

Article

The Impact of Zoning Designations on Bird Communities: A Case Study of National Nature Reserves in Guangdong Province

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Abstract: One of the main management strategies of China's nature reserve is "zonation", dividing reserves into three zones (core, buffer, and experimental zones) to which different levels of restrictions on anthropogenic activities are applied. While zonation has a positive effect on the conservation of target species, it is unclear whether management zones can be effective in conserving biodiversity. Using bird data collected from five national nature reserves of Guangdong province in China during 2018–2019, we investigated how management zones and reserves are associated with bird diversity and community composition. We considered species richness, the community-weighted mean (CWM) values of 10 single traits, and beta diversity based on 2 dissimilarity indices (Jaccard and Bray–Curtis). The overall effects of zone management were weak or insignificant. Species richness and the CWMs of most traits were not associated with zone ($p > 0.08$). Reserve itself was a strong factor influencing bird traits. Dissimilarity indices also showed variations in bird community composition between reserves in the north region and those in the south region, which were largely contributed by the turnover component of beta diversity ($p \geq 0.06$ for nestedness and $p \leq 0.03$ for turnover in both dissimilarity indices). The dominance of turnover indicates that these reserves could be equally important to maintain regional bird diversity, requiring a multiple-site management plan. Our study also suggests that current zoning designations of the five reserves may not be as effective in conserving bird species diversity and traits; however, caution is needed due to the limitations of our study design, such as potential observer effect and insufficient sampling effort.

Keywords: beta diversity; bird diversity; community-weighted mean; nature reserve; species trait; zonation



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1. Introduction

Protected areas (e.g., nature reserves, national parks, and wilderness areas) are critical to conserve global biodiversity as well as ecosystem function, although their effectiveness is also influenced by factors such as funding, management, and local community support [1–5]. Approximately 16.64% of the world's terrestrial surface and inland waters are protected and conserved, and 7.84% of the world's terrestrial land is both protected and connected [6]. China contains 15% and 12% of the world's vertebrate and plant species [7] as it has a wide range of ecosystems, from cold temperatures to tropical forests [8]. However, China is also one of the countries experiencing significant biodiversity loss [9]. One-third of

China's lands face a high risk of conflict between biodiversity conservation and human activities [10].

To conserve biodiversity, China has established different types of protected areas and increased the number of nature reserves that are designated for the protection of distinctive ecosystems and endangered or native species [11]. In particular, the number of national nature reserves has substantially increased from 71 to 474 between 1993 and 2019, covering ~10% of China's land [12,13]. National nature reserves show different distribution patterns between western and eastern China. Most large national nature reserves are concentrated in western China, whereas many small, isolated ones are in southeastern China; for example, subtropical evergreen broad-leaved forests that have highly diverse plants in China are conserved in small and fragmented nature reserves in southeastern provinces [14,15].

Zonation, i.e., dividing a landscape into several zones for different purposes, has been an important part of the protected area management strategy in China. National nature reserves are often divided into three zones by referring to the guideline of UNESCO's Man and Biosphere Programme [16], which considers not only biodiversity conservation but also the economic development of local communities: core, buffer, and experimental zones [17]. While a two-zoning (also called mixed zoning) scheme is recommended as a standard design, especially for national parks in recent reform [18], a three-zoning scheme has been common practice. A major difference between the three zones is the type and level of human activity allowed [19]. A core zone is strictly protected, allowing only individuals or units with approved scientific research to enter the area. Scientific experiments, educational activities, and tourism can occur in experimental zones. Similar activities may be allowed in buffer zones; however, they are largely observational. Although the total area of nature reserves has increased during the past several decades, the percentage of core zones have declined and the loss of nature reserve areas or their boundary adjustments often occur in regions with fast economic growth [20]. This suggests that conflicts between economic growth and conservation can increase pressure on reserve management for the sustainable use of these protected areas over conservation.

Nature reserves play an important role in maintaining or promoting the population of threatened species and ecosystem services [11,21,22]. However, the zoning of nature reserves has sometimes been designated without sufficient field data [11]; zoning can be unreasonable (e.g., a lack of buffer zones, subjective zoning, and disconnection between core zones of neighboring reserves), and the management of zones and monitoring efforts are limited [23–25]. The effectiveness of reserve management for conserving biodiversity other than the species of interest also remains speculative [9]. For example, in the Giant Panda Nature Reserve in the Qinling Mountains, the detection of and suitable habitat for the giant panda is largely concentrated in the core zone, whereas some protected bird and mammal species can often be found outside of the core zone, i.e., in the buffer and experimental zones [26]. There is also a discrepancy between management zones including reserve boundary and species distribution [27,28].

We assessed how the management zones of China's nature reserves influence bird communities by using data collected from five national nature reserves representing subtropical evergreen broad-leaved forests in Guangdong province, which has the largest economy in southern China. Protected areas occupy approximately 14.3% of the terrestrial lands of Guangdong and half of the areas are national nature reserves [29]. Guangdong is one of the southern provinces that contains the highest number of threatened species in China; however, its biodiversity has significantly decreased due to industrial activities [30]. We examined variations in species richness and the community-weighted mean (CWM) values of bird traits between management zones including outside the reserves (three zones—core, buffer, and experimental zones, and reserve boundary area). It is expected that the CWMs of migratory birds and large-sized birds could be higher in the core and buffer zones than in the other zones as these birds can be susceptible to human disturbance [31–33]. Conversely, the CWM of omnivorous birds may show the opposite pattern, i.e., higher values in experimental zones and reserve boundary areas, considering that

the abundance or species richness of omnivorous birds is often high in human-altered landscapes [32,34]. We also explored two components (nestedness—species gain/loss and turnover—species replacement) of beta diversity of birds to understand the changes in species composition of the bird communities between five national nature reserves, which can be useful information for the development of conservation management planning at the regional level.

2. Materials and Methods

2.1. Study Sites and Bird Surveys

This study was performed in five national nature reserves in Guangdong province, China: Chebaling National Nature Reserve (CBL), Nanling National Nature Reserve (NL), Shimentai National Nature Reserve (SMT), Xiangtou Mountain National Nature Reserve (XTS), and Yunkai Mountain National Nature Reserve (YKS). The first three reserves are located in northern Guangdong and the other two in southern Guangdong (Figure 1). Most of these reserves were designated as provincial nature reserves in the early stage and were later upgraded to national nature reserves: CBL in 1988, NL in 1994, SMT in 2012, XTS in 2002, and YKS in 2014.

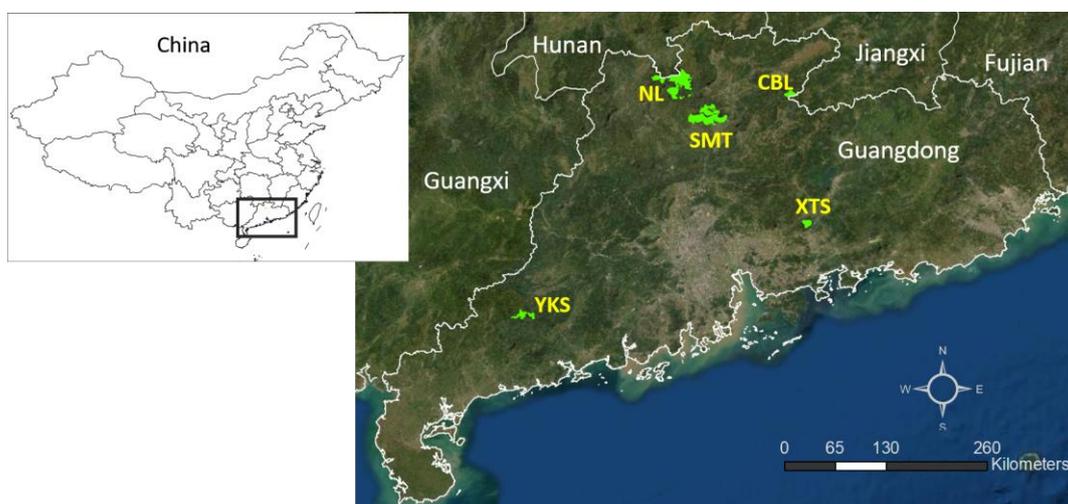


Figure 1. Location of five national nature reserves (green color) in Guangdong province, China: Chebaling National Nature Reserve (CBL); Nanling National Nature Reserve (NL); Shimentai National Nature Reserve (SMT); Xiangtou Mountain National Nature Reserve (XTS); Yunkai Mountain National Nature Reserve (YKS). White line represents provincial boundary. Source of satellite image: Esri, Maxar, GeoEye, Earthstar Geographics, CNESAirbus DS, USDA, USGS, AeriGRID, IGN, and GIS User Community.

The two northmost national nature reserves of Guangdong province, NL and CBL, are at the boundary between Easter Hillock-Hainan zoogeographic subregion and Min-Guang Coastal zoogeographic subregion, which are considered a tropical forest and subtropical forest, respectively [35]. Three reserves (NL, CBL, and SMT) in northern Guangdong are part of the Nanling Mountains, one of the most biodiversity-rich regions, especially mammal and endemic plant diversity-rich regions, in China [36]. Globally endangered species, Mangshan Pit Viper (*Protobothrops mangshanensis*), and the critically endangered species, Yingde Leopard Gecko (*Goniurosaurus yingdeensis*), are found in NL and SMT, respectively. Each reserve has 2 or 4 flagship species. White-eared Night-heron (*Gorsachius magnificus*) is considered a flagship species in CBL, NL, and SMT, while Chinese Pangolin (*Manis pentadactyla*) is regarded as one in XTS and YKS. Of the five reserves, NL has the largest protected area (58,700 ha) and CBL has the smallest (7500 ha). The elevation of YKS reaches up to 1700 m and the elevation of NL to 1900 m, whereas the highest peak of XTS is only 1000 m. Although all five reserves may be classified as Easter Hillock-

Hainan zoogeographic subregions [35], they are considered subtropical evergreen broad-leaved forests and they have been established to preserve these forest ecosystems, rare and endangered animals, and their habitats. In particular, in NL and CBL, the aim is to protect the central subtropical evergreen broad-leaved forest ecosystems, and in YKS and XTS, the aim is to protect the south subtropical evergreen broad-leaved forest ecosystems. The five reserves are dominated by trees and shrubs that belong to the genera *Castanopsis*, *Eurya*, *Itea*, *Machilus*, *Schima*, and *Symplocos*. Pine trees are relatively common in the three reserves of northern Guangdong, especially NL, whereas plants of the family Rubiaceae are often found in the two reserves of southern Guangdong. All reserves have a subtropical monsoon climate with an annual average temperature of 17–21.8 °C. The size of each management zone and the elevation and flagship species of each reserve are summarized in Supplementary Material Table S1.

In each reserve, we selected 5 trails considering travel time and accessibility and established 10 points (150–300 m apart) along a trail, except 1 trail in CBL that had 6 points. While sample points were largely located within the same management zone along a trail, several trails had points located across two different management zones (Supplementary Material Figure S1). Similarly, elevation also varied along the trails: the elevation difference between the lowest and highest points at each trail ranged from 30 m to 370 m.

We carried out bird surveys using a point count method once a season between 2018 and 2019, resulting in a total of four visits per point. Only 1 trail of SMT was visited three times with no survey in winter. Most surveys were performed in the morning (AM); however, 27% of sites were surveyed in the afternoon (PM) during some seasons in CBL and XTS. At each point, an observer identified and recorded bird species detected visually or aurally within a 50 m radius area surrounding a point for 10 min. Each reserve was largely surveyed by the same observer throughout the study period due to logistic issues. We trained all observers for bird surveys to minimize variations in detectability between observers. Surveys were not performed on windy or rainy days as the weather conditions could affect bird activities and consequently detections.

2.2. Analysis

Considering variations in elevation and zonal location along the trails, we focused on a “point” as a sample unit for analysis. However, points were closely located when trails were meandering, increasing spatial dependence between points. Point-by-point bird detection was also low. At each trail, we selected 3 pairs of points, i.e., 3 pairs of 2 adjacent points, based on Euclidean distance between pairs, and combined the bird data of two adjacent points while maintaining all detection records at each point. The pulled data represented an independent sample unit for analysis (referred to as site hereafter). The mean nearest distance between sites, i.e., from the center of pairs to the center of adjacent pairs, was 595 m, with a standard deviation of 215 m. Elevations of a pair of points were averaged and the mean value was used as the elevation of the site (see Supplementary Material Table S1 for the range of elevations of sites within each reserve).

We pulled the data from the 4 visits together due to sparse detection. We considered all species detected at least once during the 4 visits and observed >1 sites across all reserves, resulting in a total of 86 species. For each species, the maximum count of 4 visits was used as abundance. For species traits, we focused on body mass, diet type (insect, fruit/nectar, plant/seed, and omnivorous diet), foraging stratum based on height (ground, low, low to high, and high), and migratory status (migrant or resident). The first three traits of species were compiled from Wilman et al. [37]. Migratory status was determined by referring to Zou and Ye [38] and experts’ opinions. The list of species and species’ traits is summarized in Supplementary Material Table S2. Species’ detection/non-detection at each reserve and zone are also shown in Supplementary Material Figure S2.

We calculated the community-weighted mean (CWM) value for each trait using “FD” package [39] in R version 4.2.0 [40]. The community-weighted mean is the mean trait value weighted by species’ relative abundance in the community, which informs the dominant

trait [41]. The CWM values range from 0 to 1. The CWM is widely used to examine trait–environment relationships due to its simplicity [42–46], although there has been a concern that the CWM may increase type I errors in some situations [47].

In addition to the CWMs of traits, we considered species richness, i.e., the number of species, leading to 10 response variables. For each response variable, we constructed two generalized linear models (GLMs): a full model including elevation (standardized value), management zone, and reserve identity as explanatory variables; a null model (no explanatory variables, i.e., an intercept-only model). The GLMs of species richness were built with Poisson distribution, those of body mass with Gamma distribution after being log-transformed, and those of CWM with beta distribution (“betareg” package) [48]. The full model was compared with the null model based on Akaike’s Information Criterion adjusted for a small sample size, i.e., AICc in “MuMIn” package [49]. If AICc of the full model was lower than that of the null model and the AICc difference (Δ AICc) between the two models was >2 , the full model was used to make an inference [50]. If the null model showed a lower AICc, we concluded that there was no association between the response and explanatory variables. However, when the AICc values of full and null models were similar (i.e., Δ AICc < 1), we performed a likelihood ratio test. If the test result was significant ($p < 0.05$), the full model was selected. When a significant effect of reserve or management zone was found, we compared their least-squares means (lsmeans; estimated marginal means) and 95% confidence intervals (CIs) as a post-hoc analysis (“emmeans” package) [51]. We considered that if 95% CIs did not overlap, their lsmeans were different at the $p < 0.05$ level.

Variations in the time of the survey (i.e., AM or PM) between seasons may affect species detection at sites. Before the model’s selection, the potential effect of the time of the survey was tested by including the frequency of AM surveys in the full model as an additional explanatory variable. The frequency of AM surveys did not have an impact on the response variables ($p \geq 0.12$ for all cases). Thus, we assumed that any bias associated with differences in the survey time would be minimal in our study and excluded the variable from the final analysis.

We also conducted Moran’s I test to investigate spatial dependence in our data using “ape” package [52]. Spatial dependence was not found in the residuals of all models ($p > 0.2$) except for body mass ($p = 0.03$). However, the null model of body mass was the top model (see the results below), and thus we did not make any further inferences on body mass. The values of variation inflation factor were < 1.7 in all models, suggesting no issue of multicollinearity. We examined the standardized residual plot of the full model to check model assumptions and outliers. While we did not find specific patterns in the plots, 8 out of 10 CWM response variables had 1 (mostly) or 2 outliers. We excluded the outlier(s) for the analyses.

The overall difference in species composition between reserves was also investigated by comparing beta diversity based on two indices, i.e., Jaccard index and Bray–Curtis index, which use incidence (presence/absence) data and count (abundance) data, respectively (“betapart” package) [53]. We $\log(x + 1)$ -transformed the abundance data because the Bray–Curtis index can be sensitive to high abundance values. Beta diversity was also partitioned into two and calculated following Baselga and Orme’s method [54] that is implemented in “betapart” package: turnover (species replacement) and nestedness (species gain/loss) components. Beta diversity measures heterogeneity in the species composition of communities along environmental gradients or between sites [55]. Investigating beta diversity components has been emphasized in contemporary conservation efforts as it can provide insights for conservation management and reserve design; the dominance of turnover indicates that reserves may be equally important to regional diversity and require a regional level of management planning, whereas the dominance of nestedness suggests that biodiversity-rich reserves need to be prioritized for management planning [56,57]. We used a permutation test to determine the significance of community dissimilarity between reserves (“vegan” package) [58].

3. Results

While the majority of species (~60%) were observed at <10% of points, Chestnut bulbul (*Hemixos castanonotus*) was detected at 72 out of 74 sites and in all zones (Supplementary Material Table S2 and Figure S2). Grey-cheeked Fulvetta (*Alcippe morrisonia*) was also common, detected at 65 sites, and the most abundant (mean maximum abundance = 9.1 per point; Supplementary Material Table S2). Of 86 species, 71 species were detected at ≥ 2 reserves, and 8 species were only identified in NL during the survey periods (Supplementary Materials Figure S2).

The full models of the three diet traits (insect, omnivorous diet, and fruit/nectar) and the one foraging stratum trait (low foraging) had lower AICc values than those of their null models and significantly differed from their null models (Table 1). While the null model of a high foraging stratum trait showed a slightly lower AICc value compared to the full model, both models significantly differed (likelihood ratio test, $p = 0.017$). All of these traits were strongly associated with reserve identity (Table 2). Reserve was also significant in other response variables: their null models were the top model (Supplementary Material Table S3). In NL, the CWMs of insectivorous and omnivorous diet traits were higher and lower, respectively, compared to other reserves based on non-overlapping 95% confidence intervals between NL and others; the bird community of NL was composed of more insectivorous birds but less omnivorous birds than other reserves (Figure 2). The CWM of the fruit/nectar trait was lower in CBL and NL compared to SMT (Figure 2). While CBL showed a lower CWM of a low foraging trait compared to XTS, the CWM of high foraging was higher in CBL and somewhat higher in YKS compared to SMT and XTS. For species richness, the explanatory power of the full model was lower than that of null model.

Table 1. A summary of model comparisons based on the values of AICc (Akaike's Information Criterion adjusted for a small sample size): null model (null, intercept-only model) vs. full model including all explanatory variables (full). df and logLik represent the degree of freedom and log-likelihood, respectively. Response variables for which the full model was selected as the top model are in bold.

Response Variable	Model	df	logLik	AICc	Δ AICc	AICc Weights
Species richness	Null	1	−196.287	394.6	0.00	0.832
	Full	9	−188.508	397.8	3.20	0.168
Body mass	Null	2	−25.137	54.4	0.00	0.997
	Full	10	−21.387	66.3	11.82	0.003
Insect	Full	10	37.913	−52.3	0.00	1.000
	Null	2	16.988	−29.8	22.47	0.000
Fruit/nectar	Full	10	125.009	−226.4	0	0.999
	Null	2	107.923	−211.7	14.74	0.001
Omnivorous diet	Full	10	42.806	−62.1	0	0.999
	Null	2	26.602	−49	13.03	0.001
Plant/seed	Null	2	245.795	−487.4	0	0.999
	Full	10	248.847	−474.2	13.22	0.001
Ground	Null	2	91.904	−179.6	0.00	0.999
	Full	10	94.654	−165.8	13.82	0.001
Low	Full	10	99.517	−175.5	0.00	1.000
	Null	2	80.254	−156.3	19.15	0.000
Low to high	Null	2	53.051	−101.9	0.00	0.681
	Full	10	62.009	−100.4	1.52	0.319
High *	Null	2	31.614	−59.1	0.00	0.584
	Full	10	40.938	−58.4	0.67	0.416
Migrant	Null	2	49.638	−95.1	0	0.735
	Full	10	58.336	−93.1	2.04	0.265

* Likelihood ratio test: $p = 0.017$.

Table 2. ANOVA test results indicating the significance of the three variables, i.e., elevation, management zone, and reserve identity of birds’ traits. Traits for which their full models were selected as the top model are shown. See Supplementary Material Table S3 for the responses of the other traits.

Response Variable	Explanatory Variable	Chi-Square (Chisq)	<i>p</i> (>Chisq)
Insect	Elevation	1.131	0.288
	Zone	2.945	0.400
	Reserve	40.601	<0.001
Fruit/nectar	Elevation	5.479	0.019
	Zone	1.917	0.56
	Reserve	19.491	<0.001
Omnivorous diet	Elevation	0.228	0.633
	Zone	2.945	0.400
	Reserve	40.601	<0.001
Low	Elevation	10.795	0.001
	Zone	5.066	0.167
	Reserve	23.878	<0.001
High	Elevation	1.760	0.185
	Zone	3.457	0.326
	Reserve	18.217	0.001

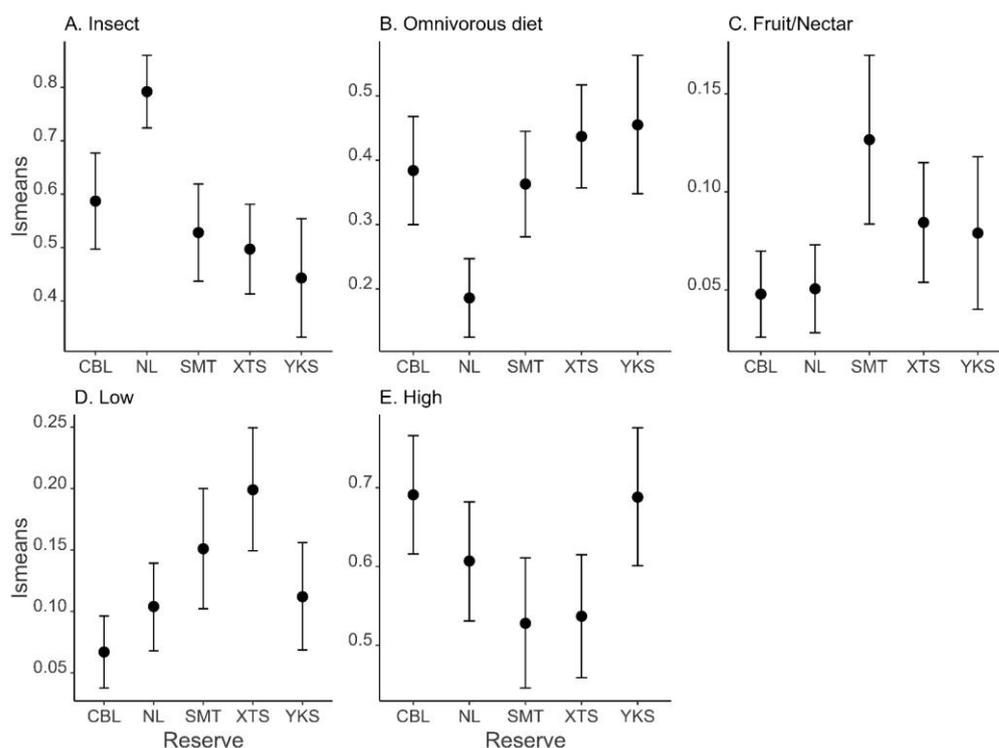


Figure 2. Differences in community-weighted mean values (CWMs) of five traits (three diet traits—(A–C); two foraging stratum traits—(D,E)) between reserves. *y*-axis represents least-squares means (Ismeans) of CWMs. Bars on the graphs are 95% confidence intervals. See Figure 1 for full name of each reserve.

The overall effects of management zone and elevation were weak or insignificant (Table 2). The CWM of the low foraging stratum trait and fruit/nectar diet trait showed a significant response to elevation: the proportion of low-height-foraging birds in a community increased with elevation, whereas the proportion of fruit/nectar-eating birds decreased (Supplementary Material Figure S3). Most other responses were unclear given their wide 95% confidence intervals; however, for the CWMs of seven traits, their values in zone four

or both zone three and zone four were slightly different from the values in other zones. For example, the CWMs of high foraging stratum, migrant, and body mass traits tended to be low in zone four (outside reserve) and high in zone one and two, i.e., core and buffer zones (Supplementary Material Figure S4). The CWMs of low foraging and low to high foraging tended to be high in zone four, and the CWM of omnivorous diet traits tended to be high in zone three and four (Supplementary Material Figure S4).

Both dissimilarity indices showed clear variations in bird community composition between reserves, especially in the north region and the south region ($p = 0.009$ for Jaccard and $p = 0.001$ for Bray–Curtis; Figure 3). These patterns were largely contributed by the turnover component of beta diversity ($p \geq 0.06$ for nestedness and $p \leq 0.03$ for turnover in both indices; Supplementary Material Figure S5). Of the five reserves, bird communities in NL tended to differ from others, particularly YKS.

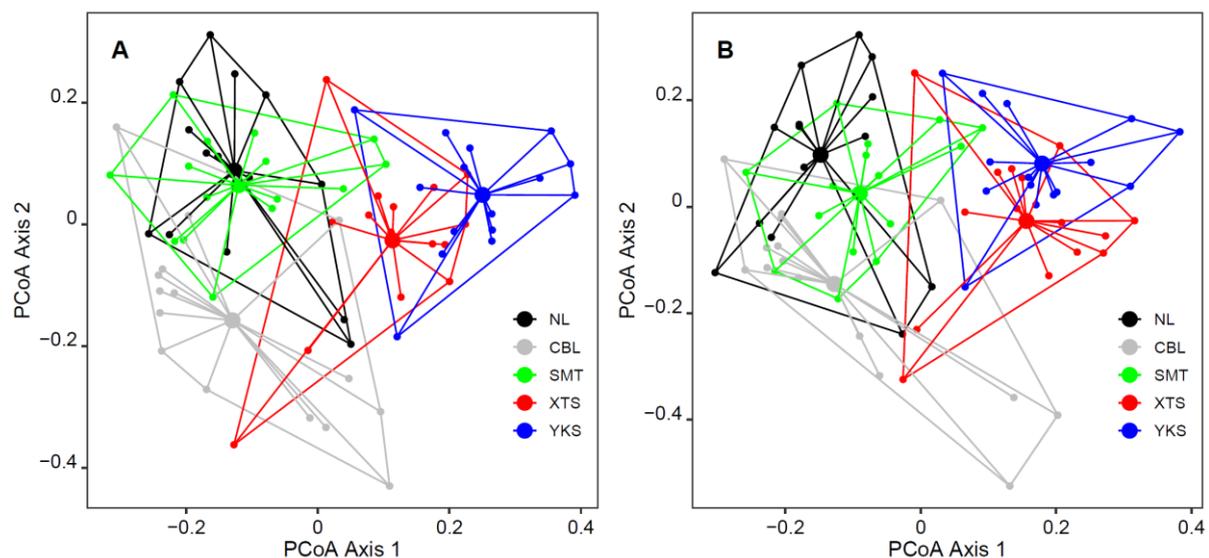


Figure 3. Biplot showing variations in species dissimilarity between reserves: (A), dissimilarity matrix accounting for beta diversity, measured as Jaccard pair-wise dissimilarity; (B), dissimilarity matrix accounting for beta diversity, measured as Bray–Curtis pair-wise dissimilarity.

4. Discussion

The findings of our study show almost no or weak effect of management zones on bird diversity and traits in five national nature reserves of Guangdong province, which may suggest a need for the revision of current zoning schemes and designations through further evaluation. The strong association of the reserve itself with the bird community, i.e., species traits and composition, indicates that each reserve could be important to conserving regional bird diversity. This is also supported by the significant relationship between reserves and the turnover of beta diversity.

The coverage of protected areas has continuously increased and reached over 16.6% of the global land surface in 2020. It is expected to surpass the 17% coverage target of Aichi Biodiversity Targets as more protected areas are identified and reported [6]. Protected areas conserve the characteristic or threatened species and maintain higher species diversity than unprotected areas [59,60]. However, the vast majority of protected areas are also suspected to be little more than “paper parks”, calling for attention to be paid to the efficacy and quality of protected area management [61].

In China, heterogeneous spatial distribution of protected areas is associated with different ecosystem distributions and biodiversity; however, forest and wetland ecosystems that are very species-rich have been influenced by human activities as they are suitable for human settlement [62]. Zonation is a basic but essential strategy for managing China’s nature reserves to achieve not only conservation but also local economic development.

With strong restrictions on human settlements and other activities, core zones can maintain relatively suitable habitat conditions for target species [18]. Core and buffer zones can be effective in protecting forest ecosystems by minimizing the forest loss area within a reserve [63]. However, several studies have reported moderate occurrence of the target species or large suitable habitats in buffer zones or even outside nature reserves [27,64,65]. It is also questionable that other protected species and common species would show similar responses, e.g., higher abundance or occurrence in core zones than buffer and experimental zones, and subsequently how effectively zoning designations can conserve biodiversity [27]. In some nature reserves of China, three zones have also been designated without sufficient field data, causing an inadequate placement of the core zones [11]. Similarly, our results may indicate the limited efficacy of current zone designations in conserving bird species diversity and traits in the national nature reserves of Guangdong province.

However, these reserves showed a pattern of slightly higher portions of species foraging in the canopy or at high places (trees/shrubs > 8 m in height) in the three main zones compared to the reserve boundary area. This may indicate that the national nature reserves, which represent subtropical forests, likely maintain better forest cover (e.g., old and tall trees and other vegetation) than unprotected forests, as found in other studies [66,67]. It is also noteworthy that omnivorous birds were low in the core and buffer zones. Although the full models of body mass and migratory status traits were not better than their null models, migratory birds and large birds also tended to be low in the experimental zone and reserve boundary area (Supplementary Material Figure S3). Omnivores are often habitat generalists that are less affected by disturbance, whereas migratory birds and large-sized birds are somewhat sensitive to landscape changes by human activities [31–34]. These patterns are slightly similar to the findings of Martin and Blackburn's study [68] in Parque Nacional Cusuco, a tropical montane cloud forest park in northwest Honduras. The forest park has two zones, i.e., a core zone and buffer zone, which were divided into (deep) core, boundary core, and buffer in Martin and Blackburn's study. The boundary core area and buffer zone can be considered the buffer zone and experimental zone (with a part of the buffer zone) in our study, respectively. Martin and Blackburn found low species diversity in the core zone followed by the boundary core area but a high concentration of conservation-related species in the core zone. The relative density of habitat generalists was also low within the core zone and boundary core area. Although most of our findings seem to indicate limited efficacy of zoning in conserving bird diversity, they also suggest that core and buffer zones where human activities are restricted can benefit some bird species to a certain degree. Protected lands in national nature reserves may still be effective in conserving these species and perhaps their habitats and ecosystems, as shown in the studies of global meta-analysis [59,60], as well as tropical ecosystems [1].

The overall weak or insignificant relationships between management zones and birds could be in part affected by the ambiguity or misplacement of zone designations [9,23]. For example, while the buffer zone is expected to surround the core zone, not all of the boundary area of the core zone is buffered (XTS and NL). The core zone is adjacent to the reserve boundary area (NL and SMT), although the boundary area has a low level of land use. The buffer zone is also relatively narrow (YKS and CBL) or close to reserve boundary areas (XTS and CBL). The actual boundaries between zones at the ground level are often unclear or not labeled well, which is a common problem in China's nature reserves [23]. Some reserves such as XTS are also embedded in urbanized landscapes that have experienced rapid changes. This pattern is not surprising given that almost 60% of national-level protected areas in China have confronted increasing development pressures from outside reserves [69]; however, it requires the adjustment of management zones by considering landscape changes surrounding reserves.

It should be pointed out that variations in bird assemblages among reserves were more associated with the turnover of beta diversity. Two components of beta diversity, i.e., nestedness and turnover, have different implications for reserve design and management. Nestedness occurs when the poorest site, i.e., a site with the lowest number of species,

is a subset of the richest site [70]. The dominance of nestedness of species assemblages indicates that the richest site can support more rare species and it may serve as a source habitat for species-poor sites, suggesting that the site should be prioritized for conservation. Conversely, a dominating turnover implies that differences in bird assemblages among sites are attributed to heterogeneous species compositions rather than differences in species richness, requiring multiple-site management plans [56]. In our study, the stronger contribution of turnover over nestedness to beta diversity shows that all reserves can contribute more equally to regional diversity in Guangdong province.

Our study also reveals that bird assemblages somewhat differ between reserves in the northern and southern regions of Guangdong province compared to within each region. Three reserves (NL, CBL, and SMT) in northern Guangdong are part of the Nanling Mountains. NL and CBL are close to the Min-Guang coastal zoogeographical subregion [35]. Although all five reserves are considered subtropical forests, half of XTS belongs to the Indo-Burma Biodiversity Hotspot region and YKS is also adjacent to the region. In terms of longitude and elevation, YKS is distinguished from the other four reserves. The compositional variations in bird assemblages between reserves in northern and southern regions likely reflect geographical differences between the two regions. The geographical differences, combined with elevation differences between reserves and between sample sites used for our study, can also lead to a strong reserve effect on birds.

However, the reserve effect might be confounded with observer effects because observers were rarely alternated among reserves due to logistic issues. Although all observers were trained for bird surveys, we acknowledge that bird detections between observers may slightly differ. We cannot exclude the possibility that the heterogeneous detectability may have an impact on our findings, i.e., the reserve effect. In addition, for each zone, the number of sites varied by reserve: in particular, CBL and NL had fewer sites in the core and buffer zones than the other sites had. This might result in low species richness in CBL and NL. Moreover, compared to the size of NL (i.e., the largest of the five reserves), the number of transects surveyed in NL are likely too low to detect some birds, especially rare species. The bird data of NL may be biased due to insufficient sampling. Our overall sampling efforts (a total of four visits) may not be sufficient to detect rare species that could be unique not only in NL but also in other reserves. There is a strong need for further studies to verify the reserve effect with a better study design and more surveys.

Human activities from hunting and recreational activities for resource exploitation and land use are considered major threats to protected areas [71]. The zonation of protected areas is suggested as a way of making compromises between conservation and economic growth; however, balancing the two different needs is often problematic, especially in developing countries where the latter is the top priority. In China, conflicts between local economic development and reserve management and between people living inside the reserve and zoning designations have been an issue for decades [72,73]. Nature reserves established for the protection of forests and wetlands and those in east and south China are expected to be more affected by the expansion of human settlements than reserves in other regions [74]. Evaluating the efficacy of zoning schemes for biodiversity conservation is imperative in southern China, like in Guangdong province. Our study shows that current zoning designations for nature reserve management in Guangdong province may not be as effective in conserving bird diversity. Although our findings suggest that there may be a need to adjust the zoning scheme, it is important to interpret them with caution because our study design and survey have limitations, such as the potential observer effect, insufficient sampling efforts, and a biased sample size between different zones. Moreover, we know little about how zoning designations affect other taxa, such as plants, mammals, amphibians, and reptiles. We need to be careful when making recommendations solely based on our findings. We also emphasize that future zoning schemes need to account for land use changes surrounding reserves and the unique features of each reserve that could be important to conserve bird diversity at the regional level as well.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/d16040222/s1>, Table S1. General information about each reserve and the elevation of sample sites used for the study; Table S2. List of bird species and their traits. Mean abn represents mean abundance per point and # of sites is number of paired points where species were detected across all surveys; Table S3. Significance of associations between response (species richness and community-weighted mean values of each trait) and explanatory variables. Zone represents type of management zone (i.e., core, buffer, experimental, and boundary areas); Figure S1. The number of sites used for analyses. Abbreviations: NL, Nanling National Nature Reserve; CBL, Chebaling National Nature Reserve; SMT, Shimentai National Nature Reserve; XTS, Xiangtuo Mountain National Nature Reserve; YKS, Yunkai Mountain National Nature Reserve; Zone 1, core zone; Zone 2, buffer zone; Zone 3, experimental zone; Zone 4, reserve boundary area zone (outside of reserve); Figure S2. Matrix of species detection/non-detection at each zone and in each national nature reserve; Figure S3. Effects of elevation on community-weighted mean values (CWMs) of frugivore/nectarivore trait (A) and CWMs of low height foraging trait (B). Elevation of X-axis in A is standardized. Shaded areas on graphs represent 95% confidence intervals; Figure S4. Effects of management zone on species traits (A–I and K) and species richness (J). Abbreviation: Zone 1, core area; Zone 2, buffer area; Zone 3, experimental area; Zone 4, reserve boundary area zone (outside of reserve); Figure S5. Biplot showing variations in species dissimilarity between reserves: A, dissimilarity matrix accounting for spatial turnover, measured as Jaccard (left) and Bray–Curtis (right) pair-wise dissimilarity (monotonic transformation of beta diversity); B, dissimilarity matrix accounting for spatial nestedness, measured as Jaccard (left) and Bray–Curtis (right) pair-wise dissimilarity.

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Institutional Review Board Statement: Our field data were collected based on observation: counting birds by sight and sound. We confirm that our study did not involve the handling of any animal and therefore did not require approval from an Institutional Animal Care and Use Committee or equivalent animal ethics committee.

Data Availability Statement: The datasets used in the present study are available from the corresponding author on reasonable request.

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