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Bird Communities Vary under Different Urbanization Types—A Case Study in Mountain Parks of Fuzhou, China

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Abstract: Bird habitats are becoming increasingly fragmented as a result of rapid urbanization. As one of the essential refuges for urban bird communities, mountain parks are of practical significance for studying the spatial changes of birds, which can inform the future planning of mountain park planning. In this study, we assessed the α, β, and functional diversity of bird communities in mountain parks in Fuzhou, China, at three levels of urbanization (urban, peri-urban, suburban) and explored how diversity (abundance, richness, α-diversity, Chao1) varies along the urbanization gradient. A three-month bird survey was conducted using the transect method to examine the impact of urbanization on bird community structures in mountain parks. In addition, we evaluated the functional diversity of bird guilds in order to identify potential indicator species for monitoring different urbanization gradients in mountain parks. The results showed that: (1) During the three bird surveys from December 2021 to February 2022, 96 bird species and 2429 individuals of 9 orders, 34 families, and 63 genera were identified. (2) Urbanization had a significant impact on the overall bird α-diversity ($p = 0.040$) and richness ($p = 0.024$) but not on the overall bird abundance ($p = 0.056$). (3) The results of non-metric multidimensional scaling showed significant variations among overall birds in mountain parks along with three urbanization levels (stress = 0.155, $p = 0.027$). Similarly, significant differences were observed in the upper-stratum guild (stress = 0.183, $p = 0.049$) but not in other diet and vertical foraging stratum guilds. (4) Five species were identified as potential candidates for monitoring the trends of urban gradients. Moreover, compared to insectivorous or omnivorous guilds, most carnivorous and herbivorous guilds may not be suitable for monitoring the negative effects of urbanization in mountain parks. Our findings can help inform urban mountain park management or restoration strategies intended to mitigate the adverse impacts of urbanization.

Keywords: biodiversity; bird guilds; mountain parks; urbanization gradient

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1. Introduction

Urbanization is one of the most significant threats to biodiversity [1,2]. It is also a major contributor to the loss, fragmentation, and degradation of natural habitats (such as woodlands and forests) [3]. In addition to being important refuges for wildlife, urban green spaces offer a variety of economic and social benefits to the general public. A wide range of ecosystem services is provided by wildlife, particularly bird communities, in urban green spaces [4,5]. Insectivorous guilds, for example, can regulate pest population in forests and urban green spaces by preying on pests [6]. Fruit-eating and grain-eating birds may aid in seed dispersal and crop pollination in green space [7]. Therefore, rational protection of urban green space (e.g., parkland, gardens, and green parks) to preservice long-term wildlife coexistence and biodiversity can yield huge ecological service benefits [8–10].

Studies have indicated that urban biodiversity is declining linearly [11–13]. Along the "urban–suburban" gradient, there is a significant homogenization phenomenon [14,15], resulting in a decrease in specialist species and an increase in the proportion of generalists in the city [16–18]. Although some species can survive in highly urbanized areas and resist the effects of habitat fragmentation [19], most are highly vulnerable to urbanization. Primarily, they inhabit natural and semi-natural habitats in the suburbs or outer suburbs. These phenomena are essential signals of "ecological stress" [20], forcing birds to passively migrate in search of high-quality habitat in forest patches, woodlands, or agricultural regions. Compared to the city center, these areas are typically less developed, have less foot traffic, and are less impacted by urbanization. Furthermore, bird communities in urban parks or natural woodlands respond differently to habitat size and structure across several spatial dimensions [21–23], and there are functional or ecological implications in relation to changes in urbanization. Within the same geographic area, the species richness of bird communities in more urbanized areas may be lower than in pristine sites. In addition, bird assemblages at the functional level also respond differently to urbanization in multiple spatial dimensions. Therefore, understanding how urbanization influences the aggregation patterns of bird communities is critical for green space management and decision making in local governments. In-depth knowledge of the dominant driving factors in bird community composition or function on a broader scale can better inform urban landscape management and future planning strategies [24].

Unlike typical urban parks, mountain parks are usually built within a specific geographical and natural ecosystem [25]. They are essential components of the urban green space system. A considerable number of mountain parks are located in the southeastern coastal regions of China, making them more typical and of crucial scientific significance [26,27]. On the basis of a synthesis prior literature on bird indicators, our study assessed bird α and β diversity in mountain parks in Fuzhou, China, and analyzed whether these indicators altered along urban gradients. α-diversity quantifies species composition or richness, weighted by their abundance. β-diversity is a measure of the variation in species diversity along a gradient of environmental changes or a comparison of the similarity of assemblages across spatial units. We selected bird guilds according to their habitat requirements. The functional diversity of bird guilds in mountain parks under different types of urbanization was compared in order to explore the functional redundancy of habitats or ecosystems. We finally identified indicator species in mountain parks that could be used to track environmental changes in urban gradients.

The following hypotheses were proposed: (1) These parks can support more species richness and abundance because mountain parks with lower urbanization may have more ecological niches available for species use. (2) Urbanization intensity has little effect on the α-diversity of bird species, different diet guilds, and vertical foraging stratum guilds in mountain parks due to the high vegetation cover. The mountain park itself serves as an ideal refuge for species. (3) Both carnivorous and herbivorous species may be suitable for monitoring trends in mountain parks affected by urbanization. Furthermore, exploring the composition of bird guilds under diverse urbanization effects is of practical importance for future biodiversity conservation in urban areas. Our study is vital for the management of mountain parks along the "urban–suburban" gradient, particularly for the application of protective measures for bird communities to promote taxonomic and functional diversity and enhance the ecological stability of mountain parks [28]. In addition, this study also highlights the important aspects of the bird-specific portfolio-oriented conservation guidelines, etc., thus contributing to the potential of future urban tourism planning in Fuzhou city.

2. Study Area and Methods

2.1. Study Area

We selected Fuzhou, China, as the study area, which has a warm and humid climate that is conducive to the growth of various plant species (25°15′ N~26°39′ N, 118°08′ E~120°31′ E). Fuzhou is a mountainous city (600~1000 m a.s.l.) with numerous mountain parks. In the near future, the municipal government plans to convert more urban mountains into parks with complete facilities and an excellent green environment that allows visitors to enjoy scenic vistas, outdoor exercise, and other recreational and leisure activities [26,27,29]. Consequently, Fuzhou represents an exceptional case study to investigate bird diversity in mountain parks. According to Fuzhou's urban planning and vegetation conditions [30,31], the mountain parks were chosen based on the following criteria: (1) distinct geographical locations within the urban center; (2) vegetation composition and structure need to be diverse, more representative of the habitat, and abundant in bird resources. Fushan Country Park (235.59 ha), Yushan Park (7.94 ha), Wushan Park (14.68 ha), Pingshan Park (11.86 ha), and Jinji Mountain Park (42.80 ha) were designated as the five most representative mountain parks in Fuzhou. The selected mountain parks are evenly distributed inside or around Fuzhou's metropolitan area, with great accessibility, a high amount of vegetation coverage, and rich habitat types. Figure 1 shows the geographic locations of the five mountain parks. The five mountain parks are the most popular spots for bird watching due to their abundance of bird species.

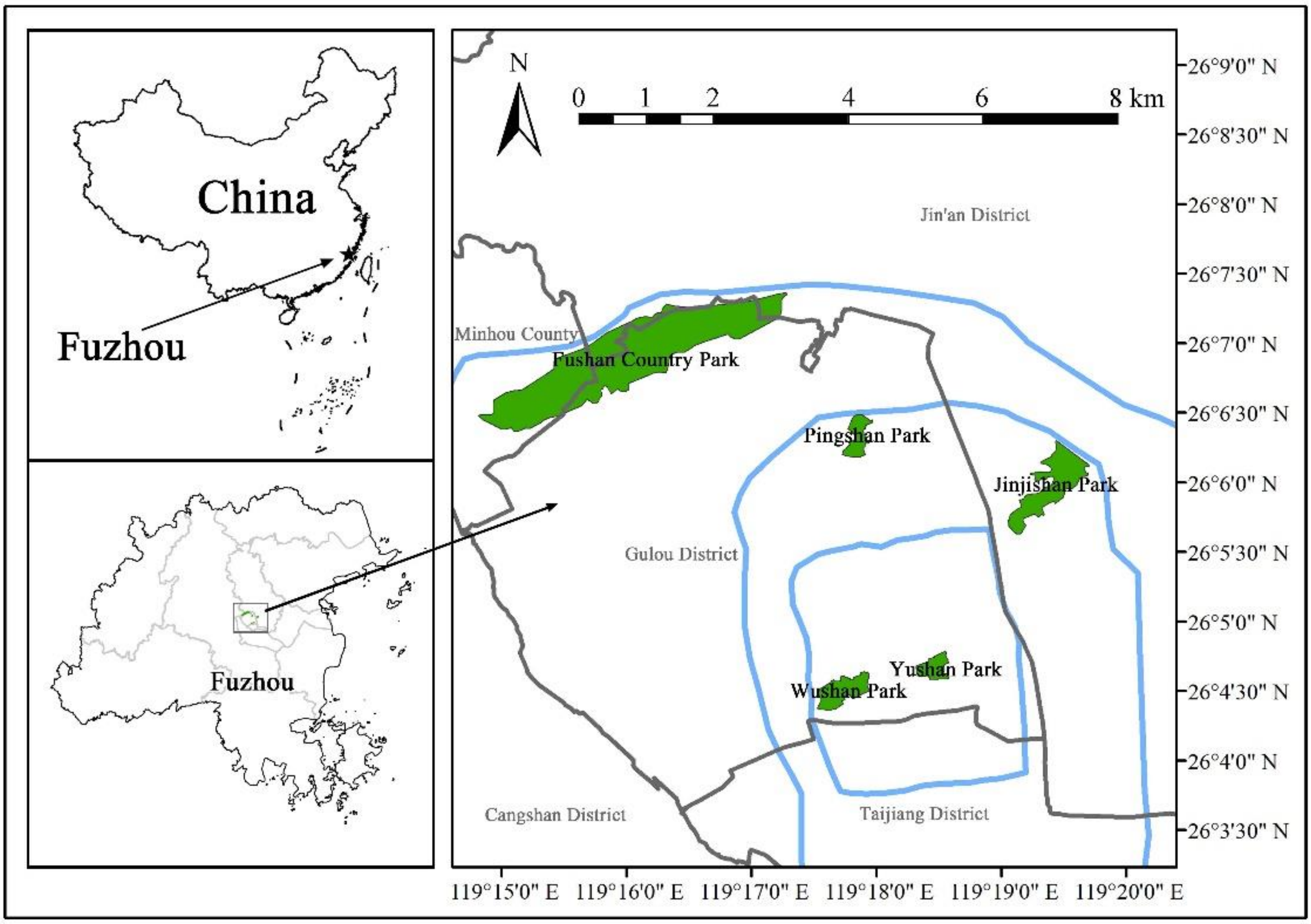

Figure 1. The location of the study area and the distribution of five urban mountain parks in Fuzhou city. The blue lines represent the Fuzhou high-speed ring road, which is the first ring, the second ring, and the third ring from the inside to the outside.

2.2. Classification of Urbanization Types

In accordance with the planning of the First Ring Road to the Third Ring Road in Fuzhou, we amended the urbanization classification methods from previous studies [32–34] and reclassified mountain parks as follows: (1) urban mountain park, (2) peri-urban mountain park, and (3) suburban mountain park. Mountain parks within the First Ring Road are considered the most influenced by urbanization, namely, Wushan Park and Yushan Park. This is because the First Ring Road encloses the earliest developed area in Fuzhou, which has a high density of construction space and population (percentages of the built-up area = 87.13%) and far less green space coverage than other locations. Between the Frist and the Second Ring Roads (percentages of the built-up area = 76.81%) are Pingshan Park and Jinji Mountain Park, which are peri-urban mountain parks due to their lower urbanization than the First Ring Road. Fushan Country Park is a mountain park located between the Second and the Third Ring Roads (percentages of the built-up area = 62.34%). It is the farthest away from the city center and is characterized by the lowest surrounding construction density compared to the other four parks. Additionally, Fushan County Park relies on natural mountain resources and makes good use of native forest vegetation. Hence, it is known as a suburban mountain park.

2.3. Sampling Criteria

As the basic unit of bird survey, transects of 100 × 50 m are randomly laid along the internal road of the mountain park, with 100 m being the length and 25 m being the radius. Individuals of each species were counted inside these transects [18,24]. Twenty-five meters is a reasonable radius for transects. The shortest distance between transects should be longer than 100 m to decrease spatial correlation, and the locations should be scattered as evenly as possible. To ensure the validity of subsequent statistical analysis, we employed a systematic sampling method to randomly select 10 transects in each urbanization type. The transects of each urbanization type are as follows: urban (Wushan Park, n = 6; Yushan Park, n = 4), peri-urban (Pingshan Park, n = 4; Jinji Moutain Park, n = 6), suburban (Fushan Country Park, n = 10).

2.4. Bird Survey

A total of 4 observers participated in this study, all of whom have a specialized ecological background and have been members of the Fujian Bird Watching Society for more than one year. According to statistics from the China Bird Watching Recording Center (http://www.birdreport.cn/, accessed on 20 June 2022), as of 20 June 2022, a total of 501 species have been successfully observed in Fujian Province. All four observers are familiar with and can identify more than 300 species of common birds in Fujian Province, which is sufficient for our study. This study combines "*A field guide to the birds of China*" [35] to identify bird species. Further identification was carried out by photographs or videos when bird species cannot be identified immediately. To minimize the influence of personnel changes during the bird survey, each observation was conducted by a fixed number of two observers. Transects were selected at random at the beginning of each survey to control the randomization of observation time. During the survey, observers were required to wear light-colored clothing to avoid alarming the birds and affecting the study results [36]. Secondly, after arriving at the transects, the observers had to wait 5 min before starting the investigation. The survey lasted 10–20 min per transect and ended when no additional birds were spotted.

Before the formal bird survey, we conducted two rounds of preliminary trials in the 5 mountain parks from October to November 2021. This was done to warrant the accuracy of subsequent bird species estimates. The data from the preliminary bird survey are not included in the formal bird survey. The official bird survey period is from 1 December 2021 to 20 February 2022. This is the non-breeding season for bird species, as well as the time for winter visits in Fuzhou. This is a typical timeframe for studying the distribution of bird species along the urbanization gradient. One round of survey lasted 30 days and was only undertaken in clear weather with high visibility, no wind, and no precipitation. Three rounds of bird counting were carried out. We referred to [17,37,38] to divide birds into the diet guild and the vertical foraging stratum guilds. (1) There are four subdivisions of diet guilds: insectivorous, omnivorous, herbivorous, and carnivorous. The primary food source of insectivorous guild is insects. Omnivorous guild consumes plants, animals, and other foods. Herbivorous guild feeds on plant-based foods such as flowers, nectar, and seeds. Carnivorous guild mainly eats animal materials such as rats, fish, frogs, snakes, flesh, and carrion. (2) The vertical foraging stratum guilds refer to the vertical structure in which bird species tend to forage and are divided into three guilds: upper-stratum guild (bird species that are primarily active in the arbor layer with a height of more than 2.5 m), middle-stratum guild (bird species that are mainly active in the shrub layer with a height of 0.5 m $\leq$ height $\leq$ 2.5 m), and lower-stratum guild (bird species that are most active in ground cover or herb layer with height < 0.5 m).

2.5. Data Analysis

The α- and β-diversity of different urbanization types of mountain parks in Fuzhou were examined. A comparison of the functional diversity and the identification of the indicator species were conducted. All analyses were performed in R 4.0.2 [39]. Before further analysis, the Shapiro–Wilk test, a method proposed by Samuel Shapiro and Martin Wilk in 1965 [40], was used to check the normal distribution of species richness and abundance for each urbanization type in the “mvShapiroTest” package [41]. The species richness refers to the number of bird species per urbanization type, while the abundance is the number of individuals per urbanization type. Results showed that the *p*-values of abundance (W = 0.955, *p*-value = 0.223) and species richness (W = 0.940, *p*-value = 0.091) were both greater than 0.05, indicating that both variables were normally distributed and there is no need for square-root and arcsine transformation.

2.5.1. α-Diversity Analysis

α-diversity, also known as within-habitat diversity, focuses mainly on the number of species in a locally homogeneous habitat [42]. We utilized Shannon diversity, an index under the “vegan” package [43], to describe the α-diversity of bird communities [44,45]. In addition, we analyzed the Chao1 index, an estimator based on species abundance (singletons, doubletons, etc.), with higher values representing greater diversity of species in the communities [46]. Both α-diversity (W = 0.985, *p*-value = 0.929) and Chao1 (W = 0.937, *p*-value = 0.0778) indexes followed a normal distribution. Species accumulation curves were calculated with the “iNEXT” package [47] to measure and predict the growth in species richness in a community as the sample size increases. This method is commonly used in biodiversity surveys to assess the adequacy of sample sizes and estimate community richness.

A general linear model (GLM) was used with a Poisson error structure to further examine the impact of different urbanization types on bird diversity [48,49]. α-diversity (Shannon diversity) was the dependent variable, and type of urbanization was the independent variable. To model the effect of urbanization types in bird community responses, we ran a quasi-Poisson distribution regression for fitting general linear models (GLM) in the “lme4” package with the function “lmer” [50]. Moreover, the variance inflation factor (VIF) was utilized in the models to detect multicollinearity. Then, we examined model fit, overdispersion, and homoscedasticity. The statistical significance of the impacts of different urbanization types was assessed through analysis of variance (ANOVA) Tukey post hoc with the general linear hypothesis test procedure in the “multcomp” package [51].

2.5.2. β-Diversity Analysis

The change in species composition was measured by species dissimilarity (β-diversity) [52]. It was determined based on the log (X+1) transformed Bray–Curtis resemblance matrix of the abundance data. Its formula is as follows:

$$BC_{ij} = 1 - \frac{2C_{ij}}{S_i + S_j} \tag{1}$$

where C_{ij} is the sum of the minimum values for bird species common to both i and j only. S_i and S_i are the total numbers of bird species in both i and j.

Species dissimilarity was defined as the difference in the absence or presence of species among mountain parks with different urbanization types. For the influence of the urbanization types on species dissimilarity, non-metric multidimensional scaling (NMDS) [53] analysis was applied to analyze the composition of bird communities in mountain parks. The "metaMDS" function was employed, and its stress value served as an indicator of the model's suitability [54]. Generally, a stress value lower than 0.2 is more reasonable, and the statistical difference is quantified using the similarity analysis (ANOSIM) under the "vegan" package of the "anosim" function [55]. On the basis of the results of the preceding tests, 999 permutations were performed for all bird species before being repeated on each bird guild. Finally, we derived ANOSIM results and probability distributions with pairwise difference significance levels.

2.5.3. Functional Diversity and Indicator Species

Functional diversity [56] was utilized to investigate the overlap or redundancy of bird functions and determine the link between species richness and α-diversity for the overall bird communities, diet guilds, and vertical stratum guilds along three urbanization gradients. These relationships were identified using scatterplots in the "ggplot2" package [57]. The assessment of species indicator value could distinguish bird species that may be useful for tracking habitat change across the urbanization gradients. Indicator species [58] can also explain some variables, and their ecological properties reflect environmental conditions. The "indicspecies" package [59] combines the average abundance and occurrence probability of a species within a quadratic group. A high indicator value for a species implies greater average species abundance in this quadrat group than in other quadrat groups (specificity), and the species is present in most of the quadrat groups in this group (evenness).

3. Results

3.1. Overview

During the bird surveys conducted from October 2021 to February 2022, 96 species of 9 orders, 34 families, 63 genera, and 2429 individuals of birds were recorded in the study areas. Among them, the five most common bird species were the *Japanese white-eye* (610 individuals), *Chinese bulbul* (221 individuals), *red-whiskered bulbul* (138 individuals), *black-throated tit* (131 individuals), and *yellow-rumoed willow warbler* (112 individuals). Surprisingly, for the overall bird community, a higher number of birds was observed in the urban (807 individuals) than in the suburban (733 individuals) areas. For bird guilds, we found that insectivorous guild has the most species (44 species), followed by omnivorous (27 species), then the herbivorous (16 species), and finally the carnivorous guild (9 species). However, only one crested goshawk was recorded for the carnivorous guild in the urban area. Among vertical foraging stratum species, the largest number of individuals (1627 individuals) resided in the upper sub-stratum guild. This was accompanied by the middle sub-stratum guild (414 individuals) and the lower sub-stratum guild (388 individuals) (Table 1).

Table 1. Bird guilds in mountain parks under three urbanization gradients, including α-diversity, richness, abundance, and Chao1 index.

Type of Urbanization	Grouping Variable	Parameter			
		α-Diversity	Richness	Abundance	Chao1
Urban	Birds overall	2.56	27	807	27.00
	Omnivorous guild	1.59	11	476	22.33
	Herbivorous guild	1.00	4	138	4.00
	Carnivorous guild	0.00	1	1	1.00
	Insectivorous guild	2.06	12	193	12.00
	Upper stratum guild	1.85	13	588	13.00
	Middle stratum guild	1.63	6	98	6.00
	Lower stratum guild	1.61	8	121	8.00
Peri-urban	Birds overall	3.34	74	889	79.57
	Omnivorous guild	2.14	22	470	21.00
	Herbivorous guild	2.04	14	116	15.50
	Carnivorous guild	1.40	5	15	6.25
	Insectivorous guild	2.73	32	287	33.00
	Upper stratum guild	2.44	33	552	37.00
	Middle stratum guild	2.18	20	156	20.60
	Lower stratum guild	2.54	20	181	20.00
Suburban	Birds overall	3.32	67	733	68.75
	Omnivorous guild	1.83	20	351	11.00
	Herbivorous guild	2.00	10	89	10.00
	Carnivorous guild	1.56	5	8	5.00
	Insectivorous guild	2.98	32	285	32.17
	Upper stratum guild	2.46	32	487	32.43
	Middle stratum guild	2.56	19	160	19.00
	Lower stratum guild	2.36	16	86	17.50
Overall	Birds overall	/	96	2429	/
	Omnivorous guild		27	1297	
	Herbivorous guild		16	343	
	Carnivorous guild		9	24	
	Insectivorous guild		44	765	
	Upper stratum guild		44	1627	
	Middle stratum guild		27	414	
	Lower stratum guild		25	388	

3.2. α-Diversity Varied along Different Urbanization Gradients

The rarefaction curves (Figure 2) demonstrate that as the number of individuals increased, the curves gradually flattened. Additional individuals of birds had a minor marginal contribution to the discovery of new species, indicating that the number of bird species reached saturation and the overall dataset was reasonable. The results of GLM revealed that urbanization did not have a significant effect on the overall bird abundance ($p = 0.056$), but it did have a considerable impact on the overall bird α-diversity ($p = 0.040$) and richness ($p = 0.024$) (Table 2). According to the analysis of variance Tukey post hoc results, the α-diversity of the overall birds detected pairwise differences between urban and peri-urban ($p = 0.042$) and between urban and suburban ($p = 0.009$) (Figure 3). For the insectivorous guild, there were pairwise differences in α-diversity ($p = 0.015$) and richness ($p = 0.048$) under urban and suburban, but no difference was seen for other diet guilds (Figure 4). Likewise, α-diversity ($p = 0.037$) and richness ($p = 0.022$) differed significantly along with urbanization types in the upper stratum guild. In contrast, two other vertical foraging stratum guilds exhibited no significant differences in α-diversity, richness, and abundance (Figure 5).

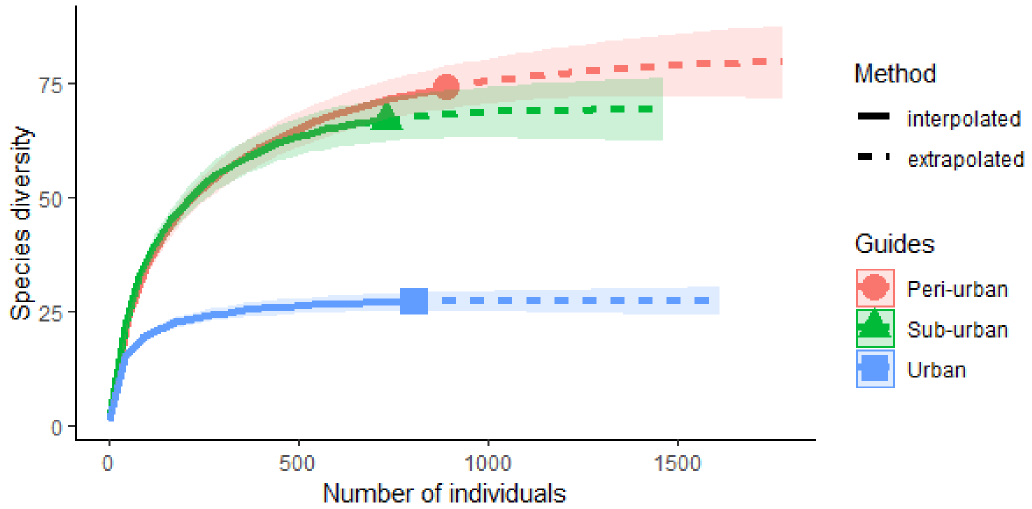

Figure 2. Comparison of individual-based interpolation (rarefaction) and extrapolation of species diversity in different urbanization types of mountain parks. When the curve tends to be flat, the observed number of species is gradually reasonable, and more individuals will only produce fewer new species.

Table 2. Results of GLM test for the effect of disturbance on within-diet and foraging-stratum guild a-diversities across the three disturbance levels (* = $p < 0.05$).

Variable	Level	Parameter	Estimate	Std. Error	*p*	df
All birds	—	α-diversity	−0.230	0.889	0.040 *	29
		Abundance	0.007	0.004	0.056	
		Richness	−0.050	0.064	0.024 *	
Diet-guild	Herbivorous guild	α-diversity	−0.358	0.960	0.708	27
		Abundance	0.039	0.023	0.031	
		Richness	−0.062	0.378	0.870	
	Carnivorous guild	α-diversity	−17.910	29.083	0.538	6
		Abundance	−0.560	1.069	0.601	
		Richness	9.870	16.565	0.551	
	Insectivorous guild	α-diversity	−0.182	0.639	0.047 *	29
		Abundance	0.016	0.015	0.286	
		Richness	−0.114	0.145	0.043 *	
	Omnivorous guild	α-diversity	0.663	0.723	0.359	29
		Abundance	0.011	0.008	0.157	
		Richness	−0.199	0.154	0.196	
Vertical foraging stratum guild	Upper-stratum guild	α-diversity	0.238	0.782	0.037 *	29
		Abundance	0.012	0.007	0.022 *	
		Richness	−0.164	0.109	0.132	
	Middle-stratum guild	α-diversity	0.197	0.592	0.739	27
		Abundance	0.017	0.025	0.506	
		Richness	−0.189	0.221	0.079	
	Lower-stratum guild	α-diversity	−0.005	0.584	0.993	28
		Abundance	0.010	0.017	0.549	
		Richness	−0.081	0.227	0.719	

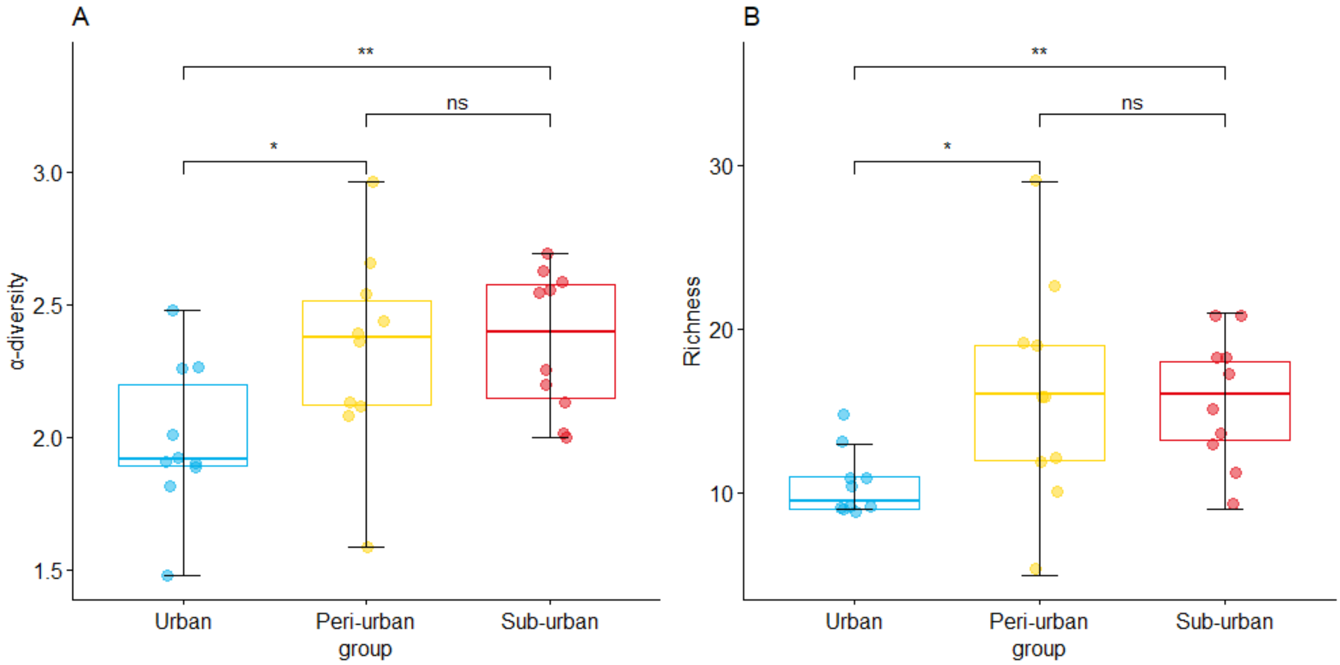

Figure 3. Bird overall α-diversity (**A**) and richness (**B**) under different urbanization types of mountain parks. Boxplots show the range of data about the median, with open circles representing outliers and filled circles representing the mean. Stars indicate significance levels (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$).

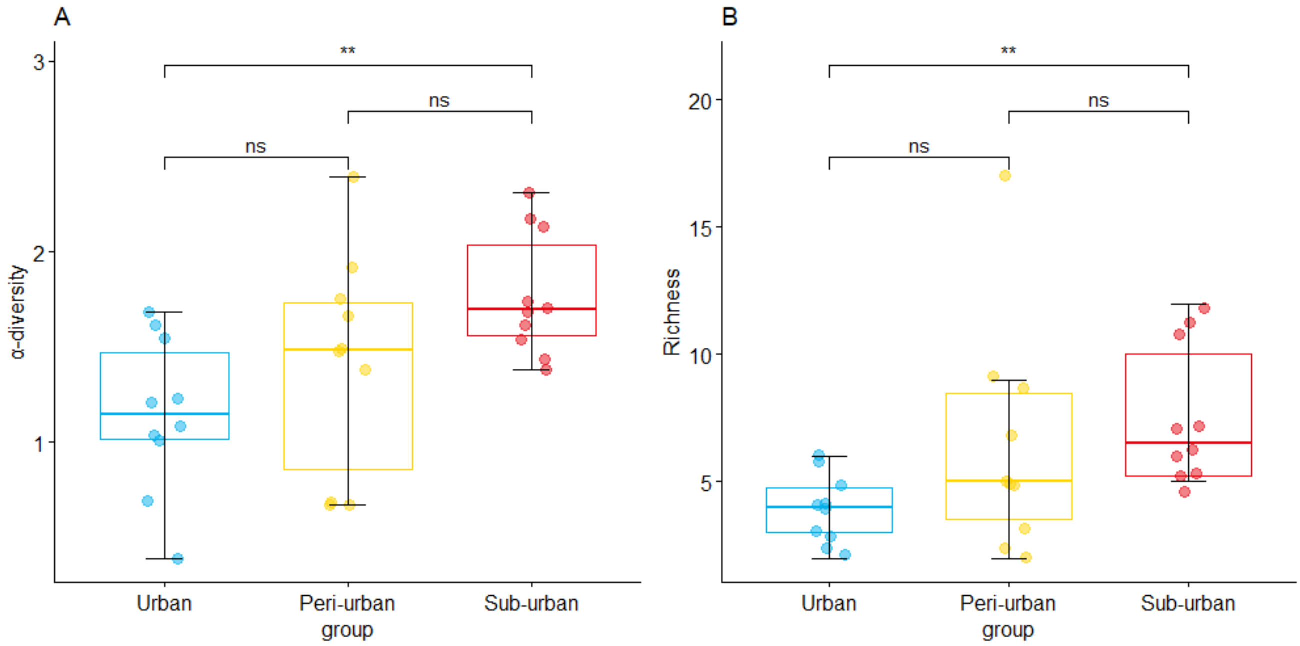

Figure 4. Insectivorous guild α-diversity (**A**) and richness (**B**) under different urbanization types of mountain parks. Boxplots show the range of data about the median, with open circles representing outliers and filled circles representing the mean. Stars indicate significance levels (ns = not significant; ** = $p < 0.01$).

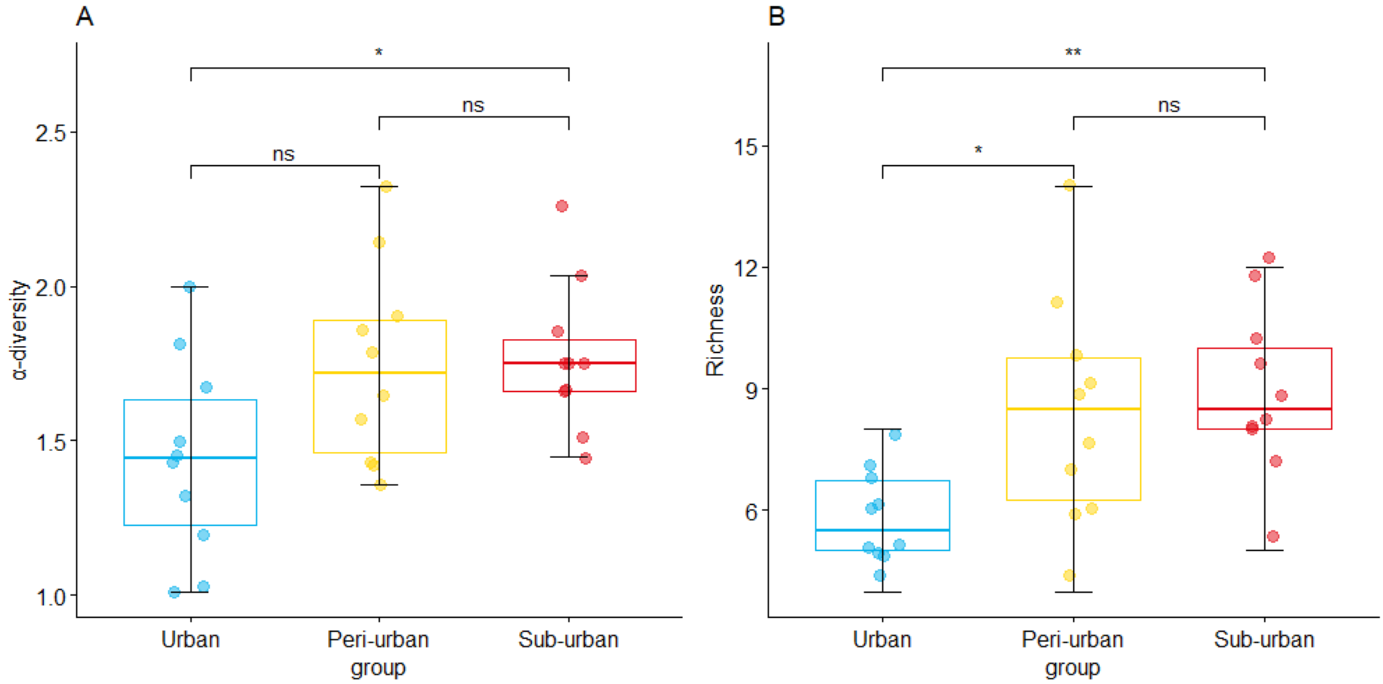

Figure 5. Upper-stratum guild α-diversity (**A**) and richness (**B**) under different urbanization types of mountain parks. Boxplots show the range of data about the median, with open circles representing outliers and filled circles representing the mean. Stars indicate significance levels (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$).

3.3. *β-Diversity Varied along Different Urbanization Gradients*

The Bray–Curtis function calculated and ranked the distances between the overall bird community, diet guild, and vertical foraging stratum guild in mountain parks under varying levels of urbanization. This method tests whether the difference between bird guilds is significantly greater than the difference within guilds. Among them, ANOSIM similarity analysis was suitable for nonparametric tests. The results of 999 permutations suggested that the overall bird in mountain parks under varying levels of urbanization (Figure 6A) differed between groups (stress = 0.155, $p = 0.027$). There were also distinctions in the upper-stratum guild (stress = 0.183, $p = 0.049$) (Figure 6B). However, no difference was found in other diet guilds and other vertical foraging stratum guilds.

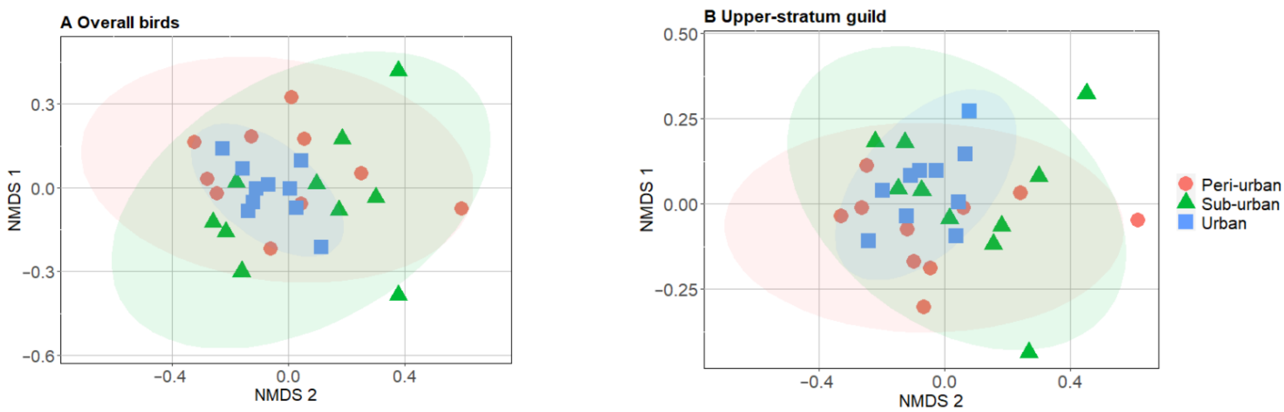

Figure 6. NMDS two-dimensional plot of overall birds (**A**) and upper-stratum guild (**B**) from 30 sampling transects (10 urban = blue squares, 10 peri-urban = red circles, 10 sub-urban = green triangles). The stress values of overall birds and upper-stratum guild were 0.155 and 0.183, respectively.

3.4. Functional Role and Indicator Species

We used the "lm" function to explore the relationship between α-diversity and species richness of bird functional groups in mountain parks under three urbanization types. Since very few carnivorous species were found, they were excluded from the functional role analysis. The results showed that α-diversity and species richness in the suburban area were significantly positively correlated both for herbivorous ($p < 0.001$) and insectivorous (p-value = 0.020) guilds. A significant positive connection ($p < 0.001$) was also found for herbivorous in the peri-urban area. When the middle sub-stratum guild was analyzed individually, we detected a significant positive correlation both in urban and suburban groups (p-values = 0.012 and 0.001, respectively). Moreover, when we did a separate analysis on the low sub-stratum, a positive correlation between alpha diversity and species richness was only detected in the peri-urban ($p = 0.021$) area. No significant associations were found in other guilds or urbanization types (Table 3). For mountain parks under three urbanization types, only a few indicator species were identified. In the most urbanized mountain parks, the *tree sparrow* was the most distinctive species (IndVal = 0.260, $p = 0.029$), whereas in the peri-urban mountain parks, the *sooty-headed bulbul* (IndVal = 0.522, $p = 0.012$) and *yellow-rumoed willow warbler* (IndVal = 0.369, $p = 0.021$) were more abundant. Similarly, we also found two distinct species in the suburban area, namely, the *grey-chinned minivet* (IndVal = 0.286, $p = 0.020$) and the *black-naped oriole* (IndVal = 0.282, $p = 0.033$) (Table 4).

Table 3. The linear regression model showing the relationship between α-diversity and species richness of bird functional groups in mountain parks under different urbanization types. The meanings of each abbreviation in the table are as follows: HD means herbivorous α-diversity, ID means insectivorous α-diversity, OD means omnivorous α-diversity, UD means upper sub-stratum α-diversity, MD means middle sub-stratum α-diversity, LD means lower sub-stratum α-diversity, SR means species richness.

Node	Bird Guilds	Type of Urbanization	Model	F	R^2	Sig.
1	Herbivorous guild	Urban	HD = 0.132 + 0.039 SR	0.275	0.100	0.616
2		Peri-urban	HD = 1.110 − 0.013 SR	0.174	0.115	0.689
3		Suburban	HD = −1.267 + 0.128 SR	38.810	0.808	0.000
4	Insectivorous guild	Urban	ID = 0.411 + 0.070 SR	1.179	0.020	0.309
5		Peri-urban	ID = 0.170 + 0.077 SR	39.090	0.809	0.000
6		Suburban	ID = 0.876 + 0.057 SR	8.243	0.446	0.020
7	Omnivorous guild	Urban	OD = 0.160 + 0.099 SR	4.939	0.304	0.304
8		Peri-urban	OD = 0.971 + 0.028 SR	1.847	0.086	0.211
9		Suburban	OD = 0.785 + 0.025 SR	0.856	0.016	0.382
10	Upper stratum guild	Urban	UD = 0.525 + 0.087 SR	3.638	0.227	0.093
11		Peri-urban	UD = 1.281 + 0.028 SR	4.831	0.299	0.059
12		Suburban	UD = 0.525 + 0.089 SR	4.111	0.257	0.077
13	Middle stratum guild	Urban	MD = −0.542 + 0.108 SR	2.608	0.152	0.145
14		Peri-urban	MD = 0.197 + 0.050 SR	3.238	0.242	0.012
15		Suburban	MD = −0.374 + 0.090 SR	3.005	0.182	0.001
16	Lower stratum guild	Urban	LD = −0.574 + 0.123 SR	3.270	0.201	0.108
17		Peri-urban	LD = −0.185 + 0.072 SR	8.133	0.442	0.021
18		Suburban	LD = 0.103 + 0.049 SR	2.108	0.122	0.190

Table 4. Bird species indicate different urbanization types of mountain park. We indicated the species that obtained the highest correlation, the value of indicator species (IndVal), and the statistical significance of the association (*p*-value, * = $p < 0.05$;).

Indicator Species	Type of Urbanization	IndVal	Frequency	*p*-Value
Tree sparrow	urban	0.260	10	0.029 *
Sooty-headed bulbul	peri-urban	0.522	6	0.012 *
Yellow-rumoed willow warbler	peri-urban	0.369	17	0.021 *
Grey-chinned minivet	suburban	0.286	5	0.020 *
Black-naped oriole	suburban	0.282	13	0.033 *

4. Discussion

4.1. Urbanization Affects Bird Diversity in Mountain Parks

Our findings revealed that, in mountain parks, urbanization affected overall bird species richness and α-diversity, but not abundance. Similar to Maarten de Groot's (2021) findings [21], we found 807 individuals in the urban area, which is higher than that in the suburban area (number of individuals = 733). Among the three urbanization levels, peri-urban had the highest overall species richness and α-diversity, which is consistent with the intermediate disturbance hypothesis [60] and confirms that mountain parks with moderate urbanization intensity maintain higher species diversity. Lower urbanization intensity will lead to the complete dominance of a few highly competitive species. However, a study on a south-eastern European city reached a different result, reporting that the species composition of peri-urban areas was similar to urban areas [21]. Other studies, in contrast, indicated that higher urbanization intensity allows species a fast growth rate and strong encroachment ability to survive, leading to a species composition that is different from that of other regions [5,14,30]. For example, in the most urbanized mountain parks, Wushan Park and Yushan Park, we found a considerable proportion of *tree sparrow*, an indicator species of urban types. This is because *tree sparrows* are omnivorous and can survive by eating human food scraps or domestic waste despite the adverse effects of urbanization. Moreover, poor sanitation in urban areas may lead to a greater proliferation of tree sparrows, as the urban environment does not pose a barrier to their nesting. They can locate many nesting habitats in the city. Mountain parks contain various habitat types that can serve as refuges for diverse bird species, and their dense vegetation coverage can enhance the safety of bird habitats [27]. More bird species can be accommodated in mountain parks thanks to their taller trees and greater vegetation canopies, especially those that require wider tree canopies [26]. Despite the fact that overall bird abundance did not respond significantly to urbanization, we observed that urban had the lowest richness with only 27 bird species. When compared to the less urbanized Fushan Country Park, Pingshan Park, and Jinjishan Park, this finding displays the adverse effects of urbanization on species richness and is similar to Asefa's (2017) report [14] on the higher species richness and abundance in some unprotected forests in Ethiopia.

4.2. Urbanization Affects Bird Guilds in Mountain Parks

Our results verify that urbanization significantly affects the α-diversity ($p = 0.047$) and the richness ($p = 0.043$) of the insectivorous guild in mountain parks. Additionally, vertical foraging stratum guilds along urbanization gradients differ significantly in abundance and α-diversity, which is in line with the findings of Hinsley et al. (2009) [61] and Otieno NE (2020) [19], who reported more bird individuals found in the upper stratum in less urbanized stands. A greater variety of bird species can be attracted in less urbanized places because they help conserve the woodland canopy and provide vertical vegetation refuges for birds [1,2,62]. Our study also illustrates that urbanization reduces the foraging resources for the middle stratum and lower stratum bird guilds. Regardless of the urbanization intensity, only the upper stratum accesses the resources necessary to satisfy the foraging demand of a large number of birds [19]. Therefore, in order to reduce the vertical distribution differences of bird communities under urbanization effects, it is necessary to restore the lower stratum vegetation condition to improve structural heterogeneity and promote a more naturally vertical distribution of green space resources [21,59,63]. Unlike other diet guilds, the diversity and distribution of omnivorous and insectivorous guilds have little impact on urban habitat change or urbanization due to their low food and environmental requirements, as well as their wider variety of living resources. Similar findings have been drawn from previous studies. Urban wastes are more accessible to the omnivorous guild due to poor waste management. Additionally, the large proportion of vegetation in mountain parks and the abundant supply of arthropods in trees, grasslands, etc., provide the insectivorous guild with a wide range of food sources and living space [64].

4.3. Urbanization Affects Bird Functional Roles and Indicator Species in Mountain Parks

The functional diversity of bird species in mountain parks is different under three urbanization types. The species richness and α-diversity of insectivorous and herbivorous guilds were significantly and positively correlated in the suburban area. This indicates that the suburban mountain parks have abundant living resources to support the two guilds without competitive exclusion, which may lead to overlapping specific functions. This is comparable to the findings of Mbiba et al. (2021) [23]. In contrast, a negative correlation between species richness and α-diversity was found for the herbivorous guild in the peri-urban area, suggesting the potential influence on food and plant groups from competitive species under this type of urbanization, which may lead to a shortage of resources and the duplicate species functions [65]. This underscores the complexity and importance of habitat structure in mountain parks and the negative impacts of urbanization, which could result in a decline in habitat quality and thus overlapping or redundant bird functions. Finally, our study identified five bird species candidates for tracking urbanization trends in mountain parks: *tree sparrow* (urban), *sooty-headed bulbul* (peri-urban), *yellow-rumoed willow warbler* (peri-urban), *grey-chinned minivet* (suburban), and *black-naped oriole* (suburban). The Indval index explains the abundance and frequency of each species. None of the five species is the most abundant in their respective sample plots, nor are they the most frequently encountered at any place [21]. However, the aforementioned indicator species are predominantly omnivorous or insectivorous, implying that the species abundance of the herbivorous or carnivorous guilds is insufficient to provide them with specificity, fidelity, or the ability to adapt to different urbanization impacts. Chamberlain et al. (2018) [11] similarly suggested that insectivorous prefer to track urban habitat quality, as there may be a bigger chance of survival with food resources in varied habitats or vegetation structures. Moreover, future research should further explore whether conclusions would be different if the granivorous guild was excluded from herbivorous.

4.4. Limitations of This Study and Possible Developments

In future biological conservation research, it is necessary to delve deeper into the potential environmental factors that may affect bird diversity at different scales [66]. Research on habitat or landscape [9], including types of urban green space and how they would support bird biological characteristics or diversity, remains to be explored. In addition, future research will focus on remote sensing images or big data platforms [67], such as mobile phone signaling data and nighttime lighting data, to explain the impact of multi-dimensional urbanization features on biodiversity from the perspectives of climate, land use, and nighttime lighting. The effect of the urban built environment on bird species can be reflected in individual or population behaviors [68]. For example, climate change may influence migratory routes for birds and even the timing of roosting along the way [10,69]. Changes in the urban environment may impact the evolution of bird communities, with homogenization of urban bird communities being the most pressing concern currently. Therefore, exploring the consequences of urban built environment on bird diversity from the viewpoints of bird migration, predation, and evolution is a research direction that can be further explored. Due to budgetary limitations, our sampling strategy did not allow us to achieve perfect proportionality between the number of transects and park areas. This could have partly biased our results, in particular with regard to the assessment of bird richness. In addition, as the five parks are within a short distance in space, it is possible that on certain occasions the same individuals have been sampled in more than one park, thus producing several non-independent observations due to an indefinite number of replicates. Moreover, the five parks have been considered as five separated bird communities in this study but, given the ability of birds to easily shift among these parks, future studies could adopt a meta-community (i.e., a group of interacting communities) approach from both theoretical and methodological viewpoints. In addition, contemporary research focuses almost exclusively on the direct impact of the environment on the target species while ignoring the indirect effects of internal ecosystem interactions. Therefore, the way in which to incorporate the constraints within the ecosystem into the analysis of the target species' response to environment is also an urgent research problem to be addressed [15,21,24].

5. Conclusions

In this study, we investigated how the bird communities varied in mountain parks under different urbanization influences in Fuzhou, China. Five conclusions were drawn. (1) In mountain parks, the species richness, abundance, and composition are affected by urbanization levels. The most urbanized areas have lower richness and abundance. Our study also found that, in mountain parks, urbanization has a significant impact on the assemblage and composition of insectivorous guild, upper stratum guild, and overall birds, but no significance on other guilds. (2) We clarified that omnivorous and insectivorous guilds appear to be more resilient to the negative effects of high urbanization, possibly because these two guilds have a wider range of food sources than herbivorous or carnivorous and are less demanding of habitat or living space. (3) Compared with the urban area, mountain parks in peri-urban and suburban areas have a richer composition and an abundance of birds. To promote taxonomic and functional bird diversity, however, we still emphasize the necessity of effective conservation of mountain parks under varying urbanization intensities. (4) Our study also validated that the "intermediate disturbance hypothesis" still holds true in mountain parks, implying that moderately urbanized areas can support greater bird diversity. (5) We confirmed that insectivorous or omnivorous guilds (such as *sooty-headed bulbul*, *tree sparrow*, and *grey-chinned minivet*) might be more suitable as indicator species for monitoring the effects of urbanization in mountain parks rather than carnivorous and herbivorous birds. However, in addition to optimizing ecosystem services for birds, mountain parks should also prioritize improving habitat heterogeneity in order to increase species diversity. This may involve research on habitat density, patch connectivity, ecological corridors, etc. Overall, our study helps inform future urban mountain park management and biodiversity restoration programs in an effort to mitigate the adverse impacts of urbanization on wildlife.

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