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# The vulnerability of breeding birds to forest fragmentation

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**Abstract** Qualitative research on breeding birds was carried out in 224 woods located in an agricultural area of eastern Poland and with areas of between 0.01 and 450 ha. The results confirmed that a total of 84 species of bird nested in them. The breeding avifauna included: a group of species tolerant of small woods with areas of several hectares or less and a group of species which only occurred in medium-sized woods. The species occurring in the large forests of eastern Poland and not reported in the woods studied may be defined in general as birds of the forest landscape.
For the various groups of forest bird, mean values for miniumum forest area (MFA) were calculated, along with values for the threshold of regular presence in the bird community (TRP). These allowed it to be stated that different groups of species are vulnerable to forest fragmentation to varying degrees. Most vulnerable were species in the following groups: true residents, hole-nesters, herbivorous birds, birds feeding on vertebrates and insectivorous birds which form mixed feeding flocks in the forests of this region in winter. It emerged that the species least sensitive to forest fragmentation were omnivorous birds, the remaining insectivorous birds, ground-nesters, birds nesting in the crowns of trees and bushes, and non-residents. Significant differences in vulnerability to forest fragmentation were not noted for species foraging both in tree stands and beyond the forest.

Forest fragmentation is a factor posing a great threat to the diversity of the breeding avifauna of forests.

**Key words**: forest birds, life strategies of birds, forest fragmentation.

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## INTRODUCTION

Many recent studies have considered the significance of the fragmentation of forests on the occurrence of communities of breeding birds and on the probability that populations of forest birds species in insular ecosystems will persist (Petterson 1985, Rolstad & Wegge 1987, Whitcomb *et al.* 1981). Different species of breeding bird have been found to possess varying degrees of vulnerability to the fragmentation of forests (Blake 1983, Cieślak & Dombrowski 1992, Nilsson 1986).

The relationship between forest fragmentation and the occurrence of various ecological groups of species was analysed, in an attempt to answer the question concerning the possible connection between certain life strategies among forest birds, and their respective vulnerabilities to the fragmentation of forests and the threats resulting from it. Analysis involved groups of species differing in terms of the places where they foraged, the food selected, the location of the nest and the migration strategy.

## MATERIALS AND METHODS

### Description of the study area

Studies were carried out in eastern Poland, in the Voivodeships (Provinces) of Siedlce and Biała Podlaska. Agricultural landscapes are dominant in the study area, with forests highly fragmented and covering a total of about 20% of the land. Observations were made in 224 woods and forests covering 0.01 to 450 ha (Table 1). Prevalent were tree stands with pine or domineted by pine. In mixed stands also were found birches *Betula spp.*, oaks *Quercus spp*, spruce *Picea abies*, aspen *Populus tremula*, hornbeam *Carpinus betulus* and alders *Alnus spp*. Woods chosen for the research were those with tree stands at least 50 years old (i.e. those accessible to the majority of hole-nesters). A trend was noted for the internal structure of a forest biotope to be more highly diversified in forests of greater size: the number of age classes in the tree stands increased, as did the number of species of tree (Cieślak 1985).

Table 1. Number of forests (n) and their total area (T ha) in accordance with divisions of forests size (R ha).

[Tabela 1. Liczba lasów (n) oraz ich łączna powierzchnia obszar (T ha) w różnych kategoriach wielkości lasu (R ha).]

| R ha | n | T ha |
|---|---|---|
| 0.01-0.09 | 32 | 1.75 |
| 0.1-0.29 | 36 | 6.28 |
| 0.3-0.99 | 49 | 27.83 |
| 1-2.99 | 30 | 47.95 |
| 3-9.9 | 23 | 135.07 |
| 10-29.9 | 18 | 372 |
| 30-99 | 19 | 1020.5 |
| 100-450 | 17 | 3239 |
| total | 224 | 4850.38 |

## Methods of field research

The species composition of communities of breeding birds were determined in the course of 2–5 monitoring visits made to each wood in the course of the breeding season (April 20th to July 1st). Visits were made at different times during the season: usually 2–3 to small woods, and 4–5 to larger ones. The duration of a single visit was greater where larger woods were concerned, but there was no direct relationship between the size of a wood and the length of a visit. In the case of larger woods, it was only the greater number of observations which led to the total observation time being proportional to the size of forests. Lists of species for breeding communities were established on the basis of the following criteria:

– a single report of a singing male of a small Passerine species,

– a single observation of a courting or alarmed bird (for *Falconiformes*, *Corvidae*, *Piciformes* and *Columbiformes*, or two observations of these species),

– a single observation (*Strigiformes*, *Galliformes*).

Study of the composition of communities omitted the Cuckoo (*Cuculus canorus*), a non-territorial species which is dependent on the occurrence of other species of birds.

## Data analyse methods

In analyses of the vulnerability of species to the fragmentation of forests, use was made of two parameters: minimum forest area (MFA) and threshold of regular presence (TRP).

If the forests in which given species were noted to occur are arranged in order of increasing size and identified as "a","b", "c","d" etc., then the size of wood "b" was used in calculations as the minimum area ("a" was used in the case of the 8 species observed in one forest only).

Table 2. Values of minimum forest area (MFA) and thresholds of regular presence (TRP) for the 34 species for which the TRP value was defined. Included in parenthesis are the TRP values defined on the basis of the frequency occurence 90–95%.

[Tabela 2. Wartości minimalnej wielkości lasu (MFA) i progu regularnej obecności (TRP) dla 34 gatunków, dla których wartość TRP została obliczona. W nawiasach wartości TRP obliczone na podstawie częstości występowania 90–95%.]

| Species | MFA (ha) | TRP (ha) |
|---|---|---|
| *Emberiza citrinella* | 0.03 | 0.4 |
| *Emberiza hortulana* | 0.03 | 14.5 |
| *Fringilla coelebs* | 0.04 | 0.3 |
| *Phylloscopus trochilus* | 0.04 | 3 |
| *Anthus trivialis* | 0.08 | 1.6 |
| *Carduelis chloris* | 0.08 | (152) |
| *Phylloscopus collybita* | 0.09 | 1 |
| *Parus major* | 0.12 | 5 |
| *Sturnus vulgaris* | 0.15 | 29 |
| *Phylloscopus sibilatrix* | 0.2 | 2.6 |
| *Hippolais icterina* | 0.2 | 6.3 |
| *Lanius collurio* | 0.2 | (80) |
| *Columba palumbus* | 0.23 | 31 |
| *Sylvia atricapilla* | 0.27 | 4.5 |
| *Turdus philomelos* | 0.31 | 8.5 |
| *Sylvia curruca* | 0.31 | (130) |
| *Erithacus rubecula* | 0.43 | 2.1 |
| *Sylvia borin* | 0.43 | 27 |
| *Parus caeruleus* | 0.75 | 30 |
| *Parus montanus* | 0.75 | (112) |
| *Oriolus oriolus* | 0.8 | 8 |
| *Luscinia luscinia* | 0.8 | (95) |
| *Turdus merula* | 0.89 | 5 |
| *Lullula arborea* | 1.02 | (145) |
| *Dendrocopos major* | 1.08 | 26.5 |
| *Coccothraustes coccothr.* | 1.23 | 100 |
| *Muscicapa striata* | 1.36 | 58 |
| *Garrulus glandarius* | 1.8 | 34 |
| *Troglodytes troglodytes* | 10.5 | 95 |
| *Parus cristatus* | 16 | (145) |
| *Buteo buteo* | 21 | 160 |
| *Certhia familiaris* | 30 | (131) |
| *Sitta europaea* | 34 | (131) |
| *Parus ater* | 42 | (112) |

Accepted as the threshold of regular presence was the area of the wood with a given species which provided a lower limit to the range of forests with greater area in which the species occurred in 95% of cases. This value was established for 24 species only, but a similar measure was produced for the next 10 species using a less stringent criterion – presence in 90–95% of forests larger than the one establishing the threshold of regular presence. This is indicated in Table 2. On the basis of the material presented, the highest possible value of TRP to be defined was 160 ha (the size separating off the group which included the ten biggest forests studied).

$Log_{10}$-transformed versions of the sizes for MFA and TRP were used in the processing of material (analysis of distribution, calculation of means, correlations and tests for the statistical significance of differences between means).

The classification introduced by Tomiałojć *et al.* (1984) was used in the division of species into ecological groups (based on foraging in the forest and beyond, nesting and migration strategy). Consideration was given to the fact that a few species were not present in Puszcza Białowieska.

The dominat kind of food was the basic on which species were preliminarily divided up to the following categories: herbivorous birds, insectivorous birds (including those eating other invertebrates), birds feeding on vertebrates, and omnivores.

In turn, the group of insectivorous birds was further divided into birds wintering in mixed-species flocks (WMSF) and other insectivorous. Following Cieślak (1983) in the forests of central Poland winter flocks form: *Parus spp. Dendrocopos spp., Certhia spp., Sitta europaea, Regulus regulus, Aegithalos caudatus*. Also *Dryobates martius* was included to WMSF feeding group.

Statistical calculations were performed with the aid off software CSS Statistica (StatSoft 1991).

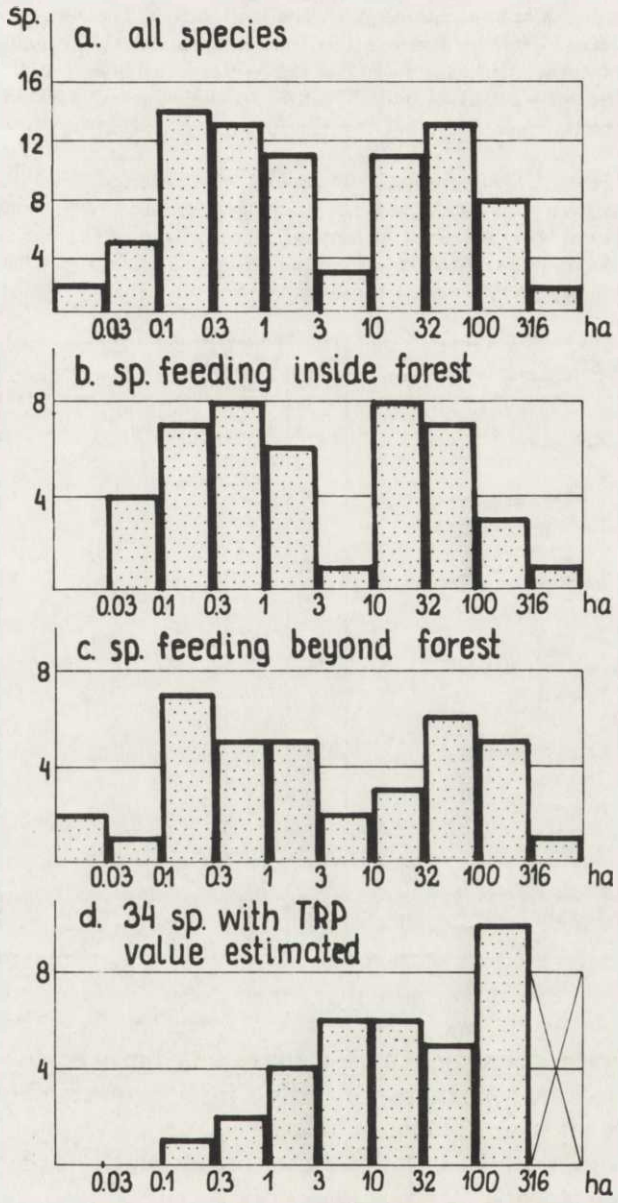


Fig 1. Distribution of values for minimum forest size for variuos groups of species (a,b,c), and threshold of regular presence (d) in accordance with divisions of forest size.

[Fig 1. Rozkład wartości minimalnej wielkości lasu u różnych grup gatunków (a, b, c) oraz progu regularnej obecności gatunków (d) – w odniesieniu do wyróżnionych kategorii wielkości lasów.]

## RESULTS

82 species were reported to occur in the woods under study. The non-territorial species *Cuculus canorus* was also recorded, as was a pair of *Anthus pratensis* found in a meadow in the middle of a wood. Cieślak (1991) gives the full list of bird species, the number of woods from which they were reported, the size of the smallest woods in which they were found and the frequency of occurrence of species in 4 divisions of forest size. Table 2 presents TRP values for some 34 species.

As can be seen in Fig. 1a., the distribution of log MFA values diverged from a normal distribution.

Table 3. Mean values of minimum forest area (MFA) for various group of species, number of species in groups (N) and results of t-tests for the significane of differences between means (t). Significances are marked at the ends of the vertical dotted lines, with the letters: S – $p<0.01$, s – $p<0,05$. WMSF – species wintering in mixed-species flocks.

[Tabela 3. Średnie wartości minimalnej wielkości lasu (MFA) dla różnych grup gatunków, liczba gatunków w grupach (N) i wyniki testów istotności różnic (t). Istotność różnic oznaczono na końcach pionowych kropkowanych linii jako S ($p<0.01$) lub s ($p>0.05$). WMSF – gatunki zimujące w kilkugatunkowych stadach.]

| Group of species | N | MFA (ha) | t | | | | | |
|---|---|---|---|---|---|---|---|---|
| All species | 82 | 3.3 | | | | | | |
| Feeding inside forests | 45 | 3.2 | | | | | | |
| Feeding beyond forests | 37 | 3.5 | | | | | | |
| Insectivorous without WMSF | 42 | 1.2 | S | S | s | | | |
| Omnivorous | 8 | 1.3 | : | : | : | s | s | s |
| Vertebrate predators | 9 | 10.5 | : | : | s | s | : | : |
| Insectivorous WMSF | 14 | 14 | : | S | | | s | : |
| Vegeterians | 9 | 24 | S | | | | | s |
| Ground-nesters | 14 | 1.3 | S | | | | | |
| Tree/scrub-nesters | 40 | 2.4 | : | S | | | | |
| Hole-nesters | 28 | 8.5 | S | S | | | | |
| Tropical migrants | 24 | 1.7 | S | | | | | |
| Short-distance migrants | 16 | 2.0 | : | S | | | | |
| Resident | 29 | 2.8 | : | : | S | | | |
| True resident | 13 | 29.0 | S | S | S | | | |

Species occurring in the woods studied may be divided into two groups which differ in their vulnerability to the fragmentation of forests:
– group "SF" includes those species which tolerate small woods of size up to several hectares,
– group "MF" includes those which only occur in woods of medium size (tens of hectares).

The distributions of minimum area values for these two subgroups are close to normal distributions (Fig. 1a). The two subgroups are separated by an MFA values in the range 3–10 ha.

Similar distributions were noted for the values of minimal forest areas obtained by the groups of species foraging in forest and beyond (Fig. 1b,1c). Distinguishable amongst them, and in proportions close to those found in the sample as a whole, are "SF" and "MF" species (Fig. 1a). From this it may be suggested that the fragmentation of forests has similar effects on birds foraging in tree stands and beyond forests.

Compared to other groups of species, true residents, hole- nesters, herbivorous species, species feeding on vertebrates and species wintering in mixed flocks showed considerably higher mean values for MFA (see Table 3). The majority of these requirements for larger woods were confirmed when t-test were carried out to determine the significance of differences in the mean values for log MFA obtained by these groups of species and by the remaining groups.

Table 4. Mean values for the threshold of regular presence (TRP) for groups of species, number of species in groups (N) and results of t-tests for the significance of differences between means (t). For other explanations, see Table 3.

[Tabela 4. Średnie wartości progu regularnej obecności (TRP) u różnych grup gatunków, liczba gatunków w grupach (N) i wyniki testów istotności różnic (t). Inne oznaczenia jak w tabeli 3.]

| Group of species | N | TRP (ha) | t | |
|---|---|---|---|---|
| All species | 34 | 19.5 | | |
| Feeding inside forests | 26 | 17 | | |
| Feeding beyond forests | 8 | 33 | | |
| Insectivorous without WMSF | 24 | 12 | s | |
| Vegeterian | 1 | 31 | : | |
| Omnivorous | 1 | 34 | : | |
| Insectivorous WMSF | 7 | 63 | s | |
| Vertebrate predators | 1 | 160 | | |
| Ground-nesters | 10 | 6.8 | S | |
| Tree/scrub-nesters | 14 | 20 | : | |
| Hole-nesters | 10 | 54 | S | |
| Short-distance migrants | 10 | 8.3 | S | |
| Tropical migrants | 11 | 16 | : | S |
| Resident | 8 | 25 | : | : |
| True resident | 5 | 126 | S | S |

TRP values were found to be distributed similarly to MFA values (compare Figs 1d and 1a respectively). This is of course the case after account is taken of shifts resulting from differences in the MFA and TRP values of individual species.

As Table 4 shows, mean TRP values for the groups of species distinguished are, like the results of tests on the significance of differences in mean values, close to the results of analysis of mean MFA values (Table 3).

It should be pointed out that, in the analysis of TRP values, some feeding strategy groups were represented by one species only.

## DISCUSSION

### Methodological comments

On the basis of comparisons between the results obtained, and those in the cartographic studies of Cieślak and Dombrowski (1993), it may be stated that:
– some 90–95% of the species reported using the cartographic method were found by the method adopted here,
– for some species, minimum forest area values may have been lowered artificially as a consequence of the inclusion of the non-territorial singing males of Passerine species to the community (Cieślak 1991).

It was for these reasons that the size of forest "b", rather than that of forest "a", was adopted as the basis to define the minimum forest area value (MFA) for a given species. If both values were similar, the effect on the calculation of mean values was insignificant. On the other hand, if the two values differed significantly, then there was reduced risk of adopting an excessively small value for MFA on the basis of, for example, the presence of a non-territorial male of a species.

Cieślak and Dombrowski (1993) using cartographic field studies defined the minimal forest area (MFAcd) for 48 bird species present in small woods in the same region, and also reported in the woods under study here. The following relationships are between values MFAcd and MFA derived on the basis of the sizes of woods "a" and "b" respectively:
log MFA"a" = -0.32 + 0.80 log MFAcd, r = 0.68,
log MFA"b" = -0.01 + 0.92 log MFAcd. r = 0.76.

The appropriateness of adopting the size of forest "b" as the basis for the calculation of MFA is indicated by the values of coefficients in the second function (the first being close to 0 and the second close to 1) as well as by the higher value for the correlation coefficient.

The adoption in calculation of the size of forest "b" gives a more adequate description of the relationship of regional population to the forest fragmentation – this is even the case for *Corvus corax* and some *Falconiformes*, whose nesting was confirmed by occupied nests. Compilation of successive smallest areas for some of these species indicates why this was so. In the case of *Buteo buteo*, the smalles wood were of 0.31, 21, 26, 34, 39 and 42 ha etc, and in case of *Corvus corax* 1.32, 42, 50, 80, 115, 130 ha etc. It is clear from these examples that the basing of minimum forest areas on the sizes of forest "a" would to distort the general picture of the relations of these species to forest fragmentation.

The method applied made it possible to overlook species in the larger forests under study. For this reason, the definition of threshold of regular presence in communities of forests bigger than the threshold area made use of a frequency of occurrence of the species in 90–95% of cases, rather than 100%.

The next matter concerns the adoption, following Tomiałojć *et al.* (1984), of the division into groups foraging within or beyond the forest, and into groups with different migratory strategies. These divisions related originally to the conditions of the large forest of Puszcza Białowieska. The system was adopted for this work in the absence of data concerning the winter residence of forest birds in fragmented forests of the agricultural landscape in the region. It should be anticipated that – in the conditions of fragmented forests in an agricultural landscape – species may forage differently and may differ in migration strategy – especially where the categories "true resident" and "resident" are concerned.

### The distribution of vulnerability

As can be seen in Fig. 1a., very well-represented in the group of "SF" species tolerating forests covering several hectares are birds preferring fragmented forests and reacting by increasing in numbers (Cieślak & Dombrowski 1992), as well as those which prefer the forest edge (Cieślak in press). The latter group includes species which are dominant in the communities of birds breeding in pine forests.

Species like *Fringilla coelebs*, *Phylloscopus collybita* and *Parus major* in large forests have territories many times greater than the MFA values. It may be that, when nesting in small woods, these species may forage beyond them – in breeding territories that extend into non-forest areas and that therefore allow them to reduce their requirements in relation to forest size.

An increase in area in forests covering more than about 10 ha is more and more often accompanied by presence of species from the "MF" group, which are sensitive to strong forest fragmentation.

The group of "MF" species is dominated by those which forage in tree stands (woodpeckers, *Sitta europaea*, *Certhia spp*, some *Parus spp.*) and whose territories cover areas greater than several hectares – the threshold delimiting this groups. Those species foraging in tree stands are not tolerant of strong fragmentation of forest into small areas. Forests smaller than the territory of a single pair are inaccessible to this group of species, which forages exclusively in tree stands ( e.g. *Dryocopus martius*, *Parus ater*, *Certhia familiaris*, *Sitta europaea etc.)*. These species do not settle the forest edge, which is occupied by communities in which a majority of species feed beyond the forest (Cieślak in press).

Species from this group (like *Certhia familiaris*, *Parus ater*, *Sitta europaea* etc.) have TRP values that are only several times greater than the MFA values. This indictes that forest fragmentation has a strong limiting effect on these species. Reported sporadically in forests of 30–40 ha, these species are already regular in bird communities in forests greater than 100 ha.

The functioning of metapopulations of these species is highly dependent on there being forests of appropriate size in the landscape (Opdam 1990, Rolstad 1991, Verboom et al 1991). This is because these species cannot nest in other suboptimal biotops, like mid-field afforestations or very small woods. In this respect they differ from species in the "SF" group.

The "MF" group is supplemented by species which do forage beyond the forest, but which – in eastern Poland – require forest covering several tens of hectares for nesting. It may be that the smallest "a" areas of forest in which *Buteo buteo*, *Falco subbuteo* and *Corvus corax* were reported are indicative of an ongoing process of adaptation to forest fragmentation among regional populations of these species.

It is important to mark as "LF" birds those 19 species which were not reported in the forests studied and which clearly require large areas of forest in eastern Poland. Examples of these species are *Ciconia nigra*, *Aquila pomarina*, *Picoides tridactylus*, *Dendrocopos leucotos*, *Nucifraga caryocatactes*, and *Caprimulgus europaeus*. This group may be generally defined as birds of the forest landscape.

Thus, the species of bird occuring in the forests of eastern Poland may be divided into following groups in relation to their vulnerability to forest fragmentation:

"SF" – about 45 species which tolerate small forests (of up to several hectares),
"MF" – about 35 species which require forests of moderate size (several hectares at least),
"LF" – about 20 species of the forest landscape or big forests, which did not nest in the forests studied, but which are reported in large forests of the region.

**The vulnerability of ecological groups**

As can be seen from Figs 1b and 1c, minimum areas for the group foraging beyond the forest are not distributed differently from those for the group of species foraging within tree stand. The small size of forests may emerge as a limiting factor for some species from this group also. Species foraging beyond the forest (and particularly those from the "MF" group) may also require an appropriately large area of forest, if they are to start breeding. The territory of a pair of certain species, like those from order *Falconiformes*, includes a fragment of forest and a very extensive feeding area beyond. However, for ethological reasons (a sense of safety) these species have definite requirements regarding the size of a forest in which they will nest.

Herbivorous species emerged as the group most vulnerable to the fragmentation of forests. This is understandable, where the species concerned (e.g. forest *Galliformes*) feed in the forest, as sufficient amounts of low-calorie plant plant food require (particularly in winter) a territory that is of sufficient size.

In an agricultural landscape, it is mainly the area beyond the fragmented forests that must be used if species feeding on vertebrates (*Falconiformes* and *Strigiformes*) are to obtain food. At the same time, however ( and as has been mentioned previously under species foraging beyond the forest), these species have definite requirements where the size of the nesting biotope is concerned. On the other hand, the abundance of food (rodents) in fields may be a feature which favours species like *Buteo buteo*, *Falco tinnunculus* and *Asio otus*, and which encourages the settling of small woods.

The group of insectivorous species is both the most numerous and the most diverse: it includes species so different species e.g. warblers, flycatchers and large woodpeckers. There are significant differences between the mean values for MFA and TRP for the insectivorous forming mixed winter flocks, and for the other insectivorous species. This attest to the value of splitting the insectivorous group into two subgroups.

Many insectivorous species, other than WMSF, forage beyond tree stands or at the edges of them. These may gain by exploitating invertebrates that are enriched qualitatively and quantitatively at the edge of a forest and in the immediate vicinity (Hansson 1983, Helle & Muona 1985).

Fragmentation of forest foraging grounds is a direct threat to those insectivorous species which do winter in the mixed-species flocks that forage in tree stands. It may be anticipated that also during breeding season the food resources at the forest edge are qualitatively less suitable for most species of WMSF group. Species preferring the forest-edge biotope are strong competitors in this zone. To a great extent, the WMSF species are also characteristic of other strategies severely threatened by forest fragmentation (hole-nesting, true sedentariness).

Omnivorous species emerged as those of limited vulnerability to forest fragmentation. These species are adapted to foraging in the different biotopes of an open landscape, or at the forest edge. Some (e.g. *Corvus monedula, C. frugilegus, Passer domesticus* and *Pica pica*) are more frequent in non-forest biotopes and urbanized areas, than in forests.

True resident species spend the winter in the forests they breed. In comparision with the breeding season, food resources are considerably less easily available at this time. This may lead to greater requirements in relation to forest size. Some of these species form mixed flocks in the winter, and it is thanks to these that they are able to make more effective use of the food resources of the biotope (Cieślak 1983). There is a lack of data concerning the behaviour of species forming winter mixed-species flocks when in fragmented forests situated in an agricultural landscape.

The fragmentation of forests may force winter flocks to enter a larger number of small and medium-sized forests, if they are to obtain sufficient quantities of food. The crossing of open areas may increase the risk that predators (*Accipiter spp, Falco spp*) will reduce the populations of these species. In large forests, it may not be necessary for flocking species to leave the forest and these birds can avoid exposure to predators and the loss of energy.

Fragmented forests provided limited possibilities for true resident species to exchange genetic information. The small populations of fragmented forests may thus be threatened by inbreeding and less well-able to persist than those of nomadic and migratory species. The significance of the isolation of forests for small, isolated populations of true resident birds has been confirmed by Opdam *et al.* 1985, Petterson 1985, Opdam 1990, Rolstad 1991, Verboom *et al.* 1991.

Hole-nesters are the group of species showing the highest degree of adaptation to nesting and living in forest. It may be that nesting in holes is an expression of a high level of adaptation and conservatism in relation to the ecological conditions created by the forest biotope. There is no doubt that the fragmentation of forests leads to the degradation of these ecological conditions (the microclimate changes, human penetration, domestic predators). Intensive exploitation of forests may also limit the nesting possibility for many hole-nesters.

Among the birds studied, it was the true resident species nesting in tree-holes that were over-represented ($x^2$ test, $p = 0.06$). This indicates that the coincidence of these two strategies is not accidental, but is rather the combined strategy of this group of species. A majority of species in this group combine together the three strategies most vulnerable to forest fragmentation, i.e. sedentary lifystyle, nesting in holes and formation of mixed-species flocks in winter.

The above analysis showed that the forest avifauna of eastern Poland is characterized by the requirement for the largest areas noted, amongst hole-nesters, true resident species and three feeding strategy groups (insectivorous species wintering in mixed-species flocks, herbivorous species and species feeding on vertebrates).

According to Helle (1986), it is the true resident species and the hole-nesters which prefer tree stands in the interior of forest. It was shown by Helle & Jarvinen (1986) that together with a decline in the area of old tree stands, it was the fragmentation of forests in Finland which explained the decrease of several true resident species populations, which were mainly hole-nesters (*Parus cristatus, P.montanus, P. cinctus, Certhia familiaris, Perisoreus infaustus*). The decline in the numbers of these true resident species was accompanied by increase in the numbers of many migratory species (see Helle 1986).

The results of other studies also point to the threat posed by forest fragmentation to the following species of birds that are true resident and/or hole-nesters:
– *Parus cinctus* – Finland (Virkkala & Liehu 1990);

– *Parus palustris* – The Netherlands (Opdam *et al.* 1985);
– *Certhia familiaris* – Finland (Kuitunen & Helle 1988, Helle 1984), The Netherlands (Opdam *et al.* 1985);
– *Sitta europaea* – The Netherlands (Opdam *et al.* 1985, van Dorp & Opdam 1987, Verboom *et al.* 1991);
– *Dendrocopos medius* – Sweden (Petterson 1985), Switzerland (Muller 1982);
– *Tetrao urogallus* – Norway (Rolstad & Wegge 1987).

Absent, or occuring only sporadically, in forest on small or medium sized islands in the Baltic are forest resident of the families *Tetraonidae*, *Strigidae*, and *Paridae*, as well as woodpeckers, *Certhia familiaris* and *Sitta europaea* (Haila *et al.* 1985, Martin 1983). The same is true of forested islands in Scandinavian lakes (Ahlen & Nilsson 1982, Haila 1983). The group of species under discusion was very poorly-represented in the breeding avifauna of small forests and/or plantations in Lithuania (Kurlavicius 1986), eastern Poland (Cieślak, Dombrowski 1993), western Poland (Gromadzki 1970, Wuczyński 1990), eastern Germany (Bastian *et al.*1989), western Germany (Zenker 1982) and Great Britain (Moore & Hooper 1975, Taylor et al. 1987).

Reed (1987) made a study of capacity of 6 species of birds to colonize isolated areas. This showed that 3 species of tits (*Parus caeruleus*, *P. major* and *P. ater*) were characterized by low capabilities of dispersion and colonization. Coincidence between strategies vulnerable to forest fragmentation and the possibilities of dispersion and colonization were shown in the results of studies in the Hanko peninsula of south Finland (Raivio 1988). Found to decrease from the base od peninsula to the tip were the densities of following species or groups of species: *R. regulus*, *Parus cristatus*, *Paridae*, WMSF, hole-nesters and true residents. The opposite trend was shown by ground-nesting species and by species nesting in trees and scrub. It emerges that the dispersion capabilities of species are significant in determining the degree of threat posed to birds by the fragmentation of forests.

The strategy of forming winter flocks is also shown in Australian conditions by species of so-called "forest specialists", which avoid the forest edge (Catteral *et al.* 1981). Species from this group also avoid settling in small forests and belts of planted trees (Lynch & Saunders 1991, Saunders & de Ribeira 1991).

Few studies concerning North American birds have shown that the group of true resident species (woodpeckers, *Sitta-*, *Certhia-*, *Parus spp.*) are characterized as species of the forest interior (Blake 1983) and are vulnerable to forest fragmentation (Blake 1983, Blake & Karr 1987).

However, numerous studies show that – in breeding avifauna of forests of North America – it is the Neotropical migrant birds which are most vulnerable to the fragmentation of forests (e.g. Blake & Karr 1984, Lynch & Whigham 1984, Robbins 1988 and Wilcove 1988).

Several features may be invoked to account for such a significant difference between Europe and North America in the results of evaluation of the vulnerability of birds to forest fragmentation:
– different methods of field study and different methods of measuring vulnerability of birds to forest fragmentation;
– a different history of deforestation and fragmentation of forests in the two continents;
– differences in the composition of the breeding avifauna of forests in the areas compared, e.g. Europe's lack of species corresponding to the American *Parulidae* – Neotropical migrants nesting deep in the forest (L.Tomiałojć – pers. comm.).

## CONCLUSION

It emerged that, as in other studies in Europe, the species most vulnerable to forest fragmentation in the area studied were: true resident species, hole-nesters, herbivorous species, species feeding on vertebrates, and insectivorous species which form in winter mixed-species flocks. It is thus the following taxa of forest species which are seen to be most threatened by the fragmentation of forests:

– forest *Galliformes* (*Tetrao urogallus*, *T. bonasia*) – resident and herbivorous;

– woodpeckers – hole-nesters which partly winter in mixed-species flocks and are resident;

– *Paridae*, *Sitta europaea* and *Certhia spp.* – resident which nest in holes and which winter in mixed-species flocks;

– *Strigiformes* – true residents (with exeption of *Asio otus)* which are hole-nesters and which feed on vertebrates.

In contrast, it would seem that – in condition of fragmented forests in a agricultural landscape – the strategies most profitable for birds are omnivory, mi-

gration, nesting on the ground and in open nests in trees and scrubs.

The compilation of mean MFA values for variously-threatened groups, acording to Głowaciński and others (1980), gives an indication of the threat posed by fragmentation of forests to the breeding avifauna:
- 25 species not threatened by extinction 0.36 ha,
- 39 species potentially threatened 5.26 ha,
- 16 species threatened in a long period 23.99 ha.

A t-test revealed significant differences between the mean values for logMFA for all the pairs of groups compared ($0.0<p<0.043$).

The appropriate management of existing forests is required for the protection of the species most vulnerable to forest fragmentation (i.e. old tree stand protection for hole-nesters). Supplementary afforestations are also necessary to improve the spatial structure of forests in an agricultural landscape (enlarging the existing forests, improving their shape and joining those situated in close proximity to one another).

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## STRESZCZENIE

**[Wrażliwość ptaków na rozdrobnienie lasów]**

Wyniki ilościowych badań ptaków lęgowych przeprowadzonych w 224 lasach wschodniej Polski o powierzchni 0.01–450 ha (tab.1) wykazały występowanie 84 gatunków ptaków (Cieślak 1991). W awifaunie lęgowej tych rozdrobnionych lasów można wyróżnić dwie grupy gatunków: ptaki które tolerują jako biotop gniazdowania małe lasy – do kilku hektarów (SF) oraz ptaki, które do założenia gniazda potrzebują lasów średniej wielkości (MF).

Grupę gatunków występujących w dużych lasach wschodniej Polski a nie występujące w badanych lasach (LF) można określić jako gatunki krajobrazu leśnego.

Dla stwierdzonych gatunków określono minimalne wielkości lasu (MFA) w których gniazdowały. Dla 34 gatunków określono również próg wielkości lasu (TRP) powyżej której gatunki te osiągały frekwencję na poziomie 90–95% badanych lasów (tab. 2).

Średnie wartości MFA i TRP obliczono dla grup gatunków ptaków wyróżnionych w oparciu o strategię migracyjną, sposób umieszczenia gniazda, żerowania w drzewostanie i poza lasem oraz rodzaj pokarmu. Średnie wartości obu parametrów obliczone dla poszczególnych grup gatunków posłużyły do oceny ich wrażliwości na rozdrobnienie lasów.

Najbardziej wrażliwymi na rozdrobnienie lasów okazały się grupy gatunków osiadłych, gniazdujących w dziuplach oraz odżywiających się pokarmem roślinnym, kręgowcami i grupa ptaków owadożernych, które zimując w lasach tego regionu formują mieszane stada (tab. 3, 4). Gatunki, które łączą kilka strategii najmniej korzystnych w rozdrobnionych lasach można wskazać jako najbardziej wrażliwe na rozdrobnienie.

Gatunki żerujące w drzewostanach i żerujące poza lasem nie wykazały istotnych różnic wrażliwości na rozdrobnienie lasów (ryc. 1b,c). Najmniej wrażliwe na rozdrobnienie okazały się gatunki wszystkożerne, pozostałe owadożerne, gniazdujące na ziemi i w koronach drzew i krzewach oraz gatunki nieosiadłe (tab. 3, 4).

Wrażliwość ptaków na rozdrobnienie lasów wykazuje silny związek ze stopniem zagrożenia wyginięciem gatunków.

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