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Impoverishment of resident old-growth forest bird assemblages along an isolation gradient of protected areas in eastern Finland

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Fennoscandian conifer forests have experienced a major landscape transformation during the 1900s. Currently, only scattered patches of old semi-natural forests exist in eastern Finland. However, on the Russian side old and mature forests still cover large tracts. We aim to show how the proximity of protected areas to the Russian border affects their species assemblages. We also ask how well the multi-scoring procedure applied by governmental ministries to design reserve networks performs in terms of bird protection. Censuses were conducted in fifteen old-growth forest areas located at varying distances (0–120 km) from the Finnish-Russian border in 1997. Data were gathered on ten non-migratory species that are mostly associated with old-growth or mature forests, many of which show decreasing population trends in Finland during the 1900s. Both the total density and number of species decreased as distance from the Russian border increased. Of the individual species, the Black Woodpecker (*Dryocopus martius*) showed the highest decrease in its relative population density. The Siberian Jay (*Perisoreus infaustus*) and the Treecreeper (*Certhia familiaris*) occurred only in the areas closest to the Russian border. The number of species peaked close to the border: the average number of species in the standardized 50 ha area decreased from 5.0 to 2.0 as distance increased from 0–10 km to 80–120 km. The results support views of the negative impact of isolation on old-growth specialist bird species. However, the habitat quality within the remaining patches — such as the amount of coarse woody debris — may also affect local bird assemblages. The ranking procedure applied in the old-growth areas in Finland turned out to be non-informative for birds. The ranks were not related to the population densities or number of resident species.

1. Introduction

Boreal forest landscapes in Fennoscandia have experienced major changes during the past 200 years (Östlund *et al.* 1997, Kouki & Löfman 1998, Kouki *et al.* 2000, Löfman & Kouki 2001). Most of the changes are caused by intensified forest management and timber production. The changes are especially clear in the age distribution of the forests, both in Finland and in Sweden (Anon.

1995, 1997). Coverage of older age classes has decreased and the age-class distribution has become more even. Currently, only scattered remnants of natural or semi-natural old-growth forests occur in southern and eastern Finland and most of them are protected. The protected areas, however, cover only a fraction (3.6% in Finland) of the forest land and most of the protected areas are located in the north (Anon. 1999).

Besides covering only a fraction of the forest area, the protected areas are often small and isolated. An obvious current concern is how the protected areas will facilitate the survival of the threatened biota (Virkkala *et al.* 1994). It is likely that small forest areas cannot always maintain their characteristic animal and plant communities when located in the middle of intensively managed forests (Janzen 1983, Väisänen *et al.* 1986).

Theories and models explaining population dynamics or community characteristics in fragmented environments indicate that isolation may play a crucial role in determining local ecological communities. For example, island biogeography theory predicts that isolation should reduce the number of species found in small, isolated patches. This prediction has also received empirical support in several studies (Helle 1985, McLellan *et al.* 1986, Opdam & Schotman 1987, Andrén 1994, Aaberg *et al.* 1995, Bellamy *et al.* 1996, Kuokkanen 1997, Schmiegelow *et al.* 1997, Mönkkönen *et al.* 2000).

Areas close to the border between Finland and Russia provide an exceptional opportunity to study the impact that fragmentation and intensive forest management may have had on ecological assemblages. The forests close to the border zone are biogeographically very similar, but the past management intensity is completely different. During the past 50 years forests on the Finnish side have been under intensive management and its consequences are nowadays reflected in many regional and local characteristics (Kouki & Niemelä 1997). The forests on the Russian side, on the other hand, have until recently remained close to natural conditions, during the same period. Russian forests still form extensive tracts of old-growth areas (Bryant *et al.* 1997). Several comparative studies revealing forest characteristics and plant and animal communities in this border region have already been published (Siitonen & Martikainen 1994, Martikainen *et al.* 1996, Uuttera *et al.* 1996).

In the current study we first aim to show how the proximity of the protected forest fragments on the Finnish side to the continuous Russian forests affects breeding bird assemblages. Our hypothesis — based on the principles of island biogeography theory (MacArthur & Wilson 1967) — is that bird assemblages in these fragments may be impoverished, and the more so the further from the Russian border they are.

Our second aim was to analyse how well the previously developed method (Anon. 1992b) to quantify conservation value of old-growth areas reflects the bird assemblages in these areas. As this method does not take into account birds, size or isolation of the forest area, we expect that the method perhaps needs some modification when applied to bird species associated with old-growth forest.

2. Material and methods

We concentrated on species that are mainly resident and that are known to be associated mostly with mature or older forest habitats (e.g. Väisänen *et al.* 1998, Elmberg & Edenius 1999). The species included in this study are Hazel Grouse (*Bonasa bonasia*), Capercaillie (*Tetrao urogallus*), Black Grouse (*Tetrao tetrix*), Black Woodpecker (*Dryocopus martius*), Great Spotted Woodpecker (*Dendrocopos major*), Three-toed Woodpecker (*Picoides tridactylus*), Crested Tit (*Parus cristatus*), Willow Tit (*Parus montanus*), Treecreeper (*Certhia familiaris*) and Siberian Jay (*Perisoreus infaustus*). This list covers all the major species that are residential old-forest dwellers in our study area. The resident species are probably good indicators of mature forest quality as their occurrence is not determined by annual colonization typical for migratory species (Haila *et al.* 1993). Most of the studied species show clearly decreasing population trends in Finland during the past 50 years (Järvinen *et al.* 1977, Väisänen & Solonen 1997, Väisänen *et al.* 1998).

Our study area is in North Karelia, eastern Finland (Fig. 1). The study area is located in the transition zone between southern and middle boreal zones. Forests in the area are dominated by Scots Pine (*Pinus sylvestris*) and Norway Spruce (*Picea abies*). The area has experienced major landscape transformation during the past 50 years (Kouki & Löfman 1998, Kouki *et al.* 2000). The most obvious change has been reduction of mature and especially natural old-growth areas and their division into smaller fragments. Differences in human activities between Finland and Russia are clearly seen also in the current road network (for a map, see Martikainen 2000).

Bird censuses were made on the protected old-growth sites, of which 37 exist in North Karelia (Anon. 1992b). We randomly selected 15 areas out of these 37, divided along four lines (Fig. 1). The basic characteristics of the studied forests are listed in Table 1. The areas along each line were located at different distances from the Russian border. The distance categories were approximately 0–10 km, 11–40 km, 41–80 km, and 81–120 km from the border as measured along east-west transects. The areas were selected so that they fulfilled the minimum area requirement of 50–60 ha and were as similar in forest habitat type and age as possible. Some of the protected areas were not large enough, but were still included if comparable old-growth forest occurred adjacent to the protected area so that the total census area was about 50 ha. This procedure was necessary to get representative areas from each of the four lines and to standardize the sample size. Forests on the Russian side of the border have mostly retained their natural or semi-natural characteristics (Siitonen *et al.* 1995, Uuttera *et al.* 1996) and they still form relatively large tracts of continuous forest (Bryant *et al.* 1997).

Landscape surroundings of the studied forest fragments were not quantified. However, based on our field experience and other information on the forests in the study region (Anon. 1992b, 1999, Räsänen *et al.* 2000), the old-growth fragments are typically quite isolated. Small (about 10 ha) old-growth fragments may occur in the region, but larger (at least 50 ha) old-growth fragments are highly isolated and most of them are included in the protected areas. In the present study we assume that the immediate landscape surroundings are more or less similar between the studied fragments and consist mostly of regenerating successional stages, an assumption substantiated by forest statistics (Anon. 1995, Räsänen *et al.* 2000)

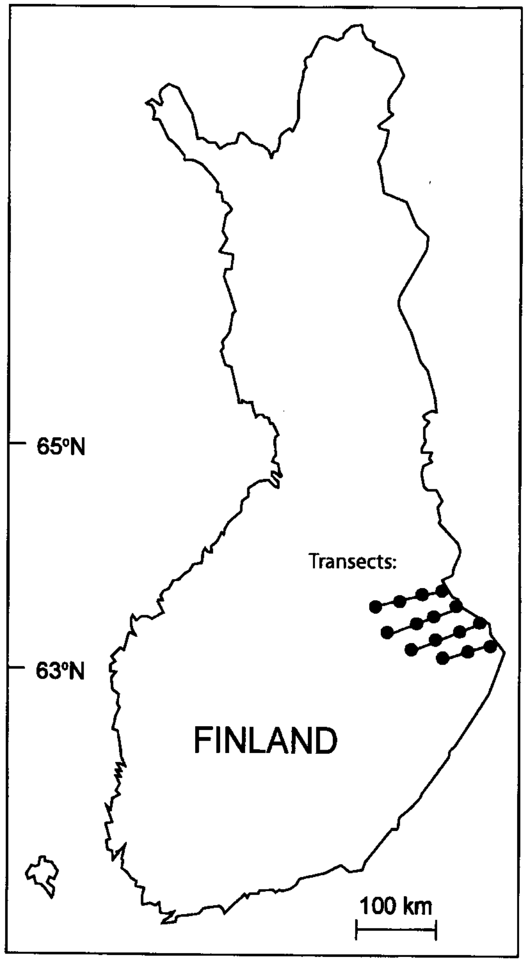

Figure 1. Location of the transects and study sites. Dots represent approximate locations of the studied forest fragments along the isolation gradient.

and forest protection programmes (Anon. 1992b, 1999).

In each area, two censuses were conducted between 22 May and 26 June, 1997. The censuses were made during early morning hours, between 04.00–09.00, by walking slowly and systematically through each area so that no place remained further than 50 m from the transect. All the censuses were made by a single observer (A. Väänänen) in good weather conditions. For each species and area we used the maximum number of singing and alarming males (woodpeckers, passerine species), or maximum number of observed male or female individuals (tetraonids) in the two censuses. Attention was especially paid on avoiding duplicate observations of the same individuals in the area.

The census period was not optimal for all the studied species (Jokimäki & Huhta 1996, Elmberg & Edenius 1999). However, this may result in biased relative density estimates, but should not considerably affect the comparisons of different areas as all the areas were similarly checked. Our method — a study plot census of two visits — probably provides better estimates of the breeding birds than point or transect counts. Since many of the species in this study are unsuitable for point or transect counts and since many fragments are quite small, the method applied here should provide better relative density estimates of the selected species. However, the density estimates obtained are not directly comparable to other studies. For example, our method does not always cover the complete home ranges of all the species. This probably leads to overestimates of densities for some species (Haila 1988), such as the Black Woodpecker. Despite this, the estimates can be used as relative estimates to compare the areas included in this study, but the obtained values may better be regarded as relative importance values of the areas than true density estimates.

In addition to the isolation effect, the old-growth fragments used in this study may differ in terms of habitat quality, even though the areas were chosen to be as similar as possible. Since the amount of coarse woody debris is a relatively good indicator of the naturalness of the forest in eastern Finland, and is also an important factor for many birds (Angelstam & Mikusinski 1994), we measured the amount of standing and fallen dead wood in the study areas. From each area we randomly selected ten sample plots with a radius of 10 m. All the logs with at least 7 cm dbh and 1.3 m long were measured. The measurements

Table 1. Study areas, their distances from the Russian border, sampled areas and the conservation value points according to the Finnish Ministry of the Environment (Anon. 1992b). – = area not ranked. Isolation groups are shown by the Roman numerals: I = 0–10 km from the border, II = 11–40 km, III = 41–80 km, and IV = 81–120 km.

Transect and area	Distance (km)	Census area (ha)	Conservation points	Dead wood (m^3/ha)		
				Standing	Lying	Total
Transect 1:						
I Otrosvaara	5	55	33	17.0	4.0	21.0
II Paistinvaara	38	58	37	19.8	12.5	32.3
III Kivimäki	58	58	34	3.0	1.4	4.4
IV Piilopirtinaho	75	56	31	10.0	4.6	14.6
Transect 2:						
I Massivaara	1	55	46	12.3	5.9	18.2
II Sinivaara	10	60	39	8.6	8.4	17.0
III Päävaara	26	55	44	17.6	12.1	29.7
IV Keihäsjoki	85	56	29	6.2	0.8	7.0
Transect 3:						
I Ruunavaara	1	54	39	59.4	27.0	86.4
II Jyrinvaara	8	60	35	14.9	9.5	24.4
III Porovaara	40	55	32	20.0	15.9	35.9
IV Tahkovaara	110	56	32	6.3	2.4	8.7
Transect 4:						
I Lahnavaara	0.5	57	31	7.5	8.2	15.7
II Pampalo	12	55	–	8.0	16.0	24.0
III Oinasvaara	40	61	40	14.2	7.3	21.5

were transformed to volume estimates using the Smalian II equation (Kangas & Päivinen 1994):

$$v = 0.4 \times d^2 \times h, \qquad (1)$$

where v = volume of the log, d = diameter at breast height (dbh) and h = length of the log. Relationships between avian density and the independent variables of isolation and amount of dead wood were examined using Spearman's rank order correlations.

To compare the bird assemblages with the overall conservation value assigned to the protected areas, we applied the method used by the Finnish Ministry of the Environment when it established the current conservation network (Anon. 1992b). In this method, several forest characteristics are evaluated and "conservation points" are assigned. The factors that affect this ranking include, for example, amount and quality of coarse woody debris, vertical structuring of the forest, marks from intensive forest use, occurrence of large deciduous trees, and fire scars on tree trunks. Since neither bird assemblages nor isolation of the areas is taken into account in this procedure, our aim was to investigate if the bird assemblages are related to the previously assigned conservation value. The points assigned by the Ministry of the Environment to our study areas are presented in Table 1.

3. Results

The total relative density of the resident bird species decreased as the distance from the Russian border increased (Fig. 2). Overall, the reduction in relative density was dramatic, declining from 16.8 pairs/km^2 close to the border down to 4.2 pairs/km^2 at the distance of 81–120 km.

A similar trend was observed for the number of resident species recorded (Fig. 3). Close to the border each 50–60 ha forest fragment contained about half of the 10 species while in more isolated areas the assemblage included only two species (Table 2).

Our sample size on the occurrence of single species is limited and consequently results at the species level are hard to reach (Table 2). Of the studied species, the clearest decrease from east to west was observed in the Black Woodpecker (Table 2). Also the Siberian Jay and the Treecreeper occurred solely in the areas close to the border and the species were completely missing from the more isolated forest fragments (Table 2). Other species did not show clear patterns related to the isolation. For example, the Capercaillie density remained at the same level regardless of the isolation of the area.

The amount of coarse woody debris showed quite variable patterns in the study areas. The total amount varied from 4.4 m^3/ha to 86.4 m^3/ha. There was no linear trend associated with isolation, although the most isolated areas showed lower levels of dead wood (Table 1). All the areas up to 50 km from the border had dead wood amounts of roughly 20 m^3/ha. For the birds, standing dead wood may be more important than the total amount. Similar general patterns held also for the amount of standing dead trees.

The amount of dead wood and the total relative bird density were correlated ($r_s = 0.573$, $P = 0.023$), but even when the amount of standing dead trees was controlled for, the partial correlation indicated the isolation effect (partial $r = -0.718$, $P = 0.004$). Also, the number of species was related to the distance from the border when the amount of standing dead trees was controlled for (partial $r = -0.595$, $P = 0.025$). Thus, it seems likely that isolation of forest fragments affects species and community composition in the small forest fragments, but this effect is somewhat modified by the habitat quality of the fragments.

General conservation value as measured with assigned conservation points (Table 1) was not related to the number of breeding bird species ($r_s = 0.345$, $P = 0.23$) or relative breeding bird density ($r_s = 0.415$, $P = 0.11$).

4. Discussion

Fragmentation of habitat and its consequences for biota have recently become central issues in biogeographical studies (Andrén 1997). This emphasis is partly due to potential applications that these studies have on conservation of species.

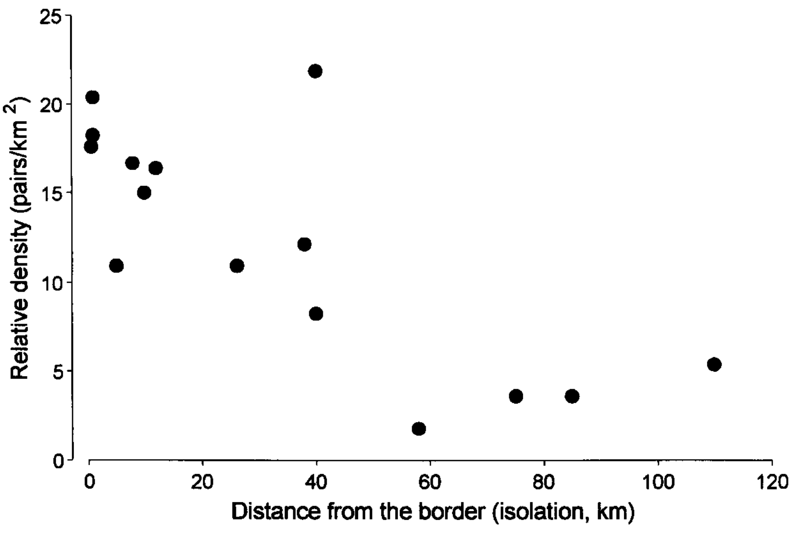

Figure 2. Average relative density indices of the ten forest-dwelling species in relation to the distance from the Russian border (r_s = –0.720, P = 0.0023). Census conducted in a 50–60 ha area in each of the 15 forests.

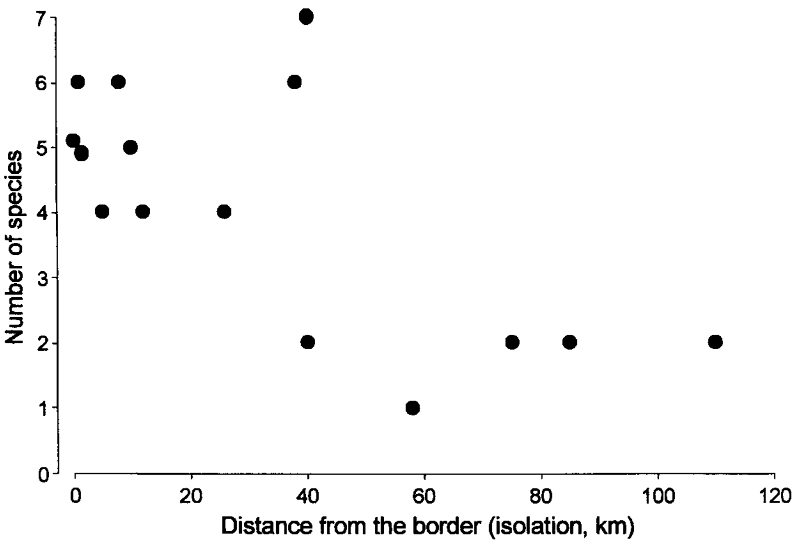

Figure 3. Average number of species in the studied forest fragments located at different distances from the Russian border (r_s = –0.600, P = 0.0182). Census conducted in a 50–60 ha area in each of the 15 forests. Two points close to the y-axis have been slightly displaced to avoid overlap.

Several studies have shown that forest-dwelling birds differ widely in their responses to fragmentation (Wiens 1995, Bellamy *et al.* 1996, Edenius & Elmberg 1996, Jokimäki & Huhta 1996, Berg 1997, Edenius & Sjöberg 1997, Sisk *et al.* 1997). Based on these responses, species have often been divided into forest interior specialists versus others, such as edge species or generalists. An important message arising from these studies is that to understand how fragmentation of old-growth forests affects bird communities, the species must be classified before the analyses into groups that differ in their general habitat requirements. Total species diversity, community characteristics or densities are inadequate variables for measuring the impact of fragmentation. Rather, it may be expected that only a subset of species is affected by fragmentation (Villard *et al.* 1999). We found it thus quite justified to focus our current analyses on the species that are mostly resident breeders and that prefer mature or old-growth forest habitats. These are also the species that are typically affected by forestry operations and require special attention from the conservation viewpoint in Finland (Anon. 1992a, Väisänen *et al.* 1998).

The results of this study corroborate views that increasing distance from the Russian border plays a significant role in determining breeding bird assemblages (see also Kuokkanen 1997, Mönkkönen *et al.* 2000). Since our results concern the non-migratory species in the old-growth forest patches, it is possible that the findings are not applicable to all bird species. Migratory species select their breeding sites annually and may be more capable in finding all the suitable habitat patches (Haila 1983). We expect that habitat area has more effect on their occurrence than isolation of the habitat patches (but see Villard *et al.* 1995). Their occurrence may be determined more by the random sampling hypothesis as was found by Haila (1983) in true archipelagoes in southern and northern Finland and by Tellería and Santos (1999) in the Mediterranean oak forests (see also Andrén 1999, Mönkkönen & Reunanen 1999, Villard *et al.* 1999).

The areas studied here are all protected areas. These forests have been protected on the basis of local structural characteristics with no attention to regional patterns of the reserve network. The local characteristics are known to be important for many old-growth specialist species (e.g. beetles and polypore fungi) and it is thus likely such areas facilitate survival of these species (Siitonen & Martikainen 1994, Kotiranta & Niemelä 1996). However, our study adds an important element to this consideration. We found that priority ranking applied previously in the areas is a poor predictor in terms of the value of these areas to breeding resident birds. Since isolation and size of the area were not included in the consideration when protected areas were ranked, any impact that these may have on biota has been overlooked. Our study suggests that isolation of the area may be equally or even more important determinant of the bird assemblage than local characteristics. Thus, for the non-migratory breeding species old-growth areas close to the Russian border are highly v`ºu-±ble. We also anticipate that any management actions that may increase fragmentation of the continuous forests on the Russian side may have important consequences for the breeding birds on the Finnish side.

Our findings match well with earlier observations on breeding birds in isolated areas. For example, Haila *et al.* (1979) found that long-term population changes in the Åland archipelago, southwestern Finland, are merely reflections of population trends on the mainland of Finland and that changes in the island populations are not associated with any local environmental changes. Similarly, when Väisänen *et al.* (1986) followed long-term changes of the bird assemblage in one isolated old-growth forest area in northern Finland, they found that regional changes in the bird community are reflected in the assemblage of this local forest. When the surrounding areas came under intensive management and their assemblages changed, similar changes were observed also in the remaining old-growth patch, even though it had remained untouched. Later, Virkkala (1996) found that old-growth specialists (e.g. Capercaillie, Three-toed Woodpecker, Treecreeper and Siberian Jay) were recorded at lower densities in the protected areas when the size of the reserve fell below 10 km^2.

Recently Mönkkönen *et al.* (2000) reported very similar isolation patterns of old-growth bird assemblages in northern Finland. Quite interest-

Table 2. Average relative density indices of the studied species in the four differently isolated forest fragments (pairs/km^2) and selected summary statistics of the studied fragments. Isolation groups: I = 0–10 km from the border, II = 11–40 km, III = 41–80 km, and IV = 81–120 km.

	Degree of isolation			
	I	II	III	IV
Species				
Bonasa bonasia	1.8	3.5	1.4	0.0
Tetrao tetrix	1.8	0.8	1.3	0.6
T. urogallus	0.9	0.9	0.9	1.2
Dryocopus martius	5.4	2.9	0.9	0.6
Dendrocopos major	3.6	2.2	2.6	0.0
Picoides tridactylus	0.0	0.4	2.3	0.6
Parus montanus	0.9	2.2	0.9	1.2
P. cristatus	0.9	0.8	0.5	0.0
Certhia familiaris	0.5	0.8	0.0	0.0
Perisoreus infaustus	0.9	0.4	0.0	0.0
Characteristic				
No. of species/area	5.0	5.3	3.5	2.0
Total relative density	16.8	15.0	10.7	4.2
Average distance	1.9	17.0	41.0	90.0
Dead wood (m^3/ha)	35.3	24.4	22.9	10.9
No. of areas studied	4	4	4	3

ingly, they observed a slightly weaker relationship between the distance from the Russian border and species richness. Although the species pool in their study is different from ours and the study areas were larger, the slightly different results may indicate that the isolation effect is stronger in southern areas. This is expected as the old-growth areas in northern Finland are probably less isolated from other comparable areas than the old-growth fragments in southern Finland.

Coupled with previous findings, the present results suggest that isolation and regional changes — both habitat and population changes — are highly important for local resident bird assemblages. Successful protection of the species associated with old-growth forest requires special attention to be paid to the regional pattern of the forest reserve network and areas that are either large (over 10 km^2 of old growth forest) or that are close to large, continuous old-growth areas.

Attempts to protect breeding birds in old-growth remnants in southern Finland do not seem that promising. Even the suitable areas in southern Finland are so small and isolated that populations living in these areas are likely to be susceptible to larger regional changes in the avifauna and also to the inflow of populations that live in the surrounding managed forests (e.g. Väisänen *et al.* 1986). When this is the case, the highest benefits in developing the conservation network may actually be gained if new areas are located close to non-isolated Russian forests. However, for other taxa that may contain species whose geographical range extends only to southern Finland and that are dependent on the old-growth areas, the only solution seems to be strengthening the conservation network in the southern parts of the country.

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Selostus: **Eristyneisyyden vaikutus vanhojen metsien suojelualueiden paikkalinnustoon Venäjän rajan läheisyydessä Itä-Suomessa**

Vanhojen lähes luonnontilaisten metsien osuus on 1900-luvulla vähentynyt etenkin Etelä- ja Itä-Suomessa. Suojeltu osuus metsämaasta on vain 3.6%, ja lisäksi yksittäiset vanhojen metsien suojelualueet ovat usein kooltaan pieniä ja eristyneitä. Venäjän Karjalan metsien käyttö on ollut vähäisempää koko 1900-luvun, minkä seurauksena laajoja, verraten yhtenäisiä vanhan metsän alueita esiintyy vielä välittömästi Suomen itärajan takana. Tutkimuksessa selvitettiin, millä lailla Suomen puolella olevien vanhojen metsien linnusto muuttuu, kun suojelualueen etäisyys Venäjän rajasta ja Venäjän yhtenäisistä metsistä kasvaa. Tutkimukseen valittiin 15 suojelualuetta Pohjois-Karjalasta (Taulukko 1). Tutkittujen alueiden etäisyys rajasta vaihteli 0–120 km ja kukin laskenta-alue oli kooltaan 50–60 ha. Kaikki tutkimusalueet laskettiin kahteen kertaan kesällä 1997. Tutkimuksessa olivat mukana vain sellaiset lajit, jotka pääsääntöisesti suosivat varttuneita tai vanhoja metsiä (Taulukko 2). Linnuston suhteellinen tiheys väheni selvästi, kun alueen etäisyys rajasta kasvoi (Kuva 1). Yksittäisistä lajeista palokärki, kuukkeli ja puukiipijä vähenivät selvimmin (Taulukko 2), mutta lajitasolla aineisto on vähäinen lopullisten johtopäätösten tekemiseen. Käytetyn laskentamenetelmän vuoksi saatuja tiheysarvoja ei voi suoraan verrata muihin — esim. linjalaskennalla tehtyihin — tutkimuksiin. Erityisen selvästi väheni suojelualueen lajimäärä, kun etäisyys rajasta kasvoi (Kuva 2). Kymmenestä tutkitusta lajista keskimäärin viisi esiintyi rajan läheisyydessä olevilla suojelualueilla, mutta 100 kilometrin päässä rajasta keskimäärin vain kaksi lajia tavattiin kultakin alueelta. Vanhojen metsien suojeluohjelmassa käytetty alueiden pisteytysmenetelmä ei kuvannut alueen merkitystä linnuston kannalta. Tulokset korostavat eristyneisyyden ja Venäjän Karjalan yhtenäisten metsien merkitystä myös Suomen vanhojen metsien

linnustolle. Linnuston suojelun kannalta arvokkaimmat vanhojen metsien suojelualueet sijaitsevat lähellä rajaa.

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