Pakistan J. Zool., pp 1-8, 2023. DOI: https://dx.doi.org/10.17582/journal.pjz/20230412120421

Review Article

β-diversity Patterns of Bird Communities in Natural Protected Areas in Anhui by Separating the Turnover and Nestedness Components

Kai Dong, Huidong Xu, Yongmin Li*, Jianchun Zhang, Weigen Wang and Dongwei Li

College of Biology and Food Engineering, Fuyang Normal University, 100 Qinghe West Road, Yingzhou District, Fuyang City, Anhui Province, China 236037

Article Information
Received 06 February 2023
Revised 05 June 2023
Accepted 27 June 2023
Available online 27 October 2023 (early access)

Authors' Contribution
KD completed the preparation and writing of the paper. HX collected the data and built the model. YL designed the research direction and gave guidance. JZ, WW and DL provided help for the research method and data analysis.

Key words
Anhui province, Protected areas, Avian community, β-diversity

ABSTRACT

β-diversity can be used to measure the differences between sites at spatial scales to reflect the variability of species composition. Therefore, understanding β-diversity is necessary to protect regional diversity and improve conservation strategies. In this study, we collected data on birds in 44 protected areas in Anhui Province, and decomposed the β-diversity of bird communities into spatial turnover and nestedness-resultant components to assess their relative contributions and respective relationships to differences in the geographical divisions (Jiangnan region, Jianghuai region and Huaibei region) and the types of protected areas (forest and wetland protected areas). The results show that the turnover component of protected areas in Anhui Province contributes more to β-diversity than the nestedness. Geographically, the Jianghuai region has the largest total difference due to its diverse landform; In terms of bird taxonomy, most of the β-diversity is dominated by turnover components; As for protected areas type, the total β-diversity and turnover rate of bird in the wetland are higher than those of forests; Among birds with foragguilds, carnivorous-insectivorous birds had the highest turnover rate of β-diversity; In terms of bird migration type, migratory birds had the highest turnover rate of β-diversity in Anhui Province. In management, attention should be paid to the protection of water sources and the maintenance of woodland, which is beneficial to the maintenance of bird communities and ecosystems.

EINTRODUCTION

Wildlife plays an important role in ecosystems; therefore, it is necessary to further understand the concept of biodiversity and improve conservation measures. In 1960, Whittaker proposed to divide species diversity into three levels: α, β, and γ diversity (Whittaker, 1960), where α and γ diversity indicate species richness within a spatial range, while β-diversity can predict the level of biodiversity within a region by quantifying community structure, reflecting differences in regional species composition (Whittaker, 1972; Harrison *et al*., 1992).

In addition, β-diversity is not limited to explaining the structure between habitats but is also conducive to maintaining ecosystems, and improving resource use efficiency and complementarity among regional species (Mori *et al*., 2018).

In 2010, Baselga brought forward the Sorensen dissimilarity index (Baselga, 2010), It decomposes β-diversity into two components, nesting and turnover, each of which represents a different ecological process (Angeler, 2013; Dapporto *et al*., 2014). Nesting patterns are affected by differences in species richness among communities, showing differences in the environmental demands of wildlife (Ulrich *et al*., 2009; Dobrovolski *et al*., 2012). The turnover pattern is mainly due to the occupation of a series of environmental gradients by different species, reflecting the uniformity of the environment between different protected areas (Si *et al*., 2015). Accordingly, if the contribution of nesting to the overall β-diversity between sites is greater than the turnover rate, this indicates that species-rich sites should be prioritized for conservation. Conversely, if the turnover component is the dominant phenomenon, then all sites should be protected (Angeler,

* Corresponding author: lyminron@163.com
0030-9923/2023/0001-0001 $ 9.00/0

2013; Baselga, 2013). There is abundant research on bird α-diversity in a single protected area of China (Xie *et al*., 2016; Zeng *et al*., 2018), but there are fewer studies linking protected areas for global analysis, especially the use of β-diversity (Si *et al*., 2015; Li *et al*., 2019; He *et al*., 2021). This study uses the additive decomposition of β-diversity to understand the replacement pattern of bird diversity in 44 protected areas in Anhui Province, and then explores conservation measures that are beneficial to bird diversity.

Anhui is located in the transitional zone of warm temperatures and subtropics with the climate characteristics of north and south (Yang *et al*., 2020). At the same time, Anhui is an intersection transition zone between the two major animal geographic regions, namely Palearctic and Oriental (Zhang, 2011). There are three major water systems including the Yangtze River, the Xin'an River, and the Huai River in Anhui, with a dense water network and rich wetland resources. Meanwhile, Anhui has developed mountain systems such as Huang Mountains, fractional Dabie Mountains, and Tianmu Mountains, diverse geographical environment, complex water system, and rich vegetation structure contribute to the abundance of bird species in Anhui Province (Supplementary Tables 1 and II). In this study, we collected bird data in 44 protected areas in Anhui Province and assessed the components of β-diversity, explored the spatial patterns of these protected areas, and addressed the following questions: (1) Whether β-diversity differs across geographic conditions? (2) Whether intraregional β-diversity is correlated with feeding habits or residence type of birds? (3) What is the potential and value of the existing protected areas in Anhui Province, and whether the conservation strategy needs to be improved?

MATERIALS AND METHODS

Study area

Anhui Province is located between 114°54′-119°27′E and 29°41′- 34°38′N, Southeast China. The total area 1.40×10^{5}km^2, accounting for 1.45% of the country's land area, there is significant seasonality, and the annual mean temperature in Anhui is 14-16°C with the extremely maximum temperature reaching more than 40°C. The average annual precipitation is between 600 and 800 mm (Fig. 1).

Anhui Province has initially established a network of protected areas with reasonable distribution in the Huaibei Plain, Jianghuai Hills, and Southern Anhui Mountains, effectively protecting the representative and typical forest and wetland ecosystems in Anhui. Most of Anhui's cities are located along the Yangtze and Huai rivers, the approximate length of these two rivers in Anhui is 430 km and 413km, respectively. They divide Anhui Province into Jiangnan, Jianghuai, and Huaibei regions, which is the geographical division of this study.

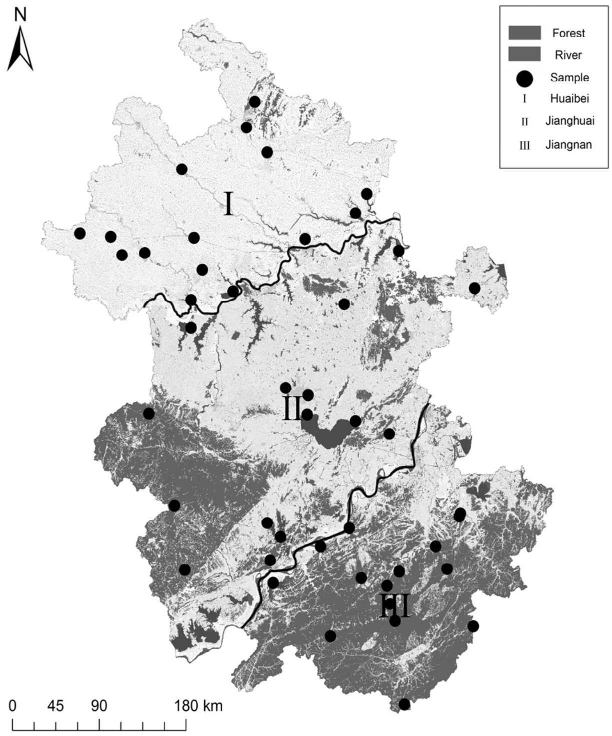

Fig. 1. Location of the 44 study regions in the protected areas of Anhui province, China. The region was divided into part I (Huaibei region), part II (Jianghuai region), and part III (Jiangnan region) by Huai River and Yangtze River.

According to the Anhui Statistical Yearbook (2021), In 2021, the forest coverage in Anhui was 30.22%, with a total area of 4.18×10^4 km^2, and the total area of wetlands in the province is 1.04×10^{4}km^2. The superior environment and abundant resources make these protected areas a suitable experimental site for studying biodiversity. Therefore, the ecological status of protected areas in Anhui Province must be investigated, and use this data to quantify the value of biodiversity in protected areas.

Data sources and collection

The data of 44 protected areas for this study was derived from field surveys and published literature. For the accuracy of the data, we compared the list with the China Bird Taxonomy and Distribution List (Third Edition) (Zheng, 2017) and consulted with researchers with fieldwork experience to remove controversial species from the lists. Feeding habits and residence types of birds in different regions draw from A Guide to Birds of Anhui.

Table I. Dissimilarity index and formula of measurement to determine β-diversity.

Family		References
Sorensen		
β_{SOR}	$\frac{[\sum_{i<j}\min(b_{ij},b_{ji})]+[\sum_{i<j}\max(b_{ij},b_{ji})]}{2[\sum_i S_i - S_T]+[\sum_{i<j}\min(b_{ij},b_{ji})]+[\sum_{i<j}\max(b_{ij},b_{ji})]}$	Baselga (2010)
β_{SIM}	$\frac{[\sum_{i<j}\min(b_{ij},b_{ji})]}{2[\sum_i S_i - S_T]+[\sum_{i<j}\min(b_{ij},b_{ji})]}$	Baselga *et al.*(2007), Baselga (2010)
β_{SNE}	$\frac{[\sum_{i<j}\max(b_{ij},b_{ji})]-[\sum_{i<j}\min(b_{ij},b_{ji})]}{2[\sum_i S_i - S_T]+[\sum_{i<j}\min(b_{ij},b_{ji})]+[\sum_{i<j}\max(b_{ij},b_{ji})]}\times\frac{\sum_i S_i - S_T}{[\sum_i S_i - S_T]+[\sum_{i<j}\min(b_{ij},b_{ji})]}$	Baselga (2010)
Jaccard		
B_{JAC}	$\frac{[\sum_{i<j}min(b_{ij},b_{ji})]+[\sum_{i<j}max(b_{ij},b_{ji})]}{[\sum_i S_i - S_T]+[\sum_{i<j}min(b_{ij},b_{ji})]+[\sum_{i<j}max(b_{ij},b_{ji})]}$	Baselga (2012)
B_{JTU}	$\frac{2[\sum_{i<j}min(b_{ij},b_{ji})]}{[\sum_i S_i - S_T]+[\sum_{i<j}min(b_{ij},b_{ji})]}$	Baselga (2012
B_{JNE}	$\frac{[\sum_{i<j}max(b_{ij},b_{ji})]-[\sum_{i<j}min(b_{ij},b_{ji})]}{[\sum_i S_i - S_T]+[\sum_{i<j}min(b_{ij},b_{ji})]+[\sum_{i<j}max(b_{ij},b_{ji})]}\times\frac{\sum_i S_i - S_T}{[\sum_i S_i - S_T]+[\sum_{i<j}min(b_{ij},b_{ji})]}$	Baselga (2012)

Data analysis

Among the protected areas in Anhui Province, 14 are located in the Jiangnan area, and 15 are in either the Jianghuai or Huaibei region. There are two types of protected areas, including 13 forests and 31 wetlands. Birds are classified into 6 foraging groups and 4 resident types before the analysis (Table I). The distribution of birds in all protected areas is formed into a matrix, in which the species that are distributed in the area are represented by 1, and those that do not exist are represented by 0.

The Sorensen and Jaccard index were used to measure β-diversity in this study (Jaccard, 1912; Sorensen, 1948). In 2012, Baselga proposed an additive decomposition of β-diversity to decompose β-diversity into turnover and nesting parts (Baselga and Orme, 2012). First, the Sorensen dissimilarity index was used to calculate the total dissimilarity (βSOR) and its turnover (βSIM) and nested (βSNE) components using a multi-site calculation method: βSOR = βSIM + βSNE. In the Baselga decomposition method, the total β-diversity and turnover components are directly calculated, and the nesting components are the minus of the first two parts (Baselga *et al*., 2007; Baselga, 2010). In addition, Baselga also proposed a β-diversity decomposition method based on the Jaccard dissimilarity index. The Jaccard decomposition method of the total β-diversity and its turnover and nested composition of multiple loci is: βJAC = βJTU + βJNE.

We also calculated the Jaccard pairwise dissimilarity index to corroborate our results, and the corresponding decomposition method of pairing calculation is: βjac = βjtu + βjne (Baselga, 2012). All analyses were performed in R 4.2.2 using packages vegan and betapart (R Core Team, 2022).

RESULTS

In this study, the total number of species belonging to the sampling point is 364, which belongs to 20 Orders. Of the 364 bird species, 118 are residents, 80 are migratory birds, 77 are winter birds, and 89 are summer birds. Likewise, insectivorous birds are dominant, with 136 species, along with 133 omnivorous, 51 carnivorous-insectivorous, 24 carnivorous, 12 herbivorous and 8 carnivorous-scavenger. Among the 3 geographic regions in which the 44 protected areas are distributed, the Jiangnan region recorded the highest average number of species with 147 species, followed by 121 species in the Jianghuai region and 113 species in the Huaibei region. There was no spatial autocorrelation in bird diversity.

Geographic region

By the Sorensen and Jaccard algorithm, the total dissimilarity of the protected areas in Anhui Province was 0.9065 and 0.9510, respectively. On the three regions

Table II. β-Diversity of Anhui Province and three regions calculated by multi-loci.

Region	Method	Turnover β_{SIM}	Proportion (%)	Nested β_{SNE}	Proportion (%)	Dissimilarity β_{SOR}
Overall	Sorensen	0.8399	92.65	0.0667	7.35	0.9065
	Jaccard	0.9130	96.00	0.0380	4.00	0.9510
Jiangnan region	Sorensen	0.5805	78.08	0.1630	21.92	0.7435
	Jaccard	0.7346	86.13	0.1183	13.87	0.8529
Jianghuai region	Sorensen	0.6390	81.38	0.1463	18.62	0.7853
	Jaccard	0.7798	88.64	0.1000	11.36	0.8797
Huaibei region	Sorensen	0.5743	82.21	0.1243	17.79	0.6986
	Jaccard	0.7296	88.70	0.0930	11.30	0.8226

Table III. β-diversity of protected area types calculated by the multi-locus.

Protected area type	Method	Turnover β_{SIM}	Proportion (%)	Nested β_{SNE}	Proportion (%)	Dissimilarity β_{SOR}
Forest	Sorensen	0.5254	73.51	0.1893	26.49	0.7146
	Jaccard	0.6888	82.63	0.1448	17.37	0.8336
Wetland	Sorensen	0.7575	88.35	0.0999	11.65	0.8574
	Jaccard	0.8620	93.37	0.0612	6.63	0.9232

of Jiangnan, Jianghuai, and Huaibei, the Sorensen and Jaccard indices of Jianghuai region had the highest total dissimilarity at 0.7435 and 0.8797 respectively, followed by Jiangnan region with 0.7435 and 0.8529 and Huaibei region of 0.6986 and 0.8226 (Table II). The β-diversity of both Anhui province and the three regions showed a turnover pattern. At the same time, we used the pairing algorithm of Sorensen and Jaccard for analysis, which confirmed that the turnover of bird β-diversity in protected areas in Anhui Province was the dominant component (Fig. 2).

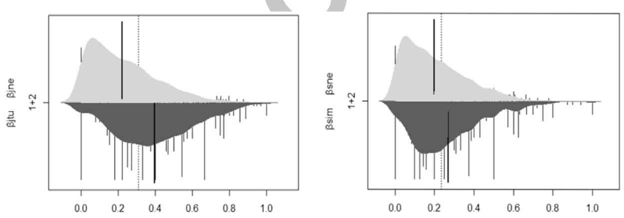

Fig. 2. Distribution of βsim (βjtu) and βsne (βjne) based on βsor (βjac) on the Sorensen and Jaccard pair algorithm, the upper half represent βsim (turnover), the lower half represent βsne (nested).

Protected area type

The Sorensen and Jaccard indices showed the β-diversity of wetland-protected areas were 0.8574 and 0.9232 respectively, which higher than 0.7146 and 0.8336 (Table III) of forest-protected areas.

Bird taxonomy

A total of 364 bird species were included in this study, which belongs to 20 different categories. The dissimilarity index of each category is calculated by the Sorensen and Jaccard algorithm. Among them, the Sorensen diversity index of Suliformes was the highest at 0.9584, and the lowest was Pigeoniformes at 0.7182. On the Jaccard index, Bustardiforms was the highestat 0.9763, and Pigeoniformes is the lowest at 0.8360 (Table IV).

Bird foraging guild

According to the main feeding habits of birds in Anhui Province, birds were divided into six groups: Herbivorous, omnivorous, carnivorous-scavenger, carnivorous-insectivorous, carnivorous, and insectivorous. Among them, carnivorous-scavenger has the highest Sorensen index of 0.9515 and Jaccard index of 0.9752 (Table V).

Bird resident types

According to their residence types in Anhui Province, the birds were divided into four groups: migratory birds, resident birds, summer birds, and winter birds. The Sorensen index of migratory birds is the highest at 0.9324, followed by winter birds (0.9117), summer birds (0.9047), and resident birds (0.8848). Among them, the nesting ratio of resident birds was highest (15.80%), and the nesting ratio of migratory birds was the lowest at 7.42% (Table V).

Table IV. β-diversity of bird taxonomy calculated by β_{SNE} the multi-locus.

Bird taxonomy	Method	Turnover β_{SIM}	Proportion (%)	Nested β_{SNE}	Proportion (%)	Dissimilarity β_{SOR}
Galliformes	Sorensen	0.7206	79.55	0.1853	20.45	0.9059
	Jaccard	0.8376	88.11	0.1130	11.89	0.9506
Anseriformes	Sorensen	0.7257	78.54	0.1983	21.46	0.9240
	Jaccard	0.8411	87.56	0.1194	12.44	0.9605
Podicipediformes	Sorensen	0.2152	25.69	0.6225	74.31	0.8377
	Jaccard	0.3542	38.85	0.5575	61.15	0.9117
Columbiformes	Sorensen	0.2632	36.64	0.4551	63.36	0.7182
	Jaccard	0.4167	49.84	0.4194	50.16	0.8360
Caprimulgiformes	Sorensen	0.7829	83.27	0.1573	16.73	0.9402
	Jaccard	0.8782	90.62	0.0909	9.38	0.9692
Cuculiformes	Sorensen	0.7772	86.38	0.1225	13.62	0.8997
	Jaccard	0.8746	92.34	0.0726	7.66	0.9472
Otidiformes	Sorensen	0.0000	0.00	0.9536	100.0	0.9536
	Jaccard	0.0000	0.00	0.9763	100.0	0.9763
Gruiformes	Sorensen	0.7665	84.54	0.1402	15.46	0.9067
	Jaccard	0.8678	91.25	0.0833	8.75	0.9511
Charadriiformes	Sorensen	0.7450	80.81	0.1770	19.19	0.9220
	Jaccard	0.8539	89.00	0.1055	11.00	0.9594
Ciconiiformes	Sorensen	0.3030	32.17	0.6390	67.83	0.9420
	Jaccard	0.4651	47.94	0.5050	52.06	0.9701
Suliformes	Sorensen	0.0000	0.00	0.9584	100.0	0.9584
	Jaccard	0.0000	0.00	0.9202	100.0	0.9202
Pelecaniformes	Sorensen	0.6498	75.68	0.2088	24.32	0.8586
	Jaccard	0.7877	85.26	0.1362	14.74	0.9239
Accipitriformes	Sorensen	0.8206	87.77	0.1143	12.23	0.9349
	Jaccard	0.9014	93.28	0.0649	6.72	0.9664
Strigiformes	Sorensen	0.7588	80.75	0.1809	19.25	0.9397
	Jaccard	0.8628	89.06	0.1060	10.94	0.9689
Bucerotidae	Sorensen	0.0000	0.00	0.8045	100.0	0.8045
	Jaccard	0.0000	0.00	0.8916	100.0	0.8916
Coraciimorphae	Sorensen	0.6294	70.18	0.2675	29.82	0.8969
	Jaccard	0.7726	81.70	0.1731	18.30	0.9456
Piciformes	Sorensen	0.5923	65.61	0.3105	34.39	0.9028
	Jaccard	0.7440	78.40	0.2050	21.60	0.9489
Falconiformes	Sorensen	0.7167	78.54	0.1958	21.46	0.9126
	Jaccard	0.8350	87.50	0.1193	12.50	0.9543
Passeriformes	Sorensen	0.7967	88.34	0.1052	11.66	0.9019
	Jaccard	0.8869	93.51	0.0616	6.49	0.9484

Table V. β-diversity of bird foraging guild calculated by the multi-locus.

Bird foraging guild	Method	Turnover β_{SIM}	Proportion (%)	Nested β_{SNE}	Proportion (%)	Dissimilarity β_{SOR}
Herbivorous	Sorensen	0.5852	64.03	0.3288	35.97	0.9140
	Jaccard	0.7384	77.31	0.2167	22.69	0.9551
Omnivorous	Sorensen	0.8312	92.34	0.0690	7.66	0.9002
	Jaccard	0.9078	95.81	0.0397	4.19	0.9475
Carnivorous scavenging	Sorensen	0.6449	67.77	0.3067	32.23	0.9515
	Jaccard	0.7841	80.41	0.1911	19.59	0.9752
Carnivorous insectivorous	Sorensen	0.8413	92.62	0.0670	7.38	0.9083
	Jaccard	0.9138	95.99	0.0381	4.01	0.9520
Carnivorous	Sorensen	0.8043	88.69	0.1025	11.31	0.9069
	Jaccard	0.8916	93.73	0.0596	6.27	0.9512
Insectivorous	Sorensen	0.8261	90.85	0.0832	9.15	0.9092
	Jaccard	0.9048	94.99	0.0477	5.01	0.9525

Table VI. β-diversity of bird resident type calculated by the multi-locus.

Bird resident type	Method	Turnover β_{SIM}	Proportion (%)	Nested β_{SNE}	Proportion (%)	Dissimilarity β_{SOR}
Migratory birds	Sorensen	0.8633	92.58	0.0691	7.42	0.9324
	Jaccard	0.9266	96.02	0.0384	3.98	0.9650
Resident bird	Sorensen	0.7450	84.20	0.1398	15.80	0.8848
	Jaccard	0.8539	90.95	0.0850	9.05	0.9389
Summer birds	Sorensen	0.8345	92.25	0.0701	7.75	0.9047
	Jaccard	0.9098	95.77	0.0401	4.23	0.9500
Winter birds	Sorensen	0.8017	87.93	0.1101	12.07	0.9117
	Jaccard	0.8899	93.30	0.0639	6.70	0.9538

DISCUSSION

Geographic region

Geographically, the Jianghuai region is located in the north-south transition zone of Anhui, which includes the Dabie Mountains and the Anhui alluvial plain, with dense river networks and complex landforms. The forest structure of mountains and types of wetlands in the Jianghuai region is diverse, providing a rich habitat for birds, resulting in the largest total difference in the Jianghuai region.

The protected areas of Jiangnan are mainly distributed in mountainous areas, and the vegetation is dominated by evergreen broad-leaved forests. There are two major mountain systems in southern Anhui: Tianmu Mountain and Yellow Mountain, and the connectivity between these two mountain systems is low. Due to geographical isolation, the bird communities in southern Anhui are obviously different.

As for the Huaibei region, it is a flat alluvial plain and an agricultural region with a long history. In the long-term reclamation, the remaining forests have been replaced by artificial shelter forests. Due to the massive loss of wildlife habitats, the total dissimilarity of β-diversity in the Huaibei region is the lowest in Anhui Province.

Protected area type

Compared with wetland, the turnover components (β_{SIM}) and the total difference of β-diversity (β_{SOR}) in forest protected areas are lower. The forests generally include only two habitats of woodland and stream for forest birds and migratory birds. However, wetlands are usually surrounded by forests as buffer zones, therefore, wetland protected areas can provide places for birds of various ecological groups to forage, drink, reproduce and inhabit. At the same time, the woodland is an important habitat for birds, which is effective in increasing bird diversity in forest and wetland-protected areas. Na Li also elaborated on the importance of woody plants in river habitats (Li *et al*., 2019). This also shows the wetland protection strategy in Anhui is effective.

Bird taxonomy

Among the recorded birds, the β-diversity of podicipediformes, columniformes and ciconiiformes shows a nesting pattern, which shows that most protected areas in Anhui have suitable habitats for them. For example, two species of Podicipediformes (*Podiceps ruficollis* and *Podicep cristatus*) are widely distributed in Anhui Province because of the developed water system. On the other hand, except for *Oenopelia tranquebarica*, the other two species (*Streptopelia orientalis* and *Streptopelia chinensis*) in Columniformes have low requirements for habitats and are widely distributed, therefore, they are widely distributed and have low turnover rate. In addition to the above birds, the other birds are dominated by turnover components of β-diversity, because Anhui is located on the East Asia-Australia Flyway, there are frequent temporal and spatial changes in birds.

Bird foraging guild

β-diversity difference of types of birds (omnivorous, carnivorous, insectivorous and carnivorous-insectivorous) is clear. These differences may be attributed to the fact that Anhui is located in the transition zone between warm temperate and subtropical zones, resulting in a diverse vegetation structure that provides food sources for birds with various feeding habits. But the human impact on protected areas they mentioned is not reflected in this study, which we need to improve.

Bird resident type

Anhui is located centrally in the East Asian-Australasian Flyway, and a large proportion of the migratory bird population of the Flyway uses its superior environment during migration. Therefore, the distribution of migratory birds shows a turnover pattern, while the turnover rate of resident birds is smaller than that of migratory birds due to their suitable environment or weak migration ability. There is a classic example in Anhui Province: Galliformes have the poor migratory ability, in which Syrmaticus reevesii is distributed in the western Anhui, and Syrmaticus ellioti is only distributed in the south.

CONCLUSION

Anhui spans 570 kilometers from north to south, with complex landforms, and diverse climates, resulting in significant environmental differences among protected areas. Geographically, the β-diversity of birds in Anhui Province was different in the three regions, indicating that the β-diversity was correlated with climate, geography, and vegetation characteristics. At the same time, the β-diversity of birds is also related to their feeding habits and resident types, this is related to selectivity to the environment of birds, and also reveals the transit station status of Anhui Province in the migratory route of birds. We also divided the protected areas in Anhui Province into forest and wetland, the comparison of turnover patterns between them shows that although wetland protected areas can accommodate waterbirds, due to the presence of buffer forest land, wetlands also contain a large number of forest birds and occupy a major position. Forest birds mainly live in forest-protected areas, so maintaining woody vegetation is crucial to support a variety of bird species when customizing conservation strategies. As far as the status of avian β-diversity in Anhui Province is concerned, emphasis should be placed on the conservation of the overall environment rather than specific areas. On the whole, the distribution of birds in Anhui Province presents a turnover pattern, which shows the potential value of protected areas in Anhui Province, and the strategy in ecological conservation is scientific and effective.

Based on the characteristics of β-diversity, we propose the following suggestions for the management of these protected areas: (1) Strengthen the network relationship between protected areas to alleviate the trend of large-scale landscape fragmentation; (2) Develop natural resource utilization policies for the peripheral areas around the protected areas; (3) Strengthen the monitoring of multi-scale ecosystems and improve the effectiveness of protected area management based on feedback from dynamic changes in protected objects.

ACKNOWLEDGMENT

Special thanks to Dr. Pancheng Xie from University of Texas, Southwestern Medical Center at Dallas, Dr. Qi Liu from Kunming Institute of Zoology, modified this paper.

Funding

This research was supported by the Provincial Nature Science Research Projects of Anhui Colleges (KJ2021A0670; KJ2021A0669).

Ethics statement and IRB approval

Ethics Committee approval was obtained from the Institutional Ethics Committee of Fuyang Normal University to the commencement of the study. This study mainly observes birds in the wild, and does not interfere with the behavior of birds and will not cause harm to animals.

Supplementary material

There is supplementary material associated with this article. Access the material online at: http://dx.doi.org/10.17582/journal.pjz/..........

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Angeler, D.G., 2013. Revealing a conservation challenge through partitioned long-term beta diversity: increasing turnover and decreasing nestedness of boreal lake metacommunities. *Divers. Distrib.*, **19**: 772–781. https://doi.org/10.1111/ddi.12029

Baselga, A., 2010. Partitioning the turnover and nestedness components of beta diversity. *Glob. Ecol. Biogeogr.*, **19**: 134–143. https://doi.org/10.1111/j.1466-8238.2009.00490.x

Baselga, A., 2013. Separating the two components of abundance-based dissimilarity: Balanced changes in abundance vs. abundance gradients. *Methods Ecol. Evol.*, **4**: 552–557. https://doi.org/10.1111/2041-210X.12029

Baselga, A., Jiménez-Valverde, A. and Niccolini, G., 2007. A multiple-site similarity measure independent of richness. *Biol. Lett.*, **3**: 642–645. https://doi.org/10.1098/rsbl.2007.0449

Baselga, A. and Orme, C.D.L., 2012. Betapart: An R package for the study of beta diversity. *Methods Ecol. Evol.*, **3**: 808–812. https://doi.org/10.1111/j.2041-210X.2012.00224.x

Baselga, A., 2012. The relationship between species replacement, dissimilarity derived from nestedness, and nestedness. *Glob. Ecol. Biogeogr.*, **21**: 1223–1232. https://doi.org/10.1111/j.1466-8238.2011.00756.x

Dapporto, L., Fattorini, S., Vodă, R., Dincă, V. and Vila, R., 2014. Biogeography of western Mediterranean butterflies: Combining turnover and nestedness components of faunal dissimilarity. *J. Biogeogr.*, **41**: 1639–1650. https://doi.org/10.1111/jbi.12315

Dobrovolski, R., Melo, A.S., Cassemiro, F.A., Diniz□Filho, J.A.F., 2012. Climatic history and dispersal ability explain the relative importance of turnover and nestedness components of beta diversity. *Glob. Ecol. Biogeogr.*, **21**: 191–197. https://doi.org/10.1111/j.1466-8238.2011.00671.x

Hailong, W., 2017. *A guild to the birds of Anhui*. Anhui Normal University Press, Wuhu.

Harrison, S., Ross, S.J. and Lawton, J.H., 1992. Beta diversity on geographic gradients in Britain. *J. Anim. Ecol.*, **61**: 151-158. https://doi.org/10.2307/5518

He, X., Brown, C. and Lin, L., 2021. Relative importance of deterministic and stochastic processes for beta diversity of bird assemblages in Yunnan, China. *Ecosphere*, **12**: e03545. https://doi.org/10.1002/ecs2.3545

Jaccard, P., 1912. Jaccard coefficient similarity. *New Phytol.*, **11**: 37–50. https://doi.org/10.1111/j.1469-8137.1912.tb05611.x

Li, N., Sun, Y., Chu, H., Qi, Y., Zhu, L., Ping, X. and Jiang, Z., 2019. Bird species diversity in Altai riparian landscapes: Wood cover plays a key role for avian abundance. *Ecol. Evol.*, **9**: 9634–9643. https://doi.org/10.1002/ece3.5493

Mori, A.S., Isbell, F. and Seidl, R., 2018. β–diversity, community assembly, and ecosystem functioning. *Trends Ecol. Evol.*, **33**: 549–564. https://doi.org/10.1016/j.tree.2018.04.012

R Core Team, 2022. R: *A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. https://www.R–project.org/.

Si, X., Baselga, A. and Ding, P., 2015. Revealing beta-diversity patterns of breeding bird and lizard communities on inundated land-bridge islands by separating the turnover and nestedness components. *PLoS One*, **10**: e0127692. https://doi.org/10.1371/journal.pone.0127692

Sorensen, T., 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species and its application to analyses of the vegetation on Danish commons. *Biol. Skar*, **5**: 1–34.

Statistics Bureau of Anhui Province, NBS Survey Office in Anhui, 2021. *Anhui statistical yearbook*. China Statistical Press, Beijing, China.

Ulrich, W., Almeida-Neto, M. and Gotelli, N.J., 2009. A consumer's guide to nestedness analysis. *Oikos*, **118**: 3–17. https://doi.org/10.1111/j.1600-0706.2008.17053.x

Whittaker, R.H., 1960. Vegetation of the Siskiyou Mountains, Oregon and California. *Ecol. Monogr.*, **30**: 279–338. https://doi.org/10.2307/1943563

Whittaker, R.H., 1972. Evolution and measurement of species diversity. *Taxon*, **21**: 213–251. https://doi.org/10.2307/1218190

Xie, S., Lu, F., Cao, L., Zhou, W. and Ouyang, Z., 2016. Multi-scale factors influencing the characteristics of avian communities in urban parks across Beijing during the breeding season. *Sci. Rep. U.K.*, **6**: 1–9. https://doi.org/10.1038/srep29350

Yang, H., Hu, D., Xu, H. and Zhong, X., 2020. Assessing the spatiotemporal variation of NPP and its response to driving factors in Anhui province, China. *Environ. Sci. Pollut. R*, **27**: 14915-14932. https://doi.org/10.1007/s11356-020-08006-w

Zeng, N., Liu, G., Wen, S. and Tu, F., 2018. New bird records and bird diversity of poyang lake national nature reserve, Jiangxi Province, China. *Pakistan J. Zool.*, **50**: 1285–1291. https://doi.org/10.17582/journal.pjz/2018.50.4.1285.1291

Zhang, R.Z., 2011. *Zoogeography of China*. Science Press, Beijing.

Zheng, G.M., 2017. *A checklist on the classification and distribution of the birds of China*. 3th ed. Science Press, Beijing.