BIODIVERSITAS
Volume 26, Number 12, December 2025
Pages: 6099-6110

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d261212

Urban bird communities and conservation status in Pekanbaru, Riau, Indonesia

HADINOTO[1,♥], ENI SUHESTI[1], EDDISYAH PUTRA PANE[2]
[1]Department of Forestry, Faculty of Forestry, Universitas Lancang Kuning. Jl. Yos Sudarso Km. 8, Pekanbaru 28265, Riau, Indonesia.
Tel./fax.: +62-761-54092, ♥email: hadinoto@unilak.ac.id
[2]Faculty of Postgraduate, Universitas Lancang Kuning. Jl. Yos Sudarso Km. 8, Pekanbaru 28265, Riau, Indonesia

Manuscript received: 11 September 2025. Revision accepted: 28 November 2025.

Abstract. *Hadinoto, Suhesti E, Pane EP. 2025. Urban bird communities and conservation status in Pekanbaru, Riau, Indonesia. Biodiversitas 26: 6099-6110.* Urban green spaces can sustain considerable avian diversity in rapidly expanding tropical cities, yet empirical evidence from Indonesia remains limited. We assessed species composition, conservation status, and functional guilds across a mosaic of green open spaces in Pekanbaru, Riau Province, Indonesia. Using standardized point counts and transect surveys, we recorded 71 species from 35 families, including three migratory taxa. Thirteen species are nationally protected; 16 appear on the IUCN Red List (CR-NT); and six occur in the CITES Appendices, notably Appendix I *Leucopsar rothschildi*. Functional composition was dominated by insectivores, indicating potential contributions to urban pest regulation. Habitat associations and feeding guilds mediated vulnerability: wetland and insectivore dependent species were most sensitive to habitat degradation, whereas granivores were affected by agricultural land use change. The co-occurrence of nationally protected and globally threatened taxa within urban green spaces underscores their dual role as refugia and actionable conservation targets within the urban matrix. Nevertheless, persistent pressures habitat loss, land use conversion, and illegal wildlife trade threaten population persistence and complicate management. We recommend integrating multi-scale urban green-space planning with active population monitoring, stronger enforcement against wildlife trade, and targeted habitat management focused on wetland elements and insect resources. These measures can help maintain avian diversity and sustain ecosystem services provided by birds in tropical cities, while offering practical entry points for city level biodiversity strategies.

Keywords: Avian guilds, bird markets, CITES trade, IUCN Red List, urban green space

INTRODUCTION

Indonesia is experiencing rapid urban expansion that reshapes land use, habitat structure, and local biodiversity. Urban habitats form a mosaic of parks, remnant forest fragments, wetlands, and built areas, creating risks and opportunities for birds. Although national bird richness is high, systematic evidence on urban bird communities and their conservation status remains limited across Indonesian cities. This gap constrains locally attuned planning and can obscure endemic or range restricted taxa that face local threats while listed as Least Concern globally. In Pekanbaru, Indonesia, city specific data are needed to guide green space planning and to limit shifts toward disturbance tolerant assemblages. Urbanization in Pekanbaru through road-corridor sprawl, infill densification, and peat-riparian draining increases impervious cover and fragments the canopy, simplifying vegetation. As a result, disturbance tolerant insectivores and omnivores dominate while wetland and forest interior specialists decline, flattening species richness and homogenizing bird communities. Such information helps managers balance development, drainage, and recreation with ecological retention in a humid tropical setting and provides a baseline for adaptive management. This study assembles a consolidated evidence base for the city that is comparable with patterns reported in Southeast Asia and beyond (Hepburn et al. 2021; Kurnia et al. 2021; Huang et al. 2022; Biosci et al. 2023; Dong et al. 2023; Khiruddin and Mansor 2023; Mulyani et al. 2023; Nugroho et al. 2024).

Birds are reliable indicators of ecosystem change because they respond to habitat alteration, resource availability, and human disturbance in cities. Indonesian studies show community shifts toward generalist and synanthropic species, with declines in specialists and forest dependent taxa. Urban green spaces such as parks, wetlands, and forest remnants can limit biodiversity loss when vegetation complexity and native flora are maintained, though effectiveness varies among cities. These habitats provide foraging areas, breeding sites, and movement corridors that sustain functional guilds and support ecosystem services. The size, configuration, and vertical layering of vegetation shape detectability and occupancy, so site specific assessment is essential for realistic planning. These patterns support place based evaluation that reflects local ecological dynamics rather than broad generalizations from other regions (Hepburn et al. 2021; Huang et al. 2022; Biosci et al. 2023; Dong et al. 2023; Khiruddin and Mansor 2023; Mulyani et al. 2023).

Conservation frameworks such as the IUCN Red List and CITES are essential for assessing extinction risk and regulating trade, yet global categories can mask local declines where fragmentation and harvesting are severe. Management is weak when monitoring lacks complete inventories linked to status evaluation. Small and isolated urban subpopulations may face habitat degradation and market pressure even when a species appears secure at broader scales. A sound appraisal should begin with site level data and be interpreted with national regulations and international instruments. This justifies empirical datasets that unite local inventories with status appraisals aligned to national and international frameworks in tropical Indonesian cities, with Pekanbaru as a focal case that guides our study design and anchors the analysis for city managers and researchers (Hepburn et al. 2021; Kurnia et al. 2021; Huang et al. 2022; Nugroho et al. 2024).

This study aims to compile a comprehensive inventory of urban bird species in Pekanbaru and to evaluate their conservation status with reference to national regulations as well as IUCN and CITES. We test the hypothesis that heterogeneity of vegetation across urban green spaces is positively associated with species richness and with the dominance of insectivorous guilds, and that a subset of locally at-risk taxa is not fully reflected by global conservation categories. The approach emphasizes methodological traceability and consistent reporting so that the protocol can be replicated across other tropical Indonesian cities. It also outlines clear metrics for repeat surveys, which allows comparison among neighborhoods.

The novelty lies in an integrative design that links site specific inventories with multi-level conservation categorization to generate a policy relevant map of conservation needs for city decision makers. The findings give the Government of Pekanbaru an operational basis to target wetland dependent habitats, improve patch connectivity, strengthen oversight of wildlife trade, and prioritize monitoring of focal species, while clarifying how functional composition, especially the prominence of insectivores, informs habitat management that supports ecosystem services valued by residents. This place based evidence provides an actionable entry point for urban biodiversity strategies in Indonesia and complements reports from other tropical and subtropical cities that emphasize vegetation structure, hydrological elements, and community participation as levers for conservation outcomes (Biosci et al. 2023; Dong et al. 2023; Khiruddin and Mansor 2023; Mulyani et al. 2023; Nugroho et al. 2024).

MATERIALS AND METHODS

Study area and period

This study was conducted in Pekanbaru City, Riau Province, Indonesia (101°25′12.41″E, 0°34′42.61″N), and included residential areas, urban forests, and bird markets. Study sites were selected across administrative boundaries to capture diverse habitat types. Fieldwork was carried out from June to August 2025, the transitional dry season, which affects bird vocalization, foraging behavior, and detectability. To ensure comparability between sites, sampling focused on daily peaks of bird activity (06:30-08:30 and 16:30-18:30 Western Indonesian Time) following standard protocols (Bibby et al. 2000). In residential areas, we used three transects (each 1,000 m long × 20 m wide). In urban forests we used point counts at eight observation points spaced 200 m apart; each point was observed for 10 minutes with 5 minutes between points to move and settle. At bird markets, We conducted structured surveys recording the number of sellers, species present, and number of individuals. Data collection at each location was repeated three times (three replicates). A habitat map of Pekanbaru City was used to stratify sampling and to inform analyses of bird distribution (Figure 1).

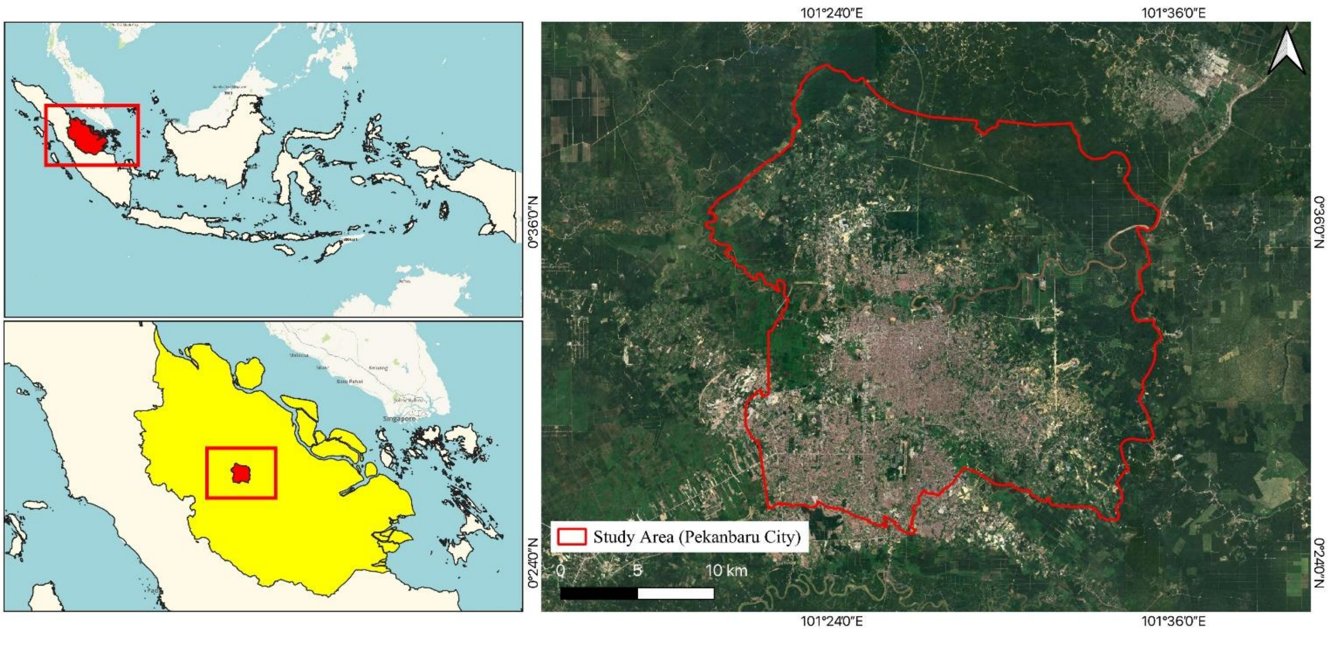

Figure 1. Research locations in Pekanbaru City, Riau, Indonesia

Procedure

Field observations were conducted across three habitat types in Riau Province: residential environments (9 days; 36 person-hours), urban forests (9 days; 36 person-hours), and a public bird market (3 days; 18 person-hours). Surveys interrupted by adverse weather were rescheduled within the same time windows to minimize detection bias. Observers carried 10×25 binoculars, a DSLR camera, a handheld GPS, an audio recorder, a field notebook, and a wristwatch; brand names are omitted because they are not essential for replication. Bird-market observations were strictly non-invasive and conducted in publicly accessible areas; no animals were handled, no purchases were made, and no images or identifying information of sellers were recorded. All activities complied with national wildlife regulations and followed IUCN and CITES guidance.

During the dry season, rainfall decreases and resources become fragmented. Water, nectar, or fruit become concentrated in a few locations. Insect abundance often decreases, reducing foraging and song activity in some insectivores. Song based counts detect fewer species, while thinner foliage and a quieter soundscape can facilitate visual and auditory detection of canopy and edge birds. Fire, smoke haze, and heat shift activity toward dawn and dusk, narrowing the survey window. This shift skews sampling toward disturbance tolerant, open habitat, and water associated species. Abundance may appear high at water or food hotspots but low elsewhere. Therefore, we state this limitation upfront, interpreting the results as a dry season baseline, avoiding claims about the wet season.

Surveys were conducted only during clear or lightly overcast weather, without rain or strong winds. If weather disturbances occurred, observations were postponed and rescheduled within the same time window. This statement addressed the reviewer's concerns about the effect of time of day and weather conditions on detection probability.

Data analysis

Legal and conservation status. Each recorded species was classified under Indonesian Ministerial Regulations P.106/2018 and P.20/2018 as either protected or not protected, to indicate its conservation relevance in urban areas and in the open market. Global conservation status was retrieved from the IUCN Red List (IUCN 2024). In addition, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendices in 2025 were consulted to identify taxa subject to international trade restrictions or monitoring, thereby contextualizing potential market exposure.

Bird community data were summarized as the total number of individuals recorded for each species across three habitat types (urban forest, residential area, and bird market). For each habitat, species richness (S), the Shannon-Wiener diversity index (H′), and the Simpson diversity index (1-D) were calculated from proportional species abundances, using the natural logarithm of H′. Because the sampling design resulted in a single combined community per habitat, without spatial or temporal replication, conventional parametric or non-parametric tests were used.

Diversity between habitats was evaluated using an individual-based permutation (randomization) test. For each comparison, all individuals from both habitats were combined into a single pool while maintaining their species identity and then randomly assigned to each habitat, maintaining the original total number of individuals in each habitat. The Shannon and Simpson indices were recalculated for each randomized dataset, and the differences between habitats (ΔH′, Δ(1-D)) were compared with the distribution of differences obtained from 5,000 permutations. A two-tailed p-value was estimated as the proportion of permutations with |Δ| greater than or equal to the observed difference. This procedure provides a distribution-free test for whether the observed diversity contrast between habitats is greater than expected by chance, given the observed species abundance structure.

In addition to the permutation test, sampling uncertainty surrounding diversity estimates was quantified using an individual-based bootstrap procedure. Within each habitat, individuals were resampled with replacement from the empirical species abundance distribution to generate 3,000 pseudo-communities of the same sample size. For each bootstrap sample, the Shannon (H′) and Simpson (1-D) indices were recalculated. The standard deviation of the bootstrap values was used as an estimate of variability, and the 2.5th and 97.5th percentiles of the bootstrap distribution were taken as 95% confidence intervals for each index.

Reporting and interpretation. All indices are defined once, symbols are used consistently throughout the manuscript, and units and capitalization follow journal conventions. Comparisons across habitats are presented in the Results with accompanying estimates and measures of variability. References to legal and conservation frameworks (national protection lists, IUCN Red List 2024, and CITES Appendices 2025) are retained to align the ecological findings with compliance and risk considerations.

RESULTS AND DISCUSSION

Results

Urban birds

Table 1 lists 3,032 individual birds representing 71 species across 35 families observed in urban settings. Species richness is highest in Sturnidae with 7 species, followed by Pycnonotidae with 6 species, and Muscicapidae and Nectariniidae with 5 species each. In terms of abundance, totals are dominated by Nectariniidae (479 individuals), Estrildidae (478), Pycnonotidae (476), and Columbidae (423).

Table 1. Species of urban birds in Pekanbaru, Riau, Indonesia

Family	Local name	Scientific name	English name	Number of individuals
Accipitridae	*Elang-alap besra*	*Accipiter virgatus* Temminck, 1822	Besra	2
Acrocephalidae	*Kerakbasi alis-hitam*	*Acrocephalus bistrigiceps* Swinhoe, 1860	Black-browed reed warbler	5
Aegithinidae	*Cipoh jantung*	*Aegithina viridissima* Bonaparte, 1850	Green iora	54
	Cipoh kacat	*Aegithina tiphia* Linnaeus, 1758	Common iora	20
Alaudidae	*Branjangan jawa*	*Mirafra javanica* Horsfield, 1821	Horsfield's bushlark	4
Alcedinidae	*Cekakak sungai*	*Todiramphus chloris* Boddaert, 1783	Collared kingfisher	9
Bucerotidae	*Kangkareng hitam*	*Anthracoceros malayanus* Raffles, 1822	Black hornbill	2
Campephagidae	*Kapasan kemiri*	*Lalage nigra* Forster, 1781	Pied triller	38
Caprimulgidae	*Cabak kota*	*Caprimulgus affinis* Horsfield, 1821	Savanna nightjar	8
	Cabak maling	*Caprimulgus macrurus* Horsfield, 1821	Large-tailed nightjar	5
Chloropseidae	*Cica-daun besar*	*Chloropsis sonnerati* Jardine & Selby, 1827	Greater green leafbird	2
Sylvidae	*Cinenen kelabu*	*Orthotomus ruficeps* Temminck, 1836	Ashy tailorbird	90
	Prenjak coklat	*Prinia polychroa* Temminck, 1828	Brown prinia	56
	Prenjak jawa	*Prinia familiaris* Horsfield, 1821	Bar-winged prinia	116
Columbidae	*Dederuk jawa*	*Streptopelia bitorquata* Temminck, 1809	Sunda collared-dove	11
	Perkutut jawa	*Geopelia striata* Linnaeus, 1766	Zebra dove	280
	Punai gading	*Treron vernans* Linnaeus, 1771	Pink-necked green pigeon	8
	Tekukur biasa	*Streptopelia chinensis* Scopoli, 1786	Eastern spot dove	124
Cuculidae	*Bubut alang-alang*	*Centropus bengalensis* Gmelin, 1788	Lesser coucal	12
	Bubut besar	*Centropus sinensis* Stephens, 1815	Greater coucal	8
	Kedasi hitam	*Surniculus lugubris* Horsfield, 1821	Square-tailed drongo-cuckoo	8
	Wiwik kelabu	*Cacomantis merulinus* Scopoli, 1786	Plaintive cuckoo	2
Dicaeidae	*Cabai jawa*	*Dicaeum trochileum* Sparrman 1789	Scarlet-headed flowerpecker	71
Dicruridae	*Srigunting hitam*	*Dicrurus macrocercus* Vieillot, 1817	Black drongo	1
	Srigunting batu	*Dicrurus paradiseus* Linnaeus, 1766	Greater racket-tailed drongo	6
Estrildidae	*Bondol haji*	*Lonchura maja* Linnaeus, 1766	White-headed munia	14
	Bondol jawa	*Lonchura leucogastra* Horsfield & Moore, 1856	Javan munia	120
	Bondol peking	*Lonchura punctulata* Linnaeus, 1758	Scaly-breasted munia	328
	Gelatik jawa	*Lonchura oryzivora* Linnaeus, 1758	Java sparrow	16
Fringillidae	*Kenari melayu*	*Chrysocorythus estherae* Finsch, 1902	Mountain serin	60
Laniidae	*Bentet kelabu (cendet)*	*Lanius schach* Linnaeus, 1758	Long-tailed shrike	8
Leiotrichidae	*Mesia sumatera*	*Leiothrix laurinae* Salvadori, 1879	Sumatran mesia	1
	Poksai hitam	*Garrulax lugubris* Müller, 1835	Black laughingthrush	5
	Poksai sumatera	*Garrulax bicolor* Hartlaub, 1844	Sumatran laughingthrush	1
Muscicapidae	*Decu belang*	*Saxicola caprata* Linnaeus, 1766	Pied bushchat	2
	Kucica hutan	*Kittacincla malabarica* Scopoli, 1788	White-rumped shama	5
	Kucica kampung	*Copsychus saulari* Linnaeus, 1758	Oriental magpie robin	32
	Sikatan bakau	*Cyornis rufigastra* Raffles, 1822	Mangrove blue lycatcher	1
	Sikatan besi	*Muscicapa ferruginea* Hodgson, 1845	Ferruginous flycatcher	1
Nectariniidae	*Burung-madu belukar*	*Chalcoparia singalensis* Gmelin, 1789	Ruby-cheeked sunbird	42
	Burung-madu kelapa	*Anthreptes malacensis* Scopoli, 1786	Brown-throated sunbird	142
	Burung-madu polos	*Anthreptes simplex* Müller, 1843	Plain sunbird	114
	Burung-madu sriganti	*Cinnyris jugularis* Linnaeus, 1766	Olive-backed sunbird	118
	Pijantung kecil	*Arachnothera longirostra* Latham, 1790	Little spiderhunter	63
Oriolidae	*Kepodang kuduk-hitam*	*Oriolus chinensis* Linnaeus, 1766	Black-naped oriole	19
Paridae	*Gelatik-batu kelabu*	*Parus major* Linnaeus, 1758	Great tit	57
Passeridae	*Burung gereja*	*Passer montanus* Linnaeus, 1758	House sparrow	120
Phasianidae	*Puyuh batu*	*Coturnix chinensis* Linnaeus, 1766	Asian blue quail	23
Picidae	*Pelatuk/ caladi ulam*	*Dendrocopos analis* Bonaparte, 1850	Freckle-breasted woodpecker	12
Platylophidae	*Tangkar ongklet*	*Platylophus galericulatus* Cuvier, 1816	Crested jay	1
Ploceidae	*Manyar tempua*	*Ploceus philippinus* Linnaeus, 1766	Baya weaver	12
Psittacidae	*Betet biasa*	*Psittacula alexandri* Linnaeus, 1758	Red-breasted parakeet	24
Pycnonotidae	*Cucak kuning*	*Rubigula dispar* Horsfield, 1821	Ruby-throated bulbul	5
	Cucak kuricang	*Brachypodius atriceps* Temminck, 1822	Black-headed bulbul	14
	Cucak kutilang	*Pycnonotus aurigaster* Vieillot, 1818	Sooty-headed bulbul	300
	Cucak rawa	*Pycnonotus zeylanicus* Müller, 1835	Straw-headed bulbul	2
	Empuloh melayu	*Alophoixus tephrogenys* Jardine & Selby, 1833	Grey-cheeked bulbul	6
	Merbah cerukcuk	*Pycnonotus goiavier* Scopoli, 1786	Yellow-vented bulbul	149
Rallidae	*Kareo padi*	*Amaurornis phoenicurus* Pennant, 1769	White-breasted waterhen	35
Rhipiduridae	*Kipasan belang*	*Rhipidura javanica* Sparrman, 1788	Sunda pied fantail	11
Sturnidae	*Jalak bali*	*Leucopsar rothschildi* Stresemann, 1912	Bali myna	1
	Jalak putih	*Acridotheres melanopterus* Daudin, 1800	Black-winged myna	3
	Jalak suren	*Gracupica jalla* Horsfield, 1821	Javan pied starling	14

Family	Local name	Scientific name	English name	Number of individuals
	Kerak kerbau	*Acridotheres javanicus* Cabanis, 1851	Javan myna	64
	Kerak ungu	*Acridotheres tristis* Linnaeus, 1766	Common myna	54
	Perling kumbang	*Aplonis panayensis* Scopoli, 1783	Asian glossy starling	58
	Tiong emas	*Gracula religiosa* Linnaeus, 1758	Common hill myna	2
Timaliidae	*Pelanduk alas*	*Malacocincla abbotti* Blyth, 1845	Abbott's babbler	1
Turdidae	*Anis kembang*	*Geokichla interpres* Temminck, 1826	Chestnut-capped thrush	2
	Anis merah	*Geokichla citrina* Latham, 1790	Orange-headed thrush	3
Zosteropidae	*Kacamata melayu*	*Zosterops simplex* Swinhoe, 1861	Swinhoe's white-eye	25
Total				3,032

The most numerous species are *Lonchura punctulata* (Scaly-breasted munia, 328), *Pycnonotus aurigaster* (Sooty-headed bulbul, 300), *Geopelia striata* (Zebra dove, 280), *Pycnonotus goiavier* (Yellow-vented bulbul, 149), *Anthreptes malacensis* (Brown-throated sunbird, 142), *Streptopelia chinensis* (Eastern spot dove, 124), *Lonchura leucogastra* (Javan munia, 120), and *Passer montanus* (Eurasian tree sparrow, 120). The list also includes several species recorded at low frequencies, such as Bali myna (*Leucopsar rothschildi*), Crested jay (*Platylophus galericulatus*), and Abbott's babbler (*Malacocincla abbotti*) with single detections.

Figure 2 presents the distribution of recorded species across families. The figure lists each family with the corresponding number of species detected during the surveys, showing the relative contribution of frequently encountered families compared to those represented by few species. Bars are arranged to ease visual comparison of species counts among families. This figure provides the empirical basis for later analyses of richness patterns at the family level.

Species richness and diversity exhibited clear and consistent differences among habitats. The urban forest supported the highest bird diversity, with 45 species and a total of 1,395 individuals (H′: 3.33, 1-D: 0.95). The bird market supported slightly lower, but still high, diversity, with 40 species and 618 individuals (H′: 3.01, 1-D: 0.93). In contrast, the residential area contained only 20 species and 1,019 individuals, yielding the lowest diversity values (H′: 2.58, 1-D: 0.90). Accordingly, both Shannon and Simpson indices consistently ranked habitats as urban forest>bird market>residential area in terms of community heterogeneity.

Permutation tests confirmed that these differences in diversity were statistically significant. Pairwise comparisons showed that Shannon diversity in the urban forest was significantly higher than in the residential area (ΔH′: 0.74) and higher than in the bird market (ΔH′: 0.32), while the bird market was also significantly more diverse than the residential area (ΔH′: 0.43. In all three pairwise comparisons, permutation tests indicated very low probabilities that such differences arose by chance ($p<0.001$, 5000 permutations). A similar pattern was observed for the Simpson index, with bird communities in the urban forest and bird market being significantly more even and taxonomically heterogeneous than those of the residential area ($p<0.001$). These results demonstrate that bird assemblages in structurally more complex or bird-focused environments (urban forest and bird market) retain substantially higher diversity than those in the surrounding residential matrix.

Bootstrap resampling indicated that the diversity estimates were highly precise, with narrow confidence intervals around H′ and 1-D in all habitats (Table 3). For example, Shannon diversity in the urban forest was 3.33 with a bootstrap standard deviation of 0.02 and a 95% confidence interval of 3.27-3.36, whereas the residential area had H′: 2.58 (SD: 0.02, 89% CI: 2.53-2.62). Similarly narrow intervals were obtained for the Simpson index, reinforcing the robustness of the observed differences in diversity among habitats.

Feeding and ecosystem services

Figure 3 presents the composition of bird feeding guilds recorded in the study, summarizing species into discrete dietary categories and showing their relative representation in the dataset. The figure serves as an overview of trophic structure by depicting how many species fall within each guild and how those categories contribute to the overall assemblage. This visual provides a concise baseline for subsequent comparisons among habitats or sites without interpreting drivers or patterns.

Migratory birds

Table 2 documents three migratory bird species: *Saxicola caprata* (*Decu belang*), *Acrocephalus bistrigiceps* (*Kerakbasi alis-hitam*), and *Muscicapa ferruginea* (*Sikatan besi/Tledekan*). The assemblage comprises two species in Muscicapidae and one in Acrocephalidae. All recorded species are insectivores. Geographic occurrence shows *S. caprata* in Java, Kalimantan, and Papua; *A. bistrigiceps* in Sumatra; and *M. ferruginea* in Sumatra, Kalimantan, and Java.

Pekanbaru's migratory signal is small but instructive: three regionally widespread migrants *A. bistrigiceps*, *M. ferruginea*, and *S. caprata* occur mainly from September to April and are all insectivores that concentrate where microhabitats retain water and structural complexity. Reedbeds and sedge margins support *A. bistrigiceps*, shaded midstory groves and riparian strips suit *M. ferruginea*, and open grass-shrub edges favor *S. caprata*. Although these taxa are regionally common, their local distributions indicate vulnerability to urbanization that simplifies hydrology, reduces vertical vegetation structure, increases pesticide use, and depresses insect prey.

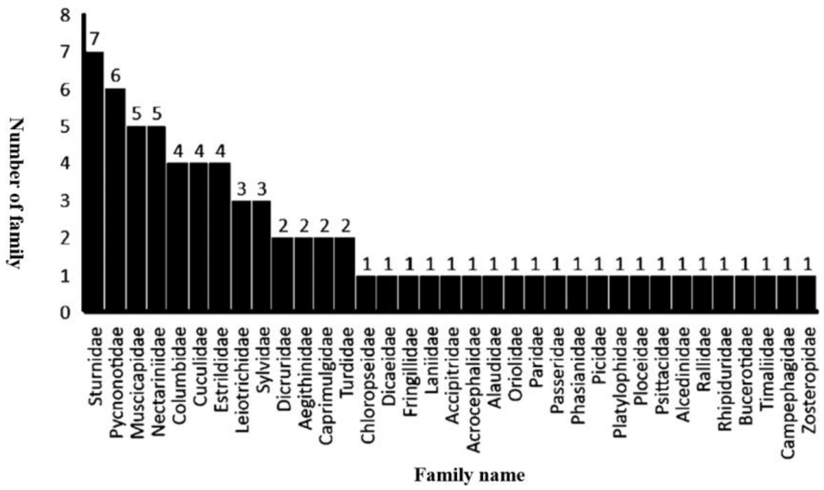

Figure 2. Families and number of bird species

Table 2. Types of migratory birds

Local name	Scientific name	Family	Habitat distribution	Diet
Decu belang	*Saxicola caprata*	Muscicapidae	Java, Sulawesi, Papua	Insectivora
Kerakbasi alis-hitam	*Acrocephalus bistrigiceps*	Acrocephalidae	Sumatera	Insectivora
Sikatan besi (tledekan)	*Muscicapa ferruginea*	Muscicapidae	Sumatera, Kalimantan, Java	Insectivora

Table 3. Diversity indices and bootstrap-based variability of bird communities in three urban habitats in Pekanbaru, Riau, Indonesia

Habitat	Species richness (S)	Total individuals (N)	Shannon diversity (H′)	SD H′	95% CI H′ (lower)	95% CI H′ (upper)	Simpson diversity (1-D)	SD 1-D	95% CI 1-D (lower)	95% CI 1-D (upper)
Urban forest	45	1,395	3.33	0.02	3.27	3.36	0.95	0.002	0.95	0.95
Bird market	40	618	3.01	0.04	2.9	3.05	0.93	0.003	0.92	0.94
Residential area	20	1,019	2.58	0.02	2.53	2.62	0.90	0.004	0.89	0.91

Notes: Species richness (S), Total number of individuals (N), Shannon-Wiener diversity (H′), and Simpson diversity (1-D) are shown for each habitat, together with bootstrap standard deviations (SD; 3000 resamples) and percentile-based 95% Confidence Intervals (CI)

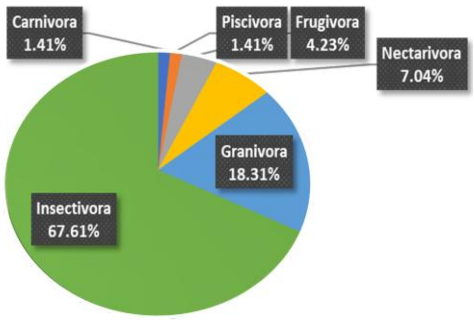

Figure 3. Types of bird food

Because migrants sit within the dominant insectivore guild, declines in these seasonal visitors can foreshadow broader trophic erosion affecting resident insectivores. Conservation should therefore prioritize maintaining reedbed belts, riparian thickets, and midstory woodland, scheduling mowing outside peak passage, and minimizing night lighting and pesticide inputs in movement corridors to safeguard both migratory use and guild stability.

Conservation status based on government regulations

Table 4 summarizes bird species covered by Indonesian government regulations, providing each species' English and scientific names, family, island-level distribution (S: Sumatra, J: Java, K: Kalimantan, P: Papua, T: Nusa Tenggara; combinations such as SKJ indicate multi-island occurrence), and primary feeding guild (for example, frugivore, insectivore, granivore, carnivore). The list highlights both island endemics and charismatic species of high conservation priority, such as the Bali myna (*L. rothschildi*), Java sparrow (*Lonchura oryzivora*), and Black hornbill (*Anthracoceros malayanus*), alongside widespread taxa that illustrate dietary and biogeographic variation across Indonesia. This synopsis enables a rapid appraisal of regulatory coverage while situating each species within its ecological niche and geographic range.

Conservation status based on IUCN

Table 5 summarizes 16 Indonesian bird taxa of conservation concern, presenting each species' local and scientific names, family affiliation, IUCN Red List category, broad island-level distribution, and primary diet. The list spans four threat classes, namely Critically Endangered (4 species), Endangered (4 species), Vulnerable (5 species), and Near Threatened (3 species). Insectivores dominate the guild composition, with a single granivore and two frugivores represented. Notable high-risk endemics include the Bali myna *L. rothschildi* (CR; confined to Java) and the Java sparrow *L. oryzivora* (EN; Java), while wider-ranging forest species such as the Black hornbill *A. malayanus* (VU; Sumatra-Kalimantan) illustrate the inclusion of non-endemic taxa. Distribution codes denote presence on major islands (J: Java, K: Kalimantan, P: Papua, S: Sumatra, T: Nusa Tenggara; combinations indicate multi-island occurrence), and diet categories provide a quick view of ecological roles. Overall, the table offers a concise view of conservation urgency, biogeographic context, and feeding guilds to orient subsequent analysis.

Conservation status based on CITES

Table 6 provides a concise overview of six Indonesian bird taxa and their listings under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), distinguishing Appendix I species *Pycnonotus zeylanicus* and *L. rothschildi* from Appendix II species *Psittacula alexandri, Accipiter virgatus, L. oryzivora,* and *A. malayanus*. For each taxon, the table pairs local and scientific names with family affiliation, CITES appendix, island-level distribution coded as J (Java), K (Kalimantan), S (Sumatra), and T (Nusa Tenggara), including multi-island combinations such as SKJ, and the dominant feeding guilds (frugivore, insectivore, granivore, carnivore). The entries span parrots, bulbuls, raptors, estrildid finches, starlings, and hornbills, enabling quick cross-referencing between legal protection status, ecological traits, and geographic presence across Indonesia's major regions. This structure allows readers to immediately identify which endemics fall under Appendix I and which widely distributed species are regulated under Appendix II while keeping the focus on core identifiers and status information only.

Discussion

Urban birds: Species, families, food types and migratory birds

Urban bird assemblages in the dataset are numerically dominated by generalist, open-habitat and human-commensal taxa, notably *P. aurigaster* (300 ind.), *G. striata* (280), *Prinia familiaris* (116), *Cinnyris jugularis* (118), *Anthreptes simplex* (114), and *L. punctulata* (328), summing to 3,032 individuals overall. These profiles are typical of Indonesian cities where widespread granivores, nectarivores, and edge insectivores flourish in residential mosaics and small green spaces.

The pattern mirrors broader Indonesian evidence that urban communities are structured by tolerant generalists such as *P. montanus* and *P. aurigaster*, which track food provisioning and shrubbery in built landscapes (e.g. parks, road verges, and house gardens). Recent studies from Java and Kalimantan likewise report high relative abundance of these species and similar evenness-richness signals in urban and peri-urban settings, underscoring the filtering effect of urbanization toward adaptable guilds (Kurnia et al. 2021). In peri-urban Bogor, diversity peaks in more vegetated successional stages, while built-up areas retain subsets dominated by frugivore-insectivores and edge insectivores, consistent with the present list's mix of bulbuls, prinias, and sunbirds (Nugroho et al. 2024).

Several records also highlight processes unique to Indonesian urban contexts. The presence of *Acridotheres* (e.g. Javan and Common Mynas) reflects both urban adaptability and the influence of the domestic songbird trade on assemblage composition and potential introductions. Regional work links myna spread to trade dynamics, which can reinforce urban establishment and biotic homogenization if not managed (Nijman et al. 2022) The single Javan Myna record is notable because the species is nationally valued yet globally listed as Vulnerable due to sharp native-range declines, illustrating how cities can act as both refuges and hubs of redistribution for traded taxa.

Table 4. Bird conservation status based on government regulations

Local name	Scientific name	Family	Habitat distribution	Diet
Betet biasa	*Psittacula alexandri*	Psittacidae	SKJ	Frugivora
Cica-daun besar	*Chloropsis sonnerati*	Chloropseidae	SKJ	Insectivora
Elang-alap besra	*Accipiter virgatus*	Accipitridae	SKJT	Carnivora
Gelatik jawa	*Lonchura oryzivora*	Estrildidae	J	Granivora
Jalak bali	*Leucopsar rothschildi*	Sturnidae	J	Insectivora
Jalak putih	*Acridotheres melanopterus*	Sturnidae	J	Insectivora
Kangkareng hitam	*Anthracoceros malayanus*	Bucerotidae	SK	Frugivora
Kenari melayu	*Chrysocorythus estherae*	Fringillidae	SJ	Granivora
Kipasan belang	*Rhipidura javanica*	Rhipiduridae	SKJ	Insectivora
Mesia sumatera	*Leiothrix laurinae*	Leiotrichidae	S	Insectivora
Poksai sumatera	*Garrulax bicolor*	Leiotrichidae	S	Insectivora
Tangkar ongklet (cililin)	*Platylophus galericulatus*	Platylophidae	SKJ	Insectivora
Tiong emas	*Gracula religiosa*	Sturnidae	SKJ	Insectivora

Note J: Java, K: Kalimantan, P: Papua, S: Sumatera, T: Nusa Tenggara

Table 5. Conservation status based on IUCN

Local name	Scientific name	Family	Conservation status (IUCN)	Habitat distribution	Diet
Anis kembang	*Geokichla interpres*	Turdidae	EN	SKJT	Insectivora
Betet biasa	*Psittacula alexandri*	Psittacidae	NT	SKJ	Frugivora
Cica-daun besar	*Chloropsis sonnerati*	Chloropseidae	EN	SKJ	Insectivora
Cucak kuning	*Rubigula dispar*	Pycnonotidae	VU	SJ	Insectivora
Cucak rawa	*Pycnonotus zeylanicus*	Pycnonotidae	CR	SK	Insectivora
Empuloh melayu	*Alophoixus tephrogenys*	Pycnonotidae	VU	SK	Insectivora
Gelatik jawa	*Lonchura oryzivora*	Estrildidae	VU	J	Granivora
Jalak bali	*Leucopsar rothschildi*	Sturnidae	CR	J	Insectivora
Jalak putih	*Acridotheres melanopterus*	Sturnidae	CR	J	Insectivora
Jalak suren	*Gracupica jalla*	Sturnidae	CR	J	Insectivora
Kangkareng hitam	*Anthracoceros malayanus*	Bucerotidae	VU	SK	Frugivora
Kerak kerbau	*Acridotheres javanicus*	Sturnidae	VU	J	Insectivora
Mesia sumatera	*Leiothrix laurinae*	Leiotrichidae	EN	S	Insectivora
Poksai sumatera	*Garrulax bicolor*	Leiotrichidae	EN	S	Insectivora
Prenjak jawa	*Prinia familiaris*	Sylvidae	NT	SJ	Insectivora
Tangkar ongklet (cililin)	*Platylophus galericulatus*	Platylophidae	NT	SKJ	Insectivora

Note: CR: Critically, EN: Endangered, VU: Vulnerable, NT: Near Threatened, J: Java, K: Kalimantan, P: Papua, S: Sumatera, T: Nusa Tenggara

Table 6. Conservation status based on CITES

Local name	Scientific name	Family	CITES status (Appendix)	Habitat distribution	Diet
Betet biasa	*Psittacula alexandri*	Psittacidae	II	SKJ	Frugivora
Cucak rawa	*Pycnonotus zeylanicus*	Pycnonotidae	I	SK	Insectivora
Elang-alap besra	*Accipiter virgatus*	Accipitridae	II	SKJT	Carnivora
Gelatik jawa	*Lonchura oryzivora*	Estrildidae	II	J	Granivora
Jalak bali	*Leucopsar rothschildi*	Sturnidae	I	J	Insectivora
Kangkareng hitam	*Anthracoceros malayanus*	Bucerotidae	II	SK	Frugivora

Notes: I: Appendix I, II: Appendix II, J: Java, K: Kalimantan, S: Sumatera, T: Nusa Tenggara

At a global scale, the community structure tallied here fits the well-documented "urban exploiter" signature: reduced representation of forest specialists, amplification of a few tolerant natives and some introduced species, and convergence toward similar guild composition across cities. This is consistent with global syntheses that link urbanization to biotic homogenization and the predominance of native generalists in city checklists. Yet, urban design matters. Evidence from tropical cities shows that connected, vegetation-rich green spaces and regular-shaped parks can raise species richness and sustain frugivory and pollination interactions, mechanisms pertinent to retaining nectarivores and frugivores already present in the list (Wong et al. 2023).

In sum, the assemblage recorded in Table 1 aligns with Indonesian and global urban-ecology expectations: a high abundance of adaptable generalists and edge species, occasional occurrence of forest-linked or traded taxa, and signals of homogenization. Strengthening tree- and shrub-rich corridors, managing trade-related releases, and safeguarding remnant vegetated patches are actionable levers to diversify and stabilize urban bird communities in Indonesian cities.

Urban bird assemblages in Table 1 show moderate to high diversity (Shannon H′: 3.40), relatively even abundance distribution (Pielou J′: 0.80), and high richness (Margalef d: 8.73) for a tropical city context. These values are consistent with Indonesian studies reporting that structurally complex, well-connected green spaces sustain higher richness and diversity than built-up zones (Utama and Nurvianto 2022; Nugroho et al. 2024). The dominance of adaptable generalists (e.g. bulbuls, prinias, sunbirds, munias) alongside a long tail of less common taxa mirrors broader Indonesian patterns in which shrub cover, canopy strata, and park configuration shape community structure helping explain the relatively high J′ despite a few abundant species (Utama and Nurvianto 2022). At the global scale, the index values and species mix align with the "urban exploiter" signature urbanization tends to depress richness, reduce forest specialists, and homogenize communities yet vegetation-rich parks can counteract these trends (Fisher et al. 2021; Sidemo-Holm et al. 2022; Wong et al. 2023). Practically, the combined evidence from H′, J′, and d indicates that maintaining and improving diversity will depend on increasing native tree and shrub layers, minimizing edge fragmentation through park design, adding water bodies where feasible, and enhancing connectivity among patches measures shown to bolster richness and stabilize urban bird communities in tropical and cross-city syntheses (Aronson et al. 2014; Wong et al. 2023).

Figure 2 shows an uneven distribution of species richness across families: a few families contribute a large share of the assemblage, whereas many others are species poor. This long-tailed pattern is typical of bird communities in which generalist, disturbance tolerant clades accumulate more species in human modified mosaics, while specialist lineages are sparsely represented. In Indonesian lowlands and peri-urban agroforestry landscapes, assemblages commonly skew toward frugivore insectivore families that adapt well to edge habitats, smallholder tree gardens, and settlement greens, consistent with regional reports of community homogenization under land-use change. These shifts mirror global findings that disturbance favors flexible foraging guilds and reduces the relative share of habitat specialists, producing family level imbalances in richness (Newbold et al. 2020). From a conservation and management perspective, the observed family-level structure supports strategies that retain native fruiting and flowering trees and maintain vegetation heterogeneity to counter homogenization and sustain representation of less common families in Indonesian landscapes, aligning with broader evidence that structurally diverse plantings can buffer biodiversity loss in human-dominated systems.

Urban bird assemblages in our study exhibit an "urban-typical" structure of feeding guilds: granivores and omnivores dominate overall abundance, followed by insectivores (foliage gleaners, ground and aerial foragers), whereas nectarivores and frugivores occur at lower yet non-trivial levels. This pattern mirrors global syntheses showing that urbanization filters communities toward diet-flexible generalists and suppresses specialists as vegetation complexity and invertebrate resources decline (Aronson et al. 2014). Joint interpretation of Figure 3 (bird food categories) and Table 1 (species list and abundances) indicates a trophic shift consistent with biotic homogenization, in which a common suite of adaptable species prospers across cities with similar built environments (Sidemo-Holm et al. 2022).

Two mechanisms plausibly underlie the observed guild structure. First, anthropogenic food subsidies both intentional bird feeding and incidental access to human food waste disproportionately benefit granivores and omnivores, restructuring local communities and at times increasing densities of urban tolerant or introduced species (Galbraith et al. 2015; Henson et al. 2023). Second, simplification of vegetation in highly managed greenspaces reduces insect biomass and microhabitats, thereby disfavoring many insectivores and frugivores that require layered understory and fruiting trees. Together, these drivers help explain why omnivores and granivores are prominent in our dataset, while nectarivores and frugivores persist primarily where flowering and fruiting plantings remain (Aronson et al. 2014).

Evidence from Indonesia aligns with these patterns. Comparative studies across peri-urban landscapes and settlements report higher proportions of omnivores and granivores in built up areas, with insectivore-rich guilds and frugivores increasing toward greener edges, plantations with shrub layers, and forest remnants (Husna et al. 2024; Nugroho et al. 2024). These findings emphasize the importance of habitat heterogeneity street trees that flower, mixed hedgerows, riparian strips, and small forest patches to support a broader range of feeding guilds within tropical cities.

From a management standpoint, our results suggest three practical directions. First, increase vegetation heterogeneity by prioritizing native, year-round flowering and fruiting species and allowing multilayered shrub-understory development to bolster insectivore and frugivore niches (Aronson et al. 2014). Second, guide public feeding practices toward responsible approaches (clean feeders, appropriate foods, limited frequency) to minimize community skew and disease risk associated with heavy provisioning (Galbraith et al. 2015; Henson et al. 2023). Third, enhance connectivity among parks, gardens, and riparian corridors so that resource-dependent guilds can move and persist across the urban mosaic, counteracting homogenization trends (Sidemo-Holm et al. 2022).

Seasonal movements of small insectivorous passerines in Indonesia broadly track the phenology of the East Asian Australasian Flyway, with autumn winter influxes into Sumatra, Java, Kalimantan, and more sparsely Papua. The Black-browed Reed Warbler (*A. bistrigiceps)* is a regular Palearctic migrant to lowland marshes, rice fields, and reedbeds across the Greater Sundas; its winter presence in Indonesia accords with regional patterns showing *Acrocephalus* as among the most abundant and habitat-structured landbird migrants in East Asia (Yong et al. 2021). The Ferruginous Flycatcher (*M. ferruginea)* winters widely in Sundaland, favoring shaded streamside and forest edge microhabitats. By contrast, the Pied Bushchat (*S. caprata)* is primarily a widespread resident in Southeast Asia; Indonesian records likely reflect local or seasonal dispersal, so inclusion in "migrant" lists is best interpreted as partial migration or post-breeding movements rather than long distance Palearctic migration. Together, these three taxa underscore an archipelagic assemblage dominated by insectivores that track seasonal prey pulses in agro mosaic and semi natural habitats.

Indonesia's national syntheses also indicate substantial migrant representation in the avifauna: approximately 15% (about 276 species) are migratory, underscoring the importance of Indonesian stopover and non-breeding habitats beyond well-studied shorebird systems. For passerines, rice agroecosystems, riparian strips, and reedbeds in Sumatra and Java support *Acrocephalus* warblers, whereas hill to submontane edges and forest margins harbor *Muscicapa* during the boreal winter. These habitat ties mirror global syntheses showing species-specific habitat selection at stopover and non-breeding sites among Palearctic landbirds. Maintaining vegetated margins, wetland heterogeneity, and low-intensity field edges is therefore directly relevant to the taxa represented in Table 2.

Emerging pressures intersect with these migratory patterns. Recent Indonesian assessments report status changes concentrated in waterbirds and migrants, while regional studies warn that landbird migrants face diffuse threats from habitat loss, climate-linked phenology shifts, and the songbird trade. Although *A. bistrigiceps* and *M. ferruginea* are currently assessed as Least Concern globally, incremental forest-cover declines within their non-breeding ranges and persistent trapping networks in parts of Sumatra and Java can erode local wintering assemblages. Strengthening oversight of passerine trade, conserving riparian buffers, and protecting small wetlands embedded in agricultural matrices are consistent with national priorities and flyway level evidence.

At the species level, current evidence aligns with the patterns implied by Table 2: *A. bistrigiceps* is a typical long-distance migrant occupying low vegetation and reedbeds; *M. ferruginea* is a forest-dependent winter visitor that selects shaded, well-structured edge habitats; and *S. caprata* in Indonesia should be treated as resident to partially migratory, moving locally across open scrub and agro-grassland in response to rainfall and resource dynamics. These distinctions matter for monitoring design: reedbed/rice-field point counts and mist netting are most effective for *Acrocephalus*; riparian transects and understory nets suit *Muscicapa*; and open-country vantage counts suit *Saxicola*. Clear separation of true Palearctic migrants from resident or dispersive taxa will improve the inferential power of Indonesian datasets and align with global recommendations for landbird-migrant assessment.

In sum, this insectivore-dominated guild provides a tractable indicator set for Indonesia's non-breeding season one reed-associate (*A. bistrigiceps*), one forest-edge flycatcher (*M. ferruginea*), and one open-country partial migrant (*S. caprata*). Priorities include safeguarding small wetlands and riparian corridors in the Greater Sundas, integrating agro-ecosystem management that retains low intensity edges, and strengthening surveillance against passerine trapping. These actions are congruent with recent national status reviews and flyway-scale syntheses and directly support Indonesia's role in conserving migratory landbird diversity.

Conservation status: Government regulation, IUCN and CITES

Indonesia's protected-species framework Ministerial Regulation P.20/2018 and its subsequent revisions aligns with the ecological and market risks faced by priority taxa in Table 4. Reductions in legal bird exports following protection upgrades indicate directional effectiveness, provided these measures are paired with systematic monitoring and consistent prosecution (Haryoko et al. 2021).

Nevertheless, risks remain concentrated in Java, Sumatra, and Kalimantan, where demand from the songbird and ornamental trade continues to drive hunting and capture. Recent field and marketplace data document measurable population depression in rural West Java and map the expansion of online trade, underscoring enforcement gaps across supply chains and marketplaces (Fink et al. 2021; Suroso et al. 2023; Padang et al. 2025).

For large frugivores highlighted in Table 4, especially hornbills habitat protection should prioritize lowland forest structure, the retention of cavity-bearing trees, and the continuity of fruit resources. Site-based evidence from Bukit Barisan Selatan offers practical levers for management, while regional analyses confirm ongoing declines and the need for targeted, species-specific actions (Fitriansyah et al. 2022; Sriprasertsil et al. 2024).

At the species level, close coupling between policy and practice is essential for high-risk endemics. Updated ecological observations for the Bali Myna support a dual strategy that combines in situ habitat protection with carefully managed releases and adaptive post-release monitoring, consistent with Red List assessments and recent conservation outcomes from Bali Barat (Sudaryanto et al. 2020; Squires et al. 2024).

Finally, Table 4's emphasis on guilds and regions aligns with growing evidence that peri-urban and mosaic landscapes can sustain bird diversity when forest patches, large trees, and continuous resources are retained. These areas provide complementary arenas for enforcement, demand reduction, and citizen engagement to deter wild-caught sourcing (Sullivan et al. 2017; Callaghan et al. 2021; Nugroho et al. 2024).

Table 5's dominance of insectivorous passerines and the concentration of species in higher IUCN threat classes (CR-EN-VU) align with the contemporary Asian songbird crisis, in which demand-driven harvesting interacts with habitat change to escalate extinction risk. Market-wide modelling for Indonesia indicates that more than a quarter of the nation's avifauna appears in trade, with demand highly skewed toward a relatively small subset of species precisely those most likely to be Red-listed (Indraswari et al. 2025). Mapping studies likewise show that online platforms extend the geographic reach and visibility of sellers, complicating enforcement and potentially accelerating pressure on wild populations (Fink et al. 2021). A recent conceptual review reframes the "crisis" through an evidence-based lens while still identifying Indonesia as a global hotspot where trade remains a primary threat (Fiennes et al. 2024; Indraswari et al. 2025).

Species highlighted in Table 5 illustrate how IUCN categories encode distinct risk pathways. For the Critically Endangered Bali myna (*L. rothschildi*), long-term releases paired with post-release management in Bali Barat National Park, Indonesia, are associated with measurable increases in free-living birds evidence that intensive stewardship can bend trajectories upward (Miller et al. 2022; Squires et al. 2024). By contrast, the Straw-headed bulbul (*P. zeylanicus*) remains a textbook case of trade-driven collapse and local extirpation across the Sundaic region, justifying its uplisting to CR and prioritization for site protection and trade controls (Machac 2020). Historical ecology further documents how the Javan pied starling (*Gracupica jalla*) shifted from common to virtually absent in the wild an arc consistent with Table 5's highest-risk categories.

Non passerines in Table 5 illustrate habitat mediated threats that compound trade. For hornbills, persistence in disturbed forests is possible but constrained by the scarcity of large nest trees, implying that production landscapes must retain old-growth structure and cavity bearing trees to meet IUCN compatible management goals (Sriprasertsil et al. 2024). Parallel species distribution and climate-response analyses for Borneo's Helmeted Hornbill underscore the urgency of safeguarding priority landscapes under accelerating environmental change. These findings dovetail with Table 5's inclusion of large forest specialists and support a policy mix that blends strict habitat retention with targeted anti-poaching.

From a governance perspective, Table 5 supports tiered interventions aligned with IUCN guidance. For CR taxa, evidence favors site level protection plus intensive management systematic monitoring, anti-poaching, and scientifically tracked releases as shown by the Bali Myna case (Miller et al. 2022; Squires et al. 2024). For EN-VU taxa, landscape-scale habitat retention and threat abatement are pivotal. Because Indonesian bird trade increasingly operates online, regulatory strengthening and digital-market enforcement are repeatedly recommended, including updates to legal instruments and proactive cyber surveillance (Leveau 2022). Finally, market-wide analyses emphasize that curbing demand is as important as supply-side action an insight directly relevant to many of the insectivores dominating Table 5 (Indraswari et al. 2025).

Together, these studies show that Table 5's species composition is not incidental: it mirrors broader Indonesian and global trends documented across international journals. Passerines especially high-value songbirds track trade intensity and are pushed into higher IUCN categories unless demand is reduced and reintroduction programs are tightly managed, whereas large forest birds require retention of functional habitat mosaics at landscape scales. Embedding these insights into local recovery plans (e.g. for CR taxa) and national strategies (e.g. habitat safeguards, digital-trade enforcement, traceable captive breeding) provides an IUCN-coherent path to stabilize and, where possible, downlist the species summarized in Table 5.

CITES stratifies the six taxa in Table 6 into Appendix I songbirds Straw-headed bulbul (*P. zeylanicus*) and Bali myna (*L. rothschildi*) and Appendix II species Black hornbill (*A. malayanus*), Java sparrow (*L. oryzivora*), Besra (*A. virgatus*), and Red-breasted parakeet (*P. alexandri*) with distinct regulatory consequences for international trade and compliance monitoring. For *P. zeylanicus*, persistent demand in Indonesian markets and anomalies in reported trade underline why strict listing must be paired with domestic oversight and provenance checks (Bergin et al. 2018; Nelson and Shepherd 2023). At the market-system level, large-scale analyses show rapid species turnover and a shift to online platforms, challenging static enforcement and calling for adaptive surveillance (Bernardino et al. 2018; Okarda et al. 2022; Indraswari et al. 2025).

For Appendix I, the Bali myna illustrates how CITES protection can translate into measurable recovery when integrated with reintroduction, post-release management, and local stewardship. Recent syntheses from Bali Barat National Park report improving outcomes after decades of trapping pressure, emphasizing husbandry, soft-release protocols, and community engagement as complements to legal protection (Squires et al. 2024). Behavioural research on neophobia and innovation further informs release design and survival prospects for reintroduced cohorts, linking captive training to post-release performance (Miller et al. 2022).

Among Appendix II taxa, risk pathways differ and require parallel tools. The Java Sparrow remains Endangered in the wild on Java despite large captive populations; recent Indonesian studies mapping microhabitat use in cities and protected areas argue that habitat retention and routine auditing of "captive-bred" claims are essential to prevent laundering while stabilizing small urban and park subpopulations (Roos et al. 2020; Morton et al. 2024). For the Black hornbill an ecologically pivotal frugivore nest-site work in West Kalimantan highlights sensitivity to lowland forest loss and the need to safeguard large nest trees within logging concessions and community forests, aligning site-level management with Appendix II controls field study (Zemljak et al. 2024); broader hornbill priorities in Squires et al. (2021), Hatten et al. (2024), and Sriprasertsil et al. (2024). For the Besra and Red-breasted Parakeet, species accounts confirm ongoing exploitation across much of their ranges, suggesting that permit verification and targeted demand reduction remain necessary alongside habitat safeguards.

At the system scale, Indonesian and global literature converge on two implementation gaps relevant to Table 6: first, the rapid migration of trade to digital platforms complicates detection and traceability; second, documentation around captive breeding can be inconsistent, enabling laundering without rigorous facility audits and genetic management plans. Indonesian work documents the online shift in bird markets and the need for platform level enforcement and data partnerships (Okarda et al. 2022), while global syntheses propose stronger procedures for captive-bred specimens to close loopholes and align CITES permits with conservation outcomes (Chan et al. 2021; Morton et al. 2024; Zhang et al. 2024). Together, these findings indicate that, for Indonesian cities and provinces, Appendix I-II categories should be operationalized through four levers: (i) market surveillance in both physical and online arenas, (ii) verification of permits and breeding-facility claims, (iii) retention of large fruiting and nesting trees for hornbills in production forests, and (iv) community-based stewardship of reintroduced and remnant songbird populations so that international listings deliver measurable recovery at site level (Bergin et al. 2018; Squires et al. 2024: Indraswari et al. 2025).

Pekanbaru can translate these findings into policy by embedding a mapped biodiversity network in its spatial plan (RTRW/RDTR) that secures wetlands, riparian strips, and small parks as core areas connected by corridors and applies the principle of no harm in permitting. Site plans should mandate layered planting of native vegetation species, functional water features, limited grass cutting and lighting near sensitive microhabitats, and bird friendly building arrangements along corridors. Mayoral regulations should establish seasonal construction windows that prohibit vegetation removal during peak migration times, require pre land clearing ecological inspections, and link occupancy to documented compliance. Local enforcement of national wildlife laws could be strengthened through a joint Natural Resources Conservation Center with Civil Service Police Unit task force for market inspections and online trade monitoring, provenance audits for "captive breeding" claims, and risk screening for city government procurement and events. Development should fund standardized pre and post construction bird surveys focusing on reed beds and riverbanks, with results published on a public dashboard. Progress should be assessed based on indicators of inspection outcomes, seizures, prosecutions, verified audits, and delisting's so that habitat protection for migratory species can be measured and aligned with national law.

In conclusion, urban green spaces in Pekanbaru continue to function as refugia, supporting 71 species in 35 families, although assemblages are increasingly filtered toward disturbance-tolerant generalists and insectivores. Records of three migrants, 13 nationally protected taxa, 16 Red-Listed species (CR-NT), and six CITES-listed species highlight both conservation value and ongoing risk. The most sensitive groups are wetland-dependent and insectivorous taxa, with principal pressures arising from habitat degradation, land conversion, and wildlife trade that is increasingly mediated online.

Priority actions include restoring hydrological elements, strengthening patch connectivity, maintaining stratified vegetation, and tightening enforcement, including audits of captive-breeding claims for CITES species. These measures should be coupled with recurrent population monitoring on seasonal to annual cycles. The study's tractable design is transferable across tropical Indonesian cities to build time series and evaluate the effectiveness of interventions. The limited sampling window indicates the need to extend survey seasons and to integrate acoustic recording and citizen science to improve diversity estimates and conservation-status appraisals.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to the Directorate of Research, Technology, and Community Service, Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia, for funding this research through the Fundamental Research Grant scheme (Grant Numbers: 138/C3/DT.05.00/PL/2025, 002/LL17/DT.05.00/PL/2025, and 0217/LPPM/Pn/2025).

REFERENCES

Aronson MFJ, La Sorte FA, Nilon CH, Katti M, Goddard MA, Lepczyk CA, Warren PS, Williams NSG, Cilliers S, Clarkson B, Dobbs C, Dolan R, Hedblom M, Klotz S, Kooijmans JL, Kühn, I, Macgregor-Fors I, Mcdonnell M, Mörtberg, U, Winter M. 2014. A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. Proc Royal Soc B Biol Sci 281 (1780): 20133330. DOI: 10.1098/rspb.2013.3330.

Bergin D, Chng SC, Eaton JA, Shepherd C. 2018. The final straw? An overview of Straw-headed Bulbul *Pycnonotus zeylanicus* trade in Indonesia. Bird Conserv Intl 28 (1): 126-132. DOI: 10.1017/S0959270917000302.

Bernardino J, Bevanger K, Barrientos R, Dwyer JF, Marques AT, Martins RC, Shaw JM, Silva JP, Moreira F. 2018. Bird collisions with power lines: State of the art and priority areas for research. Biol Conserv 222: 1-13. DOI: 10.1016/j.biocon.2018.02.029.

Bibby CJ, Burgess ND, Hill DA, Mustoe SH. 2000. Bird Census Techniques. Academic Press, London.

Biosci I, Tiwari G, Shukla A. 2023. Green zones in urban area as potential sites for bird diversity conservation. Intl J Biosci 22 (5): 35-45. DOI: 10.12692/ijb/22.5.35-45.

Callaghan C, Cornwell W, Poore AG, Benedetti Y, Morelli F. 2021. Urban tolerance of birds changes throughout the full annual cycle. J Biogeogr 48 (6): 1503-1517. DOI: 10.1111/jbi.14093.

Chan DTC, Poon ESK, Wong ATC, Sin SYW. 2021. Global trade in parrots - Influential factors of trade and implications for conservation. Glob Ecol Conserv 30: e01784. DOI: 10.1016/j.gecco.2021.e01784.

Dong K, Li YM, Li D, Hu W, Xu G. 2023. Effects of environmental factors on avian communities in urban parks in small- to medium-sized cities: A case study of Fuyang City, Anhui, China. Environ Monit Assess 195 (11): 1347. DOI: 10.1007/s10661-023-11973-5.

Fiennes S, Hardianto N, Ansari S, Dwiyahreni A, Jackson T, Holmes G, Birchall C, Hassall C. 2024. Rethinking extinction "crises": The case of Asian songbird trade. Camb Prisms Ext 2: 1-9. DOI: 10.1017/ext.2024.20.

Fink C, Toivonen T, Correia RA, Di Minin E. 2021. Mapping the online songbird trade in Indonesia. Appl Geogr 134: 102505. DOI: 10.1016/j.apgeog.2021.102505.

Fisher J, Irvine K, Bicknell J, Hayes W, Fernandes D, Mistry J, Davies Z. 2021. Perceived biodiversity, sound, naturalness and safety enhance the restorative quality and wellbeing benefits of green and blue space in a neotropical city. Sci Total Environ 755: 143095. DOI: 10.1016/j.scitotenv.2020.143095.

Fitriansyah RA, Setiawan A, Rustiati EL, Utoyo L. 2022. Spatial distribution and temporal patterns of food tree availability of hornbills (Bucerotidae) at Way Canguk Research Station, Bukit Barisan Selatan National Park, Indonesia. Biodiversitas 23 (4): 1990-1997. DOI: 10.13057/biodiv/d230433.

Galbraith JA, Beggs JR, Jones DN, Stanley MC. 2015. Supplementary feeding restructures urban bird communities. Proc Natl Acad Sci USA 112 (20): E2648-E2657. DOI: 10.1073/pnas.1501489112.

Haryoko T, O'Hara M, Mioduszewska B, Sutrisno H, Prasetyo LB, Mardiastuti A. 2021. Implementation of species protection act for the conservation of *Tanimbar corella, Cacatua goffiniana* (Roselaar & Michels, 2004). Biodiversitas 22 (4): 1733-1740. DOI: 10.13057/biodiv/d220417.

Hatten CER, Hadiprakarsa YY, Lee CKF, Jain A, Kaur R, Miller A, Cheema S, Au NJ, Khalid S, Dingle C. 2024. Predicting conservation priority areas in Borneo for the critically endangered helmeted hornbill (*Rhinoplax vigil*). Global Ecol Conserv 55 (6): e03206. DOI: 10.1016/j.gecco.2024.e03206.

Henson E, McLeod EM, Weston MA, Miller KK. 2023. Bird feeding at urban wetlands: A comparison of demographics, attitudes and norms between feeders and non-feeders. Sci Total Environ 891 (5): 164060. DOI: 10.1016/j.scitotenv.2023.164060.

Hepburn L, Smith A, Zelenski J, Fahrig L. 2021. Bird diversity unconsciously increases people's satisfaction with where they live. Land 10 (2): 1-19. DOI: 10.3390/land10020153.

Huang P, Zheng D, Yan Y, Xu W, Zhao Y, Huang Z, Ding Y, Lin Y, Zhu Z, Chen Z, Fu W. 2022. Effects of landscape features on bird community in Winter Urban Parks. Animals 12 (23): 3442. DOI: 10.3390/ani12233442.

Husna F, Nurhayati, Patria MP, Winarni N. 2024. Diversity of bird-feeding guilds in Bukit Mas Village, North Sumatra, Indonesia. Biodiversitas 25 (11): 4572-4580. DOI: 10.13057/biodiv/d251156.

Indonesian Ministerial Regulations P.106/2018 and P.20/2018. Regulation of the Minister of Environment and Forestry Number P.106/MENLHK/SETJEN/KUM.1/12/2018 concerning the Second Amendment to Regulation of the Minister of Environment and Forestry Number P.20/MENLHK/SETJEN/KUM.1/6/2018 concerning Protected Plant and Animal Species. Minister of Environment and Forestry, Jakarta. [Indonesian]

Indraswari K, Fiennes S, Cassey P, Cahyadi G, Noske R, Ihsan F, Susilawati C, Shepherd CR, Biggs D, Wilson C. 2025. Market patterns within Indonesia's songbird trade. Biol Conserv 310 (6): 280-284. DOI: 10.1016/j.biocon.2025.111318.

IUCN. 2024. The IUCN Red List of Threatened Species. Version 2024-1. https://www.iucnredlist.org/

Khiruddin FZ, Mansor MS. 2023. Green space and water body supports bird species diversity across urban parks in Kuala Lumpur, Malaysia. Res Sq 1-10. DOI: 10.21203/rs.3.rs-3312310/v1.

Kurnia I, Arief H, Mardiastuti A, Hermawan R. 2021. The potential of bird diversity in the urban landscape for birdwatching in Java, Indonesia. Biodiversitas 22 (4): 1701-1711. DOI: 10.13057/biodiv/d220413.

Leveau LM. 2022. Does spring bring colors? Seasonal bird plumage color variation along urban-rural gradients. Perspect Ecol Conserv 20: 1-10. DOI: 10.1016/j.pecon.2021.11.002.

Machac A. 2020. The dynamics of bird diversity in the new world. Syst Biol 69 (6): 1180-1199. DOI: 10.1093/sysbio/syaa028.

Miller R, Garcia-Pelegrin E, Danby E. 2022. Neophobia and innovation in critically endangered Bali myna, *Leucopsar rothschildi*. R Soc Open Sci 9 (7): 211781. DOI: 10.1098/rsos.211781.

Morton O, Nijman V, Edwards DP. 2024. Assessing and improving the veracity of international trade in captive-bred animals. J Environ Manag 354 (2): 120240. DOI: 10.1016/j.jenvman.2024.120240.

Mulyani YA, Dones R, Aida F, Yaumud R. 2023. Bird Community in Urban Habitats: Assessment using Passive Acoustic Monitoring. Bird Community in Urban Habitats: Assessment using Passive Acoustic Monitoring. [Report]. Institut Pertanian Bogor, Bogor. [Indonesian]

Nelson SS, Shepherd CR. 2023. Assessing the trade of Chinese Hwamei *Garrulax canorus* in the USA. Bird Conserv Intl 33: 1-10. DOI: 10.1017/s0959270923000096.

Newbold T, Oppenheimer P, Etard A, Williams J. 2020. Tropical and mediterranean biodiversity is disproportionately sensitive to land-use and climate change. Nat Ecol Evol 4 (12): 1630-1638. DOI: 10.1038/s41559-020-01303-0.

Nijman V, Ardiansyah A, Siriwat P, Birot H, Winnasis S, Damianou E, Imron M, Langgeng A, Lewis B, Nekaris KA. 2022. Wildlife trade and the establishment of invasive alien species in Indonesia: Management, policy, and regulation of the commercial sale of songbirds. Biol Invasions 24 (9): 2905-2916. DOI: 10.1007/s10530-022-02831-5.

Nugroho SPA, Mardiastuti A, Mulyani YA, Rahman DA. 2024. Bird communities in the tropical peri-urban landscape of Bogor, Indonesia. Biodiversitas 24 (12): 6986-6998. DOI: 10.13057/biodiv/d241260.

Okarda B, Muchlish U, Kusumadewi SD, Purnomo H. 2022. Categorizing the songbird market through big data and machine learning in the context of Indonesia's online market. Glob Ecol Conserv 39 (5): e02280. DOI: 10.1016/j.gecco.2022.e02280.

Padang K, Nuruliawati, Afifah Z, Andriansyah MI, Putri AAD, Hafizoh N, Hermawati I, Muktamarianti AI, Yulianti S, Handayani NW, Mardiah S. 2025. Online illegal wildlife trade in Indonesia: Strengthening the regulatory framework and law enforcement. Oryx 59 (2): 210-220. DOI: 10.1017/S0030605323001667.

Roos C, Cilliers DP, Retief FP, Alberts RC, Bond AJ. 2020. Regulators' perceptions of Environmental Impact Assessment (EIA) benefits in a sustainable development context. Environ Impact Assess Rev 81: 106360. DOI: 10.1016/j.eiar.2019.106360.

Sidemo-Holm W, Ekroos J, Hedblom M. 2022. Urbanization causes biotic homogenization of woodland bird communities at multiple spatial scales. Glob Change Biol 28 (21): 6152-6164. DOI: 10.1111/gcb.16350.

Squires T, Kepakisan AN, Kusumanegara H, Collar N, Yuni LPE, Owen A, Nugroho A, Sarmawi M, Nelson S, Winarni NL, Marsden S. 2024. The road to recovery: Conservation management for the critically endangered Bali myna shows signs of success. Oryx 58 (3): 367-377. DOI: 10.1017/S0030605323000777.

Squires TM, Yuda P, Akbar PG, Collar NJ, Devenish C, Taufiqurrahman I, Wibowo WK, Winarni NL, Yanuar A, Marsden SJ. 2021. Citizen science rapidly delivers extensive distribution data for birds in a key tropical biodiversity area. Glob Ecol Conserv 28 (6): e01680. DOI: 10.1016/j.gecco.2021.e01680.

Sriprasertsil V, Da-ouli N, Chootongkhum C, Strange BC, Khamcha D, Jinamoy S, Chimchome V, Nakkuntod S, Karapan S, Hayeburaheng S, Pongdee N, Gale GA, Naniwadekar R. 2024. Changes in endangered hornbill populations over space and time and potential ecological impacts in peninsular Thailand. Glob Ecol Conserv 53: e03006. DOI: 10.1016/j.gecco.2024.e03006.

Sudaryanto F, Pudyatmoko S, Djohan T, Subagja J, Suana IW, Hardini J, Subagio J. 2020. Daily activity, diet and habitat of Bali myna (*Leucopsar rothschildi*) in Nusa Penida, Bali, Indonesia. Biodiversitas 21 (10): 4474-4482. DOI: 10.13057/biodiv/d211002.

Sullivan B, Phillips T, Dayer A, Wood C, Farnsworth A, Iliff M, Davies I, Wiggins A, Fink D, Hochachka W, Rodewald A, Rosenberg K, Bonney R, Kelling S. 2017. Using open access observational data for conservation action: A case study for birds. Biol Conserv 208: 5-14. DOI: 10.1016/j.biocon.2016.04.031.

Suroso, Iskandar J, Withaningsih S, Nurjaman D, Iskandar B. 2023. Bird population and bird hunting in the rural ecosystem of Cijambu, Sumedang, West Java, Indonesia. Biodiversitas 24 (8): 4470-4484. DOI: 10.13057/biodiv/d240828.

Utama AA, Nurvianto S. 2022. The building size effect on bird community assemblages in tropical urban ecosystem. Biodiversitas 23 (5): 2775-2782. DOI: 10.13057/biodiv/d230560.

Wong JSY, Soh MCK, Low BW, Er KBH. 2023. Tropical bird communities benefit from regular-shaped and naturalised urban green spaces with water bodies. Landsc Urban Plan 231: 104644. DOI: 10.1016/j.landurbplan.2022.104644.

Yong DL, Heim W, Chowdhury SU, Choi CY, Ktitorov P, Kulikova O, Kondratyev A, Round PD, Allen D, Trainor CR, Gibson L, Szabo JK. 2021. The state of migratory landbirds in the east asian flyway: Distributions, threats, and conservation needs. Front Ecol Evol 9: 1-22. DOI: 10.3389/fevo.2021.613172.

Zemljak D, Hari D, Bratina M, Flogie A, Aber B, Kerne M. 2024. Integrating Contemporary Technologies in Education: Empowering Youth for Sustainable Future Through New Literacies. Preprints.org. DOI: 10.20944/preprints202403.0672.v1.

Zhang S, Wen L, Weng A, Cheng D, Li B. 2024. Research progress in biodiversity and human well-being, based on citespace. Biology 13 (12): 1020. DOI: 10.3390/biology13121020.