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Avian Reporting Rates in Chugcheongnam Province, South Korea Depend on Distance from Forest Edge, Size of Trees, and Size of Forest Fragments

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Abstract: Forests provide bird communities with various resources, including food and habitats. Thus, forest attributes, such as size, structure, and species composition, influence the distribution and dynamics of bird species. This study was conducted to examine the association between forest condition, bird species abundance, and diversity within Chungcheongnam Province, South Korea. Zero-inflated binomial regression models were used to analyze a total of 1646 sampling points of abundance and diversity. Forest area, distance to forest edge, and tree size class were selected as covariates. Negative associations between forest area and overall bird abundance and species richness were indicated, whereas distance to forest edge was not a significant factor. This insignificance may be attributed to the relatively small, fragmented, and homogenous forest areas across the studied region. Results for individual bird species indicated that six out of the 35 major bird species had significant associations to the forest edge and three species showed a preference for the interior of the forest. The results of this study imply that other factors, such as food availability and biotic interaction, are more important when determining habitat preference in a relatively homogenous area with a long history of human disturbance.

Keywords: bird species diversity; forest management; wildlife management; fragmentation; habitat preference

1. Introduction

Since the 1960s, South Korea has become one of the most urbanized countries in the world [1,2]. During this period of rapid development, many forested habitats were lost or fragmented [3]. Because the changes in land cover and land-use patterns affect the various ecosystem functions substantially [4], habitat loss and fragmentation are known to be the primary driving forces behind the global biodiversity crisis [5–8]. The question regarding the ecological effects of fragmented forests has yielded a series of research studies to determine the relationship between forest fragmentation and fauna and flora [9], not only in South Korea (e.g., [10,11]) but also around neighboring countries such as Japan and China (e.g., [12–15]). However, there are still knowledge gaps, especially at larger spatial scales such as landscape or regional levels [4,16].

Forests within landscapes have spatial configurations based on their structural and compositional conditions [17]. Structural and compositional attributes are often characterized by various properties such as tree size and cover [18], understory vegetation [19], abundance and distribution of snags [20], and topography [19,21]. The complexity and spatial pattern of these attributes can alter microclimates and the amounts of available resources [22,23], resulting in an array of micro and macro habitats, influencing the distribution and dynamics of wildlife populations [5,24–26].

As an example of spatial configuration influence on wildlife species distribution, it is generally assumed that forest area and bird species diversity have a positive relationship [27]. Such relationships have been found in Japan [27,28] and South Korea [29]. Natuhara and Imai [27] reported a positive relationship between forest bird richness in urban woods in Osaka Prefecture, Japan. Yamaura et al. [28] also reported a positive relationship between plantation area and bird species richness in central Japan. In South Korea, Park and Lee [29] similarly found a positive relationship in urban forests in Seoul, however, the responses of birds to spatial configuration of the habitat may be species-specific. Ornithologists categorize specialized species of forest birds into two broad categories according to their habitat preference: edge and forest-interior species [25,30–32]. In Japan, Kurosawa and Askins [33] suggested that forest interior species have a positive relationship with forest area whereas forest edge species are negatively related with forest area. In South Korea, similar classifications are anecdotal and have not previously been examined quantitatively.

Understanding species habitat preference is important for several management and conservation reasons. First, effective conservation plans for specialized species necessitate quantitative evaluation of the species [34]. Thereby, knowledge can be used as an important tool for species diversity management [35]. Moreover, responses of bird communities often play a role in gauging the impacts of natural or anthropological disturbance as well as the efficacy of forest management and restoration efforts [36,37]. At a landscape or a regional level, this information can be used to determine priority areas [38] and to maintain and build habitat networks [39].

The Biotope Mapping project in South Korea's Chungcheongnam Province provides a unique opportunity to address these topics. Between 2008 and 2014, every biotope throughout the province was classified, identified, and mapped. As a part of the project, intensive and extensive data sampling was conducted for wildlife (including bird species, with over 2000 sampling points) simultaneously. Capitalizing on the abundance of sampling data, we can establish effective and feasible forest management plans that account for the responses of bird species within the target area/region.

The study objective was to investigate the relationship between the avian community and forest condition. In particular, forest area, tree size, and distance from the forest edge were examined in relation to overall species diversity and abundance. We hypothesized that (1) forest area, deciduous forest, larger tree size class, and longer distance from the forest edge have positive associations with overall species diversity and abundance, and (2) each species has discernable preferences for those forest condition factors.

2. Methods

2.1. Study Sites

The study was conducted in the Province of Chungcheongnam, located in the western part of South Korea (35°00'~37°06' N, 126°13'~127°63' E). The total area of the province is 8226 km². Approximately 50% (4080 km²) of the total land area consists of young forests (~80% of forests have been reforested during the last four decades), with the average stocking volume of 139 m³/ha [40]. Coniferous, deciduous, and mixed forests occupied 37%, 30%, and 27% of the total forest area, respectively. The remaining land areas (31% of total area) are primarily used for agriculture, including rice paddies and vegetable fields [41].

The climate of Chungcheongnam is characterized as continental with cold winters and hot and humid summers [42]. The 30-year average temperature of Chungcheongnam is approximately 13 °C,

with the minimum and maximum monthly average temperatures being 0 °C (January) and 27 °C (July), respectively [40]. The average annual precipitation measured from 1981 to 2010 was approximately 1310 mm. This precipitation was mostly concentrated in the summer (July to September) [43].

2.2. Data Collection and Analyses

Field sampling was conducted by point counts between 2005 to 2011. To investigate assemblage composition, sampling sites across Chungcheongnam Province were randomly selected using ArcGIS 10.1 (ESRI, Redlands, CA, USA) (Figure 1). A total of 2024 sampling points were assigned with sufficient buffers to avoid counting duplications. Line transects were deployed [44], which involved walking in a straight line in a random direction for 20 minutes. During this time, the number and species of birds were observed in each sampling transect. Data were collected by audiovisual methods (with binoculars and identifying bird calls) through the morning. Three skilled observers conducted the survey consistently throughout all field samplings. Since this study focused on forested areas, sampling points (i.e., starting points of the transects) located outside of these areas were excluded.

Figure 1. Sampling sites in Chungcheongnam Province.

Using ArcGIS 10.1 (ESRI, Redlands, CA, USA), forest information within the sampling sites was extracted from the Korea Forest Cover Type Map at a scale of 1:5000 (Korea Forest Service, Daejeon, South Korea). Data for forest area, distance to nearest forest edge, and tree size classes were extracted for each sampling point (Table 1). This study utilized the Korea Forest Cover Type Map's tree size classification and forest types. The size classes were classified with the median diameter at breast height (DBH) of trees in the stand: (a) <6 cm, size class 0; (b) 6–18 cm, size class 1; (c) 18–30 cm, size class 2; and (d) >30 cm, size class 3. The forest types were classified into coniferous, deciduous, and mixed forests. Other minor forests types (e.g., bamboo forest) were excluded due to no sampling data (Table 1). These variables were used as explanatory variables throughout the analyses.

Table 1. Description of forest condition variables.

Variables (Units)	Notation	Min.	Max.	Mean	Note
Forest area (m ²)	Area	229	1,412,772	52,085	Log-transformed
Forest type (proportion: %)					Categorical variable
Coniferous	F_type1			37	Reference level
Deciduous	F_type2			30	
Mixed-species	F_type3			27	
Others	F_type4			6	Not sampled
Distance to forest edge (m)	Dist	0	88	14.5	
Tree size class (No. sites)					Categorical variable
0	SizeCL0			63	<6 cm
1	SizeCL1			412	6–18 cm
2	SizeCL2			1154	18–30 cm; reference level
3	SizeCL3			17	>30 cm

Overall species richness (number of bird species) and abundance (number of individual birds) were used to evaluate the effect of forest conditions on bird communities. Species richness and abundance were analyzed through a generalized linear modeling approach. Negative binomial distribution was introduced to incorporate count data and overdispersion.

For analysis at the individual species level, bird species detected at fewer than 50 plots were excluded from individual species analyses, which consequently involved 35 species. Zero-inflated negative binomial regression was employed to model bird count data and handle the excessive zero observations [45,46]. A standard negative binomial generalized model was used if the zero-inflation model failed to find the optimum solution. Log-transformed distance to forest edge, log-transformed forest area, and tree size classes were tested as covariates for parameter estimation for both community and species level analyses (i.e., count and zero-inflation processes). This study used the GENMOD procedure of SAS statistical software 9.4 (SAS Institute Inc. Cary, NC, USA) to fit the models.

3. Results

This survey recorded a total of 140 bird species. A total of 1646 sampling sites were used for analysis. On average, 7.0 species and 18.7 individuals were recorded per plot. There was a negative association between bird species abundance and log-transformed forest areas (Figure 2). Tree size class 3 had higher bird counts than forests with the tree size class 2 (Table 2). Bird species richness was also negatively associated with forest area. However, the tree size class 3 and coniferous stands were not statistically significant ($p = 0.0649$ and 0.0774 , respectively). There was insufficient evidence to determine the effect of distance to forest edge for overall species richness and abundance ($p = 0.4199$ and 0.7685 , respectively; Table 2).

Figure 2. Relationships between forest area and (a) abundance and (b) species richness. Note that the x-axes for both figures and y-axis for abundance were depicted through logarithmic scales for readability (base: 10).

Table 2. Test result (negative binomial regression model) summary for overall species abundance and richness. Notation: df: degrees of freedom; SE: standard error; Ln: natural logarithm; Area: forest area; Dist: distance to forest edge; F_type: forest type; SizeCL: tree size class (for further details, refer to Table 1 and the main text).

Variables	df	Abundance			Richness		
		Estimate	SE	p-Value	Estimate	SE	p-Value
Intercept	1	2.9111	0.0376	<0.0001	1.7978	0.0229	<0.0001
Ln (Area)	1	−0.1539	0.0253	<0.0001	−0.0458	0.0148	0.0020
Dist	1	0.0074	0.0252	0.7685	−0.0119	0.0148	0.4199
F_type2	1	0.0497	0.0494	0.3145	0.0523	0.0296	0.0774
F_type3	1	0.0449	0.0713	0.5289	0.0467	0.0426	0.2736
SizeCL0	1	0.0785	0.1193	0.5105	0.0559	0.0706	0.4283
SizeCL1	1	−0.0615	0.0529	0.2451	0.0180	0.0316	0.5686
SizeCL3	1	0.7935	0.2224	0.0004	0.2369	0.1283	0.0649

Of the 35 major bird species, significant negative associations of forest area with individual bird counts were observed in nine out of 35 bird species (Table 3). The species that were found frequently in shrubs or farming areas were: the Oriental turtle dove (*Streptopelia orientalis*), Eurasian tree sparrow (*Passer montanus*), and vinous-throated parrotbill (*Sinosuthora webbiana*). Meanwhile, positive associations of bird count with forest area were significant for four species: the common kestrel (*Falco tinnunculus*), Indian cuckoo (*Cuculus micropterus*), grey-backed thrush (*Turdus pallidus*), and yellow-throated bunting (*Emberiza elegans*). Analysis of the Eurasian tree sparrow showed inconsistent results for forest area between count and zero-inflation processes.

Table 3. Test result summary for individual species abundance.

Species	Scientific Name	Ln (Area) ¹	Dist	SizeCL0	SizeCL1	SizeCL3	Test Type ²
Common kestrel	<i>Falco tinnunculus</i>	0.661 ** ³	−0.840	2.527 **	−0.230	−4.172	NB
		1.127	−1.641 **	1.727	−1.014	3.784	Zero-process
Ring-necked pheasant	<i>Phasianus colchicus</i>	−0.055	−0.067	0.207	−0.036	0.213	NB
Oriental turtle dove	<i>Streptopelia orientalis</i>	−0.241 ***	0.006	0.048	0.114	−0.463	NB
Indian cuckoo	<i>Cuculus micropterus</i>	0.751 ***	−0.934 **	1.059	0.499	−7.415	NB
		1.280 **	−1.337 *	3.044	0.690	−8.309	Zero-process
Broad-billed roller	<i>Eurystomus orientalis</i>	0.098	0.320 *	−0.747	0.187	2.613 *	NB
Japanese pygmy woodpecker	<i>Dendrocopos kizuki</i>	0.231	−0.392	1.239 *	0.587	1.824 *	NB
		0.497	−0.430	1.718 *	1.449	2.160	Zero-process
Great spotted woodpecker	<i>Dendrocopos major</i>	−0.178 *	0.057	−0.200	0.150	1.587 **	NB
Grey-headed woodpecker	<i>Picus canus</i>	−0.381	−0.022	0.484	−1.009 *	−6.694	NB
		−1.321 **	−0.187	1.385	−1.477	3.491	Zero-process
Grey wagtail	<i>Motacilla cinerea</i>	−0.183	−0.070	0.051	−0.684	−22.127	NB
Olive-backed pipit	<i>Anthus hodgsoni</i>	−0.165	0.069	0.775	0.593	−0.363	NB
Brown-eared bulbul	<i>Microscelis amaurotis</i>	−0.048	−0.049	0.516 **	−0.004	−0.223	NB
Bull-headed Shrike	<i>Lanius bucephalus</i>	−0.029	−0.100	0.184	0.238	−21.743	NB
Daurian redstart	<i>Phoenicurus aureus</i>	−0.154 **	−0.083	0.593 *	−0.067	−1.030	NB
Scaly thrush	<i>Zoothera dauma</i>	−0.177	0.353 **	0.144	0.271	−22.056	NB
Grey-backed thrush	<i>Turdus hortulorum</i>	0.098	−0.010	−0.188	−0.394	−0.302	NB
Pale thrush	<i>Turdus pallidus</i>	0.228 *	−0.061	0.735	0.415	−1.389	NB
		0.844 *	−0.167	2.648	2.667 *	−17.408	Zero-process
Vinous-throated parrotbill	<i>Sinosuthora webbiana</i>	−0.222 **	0.109	0.727 *	0.077	−0.491	NB
		0.026	0.158 *	−0.059	−0.256	−0.727	Zero-process
Yellow-browed warbler	<i>Phylloscopus inornatus</i>	−0.251	−0.010	0.197	0.332	1.746	NB
Asian stubtail	<i>Urosphena squameiceps</i>	0.165	−0.017	−0.827	−0.452	−21.6280	NB
Eastern-crowned warbler	<i>Phylloscopus coronatus</i>	0.151	0.403 **	−22.772	0.240	1.779 *	NB
Long-tailed tit	<i>Aegithalos caudatus</i>	−0.028	−0.057	0.035	0.133	0.016	NB

Table 3. Cont.

Species	Scientific Name	Ln (Area) ¹	Dist	SizeCL0	SizeCL1	SizeCL3	Test Type ²
Marsh tit	<i>Poecile palustris</i>	0.261 **	−0.046	0.625	0.324 *	−0.322	Zero-process
Coal tit	<i>Periparus ater</i>	−0.056	−0.056	0.291	−0.200	0.754	NB
Great tit	<i>Parus major</i>	−0.150	0.024	−0.623	−0.255	2.1570 *	NB
Varied tit	<i>Sittiparus varius</i>	−0.062 *	−0.031	0.052	−0.030	0.462 *	NB
		−0.099	0.110 *	−0.610	−0.194	−0.356	NB
		−0.370 **	0.216 *	−0.704	−0.330	0.464	Zero-process
Eurasian nuthatch	<i>Sitta europaea</i>	−0.044	0.084	−0.300	−0.841 **	−0.612	NB
Yellow-throated bunting	<i>Emberiza elegans</i>	−0.025	−0.194 **	0.138	0.137	−1.037	NB
		0.158 *	−0.221 *	−0.683	−0.183	−0.161	Zero-process
Black-faced bunting	<i>Emberiza spodocephala</i>	−0.236	−0.004	0.508	0.052	−25.395	NB
Eurasian tree sparrow	<i>Passer montanus</i>	−0.139 *	−0.123 *	−0.469	−0.283 *	−1.232	NB
		0.157 *	−0.014	0.343	0.249	0.888	Zero-process
Black-naped oriole	<i>Oriolus chinensis</i>	−0.026	0.030	−1.346	−0.034	0.666	NB
White-cheeked starling	<i>Sturnus cineraceus</i>	−0.152	0.071	0.032	−0.401	−21.847	NB
Eurasian jay	<i>Garrulus glandarius</i>	0.010	0.003	0.183	0.014	−0.452	NB
Azure-winged magpie	<i>Cyanopica cyanus</i>	−0.143	0.050	−0.911	0.115	−1.802	NB
Long-billed crow	<i>Corvus macrorhynchos</i>	−0.462 **	0.132	3.075 ***	−0.216	0.729	NB
Common buzzard	<i>Buteo buteo</i>	−0.362 **	0.047	−1.005	0.192	−8.249	NB

¹ Notation: Ln: natural logarithm; Area: forest area; Dist: distance to forest edge; SizeCL: Tree size class 0–3 (for further details, refer to Table 1 and the main text). ² Species reported only with NB statistics were analyzed by negative binomial model. Species reported both with NB (for count data) and zero-process (for zero-count) were analyzed by zero-inflated modelling approach. ³ Significance level: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.1$.

Observation counts for nine species showed significant associations with distance to nearest forest edge (Table 3). Observation counts for the broad-billed roller (*Eurystomus orientalis*), scaly thrush (*Zoothera dauma*), yellow-browed warbler (*Phylloscopus coronatus*), varied tit (*Sittiparus varius*), and vinous-throated parrotbill showed a tendency to increase as distance to forest edge increased. In contrast, four of the nine species showed a negative association with distance: the common kestrel, Indian cuckoo, yellow-throated bunting, and Eurasian tree sparrow.

Forests with very small (size class 0) or very large classes (i.e., size class 3) of trees had higher bird counts. In both cases, there were more individuals observed of six species than in the size class 2. However, size class 1 showed inconsistent results when compared with size class 2 (Table 3).

Overall, fifteen of the 35 major bird species showed statistically significant associations with either forest area or distance to forest edge. The broad-billed roller, pale thrush (*T. pallidus*), and eastern crowned warbler (*P. coronatus*) coincide with the general classification scheme for forest interior species. Frequently, those species were observed more in forests with larger areas and bigger size classes, and were also located further from the forest edge. In contrast, the Oriental turtle dove, great spotted woodpecker (*Dendrocopos major*), Daurian redstart (*Phoenicurus auroreus*), common buzzard (*Buteo buteo*), long-billed crow (*Corvus macrorhynchos*), and great tit (*Parus major*) can be regarded as edge species. However, several species (six species with significant results) exhibited somewhat contradictory results when analyzed in relation to forest area and distance. For example, observational frequency of the common kestrel (*F. tinnunculus*) was not significantly affected by distance from forest edge.

It is also notable that there were observational differences in birds within similar species groups. For example, observations of the great spotted woodpecker were significantly, and negatively, associated with larger forest area. In contrast, observation counts of the Japanese pygmy woodpecker (*D. kizuki*) were not affected by forest area. Only large tree size class (i.e., size class 3) was associated with the number of woodpeckers counted. Similar results can also be found among tits: the coal tit (*Periparus alter*), great tit, and varied tit (Table 3).

4. Discussion and Conclusions

Forest characteristics, including size, have long been known to be significant factors affecting avian communities. Moreover, the general assumption regarding the relationship between bird species diversity and forest size is that reduced forest area causes a consequential decrease in species diversity [4,30,47–49]. However, the results of this study were unexpected in that forests patches with larger areas tended to have lower species diversity. Presumably, this can be attributed to the fact that forest sizes across the study region had been fragmented for a long time, rendering the average forest size quite small (Table 1). In the southern forests of the United States, McIntyre [47] suggests that an approximately 10–13 ha patch of forest is the threshold size that can provide similar forest conditions to a contiguous forest. In addition, she also emphasizes that there were considerable variations in avian community responses between individual patches and forest patch sizes by individual patches. A possible interpretation of these assertions is that a core habitat that has not been affected by external conditions requires a certain amount of edge habitat as a buffer [49]. However, the average forest patch size in this study region was only approximately 5 ha. Therefore, the fragmented forest patches within the study region might not hold enough larger patch sizes to detect the effects of the core habitats.

Furthermore, due to regional reforestation about 40 years ago [40], the composition and structure of the forests in this study region might be relatively simple and homogeneous [50]. As a result, even a large-sized forest in this region might provide less diverse habitats and resources. Freemark and Merriam [4] argue that habitat heterogeneity can be more important than forest size for edge species. Therefore, it can be hypothesized that small-sized forest patches, generated by various and intense human influences, have created a more diverse array of habitats (including forest edge) and food resources [37]. Thus, this increase in habitat and resource diversity results in higher avian species diversity than in larger forest patches. As a conservation implication, the establishment of

strategies to increase bird species diversity should not only take into account forest patch size but also habitat heterogeneity.

In this study, the positive relationship between tree size and avian diversity and abundance also reveals an optimistic view. Large trees are essential to some species, especially for cavity-nesting birds such as woodpeckers [51–53]. Therefore, avian communities within the study area would respond positively to an increase in tree size over time and continued forest management into the future. Furthermore, an increase in abandoned agricultural lands (e.g., rice paddies) due to socio-economic factors within the study region would create new ecological characters and consequences [54]. Therefore, further research and monitoring efforts on avian communities is needed.

To conserve species diversity, understanding habitat preferences for specific species plays a key role in developing forest management plans [20]. Without consideration of habitat suitability for target species, management efforts or plans for the species, such as constructing forested or green corridors, may limit their effectiveness [55]. To a certain extent, this study provides useful information for the conservation or management of several bird species by evaluating bird responses to shifts in habitat conditions.

In this study, several bird species showed notable trends of occurrence when related to forest size and distance to forest edge. If this study classified a species showing negative associations with forest size and/or distance to forest edge as a forest-edge species, then the forest-edge species were more distinctly and abundantly identified than the forest-interior species. This result coincides with the previously stated general expectation and the results of past studies [38,56]. The current study's findings can provide forest land managers with useful information to make decisions when accounting for the responses of those forest edge and interior bird species.

Contradictory results to the forest edge-interior species classification scheme for six bird species were also discovered in this study. The implication is that those species' occurrences were more strongly affected by the availability of other resources (e.g., food) [57], biotic interactions (e.g., predation) [58], or establishing territory [47] rather than habitat itself. For example, the vinous-throated parrotbill, which is known as an edge species, showed a conflicting result. The vinous-throated parrotbill had a higher probability of occurrence as distance to the forest edge increased. However, the vinous-throated parrotbill showed a strong preference for living in dense shrubs, which were more likely found near the forest edge area. Also, this may be an indication that the forest edge-interior species scheme is too simplistic in its implementation within the study region. For example, where an area is small and fragmented, a certain forest patch could consist of mostly large-size trees. Conversely, a juvenile forest can occupy a much larger area due to the area being recently replanted. In this case, Imbeau et al. [32] suggest that successional stages in forest growth play an important role in habitat preference for bird species. Furthermore, a long history of agriculture and urbanization in the study region has distorted the natural variation [47]. Consequently, the true effects of the tested factors might be masked by such confounding ramifications [59,60].

Interestingly, according to habitat conditions, differences were found in the frequency of bird observations among similar species. The results, presumably, represent niche partitioning. For example, woodpeckers and tits showed slightly different occurrence patterns within similar species groups (Table 3). This might be explained in part by the species development of preferred habitat due to the long history of human land use, where even smaller forest patches can support a high number of bird species in the study region [61]. Furthermore, this also suggests that conservation of old-growth and large-sized forests within the region is important to maintain bird species diversity [62].

There are several potential limitations of this study that must be considered when interpreting the results. First, this study employed point count sampling instead of nest surveys. Therefore, concomitant sampling bias [31,63], imperfect detection in practice [64], and subsequent diversity underestimation must be taken into account [47]. In addition, the modeling framework used in this study (i.e., species distribution models) assumes equilibrium between birds and environmental factors [65,66]. Thus, the ability to interpret results regarding recently disturbed forests or migratory

birds (in this study, the Indian cuckoo, eastern crowned warbler, and scaly thrush) might be limited [67]. Finally, improved model performance could be obtained by adding potentially influential explanatory variables, such as seasonality [47], forest structure, patch connectivity [68], shape complexity [69], and biotic interactions [70]. These variables were not examined in this study due to a lack of data availability.

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