



Comparative Analysis of Avian Assemblages between an Urban Ecological Restoration Site and an Adjacent Forest: The Case of Mt. Sorasan Restoration Site, Iksan, Korea

Tae-Young Choi*^{ORCID}, Jaegyung Cha^{ORCID}, Dain Kang^{ORCID}, Ho-Gyeong Moon^{ORCID}

National Institute of Ecology, Seocheon, Korea

ABSTRACT


Although urban ecological restoration projects are actively implemented in response to urbanization, research evaluating their ecological effects in relation to adjacent natural ecosystems remains limited. This study assessed the ecological impacts of an urban restoration project by comparing wild bird assemblage structures between the Mt. Sorasan Nature Garden (Jayeon-madang) project, an urban ecological restoration site in Iksan, South Korea, and its adjacent existing forest. The restoration site, in its early post-construction phase, had approximately 45% of its area planted with woody species, including pines. Wild bird surveys were conducted in both habitats over one year (May 2017–April 2018), followed by statistical analysis. Results showed significant differences in bird assemblage structure between the sites (permutational multivariate analysis of variance, $P < 0.001$). The adjacent forest, supported by a stable, long-established woodland, exhibited higher species diversity ($H' = 3.07$) and was characterized by foliage gleaners (e.g., Paridae) and bark/trunk foragers (e.g., Picidae). In contrast, the restoration site, with small trees and insufficient cover due to its recent establishment, had lower species diversity ($H' = 2.38$) and limited influx of forest-dwelling birds. However, its open grasslands and wetlands provided feeding and resting habitats for aquatic and ground-foraging birds. In conclusion, although the early-stage restoration site remains functionally limited as a forest, it complements the adjacent forest by creating heterogeneous habitats, thereby enhancing overall urban avian diversity. This study highlights the need for future restoration efforts to extend beyond simple tree planting and incorporate long-term habitat management that accounts for vegetation succession processes.

Keywords: Foraging guilds, Indicator species, Multivariate analysis, Restoration effectiveness

Introduction

The rapid global expansion of urban areas accelerates habitat loss and fragmentation, leading to the isolation of habitats within cities and a reduction in biodiversity (Hagen *et al.*, 2017). Many studies have predicted a significant future loss of biodiversity if this urban expansion continues (Newbold *et al.*, 2015; Simkin *et al.*, 2022). In response to this problem, the necessity of ecological

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***Corresponding author:** Tae-Young Choi
e-mail ty_choi2016@nie.re.kr
 <https://orcid.org/0000-0002-3543-1439>



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restoration projects to restore degraded natural environments and recover ecological functions within cities has been internationally emphasized. The United Nations (UN) declared 2021–2030 as the UN Decade on Ecosystem Restoration, and both the Kunming–Montreal Global Biodiversity Framework (Convention on Biological Diversity, 2022) and the European Union (EU) Biodiversity Strategy for 2030 (European Commission, 2021) established ecological restoration as a key objective. In South Korea, many urban ecological restoration projects have been promoted, and institutional implementation of natural environment restoration projects was strengthened with the revision of the Natural Environment Conservation Act in 2021.

However, evaluations of the ecological effects of these restoration projects remain insufficient (Ji *et al.*, 2024; Lee, 2023). In Korea, the Nature Garden (Jayeon-madang) ecological restoration project, promoted since 2012 as an ecological restoration initiative, has resulted in the completion of a total of 18 sites completed as of 2019 (Architecture and Urban Research Institute, 2019). However, research concerning the effectiveness of such restoration efforts is still lacking. Only a few studies have been reported to date, such as the heat reduction effect of urban ecological restoration sites (Choi *et al.*, 2017), the origin of planted species (Lee *et al.*, 2020), and comparison of wild bird assemblages before and after restoration (Kim *et al.*, 2020).

Against this backdrop, this study surveyed wild bird assemblages to evaluate the restoration effects of an urban ecological restoration project. Wild birds serve as indicator species for measuring ecosystem health due to their high mobility and sensitivity to environmental changes (Gregory & van Strien, 2010). Habitat isolation and degradation caused by urbanization directly impact the movement routes, breeding, and foraging success of wild birds, resulting in a reduction in the abundance of specific species and the proliferation of a few species highly adapted to urban environments (Bellocoq *et al.*, 2017; McKinney, 2006; Valente-Neto *et al.*, 2021). Prior research has focused on identifying factors influencing bird species composition, occurrence patterns, habitat structure, impervious surface cover, and landscape heterogeneity due to urbanization (Souza *et al.*, 2019). These wild bird assemblage metrics are effective indicators for assessing the ecological quality and functionality of restored habitats.

Therefore, this study comparatively analyzed the wild bird assemblage structure between an artificially created urban ecological restoration site and its adjacent, existing natural forest ecosystem. The study site, Mt. Sorasan Nature Garden was established in 2015. This study aimed to identify the habitat functions and limitations of the restoration area linked to the adjacent pine forest for wild birds through surveys and analyses conducted during the

initial restoration period (2017–2018). Furthermore, it sought to establish baseline data for long-term monitoring and provide scientific evidence for the improvement of ecological restoration projects.

Materials and Methods

Overview of the study sites

The study was conducted targeting the Mt. Sorasan Nature Garden, an urban ecological restoration site located in Iksan, Jeonbuk Special Self-Governing Province, and its adjacent forest (Fig. 1). The total survey area covered approximately 8 ha, comprising the restoration site (39,757 m²) and the adjacent forest (40,815 m²), which were nearly similar in size. The restoration site was previously an area of farmland, buildings, and reed wetlands. Following the restoration project, completed in December 2015, the site was configured as a mixed habitat including pine-dominant woody planting (44.8%) linked to the adjacent forest, grassland (20.1%), and wetland (24.9%). The main planted woody species included *Pinus densiflora* (24.2%), *Chionanthus retusus* (6.6%), *Celtis sinensis* (6.1%), and *Sorbus alnifolia* (2.6%), all of which supply preferred food sources for wild birds. At the time of the survey in 2017, the short period since restoration resulted in minimal tree growth and vegetation that exhibited a

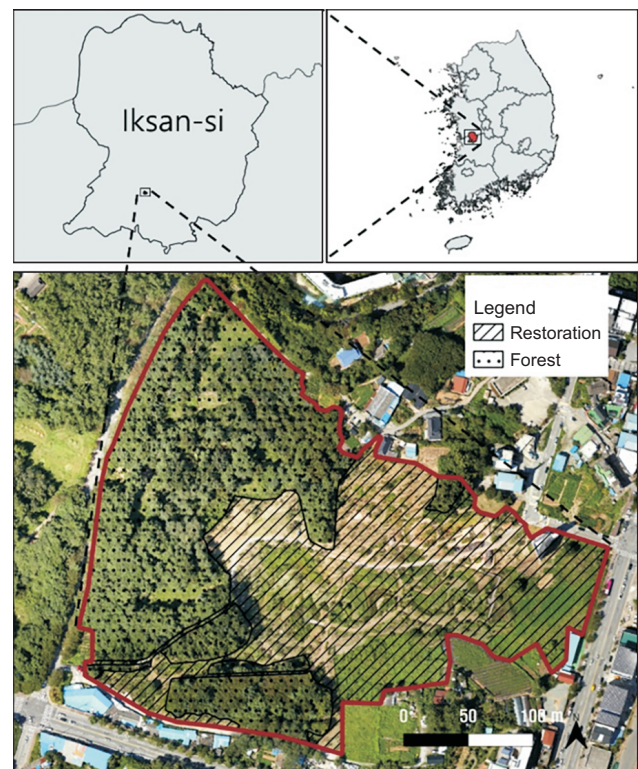


Fig. 1. Location of study site.

single-layered structure with sparse shrub layer planting. In contrast, the adjacent forest was a multi-layered woodland that distinctly contrasted with the restoration site. It was dominated by mature woody vegetation, accounting for approximately 90% of the area, primarily featuring *Pinus densiflora* (47.5%), *Robinia pseudoacacia* (11.8%), *Prunus* spp. (9.4%), and *Quercus acutissima* (7.9%), and possessed high vegetation volume across vegetation layers (Choi *et al.*, 2019) (Table 1; Fig. 2).

Wild bird survey methods

The survey period was one year, from May 2017 to April 2018, with one day of surveying conducted monthly, totaling 11 surveys. The line-transect method was used, following a predetermined route after sunrise on clear days, and observed species were identified by sight with binoculars and by calls. The survey intensity was controlled by investigating the restoration site (4 ha) and the adjacent

forest (4 ha), which are nearly similar in size, for the same amount of time (30 minutes each). The species name and abundance of all wild birds encountered during the survey were recorded, and species classification followed the National Species List of Korea (National Institute of Biological Resources, 2024).

Analysis methods

To compare the bird assemblage characteristics between the two habitats, the total species richness and total abundance for the overall period and by season were calculated. The Shannon–Weaver species diversity index (H') was calculated to assess the diversity of each habitat. Furthermore, foraging guilds were analyzed to understand the influence of habitat structure on bird occurrence. Foraging guilds were categorized based on the primary foraging space and behavior: aquatic forager (AF), aerial insectivore (AI), bark/trunk forager (BF), foliage gleaner

Table 1. Area and ratio by actual vegetation type

	Type	Area (m ²)	Ratio (%)
Forest	F1. <i>Pinus densiflora</i>	19,241	47.5
	F2. <i>Robinia pseudoacacia</i>	4,797	11.8
	F3. <i>Prunus yedoensis</i>	3,809	9.4
	F4. <i>Quercus acutissima</i>	3,209	7.9
	F5. <i>Pinus rigida</i>	2,300	5.7
	F6. <i>Castanea crenata</i>	2,295	5.7
	F7. <i>Populus tomentiglandulosa-Castanea crenata</i>	482	1.2
	F8. Bamboo	590	1.5
	F9. Cemetery	3,846	8.7
	F10. Field	246	0.6
	Subtotal	40,815	100.0
Restoration	R1. <i>Pinus densiflora</i>	9,624	24.2
	R2. <i>Chionanthus retusus</i>	2,625	6.6
	R3. <i>Sorbus alnifolia</i>	1,026	2.6
	R4. <i>Celtis sinensis</i>	2,407	6.1
	R5. <i>Salix koreensis</i>	1,158	2.9
	R6. <i>Prunus yedoensis</i>	862	2.2
	R7. <i>Diospyros kaki</i>	104	0.3
	R8. Tall grass area	2,247	5.6
	R9. Lawn	1,546	3.9
	R10. Other grassland	4,179	10.5
	R11. <i>Phragmites australis</i>	6,349	16.0
	R12. <i>Typha orientalis-Zizania latifolia</i>	3,399	8.6
	R13. Water surface	155	0.4
R14. Facilities	4,076	10.3	
	Subtotal	39,757	100.0

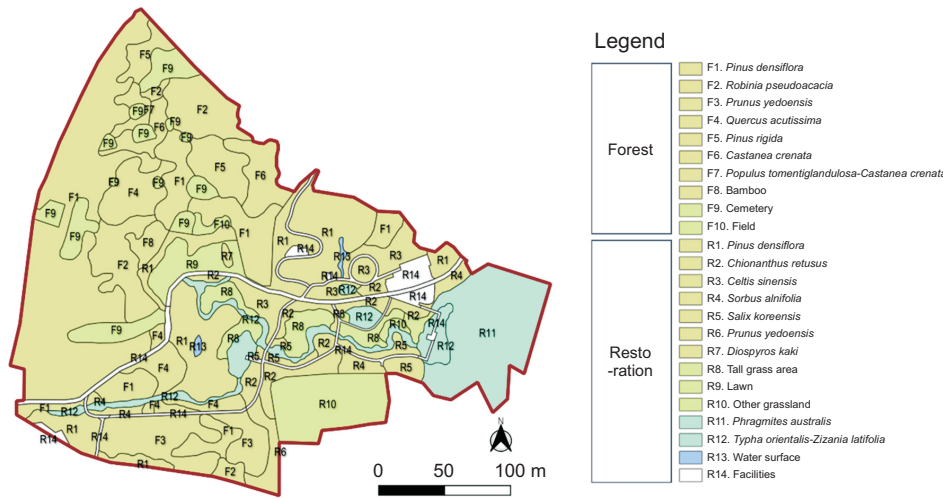


Fig. 2. Status map of actual vegetation type.

Table 2. Maximum species richness and abundance of avian assemblages in restoration and forest

	Restoration					Forest				
	Spring	Summer	Autumn	Winter	Total	Spring	Summer	Autumn	Winter	Total
Richness	14	13	12	16	28	20	19	17	19	30
Abundance	82	101	71	82	179	84	91	83	109	156
Species diversity (H')	1.99	1.59	1.72	1.95	2.38	2.68	2.51	2.52	2.67	3.07

(FG), ground forager (GF), and omnivore/generalist (OG).

Multivariate statistical analysis was performed to quantitatively verify the differences in wild bird assemblage structure between the two habitats. Permutational multivariate analysis of variance (PERMANOVA), a non-parametric multivariate analysis of variance, was applied to test for statistically significant differences in the bird assemblage structure between the restoration site and the forest. This method is suitable for ecological data that does not satisfy the assumption of normality and is a robust method for testing differences between groups based on distance metrics. Non-metric Multidimensional Scaling (NMDS) was used to visually complement the PERMANOVA results and represent the degree of similarity between assemblages in a two-dimensional space. Finally, similarity percentages (SIMPER) analysis was performed to identify which species contributed most significantly to the observed differences in assemblage structure between the two habitats.

Results and Discussion

Comparison of wild bird assemblage characteristics

During the survey period, a total of 28 species (179 individuals) were observed in the restoration site and 30 species (156 individuals) in the forest, indicating a similar scale of occurrence between the habitats (Table 2). How-

ever, the overall Shannon–Weaver species diversity index (H') was significantly higher in the forest (3.07) than in the restoration site (2.38), suggesting a more even occurrence of diverse species in the forest.

Seasonal comparison of assemblage characteristics revealed that the forest maintained relatively stable richness (17–20 species), abundance (83–109 individuals), and diversity (H'=2.51–2.68) across all four seasons. In contrast, the restoration site exhibited lower richness (12–16 species), abundance (71–101 individuals), and diversity (H'=1.59–1.99) compared to the forest, with a pronounced difference in richness and diversity, suggesting that the occurrence was concentrated in a few species. This result is attributed to the restoration site's simple and open vegetation structure in its early stage, making it unstable for the habitation of diverse birds.

The foraging guild analysis showed a distinct difference in the utilization of foraging space between the two bird assemblages (Table 3). The mean abundance of GFs in the restoration site (36 individuals) was significantly higher than in the forest (21.25 individuals), although species richness was similar (4.25 vs. 4.50 species). This suggests that the simple vegetation structure and extensive grassland environment of the restoration site favored the habitation of GFs such as the tree sparrow (*Passer montanus*). Conversely, FG showed significantly higher richness (6.75 species) and abundance (34.75 individuals) in the forest

Table 3. Species richness and abundance of avian foraging guilds in restoration and forest

	Restoration		Forest	
	Richness	Abundance	Richness	Abundance
AF	0.75±0.96	2.50±4.36	0.00±0.00	0.00±0.00
AI	0.50±0.58	0.75±0.96	0.50±0.58	0.75±0.96
BF	1.00±0.82	1.50±1.29	3.00±0.00	4.50±1.00
FG	4.25±0.50	29.25±14.82	6.75±0.96	34.75±7.76
GF	4.25±1.50	36.00±20.61	4.50±1.29	21.25±8.46
OG	3.00±0.82	14.00±5.23	4.00±0.00	30.50±3.87
Total	13.75±1.71	84.00±12.46	18.75±1.26	91.75±12.04

Values are presented as mean±standard deviation.

AF, aquatic forager; AI, aerial insectivore; BF, bark/trunk forager; FG, foliage gleaner; GF, ground forager; OG, omnivore/generalist.

Table 4. PERMANOVA results for avian assemblages comparing restoration and forest

Factor	df	Sum of Sqs	R ²	F	P-value
Group	1	1.3281	0.2839	7.9291	0.001
Residual	20	3.3498	0.7161		
Total	21	4.6779	1		

PERMANOVA, permutational multivariate analysis of variance; df, degrees of freedom; Sqs, squares.

compared to the restoration site (4.25 species, 29.25 individuals). Furthermore, BFs, such as woodpeckers, were much more abundant in the forest (3 species, 4.50 individuals) compared to the restoration site (1 species, 1.50 individuals). These results show that the multi-layered forest structure functions as a stable habitat for birds by providing diverse foraging spaces and shelter, and they are consistent with previous studies indicating that the vertical structure of vegetation is closely related to the habitation of diverse bird species (Blinkova & Shupova, 2017; de Toledo *et al.*, 2012).

Notably, AF were observed only in the restoration site (0.75 species, 2.50 individuals). This suggests that the wetlands and aquatic systems created by the restoration project function as novel habitats that are not found in the adjacent forest.

Comparison of assemblage structure between habitats

The PERMANOVA analysis revealed a statistically significant difference in the bird assemblage structure between the restoration site and the adjacent forest ($P=0.001$). Habitat type explained approximately 28.4% of the total bird assemblage variation ($R^2=0.2839$) (Table 4). This result was visually corroborated through the NMDS analysis (Fig. 3). The low stress value of the NMDS plot (0.1837846) indicates that the plot reliably represents the actual data distances (Clarke, 1993).

In the plot, the restoration site and the forest were

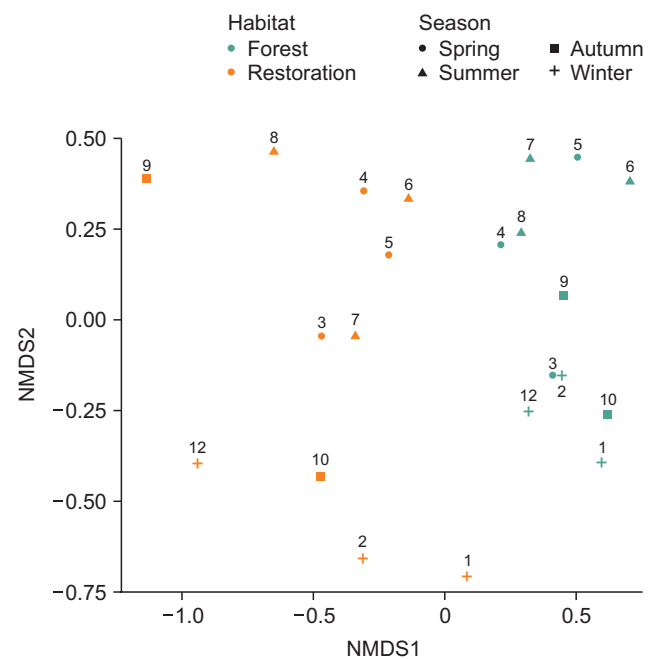


Fig. 3. Non-metric Multidimensional Scaling (NMDS) plot of avian assemblages comparing restoration and forest. Each point represents a sampling event, with numeric labels indicating the month of survey.

clearly separated into two groups along the horizontal NMDS1 axis, with the forest concentrated in the positive direction and the restoration site in the negative direction, showing the difference in bird assemblages based on habitat type. Notably, the restoration site samples were more dispersed compared to the relatively clustered forest samples, indicating the instability of the restoration assemblage, i.e., larger monthly and seasonal differences in assemblage structure.

SIMPER analysis was conducted to identify which species contributed most significantly to these differences (Table 5). The analysis showed that the difference in assemblages between the restoration site and the forest was largely contributed by the vinous-throated parrotbill (*Suthora webbiana*), tree sparrow (*Passer montanus*), azure-winged magpie (*Cyanopica cyanus*), oriental turtle dove (*Streptopelia orientalis*), and great tit (*Parus major*), in order of decreasing contribution. The top 10 contributing species accounted for approximately 77% of the total assemblage difference.

By comparing the average abundance (Group A [Restoration] vs. Group B [Forest]), *Suthora webbiana* (12.909 vs. 3.455) and *Passer montanus* (12.636 vs. 0.455) showed markedly higher occurrence in the restoration site, while *Cyanopica cyanus* (4.818 vs. 10.545), *Streptopelia orientalis* (3.727 vs. 8.000), and *Parus major* (0.364 vs. 5.545) had higher abundance in the adjacent forest. The adjacent forest provided a stable habitat for birds like *Parus major* that in the canopy and on branches. In this forest, breeding individuals and nests of species including *Parus major*, *Streptopelia orientalis*, and the black-naped oriole (*Oriolus chinensis*) were observed during the spring. Furthermore, the goldcrest (*Regulus regulus*), which primarily occurs in coniferous forests, was frequently observed from autumn to spring, highlighting the forest's function as a

stable habitat. Conversely, in the restoration site, despite the planting of various food-providing species such as *Chionanthus retusus*, the occurrence of urban-adapted species like *Passer montanus* was concentrated, contributing most significantly to the difference from the forest assemblage. This dominance of urban-adapted species reflects biotic homogenization due to urbanization (McKinney, 2006), suggesting that the restoration site provides an environment favorable to urban-adapted species, distinct from the forest assemblage.

Furthermore, analysis of species exclusively observed in each habitat showed that water-dependent birds, such as the Eurasian teal, common kingfisher, and black-crowned night heron, were observed only in the restoration site. This highlights the effect of creating new habitat space in the isolated urban ecosystem. This aligns with prior research indicating that increasing landscape heterogeneity, such as creating water spaces in urban areas, positively influences bird species richness (Morgan et al., 2025). Conversely, species requiring multi-layered forest habitats and stable food sources, such as the black-naped oriole (*Oriolus chinensis*) and brown hawk-owl (*Ninox scutulata*), were founded only in the adjacent forest. This indicates that the adjacent forest performs a unique and crucial ecological function not offered by the restoration site, acting as a core habitat for disturbance-sensitive species.

Conclusion

This study found a statistically significant difference in the wild bird assemblage structure between the Mt. So-rasan urban ecological restoration site and the adjacent forest ecosystem. The complex, multi-layered structure of the adjacent forest was identified as a stable habitat for diverse birds. The restoration site, while in its early stage,

Table 5. Species contributions to avian assemblages dissimilarity based on SIMPER analysis

Top 10 contributing species	Avg. Contrib.	Contrib./SD	ava	avb	P-value	Cum. Contrib.
<i>Suthora webbiana</i>	0.112	1.036	12.909	3.455	0.206	0.154
<i>Passer montanus</i>	0.110	0.895	12.636	0.455	0.067	0.304
<i>Cyanopica cyanus</i>	0.085	1.518	4.818	10.545	0.007	0.421
<i>Streptopelia orientalis</i>	0.059	1.271	3.727	8.000	0.006	0.502
<i>Parus major</i>	0.054	1.907	0.364	5.545	0.001	0.577
<i>Hypsipetes amaurotis</i>	0.039	1.454	0.909	4.182	0.002	0.63
<i>Pica pica</i>	0.032	1.539	1.818	4.273	0.001	0.674
<i>Regulus regulus</i>	0.029	0.744	0.000	2.636	0.002	0.714
<i>Aegithalos caudatus</i>	0.022	0.901	0.545	2.091	0.094	0.744
<i>Periparus ater</i>	0.021	0.874	0.091	2.000	0.007	0.773

Avg., average; Contrib., contribution; SD, standard deviation; SIMPER, similarity percentages; ava, average abundance in Group A (Restoration); avb, average abundance in Group B (Forest); Cum, cumulative.

showed limitations in supporting the bird species found in the adjacent forest due to its open and simple vegetation structure. However, the restoration site also played a positive role by creating a previously lacking aquatic ecosystem in the surrounding area, providing a new habitat for water-dependent birds.

These results emphasize that the goal of ecological restoration should not be limited to simply increasing the area of green space. It should, from a long-term perspective, prioritize the creation of complex, multi-layered habitats that consider the process of ecological succession, and enhance connectivity with the adjacent natural ecosystem.

The Mt. Sorasan restoration site requires management to ensure that the planted trees can mature into a stable forest environment. Given that various food-providing plants have been already planted, it is expected that the site will facilitate the influx of diverse wild bird species from the adjacent forest and expand their habitat space in the future.

This study is significant because it empirically evaluated the effectiveness of an urban ecological restoration project through direct comparison with an adjacent natural ecosystem. The findings can be used as baseline data to present short-term restoration outcomes and the direction for long-term progress.

However, the study was limited to a short-term, one-year survey, and included only a single restoration site and its adjacent forest, precluding analysis of the influence of the surrounding landscape context and connectivity to the wider region. Future research is suggested to conduct long-term monitoring to track changes in bird assemblages following vegetation succession. It is also recommended to additionally investigate the influence of the landscape context surrounding the restoration site on bird communities.

Author Contributions

Conceptualization: TYC. Data curation: TYC, DK, HGM. Formal analysis: TYC, JC, HGM. Funding acquisition: JC. Investigation: TYC, HGM. Writing – original draft: TYC. Writing – review & editing: TYC.

Conflict of Interest

The authors declare that they have no competing interests.

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Appendix 1. Total species richness and abundance of avian assemblages in restoration and forest

Scientific name	Restoration				Forest				Foraging guild
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	
<i>Acrocephalus orientalis</i>	0	1	1	0	0	0	0	0	FG
<i>Pica pica</i>	4	2	1	2	5	6	6	8	OG
<i>Oriolus chinensis</i>	0	0	0	0	3	2	1	0	FG
<i>Phasianus colchicus</i>	0	0	0	0	1	1	0	0	GF
<i>Phylloscopus inornatus</i>	0	0	0	0	0	0	2	0	FG
<i>Turdus naumanni</i>	0	0	0	1	0	0	0	3	GF
<i>Emberiza elegans</i>	0	0	6	0	0	0	4	5	GF
<i>Fringilla montifringilla</i>	0	0	0	0	0	0	0	5	GF
<i>Turdus hortulorum</i>	0	0	0	0	1	1	0	0	GF
<i>Phoenicurus aureus</i>	2	1	2	1	1	0	0	1	GF
<i>Lanius bucephalus</i>	0	0	2	1	0	0	0	0	FG
<i>Streptopelia orientalis</i>	10	4	3	5	9	17	6	14	GF
<i>Cyanopica cyanus</i>	12	11	8	4	14	18	18	15	OG
<i>Alcedo atthis</i>	0	0	1	0	0	0	0	0	AF
<i>Eophona migratoria</i>	0	0	8	4	0	0	8	4	GF
<i>Parus major</i>	1	2	1	0	5	5	10	9	FG
<i>Chloris sinica</i>	0	0	0	0	0	2	0	0	GF
<i>Suthora webbiana</i>	11	12	36	40	10	12	0	10	FG
<i>Cuculus canorus</i>	0	0	0	0	2	2	0	0	FG
<i>Phylloscopus coronatus</i>	2	0	0	0	6	0	0	0	FG
<i>Regulus regulus</i>	0	0	0	0	6	0	4	10	FG
<i>Ninox scutulata</i>	0	0	0	0	1	0	0	0	AI
<i>Dendrocopos kizuki</i>	1	3	0	0	2	2	2	2	BF
<i>Poecile palustris</i>	1	0	0	0	0	2	2	2	FG
<i>Muscicapa dauurica</i>	0	0	0	0	0	2	0	0	FG
<i>Anas crecca</i>	0	0	0	8	0	0	0	0	AF
<i>Emberiza rustica</i>	0	0	2	0	0	0	0	0	GF
<i>Garrulus glandarius</i>	0	2	0	0	2	5	2	1	OG
<i>Aegithalos caudatus</i>	2	0	0	2	3	0	8	6	FG
<i>Dendrocopos major</i>	0	0	0	1	1	3	1	1	BF
<i>Hirundo rustica</i>	2	1	0	0	0	0	0	0	AI
<i>Hypsipetes amaurotis</i>	2	4	0	4	5	6	3	8	OG
<i>Periparus ater</i>	0	0	0	1	6	0	5	4	FG
<i>Passer montanus</i>	31	57	0	5	0	2	0	0	GF
<i>Picus canus</i>	1	0	0	0	1	1	1	1	BF
<i>Lanius tigrinus</i>	0	1	0	0	0	0	0	0	FG
<i>Eurystomus orientalis</i>	0	0	0	0	0	2	0	0	AI
<i>Nycticorax nycticorax</i>	0	0	0	1	0	0	0	0	AF
<i>Emberiza tristrami</i>	0	0	0	2	0	0	0	0	GF
Total abundance	82	101	71	82	84	91	83	109	
Total species richness	14	13	12	16	20	19	17	19	

AF, aquatic forager; AI, aerial insectivore; BF, bark/trunk forager; FG, foliage gleaner; GF, ground forager; OG, omnivore/generalist.