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The frequency method in studying habitat preferences of common forest birds in south-east Poland

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Abstract

This paper presents the results of a study on the habitat preferences of selected species of the bird community in the Morgi Forest, in the Kolbuszowa Forest District (SE Poland), with the use of the point-stand bird census method. This method is a modification of the classic point count. The aim of the study was to test the effectiveness of the method in determining the frequency of colonisation of stands with different habitat parameters by the most abundant bird species. In 270 tree stands of a forest complex with diverse habitats, a bird census was carried out with four counts per stand. Next, a list of the tree stands, and the bird species recorded in the stands was compiled. The stands were divided into categories according to the forest habitat type, dominant species, and age class. The frequency of occurrence of the most abundant bird species was calculated for each stand category. Among the analysed species, the majority showed a positive correlation between the frequency of occurrence and habitat soil fertility. The influence of the dominant stand species on the frequency of bird species was largely driven by habitat soil fertility. The lowest average frequency of the identified avian species was found in stands dominated by pine *Pinus sylvestris*, birch *Betula* sp. and black alder *Alnus glutinosa*. There was generally a positive relationship between age class and the bird community parameters. It is concluded that the point-stand bird census method provides informative results for research on the habitat selectivity of bird populations.

Keywords: point-stand method, frequency method, habitat selection, forest birds

Introduction

Habitat selection is one of the most important processes shaping animal populations and determining their survival. Habitat selection is a complicated process and is driven by many factors, including predation, the spatial structure of habitats, and population size. In the case of birds, selection of an appropriate habitat is crucial for ensuring an appropriate food base or the availability of resting or breeding places (Hilden 1965, Cody 1985, Wiens 1992, Kuczyński and Chylarecki 2012, Mahon et al. 2016). The set of variables characterising bird habitats is shaped by many factors. One of the most important is the population size. The spatial distribution of populations with low abundance usually results from the colonisation of the most optimal habitats for a given species. Typically, when populations begin to reach large numbers, the range of variation of occupied habitats increases. Most often, this results from the limited availability of optimal habitats, which forces some of the individuals to occupy areas with suboptimal habitat structure. In birds, niche plasticity, manifested by the ability to colonise a wide range of habitats, is species dependent. Habitat selectivity and its extent may also change over time, because of behavioural changes or adaptation to living under changing conditions. These mechanisms are forced by irreversible changes in ecosystems and are often decisive for the survival of entire species (Donald et al. 1998, De Warnaffe and Deconchat 2008, Hewson and Noble 2009, Fraixedas et al. 2015, Mikusiński et al. 2018).

Central Europe is situated in the mixed forest biome of the temperate zone. Over the past 1,000 years, most of the continent has been deforested. The forested part of the continent has been transformed by forest management, which has altered forest ecosystems relative to their original state. The most important changes include species and structural depletion of stands, greater spatial segregation of stands with specific features, greater age uniformity of trees in stands, faster transformation of successive forest generations, and wood uptake resulting in a loss of biomass. The semi-natural management of forest can also be a differentiating factor, producing mosaic-like ecosystems consisting of varied stands. Forest management also contributes to a different allocation of stands compared with natural ecosystems, because of the implementation of spatial and temporal ordering. Currently, most of European forests are subject to various forms of management. Changes resulting from the adopted management system have forced forest bird populations to adapt to ecosystems shaped by human activity (Paillet et al. 2010). Today, forestry is undergoing profound changes, driven by new tasks that forest managers are expected to perform (Borecki and Stępień 2017). The most important of these include the obligation to protect biodiversity and the various social functions of forests (Constanza et al. 1997, Kissling-Näf 1999). Another important factor that has brought changes in forestry is the significant progress in the mechanisation of forest treatments, combined with a high demand for timber as well as other forest products, for example pulpwood and biofuel. All these factors have a strong impact on forest ecosystems, which provide habitats for numerous species of birds. Therefore, the observed changes are a motivation for research on the habitat requirements of forest birds in a changing environment.

Census methods for forest bird communities fall into two categories. Methods in the first category consist in counting whole bird assemblages. During fieldworks, the observer collects information about all of the species occurring in a given area and thus obtains data on the entire bird community (Tomiałojć 1980a, 1980b, Bibby et al. 2000, Gregory et al. 2004). Methods in the second category involve a census of species or groups of systematically related species. This method is used for less common species or other species that are difficult to detect using traditional counting techniques (e.g. Southerland 2006, Chylarecki et al. 2015).

The methods for counting bird assemblages can be broadly divided into two categories:

- methods that provide information about the absolute number of birds in a given area and period of time, i.e. censuses;
- methods that provide information about the relative population size, i.e. abundance indices, correlated with absolute bird numbers.

In the first category, the final census result is the population size; a derivative value, the population density, is then calculated as the ratio of the population size to the size of the surveyed area. In the second category, indices of the numbers and density are calculated likewise (Bibby et al. 2000, Southerland 2006, Chylarecki et al. 2015).

Since the very first studies on bird population sizes, finding appropriate census techniques has been a challenging task for researchers. The key issue is the time- and labour-intensity of the faunistic data collection process. Censuses providing absolute numbers are highly time-consuming and require considerable workload, and their results are most often limited to small sections of an area or single species (as with the mapping method). In contrast, the much faster index methods produce results with an unknown error, and their results need to be carefully verified. However, an undoubted advantage of the fast quantitative methods is the ability to obtain large data sets.

This paper shows how the results of a bird census adopting the index point-stand method can be used to calculate the frequency of occurrence of common forest bird species in stands representing various habitat categories. The objective of this paper was to verify the hypothesis stating that the point-wood stand method allows quick and simple identification of habitat preferences of birds in managed forests.

Material and methods

Study area

The study was carried out in the forests of the Kolbuszowa Forest District, within the Morgi Forest, in the Podkarpackie Voivodeship of SE Poland (50°17'12.6'' – 50°24'13.1'' N, 21°18'43.3'' – 22°05'04.1'' E). The size of the study area was 5,745 ha. The Morgi Forest is a relatively dense forest complex surrounded by farmland. In terms of woodland classification, the study area is in the 'Natural Forest Region of Małopolska'. Geographically, it is situated in the Sandomierz Basin, Tarnobrzeg Lowland and Kolbuszowa Plateau mesoregions. These areas are formed mainly by river sands, which have transformed into sand dunes. They are chiefly covered by forests; agriculture is poorly developed, and arable land is of low quality (Kondracki 2009). The study area is in the Kraków-Sandomierz climatic region (Woś 1999). This region is characterised by long and hot summers, not too harsh winters, and warm sunny autumns. The average annual temperature is 7.6 °C, the total average annual precipitation is 650 mm, and westerly and south-westerly winds prevail. In the Morgi Forest, the main soil types are brunic Arenosols, gleyic albic podzols, stagnosols and podzols (KFD 2011). The most common forest habitat type is moist mixed coniferous forest, which accounts for 41% of the habitats. The only exception is the eastern part of the complex, dominated by broadleaved forests. The dominant species in the coniferous habitats is Scots pine *Pinus sylvestris* (67% of the area within Morgi), birch *Betula* sp. or Norway spruce *Picea abies*. The species prevailing in the broadleaved forests are more diverse and, depending on the stand, consist of the following species: pine, birch, European beech *Fagus sylvatica*, black alder *Alnus glutinosa*, Norway spruce, silver fir *Abies alba*, oak *Quercus* sp., and European hornbeam *Carpinus betulus*. The species dominant in alder forests is the black alder. The average age of stands in the studied forest complex was 59 years (KFD 2011). The age structure was quite uniform, except that the area of age subclass IIIb (838 ha) was almost twice as large as the areas of the other classes. Age class I accounted for 10% of the total, and the regeneration class for 8.8% (KFD 2011).

Methods

Based on the Forest Management Plan (KFD 2011), a list of stands for the Kolbuszowa Forest Division was developed, considering the most important inventory features of the stands. The features of stands are regularly updated during a ground survey consisting in direct inspection of each stand in the forest division. This survey is carried out every 10 years in connection with the preparation of the Forest Management Plan and based on the operational regulations in the Polish State Forests (SF NFH 2012a). In Poland, forest complexes under the management of the State Forests are divided into compartments of variable size, generally around 25 ha. This division is made by superimposing a system of treeless lines in the shape of a grid of rectangles on the forest complex. Each forest compartment is divided into stands, which are homogeneous forest fragments in terms of various features. The most important features serving as criteria for distinguishing stands include age, species composition, forest habitat type, vertical structure, and many others. The average size of a stand in the State Forests is about 4 ha.

270 stands were randomly selected from the list, subject to the condition that the main dominant species, forest habitat types, age classes and vertical structure types were represented by at least 10 stands. Next, a bird census was carried out in the selected stands.

The counts were carried out during the two spring seasons of 2014 and 2015. In each spring seasons, two inspections were carried out, in the following periods: 1) April and the first half of May; 2) the second half of May and the first ten days of July. The counts were carried out in the morning hours, beginning at sunrise, and ending around 9.00–10.00 am. For one morning, 10 to 22 stands were inspected, depending on the distance between the points. In each stand, a count point was located at its geometric centre (the centroid).

The point-stand bird census method was applied (Sikora and Borecki 2020). This method is a modification of the classic point count, in which the observer counts birds typically within a 100 m radius of points placed in a regular grid pattern, most often consisting of 200 × 200 m squares (Fuller and Langslow 1984, Tomiałojć and Verner 1990, Bibby et al. 2000, Ralph et al. 1995, Sorace et al. 2000, Neubauer and Sikora 2012, Neubauer and Sikora 2016). During the bird inventory, the distance between the observer and an individual bird whose voice was heard was estimated based on the volume of the sound. In the modified method, the survey area was restricted to the area within the examined stand, at a distance not greater than 100 m from the observer. This created sample plots of varying sizes. However, the main advantage of this system was the possibility of assigning observations to a specific stand, which is a biotope with uniform structure features. Another modification was the uneven distribution of observation points in space, which was a result of the adopted sampling system. However, it should be remembered that the priority of this study was to obtain information on the occurrence of birds in the widest possible range of habitats. Placing the count points in a regular grid would have caused them to lie in the most frequent forest habitats, while some of the less common habitats would have been omitted (Sikora and Borecki 2020).

The 5-minute-long observations during the surveys made it possible to record most of the species and some of the individuals present in the area. The somewhat low detectability of birds during a single listening session was compensated for by repeating it four times during the two research seasons. This allowed identification of the species characterising each stand. At each point, the recorded variables were bird species, number of individuals, sex, and presence of the bird in the studied stand (0 – outside, 1 – inside). The data on bird occurrence collected at the listening points were entered into an electronic database. Based on the data obtained, the species composition of the bird community of the studied stands in the Morgi Forest was determined, and the 34 (a number selected arbitrarily) most numerous species were selected, for which the frequency of occurrence in stands of various categories was calculated. The stand categories were created based on the forest management system used in Poland (SF NFH 2012a). The following stand categories were distinguished:

- By forest habitat type – eight categories: 1 – fresh/moist/boggy coniferous forest, 2 – fresh mixed coniferous forest, 3 – moist mixed coniferous forest, 4 – fresh mixed broadleaved forest, 5 – moist mixed broadleaved forest, 6 – fresh broadleaved forest, 7 – moist broadleaved forest, 8 – alder/ash-alder swamp forest.
- By dominant species – eight categories: 1 – Scots pine *Pinus sylvestris*, 2 – Norway spruce *Picea abies*, 3 – silver fir *Abies alba*, 4 – oak *Quercus* sp., 5 – European beech *Fagus sylvatica*, 6 – European hornbeam *Carpinus betulus*, 7 – black alder *Alnus glutinosa*, 8 – birch *Betula* sp.
- By age class, including tree stands in the regeneration class – eight categories: 1 – age class I (stands aged 1–20 years), 2 – II (21–40 years), 3 – III (41–60 years), 4 – IV (61–80 years), 5 – V (81–100 years), 6 – VI (101–120 years), 7 – VII (121–140 years), 8 – RC (regeneration class; stands where regeneration cuts had started as part of complex felling).

It was assumed that a species occurred in a stand if it was found during at least one of inspections. The results are given as percentage values, i.e. the ratio of the number of stands with a given bird species to the total number of inspected stands of a given category (Table 1). The Kruskal-Wallis rank ANOVA test was used to compare the frequency of occurrence of the most numerous bird species (Stanisz 2006). The calculations were performed using Statistica 13 software package (TIBCO 2017).

Table 1. Frequency of the common bird species in stands of different categories (%)

Species	fresh/moist/boggy coniferous forest	fresh mixed coniferous forest	moist mixed coniferous forest	fresh mixed broadleaved forest	moist mixed broadleaved forest	fresh broadleaved forest	moist broadleaved forest	alder/ash-alder swamp forest, boggy mixed broadleaved forest	*Pinus sylvestris*	*Picea abies*	*Abies alba*	*Quercus* sp.	*Fagus sylvatica*	*Carpinus betulus*	*Alnus glutinosa*	*Betula* sp.	I	II	III	IV	V	VI	VII	Regeneration class
	Habitat forest type								Dominant species								Age class							
Number of stands	26	20	71	13	44	32	39	25	116	11	13	26	21	11	50	22	46	50	44	40	30	11	10	39
Columba oenas	4	5	4	15	11	**19**	10	8	8	9	0	13	**33**	9	6	0	4	2	2	10	7	27	**33**	21
Columba palumbus	4	5	15	**54**	20	31	38	12	16	27	38	21	48	**55**	14	10	11	14	18	20	23	27	33	**41**
Cuculus canorus	8	5	**20**	8	9	16	13	4	12	9	15	8	**19**	18	8	14	6	10	9	18	**23**	18	11	10
Picus canus	0	0	0	8	18	**25**	10	8	5	0	8	8	**19**	18	10	14	2	4	5	3	13	9	22	**26**
Dryocopus martius	0	10	10	15	0	**22**	13	8	9	0	15	**21**	14	0	4	10	9	4	2	10	17	9	**22**	15
Dendrocopos major	31	49	49	69	52	**84**	67	32	53	27	54	79	76	**82**	37	29	28	12	48	70	77	82	**89**	87
Oriolus oriolus	35	10	28	**38**	34	28	26	8	**34**	0	31	29	29	27	16	19	9	12	23	28	43	45	**67**	44
Garrulus glandarius	42	40	39	**62**	30	50	49	16	45	9	46	38	**67**	64	24	29	23	22	36	**55**	53	**55**	44	54
Periparus ater	54	**55**	46	31	41	3	0	8	55	**64**	46	4	0	0	2	14	9	20	43	35	50	**55**	44	28
Lophophanes cristatus	**50**	**50**	49	0	27	0	0	4	**53**	27	23	0	0	0	0	14	11	26	30	35	**47**	27	22	18
Poecile palustris	12	0	6	8	**34**	31	26	4	8	27	15	29	**33**	18	14	**33**	2	10	18	15	23	27	**44**	26
Poecile montanus	4	5	15	0	**16**	0	8	4	10	**27**	8	0	5	0	6	19	6	8	**14**	8	13	9	11	5
Cyanistes caeruleus	4	5	6	31	20	**69**	49	44	6	0	8	50	67	**73**	49	24	13	12	36	38	20	18	33	**44**
Parus major	38	40	61	77	68	**88**	85	64	59	73	54	79	90	**100**	63	71	30	42	70	80	90	91	**100**	87
Phylloscopus sibilatrix	8	15	10	31	27	41	**44**	24	16	27	31	29	52	**64**	16	29	4	8	25	38	37	**45**	44	31
Phylloscopus trochilus	23	**60**	41	8	34	13	21	44	34	18	31	29	5	18	41	**48**	**74**	52	20	8	10	9	0	23
Phylloscopus collybita	19	45	77	46	**89**	72	72	68	59	**91**	85	88	48	55	69	90	66	70	50	53	70	91	67	**92**
Aegithalos caudatus	4	0	3	0	**11**	6	8	0	3	9	0	4	5	0	**10**	5	2	8	5	0	3	9	0	**10**
Sylvia atricapilla	27	25	55	69	89	72	82	**96**	51	64	**100**	83	67	45	88	81	62	72	55	50	67	55	78	**92**
Regulus regulus	8	0	21	15	**34**	9	5	20	14	**100**	62	4	14	0	2	19	4	20	16	15	**30**	18	11	18
Regulus ignicapilla	0	0	11	15	**25**	3	3	8	6	**64**	54	0	5	0	2	10	0	10	9	10	13	**27**	11	10
Sitta europaea	4	5	17	46	32	**63**	46	28	19	27	38	50	**57**	55	27	29	9	6	18	38	47	45	**67**	62
Certhia familiaris	0	5	13	0	9	**28**	18	16	9	0	15	25	14	**27**	14	10	2	2	5	15	27	18	**44**	26
Troglodytes troglodytes	4	0	17	8	43	34	51	**52**	16	36	31	29	33	27	**55**	33	17	22	23	43	30	18	22	**46**
Sturnus vulgaris	4	5	4	15	18	28	**38**	32	9	0	8	**33**	24	27	**33**	10	17	2	16	15	27	9	11	**38**
Erithacus rubecula	42	70	82	**92**	73	88	79	68	71	91	92	88	95	**100**	63	71	62	80	68	73	83	**100**	89	79
Ficedula albicollis	0	0	1	23	9	28	**49**	20	2	0	23	13	48	**73**	20	24	2	6	11	**35**	20	18	0	26
Turdus viscivorus	**38**	25	14	8	9	6	10	4	**22**	9	8	0	24	0	4	10	4	8	11	18	**30**	27	22	13
Turdus philomelos	15	15	34	38	43	47	**62**	48	31	27	54	50	**67**	64	41	29	32	34	16	48	53	55	**67**	51
Turdus merula	35	25	32	**92**	73	66	74	60	41	55	69	71	71	**73**	59	62	36	42	50	63	63	45	**78**	77
Anthus trivialis	**69**	50	48	31	16	0	13	0	**52**	0	15	13	5	18	4	19	21	16	30	35	**63**	36	22	21
Fringilla coelebs	69	70	77	**100**	64	81	87	60	79	82	**92**	67	86	91	57	76	34	64	77	90	93	**100**	**100**	95
C. coccothraustes	0	0	6	46	9	**47**	38	12	4	0	8	38	57	**91**	16	10	9	6	11	33	17	9	**44**	31
Emberiza citrinella	12	5	17	**46**	27	13	33	0	16	18	8	**42**	10	18	16	19	**36**	8	16	13	10	9	33	28
Average	20	21	27	**34**	33	36	36	26	27	30	35	33	38	**39**	26	29	19	22	26	33	38	37	**41**	40

Results

During the study, 85 bird species were identified, and the habitat preferences were analysed for the 34 most numerous of these species. Of the analysed species (Table 1), a substantial majority (23) showed an increase in frequency of occurrence in stands together with increasing habitat soil fertility. Only five of the analysed species showed a higher frequency of occurrence in the coniferous habitats: the coal tit *Periparus ater*, the crested tit *Lophophanes cristatus*, the willow warbler *Phylloscopus trochilus*, the mistle thrush *Turdus viscivorus*, and the tree pipit *Anthus trivialis*. Another six species did not show a clear trend in the colonisation of stands with varying degree of fertility: the common cuckoo *Cuculus canorus*, the black woodpecker *Dryocopus martius*, the golden oriole *Oriolus oriolus*, the Eurasian jay *Garrulus glandarius*, the willow tit *Poecile montanus*, and the European robin *Erithacus rubecula*. Three species clearly avoided coniferous habitats: the green-headed woodpecker *Picus canus*, the collared flycatcher *Ficedula albicollis*, and the hawfinch *Coccothraustes coccothraustes*, while six species clearly preferred them: the crested tit, the mistle thrush, the tree pipit, the common cuckoo, the coal tit, and the willow warbler. Three species avoided alder swamp forests: the tree pipit, the yellowhammer *Emberiza citrinella*, and the long-tailed tit *Aegithalos caudatus* (however, for the latter two, this result may be an artefact), while two species clearly preferred alder swamp forest: the blackcap *Sylvia atricapilla* and the Eurasian wren *Troglodytes troglodytes*. No species clearly avoiding broadleaved forest were found, while as many as 26 species were most numerous in this forest category; 13 species preferred the mixed broadleaved forest and 13 species preferred the broadleaved forest habitats. The highest average frequency of occurrence for the common bird species was found in the stands of fresh and moist broadleaved forest (36%). The lowest average frequency was found in stands of fresh, moist and boggy coniferous forest (20%). The difference in the frequency of the most numerous bird species in groups of stands classified by forest habitat type was statistically significant ($H = 18.68$, $p = 0.0093$). However, no significant direct differences between the groups were found in the two-sided comparison test. This indicates a smooth change of the analysed parameter along a gradient of forest site types (Figure 1).

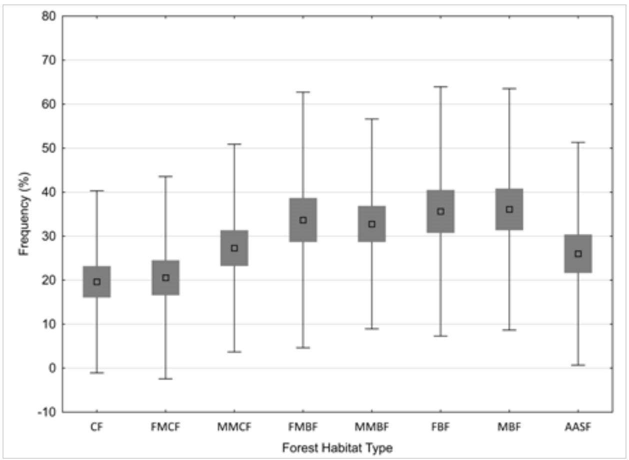

Figure 1. The observations frequency of common forest bird species depending on the forest habitat type

Note: CF – coniferous forest, FMCF – fresh mixed coniferous forest, MMCF – moist mixed coniferous forest, FMBF – fresh mixed broadleaved forest, MMBF – moist mixed broadleaved forest, FBF – fresh broadleaved forest, MBF – moist broadleaved forest, AASF – alder, ash-alder swamp forest and boggy mixed broadleaved forest; explanation: point – mean, box – standard error, whiskers – standard deviation.

Four of the analysed species (the golden oriole, the crested tit, the tree pipit, and the mistle thrush) occurred with the highest frequency in stands, where the dominant species was Scots pine. Five species (the crested tit, the willow tit, the chiffchaff *Phylloscopus collybita*, the goldcrest *Regulus regulus*, and the firecrest *Regulus ignicapilla*) occurred with the highest frequency in stands, where the dominant species was Norway spruce. Two species (the blackcap and the chaffinch *Fringilla coelebs*) occurred with the highest frequency in stands dominated by silver fir. Three of the analysed species (the black woodpecker, the starling *Sturnus vulgaris*, and the yellowhammer) occurred with the highest frequency in stands dominated by oak. Six of the analysed species (the stock dove *Columba oenas*, the common cuckoo, the grey-headed woodpecker, the Eurasian jay, the willow tit, the Eurasian nuthatch *Sitta europaea*, and the song thrush *Turdus philomelos*) occurred with the highest frequency in stands dominated by European beech. Ten species (the common wood pigeon *Columba palumbus*, the great spotted woodpecker *Dendrocopos major*, the Eurasian blue tit *Cyanistes caeruleus*, the great tit *Parus major*, the wood warbler *Phylloscopus sibilatrix*, the Eurasian treecreeper *Certhia familiaris*, the European robin, the collared flycatcher, the blackbird *Turdus merula*, and the hawfinch) occurred with the highest frequency in stands dominated by European hornbeam. Two of the analysed species (the long-tailed tit and the Eurasian wren) occurred with the highest frequency in stands dominated by black alder. Two species (the marsh tit *Poecile palustris* and the willow warbler) occurred with the highest frequency in stands dominated by birch. The highest average frequency of occurrence for the common bird species was found in stands where the dominant species was European hornbeam (39%), while the lowest such frequency was found for stands dominated by black alder (26%). The difference in the frequency of the most numerous bird species in groups of stands categorised according to the dominant tree species was statistically insignificant ($H = 5.16$, $p = 0.6403$). There were also no significant direct differences between the groups in the two-sided comparison test (Figure 2).

Only the willow warbler showed a clear decrease in frequency of occurrence with an increase in the age of the stand. Five species showed even frequencies of occurrence in the different age classes: the willow tit, the long-tailed tit, the goldcrest, the European robin, and the yellowhammer. The frequency of occurrence of the remaining 28 species increased with increasing stand age. Two bird species attained their highest frequency in a young seeding stand and sapling stands: the willow warbler and the yellowhammer. Three species preferred middle-aged stands (21–80 years old): the willow tit, the Eurasian jay, and the collared flycatcher. Eight species were most frequently found in tree stands of the regeneration class: the common wood pigeon, the grey-headed woodpecker, the Eurasian blue tit, the willow warbler, the long-tailed tit, the blackcap,

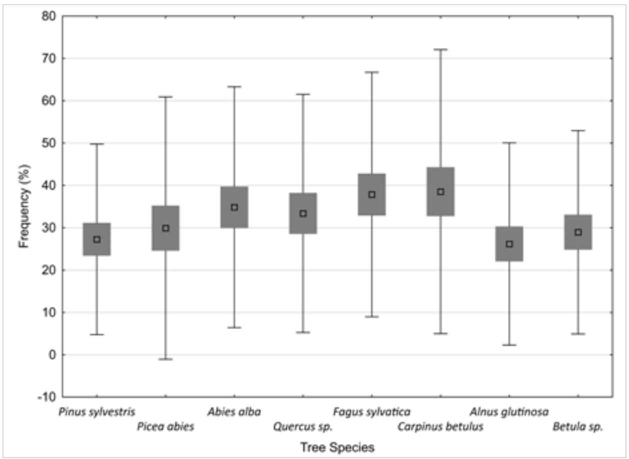

Figure 2. The observations frequency of common forest bird species depending on the dominant tree species in stand

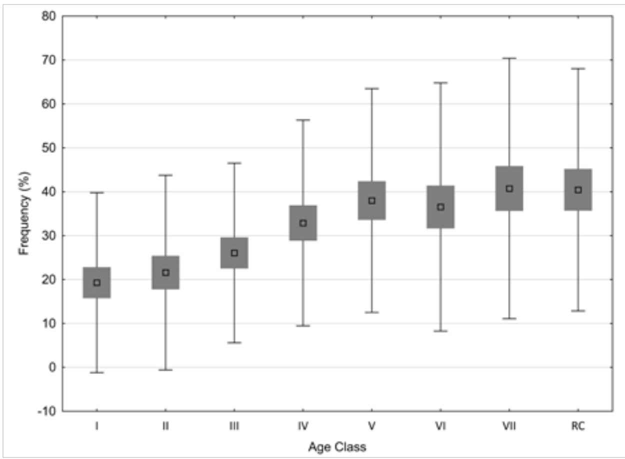

Figure 3. The observations frequency of common forest bird species depending on the age class of the stand

Note: RC – regeneration class.

the Eurasian wren, and the starling. The remaining species (21) were most often found in unmanaged old-growth forest aged 81–140 years (Table 1). The highest average frequency of occurrence for the common bird species was found in stands of age class VII (41%), while the lowest such frequency was found in stands of age class I (19%) (Table 1). The difference in the frequency of the most numerous bird species in groups of stands categorised by age classes was statistically significant ($H = 33.76$, $p < 0.001$). In the two-sided comparison test, significant differences were found between the following pairs of stand age classes: I and V, I and VI, I and VII, I and regeneration class (RC), II and V, II and VII, II and RC (z values in the range 3.18–3.95, $p < 0.05$) (Figure 3).

Discussion and conclusion

The results of this study provide an example of a relatively quick and simple way to determine the general habitat preferences of birds in managed forests. Data for this study were collected using the point-stand bird census method, which is a modification of the classic point count method (Sorace et al. 2000, Sikora and Borecki 2020). An important advantage of this method is the ability to compile large data sets, ensuring representation of the various forest systems occurring in each forest unit. Assigning observations to specific stands enables data analysis in the context of management planning, which – in the Polish forests – is based specifically on stands (SF NFH 2012a). It is also possible to create lists based on such forest administration units as districts or circles. The data collected with the point-stand method enable a quick comparison of stands that differ by one or several inventory features. The system of presenting the results in categories of stands defined on the basis of one valuation feature (forest habitat type, dominant species, age of stand), as used here, can be extended to more complicated stratification divisions of stands, based on a larger number of features, e.g. habitat-age layers. However, the use of more advanced methods of categorisation of stands will result in a need to increase the sample size. Lists of the frequencies of occurrence of birds can form a basis for determining the forest systems that are central to their protection. Reporting on the occurrence of birds with the use of stand lists will enable prediction of the dynamics of potential habitats of selected species in the future (Pretzsch et al. 2008, Szyc et al. 2020). Information on the habitat preferences of particularly valuable species may inform the introduction of different management methods in stands in the relevant habitat, age or species categories. This applies especially to the last two types of categories, which are subject to extensive regulation in managed forests, resulting from the adopted management system. Knowledge of the habitat preferences of birds in terms of age or dominant species will enable the forest ecosystem to be controlled considering the priorities of bird protection.

To date, published studies comparing the status of bird communities in different forest habitat types of a single forest complex have been scarce (Piotrowska and Wołk 1983, Rzępała and Mitrus 1995, Diaz 2006, Dmoch et al. 2012, Charbonnier et al. 2016). The comparison of the results is also made difficult by the fact that in most studies the characteristics of avifauna are based on the number or density of the bird community. In the Białowieża National Park, the highest number of species and the highest density were found in an area where the dominant forest association was ash-alder forest, which is the equivalent of the alder or ash-alder swamp forest habitat type (Wesołowski et al. 2015). Although the numbers of species and densities found in that study are difficult to compare with the results of the current study, due to the differences in the methods used and the longer, five-year study period of the Białowieża Forest study, it is worth considering the differences in each of the forest groups. In the Białowieża Forest, the highest species richness was found for the forests in hydrogenic habitats: alder and ash-alder forests, which were also distinguished by the highest bird density. Slightly lower species richness was found for oak-hornbeam forests, which had a number of species comparable to that in coniferous forests, but densities that were clearly higher than in coniferous forests. In the forests of the Kolbuszowa Forest District, the fertile fresh and moist broadleaved forest habitats clearly dominated in terms of the studied avifauna parameters. The reason for this may be the differences in management between alder swamp forest and broadleaved forest habitats. In the alder habitats, the clear-felling system is used, while the stands in the broadleaved forest habitats are managed by means of complex felling (SF NFH 2012b). Thus, the simplified structure of the clear-felled forest combined with a large share of younger age classes may be one of the reasons for the lower-than-expected species richness of forests in hydrogenic habitats. However, on the landscape (multi-stand) scale, the presence of clear cuttings may translate into an increase in avifauna diversity (Żmihorski 2008). The forests, where felling is carried out in stages, provide better conditions for a greater number of species. Multiple harvesting operations generate greater age diversity of tree groups within the stand and create woodless fragments within the forest, which translates into a greater number of potential ecological niches (Wedeles and Van Damme 1995).

The effect of the dominant stand species on the frequency of occurrence of bird species was largely determined by habitat soil fertility (Rykowski 1999, Jaworski 2011, Wesołowski et al. 2015). The lowest average frequency of the bird species was found in stands in which the dominant species were pine and birch, and, surprisingly, alder – these stands were generally characterised by the dominance of one species and the absence or small proportion of admixture species. Except for alder forests, these stands most often occurred in poor coniferous habitats with low soil fertility and limited capacity to produce complex biocenoses (Jaszczak and Magnuski 2010). In addition, pine, birch and alder are all pioneering species. Therefore, it can be concluded that the systems dominated by pioneering species do not favour high abundance and biodiversity of avifauna. This is especially clear in the case of alder stands which in the study area often occurred also in the fertile moist mixed broadleaved and moist broadleaved forest habitats. Despite their presence in such favourable habitat conditions, this did not translate into higher avifauna indices in alder stands. A higher frequency of the analysed bird species was found in the stands dominated by oak, beech, hornbeam, or fir – however, multi-species stands predominated in this group. Similar relationships have been found in the forests of Western Europe. Research on avifauna communities in Ireland, France and Portugal showed higher species richness in stands composed of oak than in coniferous stands in the first two countries. An inverse relationship was found in the forests of Portugal; however, this country is in the Mediterranean forest zone, while France and Ireland are in the zone of temperate forest (Pedley et al. 2019). In this biome, oak forests generally develop on more fertile soils (Jaworski 2011). Similar research results were presented by Charbonnier et al. (2016), who analysed the biodiversity of birds and bats in six European countries. In that study, a higher diversity of the above groups was found in deciduous forest. However, this pattern applied to temperate forest and boreal forest in Finland, while in the Mediterranean countries a higher diversity was found in coniferous forest. In studies conducted in Great Britain, the highest bird species richness was found in plant communities dominated by hawthorn (quasi-forest plant communities), oaks and willows, and the lowest one in pine and chestnut stands (Hewson et al. 2011).

The effect of stand age was generally expressed in a positive relationship between the parameters characterising the bird community and age class. The birds' preference for older stands is a result of two main factors. The first one is the growth in volume and the increase in the number of old trees with age. The second one is the loosening of the canopy layer, which increases light availability to the lower forest layers, thus enabling the growth of the forest floor vegetation and the lower stand layers, such as the undergrowth and understory. The preference of birds for old-growth stands is common and has been reported in the literature from many countries. Positive relationships between the age of the stand and the presence of birds have been found, for instance, in the forests of Italy (Mentil et al. 2018), Spain (Diaz 2006), Great Britain (Hewson et al. 2011), and Canada (Mahon et al. 2016). Wood stand analyses may provide an alternative to the BACI (Before-After-Control-Impact) system commonly used in ecological studies. In the forestry context, this method includes determination of the ecological condition of the wood stands before and after the forest treatment and identification of the difference. Next, the observed change is compared to control wood stands (with similar characteristics), in which the activity did not take place (Battisti and Marini 2018). In point-wood stand studies, which allow quick collection of numerous samples, the impact of activities may be determined by comparing ecological characteristics of wood stands in various development and management stages. This allows the time, lost in studies performed in the BACI system for waiting for the activity to take place and for its effects to be observed, to be saved.

In sum, conducting a bird census using the tree stand system provides data that enable an analysis to be made in the environmental and management context. These data can be used to analyse the effects of different forest management regimes on bird species occurrence, and from these results the management system can be adapted in favour the general needs of forest birds.

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