fact that *F. montifringilla*, a northern species, prefers the edge forests, while some tropical summer visitors such as *S. borin* and *M. striata* favour interior parts of the islands.

There is an interesting feature in the habitat selection of the forest birds breeding on the Krunnit islands. Most species begin to nest in late May — early June, when the trees have either not yet leaved or, like *Betula*, have only just begun to leaf. The only shelter offered at that time is by the flowering *Salix* bushes in the very edge of the forests and on the shore meadows and by *Juniperus communis* in the central forests (*Picea* and *Pinus* are very rare on the Krunnit islands). Because the birds favour habitats without the above shelter vegetation, this cannot be considered the most important factor in habitat selection under the present island conditions. This deviates from the situation involving *Picea* in northeastern Finland e.g. with respect to *Turdus* species (see Pulliainen 1978). Birds on the Krunnit islands seem to recognize the most suitable summer habitat even in its barren phase and to 'predict' the phenological changes taking place during the breeding season; as yet unknown factors may also be involved in the present case (for factors affecting habitat selection, see Hildén 1965).

It is very important to stress the edge effect when assessing quantitative bird studies, especially when dealing with fragmented areas (see also Sammalisto 1957). The 'classic' transect lines on the Krunnit islands are not distributed correctly with regard to the edge zones, but instead place excessive weight on the centres of the islands, with their low bird densities. Thus the densities traditionally calculated directly from the census results are an average of 31 % too low, as can be seen from the following tabulation:

	Total pairs/km ²		
	Maakrunni	Ristikari	Ulkokrunni
Calculated strictly from census results	286	295	389
Calculated after edge effect correction	424	346	633

The relatively smallest difference in the figures for Ristikari is due to the fact that the edge area/centre area ratio of the transects in Ristikari corresponds to the true distribution better than on Maakrunni or Ulkokrunni, which are larger and accordingly have relatively larger central areas with low densities.

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