Planting Profile and Avian Diversity in Taman Botani Negara, Shah Alam

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Abstract

Limited research has quantified the effects of planting profiles on bird diversity in managed landscapes. This study aimed to assess the impacts of vegetation structure, plant composition, and canopy complexity on bird species richness and diversity; as well as their implications for avian abundance, distribution patterns, and foraging guilds across designated zones in Taman Botani Negara, Shah Alam. Vegetation profiling and standardized avifaunal point-count surveys were employed, alongside diversity indices and non-parametric statistical tests. Findings indicated significant inter-zonal variations ($H = 8.24$, $p < 0.05$), with canopy cover, vertical stratification, and native plant proportions emerging as key predictors of diversity.

Keywords: Planting profile, bird species diversity, managed landscape, urban park

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1.0 Introduction

Urban expansion in tropical regions like Malaysia, particularly in rapidly urbanizing areas such as Kuala Lumpur, fragments natural habitats and reduces biodiversity (Atikah et al., 2024; Khiruddin et al., 2025), making urban parks essential sanctuaries and refugia for wildlife especially birds, which act as vital, sensitive indicators of ecosystem health and habitat quality (Cull et al., 2025). These avifaunal communities highlight the value of investigating how vegetation structure, plant composition, and canopy layering shape species assemblages, as seen in multi-layered canopies that support diverse foraging guilds, thereby advancing sustainable urban design and biodiversity conservation (Khiruddin et al., 2025; Oropeza-Sánchez et al., 2024; Zhu et al., 2024). Swift urbanization pressures birds to adapt to urban parks' suboptimal conditions, with most generalists like the Yellow-vented Bulbul (*Pycnonotus goiavier*) persisting amid invasive competitors (Hadi et al., 2024). While broad links between vegetation complexity and bird richness are established (Chiron et al., 2023; Humphrey et al., 2023), key gaps remain in species and guild-specific responses within diverse tropical parks, including limited explorations of planting profiles in managed sites like Taman Botani Negara Shah Alam, TBNSA (Zainal et al., 2021). Therefore, this study addresses these identified gaps by aiming to examine the relationships between planting profile characteristics, namely vegetation structure, plant composition, and canopy complexity, with the bird species diversity across selected zones in TBNSA. More specifically, it aims to investigate how variations in these characteristics influence bird species richness and diversity indices, and determine the impacts of native versus ornamental plant compositions on bird abundance, distribution patterns, and foraging guilds. Ultimately, by providing empirical evidence from this context, the research contributes to biodiversity-sensitive landscape planning in Malaysia and broader global urban design efforts.

2.0 Literature Review

Urban expansion and human activities have caused habitat fragmentation, vegetation loss, and biodiversity declines, especially for birds, in tropical Peninsular Malaysia (Atikah et al., 2024; Khiruddin et al., 2025). In rapidly urbanizing areas like Klang Valley, urban development has reduced tropical forests, created isolated green patches, resulted in lowered bird species richness and abundance (Hadi et al., 2024; Khiruddin et al., 2025). This underscores the critical role of urban green spaces as refugia for avian communities (Atikah et al., 2024; Zhu et al., 2024). While these spaces are essential for bird survival, their capacity to support diverse species assemblages varies considerably, influenced by park design, habitat connectivity, microclimatic factors, and vegetation characteristics (Cull et al., 2025; Hadi et al., 2024; Wong et al., 2022). Although larger parks are often associated with higher bird richness (Khiruddin et al., 2025), structural heterogeneity and landscape composition, particularly vegetation structure, plant diversity, and canopy complexity, emerge as stronger predictors of species diversity and abundance (Humphrey et al., 2023;

Oropeza-Sánchez et al., 2024; Zhu et al., 2024). Moreover, environmental heterogeneity, including multi-layered canopies and diverse planting profiles, enhances niche availability, thereby promoting greater avian diversity even in smaller urban parks (Khiruddin et al., 2025; Zhu et al., 2024). Native plants, in contrast to ornamental or exotic species, provide specialised resources such as food and nesting sites, supporting higher taxonomic and functional diversity while limiting generalist dominance (Hadi et al., 2024). Incorporating vegetation with varied growth forms creates vertically stratified habitats that accommodate diverse foraging guilds and nesting requirements (Hadi et al., 2024; Oropeza-Sánchez et al., 2024). Furthermore, studies in tropical urban settings suggest that canopy cover, woody vegetation density, and native proportions significantly predict bird richness and guild composition (Khiruddin et al., 2025; Oropeza-Sánchez et al., 2024). Despite these insights, gaps persist in quantifying species and guild-specific responses to planting profiles in managed urban landscape like Taman Botani Negara Shah Alam (TBNSA) particularly regarding native versus ornamental compositions and their effects on abundance and distribution (Khiruddin et al., 2025). Therefore, this study addresses these gaps by examining how vegetation structure, plant composition, and canopy complexity influence bird diversity across TBNSA zones.

3.0 Methodology

The methodology for this study includes the procedures for study site selection, vegetation assessment, bird survey protocols, and statistical analyses employed for data interpretation. The integrated approach combines field-based ecological surveys with remote sensing techniques to yield a comprehensive understanding of the complex relationships between vegetation structure and avian assemblages.

3.1 Study Site Description and Zonal Selection

Taman Botani Negara Shah Alam, located in Selangor, Malaysia, serves as a significant urban botanical park, forest reserve, and officially designated green lung, besides being founded to protect various tropical flora and fauna in Malaysia's equatorial climate (Zainal et al., 2026), TBNSA functions as a vital biodiversity hotspot amidst rapid urbanisation in the Klang Valley, acting as an essential sanctuary and resource for bird populations (Hadi et al., 2024; Khiruddin et al., 2025). The park is divided into thematic zones that showcase diverse planting profiles, therefore providing a variety of ecological niches (Zainal et al., 2026). The structural heterogeneity of TBNSA makes it an ideal site for investigating the impact of vegetation complexity on avian diversity, offering a unique opportunity to evaluate how varying planting arrangements, ranging from carefully curated ornamental gardens and paddy fields to more naturalistic environments, influence bird species richness, abundance, and community composition (Khiruddin et al., 2025; Zainal et al., 2026). This investigation deliberately selected four zones, namely Herbs Garden, Zingiberales Garden, Ornamental Garden, and Paddy Field, based on their distinct vegetation composition, vertical stratification, and plant typologies, thus gives a solid basis for comparative ecological analysis (Figure 1).

Figure 1: Four selected study zones namely Herbs Garden (Zone A), Zingiberales Garden (Zone B), Ornamental Garden (Zone C), and Paddy Field (Zone D).
(Source: Author)

3.2 Sampling Strategy

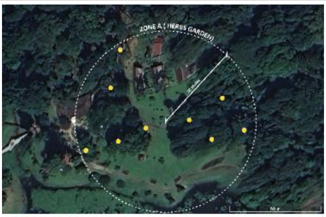
Figure 2: Location of fixed-radius circular sample areas within each of the selected planting zones.
(Source: Author)

A stratified random sampling design was employed across the four designated zones to ensure representative coverage of TBNSA's diverse habitats, hence minimising bias and variance in structurally varied urban green spaces (Hadi et al., 2024). This involved classifying the park into distinct strata based on initial assessments of vegetation types and densities (Khiruddin et al., 2025; Zainal et al., 2026). Plots were chosen at random within each zone, with boundaries and positions determined using geospatial data (Khiruddin et al., 2025). Fixed-radius circular sample areas of 50 m were established within these plots (Figure 2), following the standard point-count procedures for avian surveys in tropical urban parks in similar Southeast Asian contexts (Hadi et al., 2024). This method accounts for change in essential landscape features, such as canopy cover and park design, which are recognised predictors of bird assemblage composition and diversity (Khiruddin et al., 2025; Oropeza-Sánchez et al., 2024).

3.3 Vegetation Structure Analysis

3.3.1 Species Identification and Classification

Plant species in each sampling plot were identified to the most specific taxonomic level using standard field guides and botanical references (Alue et al., 2022). The locations of the plant species were accurately georeferenced using GPS tool (Hadi et al., 2024) and later mapped onto Google Earth to document their spatial distribution (Hadi et al., 2024; Khiruddin et al., 2025). Subsequently, all detected species were categorised according to their origin as either native or exotic, in addition to their growth form (Alue et al., 2022; Hadi et al., 2024), facilitating the assessment of the effect of planting profiles on avian niches.



ZONE A (HERBS GARDEN)

Scientific Name	Common Name	Family	Plant Type
Ceiba pentandra	Kekabu/ Kapok tree	Malvaceae	Tree
Pterygota alata	Buddha's coconut	Malvaceae	Tree
Annona reticulata	Wild Soursoup	Annonaceae	Tree
Polyalthia sclerophylla	Mempisang	Annonaceae	Tree
Ficus nota	Sacking tree	Moraceae	Tree
Artocarpus elasticus	Terap nasi	Moraceae	Tree
Koompassia malaccensis	Kompas	Fabaceae (Leguminosae)	Tree
Cassia grandis	Pink shower tree	Fabaceae	Tree
Cinnamomum iners	Medang Teja	Lauraceae	Tree
Cinnamomum verum	Kayu manis	Lauraceae	Tree
Garcinia griffithii	Kandis	Clusiaceae (Guttiferae)	Tree
Garcinia nervosa	Kandis Gajah	Clusiaceae (Guttiferae)	Tree
Ixonanthes reticulata	Pagar Anak	Ixonanthaceae	Tree
Dipterocarpus grandiflorus	Keruing belimbing	Dipterocarpaceae	Tree
Pometia pinata	Kasai daun besa	Sapindaceae	Tree
Bridelia tomentosa Blume	Kenidai	Phyllanthaceae	Tree

ZONE D (PADDY FIELD AREA)

Scientific Name	Common Name	Family	Plant Type
Turnera subulata	Dark-eyed Turnera	Turneraceae	Shrubs
Vallaris glabra	Kesidang	Apocynaceae	Climbers
Cocos nucifera	Kelapa	Arecaceae	Palm
Oryza sativa l	Padi	Oxalidaceae	Agricultural Crop
Bismarckia nobilis	Bismarck Palm	Arecaceae (Palmae)	Palm
Eugenia claviflora	Jambu arang	Myrtaceae	Tree
Saccharum officinarum	Tebu	Poaceae	Tall Grass

Figure 3: Plant distributions and data for Zone A and D.
(Source: Author)

3.3.2 Assessment of Vertical Vegetation Structure

Each sampling plot's vertical vegetation structure has been defined via a number of quantitative parameters. A direct, observation-based assessment of vertical vegetation architecture was obtained by visual stratification into specific height classes which are <2m, 2-5m, 5-10m, and >10m, in order to determine canopy height (Ferrara et al., 2023). Besides that, the line-intercept approach, which quantified the amount of canopy cover by recording the presence or absence of canopy directly above points spaced at regular intervals, was used to estimate the percentage of overhead vegetation along a predetermined transect in each plot (Ferrara et al., 2023; Hadi et al., 2024). Furthermore, a 5-point visual scale was used to assess understory density; each score represented a subjective assessment of the understory stratum's density (1 = very sparse, 5 = very dense) (Ferrara et al., 2023). Vertical complexity, a crucial component in habitat provisioning for a variety of bird assemblages, was measured by numbering the different foliage layers that comprise groundcover, shrub, and sub-canopy strata (Hadi et al., 2024). These precise measurements enable thorough analysis of how vegetation architecture facilitates niche partitioning and resource availability for various bird species (Alue et al., 2022).

3.3.3 Spatial Referencing

Smartphone-based GPS applications, which are more accessible and often used in Malaysian field research (Hadi et al., 2024) and less complicated than conventional handheld equipment (Zainal et al., 2026), were used to record the geographic coordinates of each sampling plot. To help with habitat mapping and avian diversity pattern analysis (Khiruddin et al., 2025), coordinates were cross-referenced with Google Earth satellite data to ensure accuracy in spatial studies (Hadi et al., 2024).

3.4 Avian Survey

To assess bird occupancy and richness, point count surveys were carried out within the 50m fixed-radius plots (Oropeza-Sánchez et al., 2024). Moreover, to increase the likelihood of detection, these surveys were conducted at periods of high activity, from 8:00 to 11:00 AM (Alue et al., 2022). Each sampling station was visited once in a single month (Latifi et al., 2023), with rainy or windy days were avoided for surveys since they decrease bird activity and detectability (Khiruddin et al., 2025). Point count stations were placed at least 200 meters apart to avoid double counting, and all birds that were visually or audibly detected within a 50-meter radius were noted (Hadi et al., 2024).

Besides, visual identifications were aided by binoculars and digital cameras (Khiruddin et al., 2025; Latifi et al., 2023). BirdNET, a deep-learning tool for identifying bird vocalizations in ecological studies (Latifi et al., 2023), was used to process audio recordings of difficult-to-see species. On top of that, eBird, a citizen-science resource that offers information on bird distributions, was used to validate the observations (Alue et al., 2022). Species names were then compared to the most recent regional checklist from the Malaysian Nature Society (Khiruddin et al., 2025) and the IOC World Bird List in order to further standardize the dataset and reduce taxonomic inconsistencies (Latifi et al., 2023).

3.5 Functional Guild Classification

Each avian species documented was classified into distinct functional guilds according to their primarily dietary preferences, a commonly utilized approach in avian ecological research to explain resource partitioning, habitat suitability, and response to vegetation structure in urban green environments (Bichi et al., 2024). The guilds which are insectivores, frugivores, granivores, nectarivores, and omnivores, respond to conventional classifications utilized in tropical and Southeast Asian contexts, including urban settings in Malaysia (Bichi et al., 2024; Hadi et al., 2024). The criteria to group the avian species into these guilds have been adapted based on known literature and local field guides (Bichi et al., 2024) in order to ensure uniformity, ecological significance, and relevance to TBNSA's diverse planting profiles.

3.6 Avian Diversity Indices

Species richness was determined by the total count of unique species, while abundance was measured as the total count of individual birds observed across plots (Hadi et al., 2024; Khiruddin et al., 2025; Oropeza-Sánchez et al., 2024), directly derived from on-site field records collected using point count surveys (Hadi et al., 2024; Khiruddin et al., 2025). To deliver a more thorough evaluation beyond just counts, supplementary species diversity indices namely the Shannon-Wiener index, Simpson’s diversity index, and Pielou’s evenness index were also generated (Khiruddin et al., 2025). The Shannon-Wiener Diversity Index (H') integrates both richness and evenness to assess overall species diversity (Alue et al., 2022). Simpson’s Diversity Index (λ) measures the likelihood that two randomly chosen individuals from a sample are from distinct species, therefore revealing patterns of community dominance (Alue et al., 2022). Pielou’s Evenness Index (J') on the other hand quantifies the proportionality of relative species abundances, indicating the uniformity of individual distribution among species within the assemblage (Alue et al., 2022; Khiruddin et al., 2025).

3.7 Statistical Analyses

Preliminary data indicate changes in avian diversity across TBNSA planting zones and correlations between woody plant diversity and avian richness. Therefore, the non-parametric Kruskal-Wallis H test was employed to evaluate diversity measures among the zones, as this test is appropriate for ecological count data, which frequently defy the regularity assumptions of parametric tests (Khiruddin et al., 2025). Furthermore, non-parametric methods get around distributional assumptions, hence assuring robustness with limited zone-level samples (Alue et al., 2022), while correlation analysis examined the associations between vegetative characteristics and bird richness and abundance (Hadi et al., 2024; Khiruddin et al., 2025).

3.8 Semi-Structured Interviews

Semi-structured interviews were carried out with Mr. Syamsul Idris Saleh, a Conservation and Botanical Officer with over 8 years of expertise in overseeing the park's plant conservation initiatives. This serves to authenticate the data derived from field observations, encompassing the identified plant and avian species.

3.9 Mixed Methods Data Integration

This research employed a mixed-methods approach, combining quantitative ecological data with qualitative observations gathered from interviews with principal TBNSA officials (Khiruddin et al., 2025). The gathered avian diversity metrics and woody plant characteristics were integrated with insights from qualitative interviews, which offered contextual comprehension of historical planting choices and contemporary vegetation management strategies (Hadi et al., 2024) within TBNSA. The triangulation of varied data sources improved the validity and depth of the study's conclusions, providing a more comprehensive knowledge of the intricate relationships among TBNSA's planting profiles, vegetation management, and avian diversity (Alue et al., 2022).

4.0 Results

The data gathered from the bird community survey and planting assessment conducted throughout four planting profile zones in TBNSA are outlined in the following five sections: (i) species richness and abundance, (ii) characteristics of vegetation structure, (iii) diversity indices, (iv) composition of functional guilds, and (v) statistical analysis.

4.1 Species Richness and Abundance

In terms of species richness, Zone A exhibited the greatest count with 9 species, then came Zone B with 7 species, and Zones C and D, each with 5 species (Table 1). On top of that, Zone A presented the greatest abundance, comprising 24 individuals. Conversely, Zone D displayed a high abundance of 22 individuals yet very poor species richness, predominantly characterized by a limited number of open-field generalist species (Table 1). In addition, the Kruskal-Wallis H test applied to the data in Table 4.1 produced a statistically significant result with $H = 8.24$, $p < 0.05$, demonstrating that bird species richness and diversity throughout the four zones are not evenly distributed. This indicates that at least one of the zones exhibited a bird population composition that was notably distinct from the others.

Table 1: Matrix of species richness and abundance categorized by zone.

Sampling Zone	Identified Bird Species (Abundance)	Zone Richness (S)	Total Individuals
Zone A (Herbs Garden)	P. borealis (5), G. religiosa (4), P. plumosus (4), O. chinensis (3), D. cruentatum (2), E. ochromalus (2), L. cristasus (2), D. ignipectus (1), D. trigonostigma (1)	9	24
Zone B (Zingiberales)	A. tristis (6), L. cristasus (3), G. religiosa (2), O. chinensis (2), O. atrogularis (2), P. cinereus (2), P. puniceus (1)	7	18

Zone C (Ornamental)	A. tiphia (2), O. sutorius (2), P. simplex (2), P. montanus (1), S. lugubris (1)	5	8
Zone D (Paddy Field)	A. tristis (8), L. maja (7), A. intermedia (3), C. javanicus (2), O. chinensis (2)	5	22
Study Totals	21 Unique Species Found	—	72

(Source: Authors)

4.2 Characteristics of Vegetation Structure

Vegetation profiling indicated distinct variations in canopy structure, understory density, and plant composition within the four zones.

Table 2: Structural properties of vegetation across zones.

Habitat Attribute	Zone A	Zone B	Zone C	Zone D
Primary Flora	Cinnamomum iners	Zingiber officinale	Ehretia microphylla	Oryza sativa L.
Vertical Layers	Multi-layered	Dense Canopy/Floor	Sparse layers	Single-layer
Avg. Height (m)	8.0	4.0	2.0	3.0
Canopy Cover (%)	60% (Moderate-High)	56% (Moderate)	20% (Low)	10% (Very Low)
Understory (%)	35%	60%	40%	80%
Native Status	90% (High)	65% (Moderate)	15% (Low/Ornamental)	10% (Low/Crop)

(Source: Authors)

Zone A exhibited complex, multi-layered vertical stratification, widespread canopy cover, and a significant proportion of native flora. The results across the planting zones (from Zone A to D) shown a steady decline in term of average canopy height, canopy cover and native plant proportion, with Zone D had a markedly different profile, characterized by a single-layer structure, minimal canopy cover, and a low proportion of native plants (Table 2). The understory density result revealed that Zone D exhibited the highest percentage with 80% as it is dominated by paddy crops, followed by Zone B at 60%, Zone C at 40%, and Zone A at 35% density. Additionally, the results of the Kruskal–Wallis H test in section 4.1 indicated that the disparities in bird species richness and diversity among the four planting zones correspond with the gradients in vegetation complexity seen in TBNSA.

4.3 Avian Diversity Indices

The Shannon-Wiener (*H'*), Simpson (λ), and Pielou's evenness (*J'*) indices were used to measure bird diversity; the findings are displayed in Table 3.

Table 3: Avian diversity indices by zone.

Zone ID	Species Richness (S)	Shannon Diversity (H')	Simpson Index (λ)	Pielou's Evenness (J')
A	9	2.07	0.86	0.94
B	7	1.80	0.81	0.93
C	5	1.56	0.78	0.97
D	5	1.44	0.73	0.89

(Source: Authors)

Out of all the study zones, Zone A possesses the strongest Shannon-Wiener diversity index (*H′*). Additionally, its Simpson's diversity index (1–D or 1/D) was highest. Meanwhile, Zone C showed a reasonably regular distribution of individuals across the observed species, as seen by its high Pielou's Evenness (*J*') but lower Shannon index as compared to Zone A. Zone D had the lowest Simpson's diversity index and the lowest Shannon-Wiener index (*H′*). In this zone, there was a greater chance of choosing two individuals from the same species. In Zone D, *Acridotheres tristi*s and *Lonchura maja* accounted for the majority of the bird population. Zone D also had a lower Pielou's Evenness (*J′*) than the other zones. In overall, Zone C displayed great evenness with reduced richness, Zone D had the lowest diversity indices, and Zone A had the highest diversity values altogether.

4.4 Composition of Functional Guilds

The composition of guilds varied across the four study zones, as illustrated in Table 4.

Table 4: Composition of avian functional guilds across sampling zones

Zone	**Dominant Foraging Guilds**	**Ecological Drivers**
Zone A	Insectivores (21) , Frugivores (14), Nectarivores (3)	High vertical complexity and native plant representation provide diverse niches and stable food resources (fruit/nectar) for specialists and interior-dependent species.
Zone B	Insectivores (12), Omnivores (8), Frugivores (4)	Dense flowering understory and sub-canopy layers optimize nectar availability and support high insect biomass for foraging.
Zone C	Insectivores (8), Frugivores (2)	Minimal canopy cover and non-native dominance favor disturbance-tolerant generalists; simplified structures lead to "specialist exclusion" due to scarce nesting and foraging niches.
Zone D	Granivores (7), Frugivores (2), Insectivores (2), Omnivores (10)	Single-layer structure with minimal canopy and dense paddy understory provides high seed availability and efficient access for ground-foraging birds.

(Source: Author)

Zone A displayed a rather uniform distribution of insectivores, frugivores, and nectarivores, with no single guild predominating in numbers within the assemblage; while

Zone B had a greater prevalence of nectarivores and insectivores relative to other guilds. These two feeding guilds comprised the majority number of documented species and individuals in this zone. Zone C was primarily inhabited by generalist insectivores and bulbuls, which constituted the majority of sightings. Other feeding guilds were represented in relatively smaller quantities. Lastly, Zone D exhibited a significant prevalence of granivorous and open-field insectivorous species. The majority of reported individuals were part of these guilds, although other guilds had limited representation. In summary, the guild structure differed throughout zones, with Zone A displaying a more equitable guild makeup, while Zones B, C, and D were characterized by the predominance of particular feeding guilds.

5.0 Discussion

This investigation exposes the substantial impact of vegetation structure and planting characteristics on avian diversity in TBNSA, thereby emphasizing the significance of urban green spaces in the preservation of biodiversity in the face of urbanization (Atikah et al., 2024; Khiruddin et al., 2025). Bird species richness, diversity, and functional guild distribution are predominantly influenced by habitat heterogeneity, particularly vertical stratification, canopy cover, and native plant composition.

For example, Zone A, which is distinguished by its high canopy cover, abundant native plants, and multi-layered vegetation, has the greatest diversity and richness (Khiruddin et al., 2025; Oropeza-Sánchez et al., 2024). Specialist species are supported by these attributes, which offer diverse niches, nesting sites, foraging opportunities, and protection from predators (Atikah et al., 2024; Khiruddin et al., 2025). In stark contrast, the scarcity of native plants and the simplistic, single-layer vegetation of Zone D led to a low level of diversity, which was dominated by generalist species (Atikah et al., 2024). This pattern is consistent with ecological theory, as generalists that are disturbance-tolerant are more likely to thrive in simplified habitats than specialists (Chiron et al., 2023; Humphrey et al., 2023). The guild compositions were indicative of these distinctions in which Zone A was home to a diverse combination of insectivores, frugivores, and forest species, whereas Zones C and D were dominated by generalist insectivores like Bulbuls and granivores and/or open-field insectivores, respectively (Chiron et al., 2023).

These observations were verified by statistical analyses. The Kruskal–Wallis H-test confirmed significant variations in bird diversity among zones, and correlations demonstrated positive correlations between richness and diversity and canopy cover, vertical layering, and native vegetation (Humphrey et al., 2023). Additionally, the study's conclusions were strengthened and the overall comprehension was enhanced by the integration of these quantitative data with qualitative insights from interviews on cultivation and management practices (Chiron et al., 2023).

These results have a number of major implications for urban planning. The following strategies can be employed to promote heterogeneous microhabitats: prioritizing multi-layered structures (Khiruddin et al., 2025), ensuring that ≥70% of the vegetation is native

(Chiron et al., 2023), establishing vegetative corridors and buffers to improve connectivity (Hadi et al., 2024), incorporating staggered phenologies to ensure year-round resource availability (Oropeza-Sánchez et al., 2024), and implementing data-driven monitoring, pruning, and enrichment planting to sustain long-term benefits (Chiron et al., 2023; Humphrey et al., 2023; Hadi et al., 2024). Ultimately, the integration of biodiversity metrics into planning policies will foster the development of sustainable urban green infrastructure (Khiruddin et al., 2025).

Even though this study accomplished its aims and objectives, it possessed specific limitations. Initially, bird surveys were performed exclusively during daylight hours, in a single season, therefore constraining the identification of crepuscular or nocturnal species. Moreover, the study concentrated solely on four planting zones, while other microhabitats in TBNSA may provide further insights. Consequently, future research should implement a multi-seasonal, multi-habitat, and long-term framework, augmented by technical, analytical, and participatory innovations, to enhance the comprehension of how urban planting design influences avian diversity. Adopting these recommendations would markedly enhance the accuracy, scalability, and relevance of the findings, thus furthering Malaysia's efforts in sustainable and biodiversity-conscious urban planning.

6.0 Conclusion

This study confirms that vegetation shape and composition are critical factors influencing bird diversity in tropical urban parks. The stratified vegetation profiles and avifaunal surveys conducted across TBNSA’s four planting zones indicated that areas with increased canopy cover, enhanced native plant diversity, and multi-layered vegetation fostered more diverse and evenly dispersed bird populations. Simplified or attractive vegetation architecture were linked to reduced variety and domination by generalist species. Moreover, statistical analyses elucidate the specific mechanisms through which canopy cover, vertical stratification, and native plant ratios enhance species richness and diversity indices, thus achieving a principal aim of this research: to empirically identify the ecological determinants of urban avian communities. Zones with increased vegetation complexity facilitated a wider array of feeding guilds, highlighting the ecological significance of structurally diverse environments. These findings collectively demonstrate that biodiversity-sensitive planting design and management can significantly improve ecological integrity in urban parks.

Article Contribution to Related Field of Study

This research substantially advances urban ecology and conservation by presenting an empirical framework that illustrates the direct impact of particular planting profiles and vegetation structures on bird diversity in urban green spaces. The study integrates quantitative ecological data with qualitative insights, validating the essential role of habitat heterogeneity, vertical stratification, and native plant composition in supporting diverse bird communities, while also providing a practical guide for urban planners and park managers.

The findings may serve to develop a pragmatic roadmap for urban planners, landscape architects, and park managers to include biodiversity objectives into landscape design, emphasizing the significance of parks like TBNSA as essential sanctuaries for urban wildlife in swiftly urbanizing areas. The objectives and results of this study correspond with Malaysia's dedication to the United Nations' Sustainable Development Goals (SDGs), including SDG 11, 13, and 15, as well as its National Policy on Biological Diversity.

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