Bird Diversity Patterns along Urbanization Gradients: Some Recommendations for Landscape Planner

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Abstract. Birds in an urban area often being used to indicate the quality of the city. The objective of this study was to analyze the response of birds to different intensities of urban-rural change. The high variation of house size and arrangement within housing clusters in the residential area of Sentul City (Bogor, West Java) was used as a model to mimic urbanization gradients in a city landscape. Five housing clusters were selected to represent the degree of urbanization gradients. Build to unbuild land ratio and density of mature trees were used to designate urbanization gradients in the chosen observation sites. Birds were observed using a standard point count method. Bird diversity was the highest in low urbanization (33 species) and diminishing in the higher urbanization grades (15 species). Sites with the highest urbanization rate still able to function as bird habitat, although the species number was low. The persistent bird species against urban-rural were mostly insectivores, nectarivores, and granivores (seed-eaters), while species that we’re unable to cope with urbanization were generally raptors, bush dependent species (e.g. babbler group) and thick canopy dependent species (e.g. green pigeon). The results indicate that (i) there is a negative relationship between degree of urbanization and bird species persistence in urban areas; (ii) efforts for bird conservation should not only focus on regreening but also be directed toward plant functional diversity to accommodate more diverse birds; (iii) urban landscape planner should consider maintaining or creating patch(es) of semi-nature areas as a refuge habitat for birds and other city-persistent species.

Keywords: avian community, housing, residential area, Sentul City, urban habitat

1. Introduction

Urbanization, commonly defined as a concentrated human presence in residential areas and their associated affects [1], has been happening all over the world, including in Indonesia. The urban area has the most heterogeneous landscapes, due to highly fragmented environments, resulting in a mosaic of patches of land-use types of various sizes [2, 3].

Previous research in the Greater Jakarta Region [4] showed that the urban vegetative cover mostly replaced by human-made structures, while the planted ornamental vegetation was dominated by highly discontinued single layers, especially along roads and streets. Furthermore, the habitat patches were distributed in small mosaic patches.

Birds have been known to respond to habitat changes [5]. To understand how the bird community responds to the different gradient of urbanization, field research in Sentul City residential area was conducted. Sentul City residential area complex was selected as the study area because the site has been...
arranged into clusters in such a way that represented various degrees of urbanization gradients, from a newly built cluster up to old cluster resembled semi-nature area. The objective of this research was to reveal the bird community in several clusters in Sentul City as models of various gradient of urbanization. The results will be interpreted for management recommendations for similar residential areas in Indonesia.

2. Study site and methods

Located in the periphery of the City of Bogor, West Java, the residential complex consists of 13 housing complexes (covers most area), malls, hospital, amusement park, mosques and churches, hotels, offices, apartment, market, house-shop complex, convention center, schooling, bus terminal, and 18-hole golf course occupied, covering an area of around 2,400 ha (Figure 1). To represent various urbanization gradients, five housing clusters were selected as study areas. Build to unbuilt land ratio and density of mature trees were used to designate urbanization gradients in the chosen observation sites. These clusters were Northridge, Bukit Golf Hijau-Mediterrania I, Venesia-Pasadena-Sakura, Argenia Cluster, and Bali Cluster (Figure 2).

The Northridge is very spacious, has big houses on large-sized land. A small lake can be found in this cluster. There are many unbuilt areas in between houses, and this semi-natural area cluster overall resembles a low urbanization gradient, designated as Gradient I. Gradient II was Bukit Golf Hijau-Mediterrania I complex, which was built about 20 years ago, consists of large to medium-sized maisonette-type houses. Mature raintree *Samanea saman* characterized this cluster and creates heavy shading along the major roads. Gradient III was Venesia-Pasadena-Sakura, which have medium to small houses, and located in the valley, surrounded by some open spaces. Trees in this Cluster are already reached maturity, as this Cluster was built since about 15 years ago. Gradient IV was Argenia Cluster, a relatively new cluster of medium-sized houses, built approximately 9 years ago. Trees are still in saplings and poles stages. Although this cluster is relatively new, the ratio of open to built area is relatively high. Gradient V, representing the highest urbanization gradients, was Bali Cluster (Tapaksiring, Legian, Besakih, Udayana) which has small houses, mostly town-house (arranged in rows) style. Trees in this Cluster is already reached maturity, but the ratio of open to the built area is relatively low.

During November and December 2017 the standard point count method [6] was employed to record bird species and their number, as well as family. Ten random points (radius 25 m) were established to sample the bird communities (species and number) in each gradient cluster. Observation was conducted twice a day, in the morning (05:30-9:00 am) and in the afternoon 3:30-6:00 pm), 10 mins for each point after a 2-min wait, and therefore nocturnal birds were not recorded. The duration of field observations varied between 4 to 10 days for each cluster until there were no additional new species. Nomenclature and species identification follow standard field guide [7]. Bird guilds were categorized based on their main diet. Bird community was analyzed by using Shannon-Wiener diversity indices ($H'$) [8], evenness, and Bray-Curtis similarity indices [9].
Figure 1. Map of the study site in Sentul City residential area, Bogor, West Java.
Figure 2. Diagram of housing clusters study sites in Sentul City, representing five different urbanization gradients.
3. Results

3.1. Bird diversity and guilds

A total of 2,728 individual birds were recorded in all five clusters during the study. The number of species was 38, belonging to 22 families (Appendix 1). Cluster with the lowest urbanization gradient (Grade I; Northridge) had the highest number of bird species (33 species). As expected, the number of bird species decreased with the increasing urbanization (Table 1).

In terms of the diversity indices – a quantification of the number of individuals and the number of species - also reached the highest in Grade I site (H’ 2.67), and basically decreased gradually up to Grade V (H’ 2.06). In a tropical rainforest, normally an area is categorized as having a high biodiversity of at least $H^\prime = 3.00$. Since there has been no standard for the bird diversity indices in the urban area, clusters were only compared to each other.

Gradient I was also the best habitat for birds, indicated by the most diverse bird guilds occupied in the site, including insectivores, granivores (seed-eaters), piscivores (fish-eaters), nectarivores, and frugivores (fruit-eaters). Along with the increasing rural to urban change, frugivores were missing, and then piscivores. Insectivores, granivores, and nectarivores still can be found, even in Grade V urbanization.

In all urbanization grades, evenness is high (more than 0.70), indicating that there were very few species that stands out and dominated the sites. As for similarity, it was clear that the bird composition in Grade I differed with the Grade II and others. Obviously, the Grade I was distinct compared to the four higher grades, in terms of the number of species, guild and the bird composition. Grade II up to Grade V were more or less similar to each other, although the number of species and guild gradually decreased along with the intense urbanization.

| Parameter                     | Urbanization Gradient (Low – High) |
|-------------------------------|-----------------------------------|
|                               | I   | II  | III | IV  | V   |
| Number of species             | 33  | 19  | 19  | 17  | 15  |
| H’                            | 2.67| 2.30| 2.20| 2.11| 2.06|
| Number of guilds              | 5   | 4   | 4   | 3   | 3   |
| Guild names (in order of abundance) | Insectivores | Granivores | Insectivores | Granivores | Insectivores | Granivores | Insectivores | Granivores | Insectivores | Granivores |
|                               | Grivores | Piscivores | Nectarivores | Grivores | Nectarivores | Grivores | Nectarivores | Grivores | Nectarivores |
| Evenness                      | 0.76 | 0.79 | 0.75 | 0.76 | 0.74 |
| Similarity to the next upper gradient | 0.59 | 0.72 | 0.71 | 0.71 |

3.2. Common bird species

Cave Swiftlet, an aerial insectivore, was easily encountered in all sites, and so did the Eurasian Tree Sparrow (Table 2). If these two species is excluded because of its large aerial foraging area and because of its close affinity to human-made buildings, respectively, each gradient has its own distinct typical species. Sooty-headed Bulbul was typical in Gradient I, Oriental White-eye was typical in Gradient II, Olive-backed Sunbird was typical in Gradient III, Javan Munia was typical in Gradient IV, while Scarlet-headed Flowerpecker was typical in Gradient V.

Munias (i.e. Scally-breasted Munia and White-headed Munia), and some nectar-feeding birds were also dominant in several gradients, indicating that the sites were rich in food grains and flowering plants. Striated Swallow has been known as a migratory bird, thus there is a possibility that this species would be not common if the study is conducted in other months.
Table 2. Five common bird species in each gradient in Sentul City residential area, listed by its domination.

| Gradient | Common Species |
|----------|----------------|
| I        | Cave-Swiftlet (*Collocalia linchi*), Sooty-headed Bulbul (*Pygnonotus aurigaster*), Scaly-breasted Munia (*Lonchura punctulata*), Eurasian Tree Sparrow (*Passer montanus*), Striated Swallow (*Hirundo striolata*) |
| II       | Cave-Swiftlet (*Collocalia linchi*), Eurasian Tree Sparrow (*Passer montanus*), Sooty-headed Bulbul (*Pygnonotus aurigaster*), Scaly-breasted Munia (*Lonchura punctulata*), Oriental White-eye (*Zosterops palpebrosus*) |
| III      | Cave-Swiftlet (*Collocalia linchi*), Eurasian Tree Sparrow (*Passer montanus*), Olive-backed Sunbird (*Nectarinia jugularis*), Javan Munia (*Lonchura leucogastroides*), Sooty-headed Bulbul (*Pygnonotus aurigaster*) |
| IV       | Cave-Swiftlet (*Collocalia linchi*), Eurasian Tree Sparrow (*Passer montanus*), Scaly-breasted Munia (*Lonchura punctulata*), Javan Munia (*Lonchura leucogastroides*), Yellow-vented Bulbul (*Pycnonotus goiavier*) |
| V        | Cave-Swiftlet (*Collocalia linchi*), Eurasian Tree Sparrow (*Passer montanus*), Sooty-headed Bulbul (*Pygnonotus aurigaster*), Scarlet-headed Flowerpecker (*Dicaeum trochileum*), Striated Swallow (*Hirundo striolata*) |

3.3. Urbanization-prone species
As mentioned previously, Gradient I had the most bird species, of which some of them could not be found in other Gradients. It implies that if Gradient I would experiencing more intensive urbanization, these species might be extirpated from Gradient I. In this paper, these species are called urbanization-prone species. The fourteen urbanization-prone species were basically required a certain habitat types (water body) or food for their survival (Table 3).

Table 3. List of urbanization-prone species (i.e. bird species that can be found only in urbanization Gradient I).

| Food Guild                        | Common Name                       |
|-----------------------------------|-----------------------------------|
| Insectivores                      | Banded Bay Cuckoo                 |
|                                   | Rusty-breasted Cuckoo             |
|                                   | Lesser Coucal                     |
|                                   | Common Iora                       |
|                                   | Long-tailed Shrike                |
|                                   | White-breasted Wood-swallow       |
|                                   | Black-capped Babbler              |
|                                   | Horsfield’s Babbler               |
| Piscivores and water-related vegetation | Black-crowned Night Heron         |
|                                   | White-breasted Waterhen           |
|                                   | Javan Kingfisher                  |
|                                   | Blue-eared Kingfisher             |
| Frugivores                        | Pink-necked Green-Pigeon          |
| Granivores                         | Zebra-Dove                        |
4. Discussion
There has been some research on birds in an urban area in Indonesia, including in Greater Jakarta Region [10], Bandung [11], and Semarang [12]. However, research on birds in a residential area has been very scarce, and thus comparison is also limited. Comparing bird species in Greater Jakarta Region [10] and in this study, the bird species found in the study area are typical of urban birds.

The results of this study clearly showed that the bird community is highly responded to habitat conditions. Rural to urban change has a negative effect on birds, although some birds – mainly insectivores, granivores, and nectarivores - were still able to persist in the harsh urban condition. On the other side, landscape planners might want to have as many birds as possible in residential areas, because birds can serve as an environmental quality of the residential areas.

5. Conclusion
Based on the results of this study, the most important conclusion was that the lowest urbanization gradient (i.e. more rural ecosystem) has the highest number of bird species. This result can be interpreted in many ways for management purposes. Some recommendations for landscape planner to increase bird diversity in residential areas are as follows:

(a) The $H'$ can be set at 2.50; residential area with $H'$ of more than 2.50 can be considered as a good quality for bird habitat, and conversely, below 2.50 needs habitat management; it is important to understand that $H'$ is a calculation based on number of species and its respective individual, thus it can be used in small or large residential areas;

(b) Set aside a certain wilderness area or create a wilderness-like area (resemble Grade I urbanization) within the residential area; this area will function as refuge against prey (if any) or disturbance from human;

(c) Manage a certain area to resemble nature or wilderness area, meaning that intense urbanization gradients (Gradients II to V) need to be changed forward into less urbanized gradients (Gradient I), through series of these activities:
   - Increase vegetation cover by conducting careful planting;
   - Combine various vegetation layers in the planting schemes, which include tree canopy, middle canopy, and bushes; multi-species plants arranged in multi-strata planting scheme will be much more beneficial for birds compare to the monoculture single layer planting schemes.
   - Leave some old trees for cavity-nesting birds (i.e. Fulvous-breasted Woodpecker);

(d) Add habitat and/or food source to increase build guilds:
   - The extent of water body (river, creek, pond, marsh) would increase the diversity of water-related and water-dependent birds (herons, kingfishers, waterhens, and ducks - although the later bird group was not found in the study area), as also shown in Gradient I in this study;
   - In the intense urbanization (Gradient IV and V in this study), trees producing small fruits (e.g. Antidesma bunius, Syzygium polyanthum, Muntingia calabura, Ficus benjamina) would attract various frugivoruous birds;
   - Nectarivorous birds can be invited by planting tree producing flower, for example, Delonix regia, Spathodea campanolata, Lagerstroemia speciosa, Jacaranda mimosifolia, Erythrina variegata, Callistemon viminalis; bird apparently preferred flowering trees compared to flowering shrubs due to safety reason; flowering trees and ornamental plants can be selected in such a way to provide all-year-round nectar from all over the housing complex.

(e) High bird similarity among clusters (or gradients) means that the birds may utilize each cluster inter-changeable as habitat patches, and therefore:
   - Decrease the distance between/among clusters (or gradients/habitat patch) and decrease cluster isolation by conducting more planting to create more vegetation cover;
Create some kind of habitat corridor between/among clusters (or gradients/habitat patch) through tree planting in rows;

(f) Some bird species can be selected as an indicator of a good habitat or successful management action, as seen in Table 3; habitat management can be considered successful if one (or more) birds can be found in the managed area.

References

[1] Marzluff, J.M., 1997. Effects of urbanization and recreation on songbirds. In: Block, W.M., Finch, D.M. (Eds.), *Songbird Ecology in Southwestern Ponderosa Pine Forests: A Literature Review*. Gen. Tech. Re RM-GTR-292. US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, pp. 89–102.

[2] Faeth SH, Bang C, Saari S 2011 *Ann. N.Y. Acad. Sci.* **1223**: 69–81.

[3] Wu J 2010 *Landscape Ecol.* **25**:1-4.

[4] Mardiastuti A 2016 *Considerations for Biodiversity Conservation in Modern Megacities: Lessons from Jakarta, Indonesia* Pp. 60-62 in *Tropical Conservation: Perspectives on Local and Global Priorities* Aguirre AA and Sukumar R (Eds.) Oxford: Oxford University Press.

[5] Kaban A, Mardiastuti A, Mulyani YA. 2017. Response of bird community to various plantation forest in Gunung Walat, West Java, Indonesia. Hayati Journal of Biosciences 24(2):72-78.

[6] Bibby C, Jones M, Marsden S 2000 *Expedition Field Techniques Birds Surveys* London: Expedition Advisor Centre.

[7] MacKinnon J, Phillipps K, van Balen B 1998 *Seri Panduan Lapangan Burung-Burung di Sumatera, Jawa, Bali dan Kalimantan* Bogor: Birdlife International-Indonesia Program–Pusat Penelitian dan Pengembangan Biologi LIPI.

[8] Magurran AE. 2004. *Measuring Biological Diversity*. Oxford (UK): Blackwell Science Ltd.

[9] Krebs CJ. 1998. *Ecological Methodology*. 2nd Ed. New York (US): Harper & Row Pub.

[10] Mardiastuti A, Mulyani YA, Rinaldi D, Rumblat W, Dewi LK, Kaban A, Sastranegara H. 2014. *Panduan Praktis Menentukan Kualitas Ruang Terbuka Hijau dengan Menggunakan Burung Sebagai Indikator*. Bogor. Institut Pertanian Bogor.

[11] Fardila D and Sjarmidi A 2012 *Res. J. Recent. Sci.* **1**:23-32.

[12] Rahayuningsih M and Priyono B 2016 *Int. J. Ecol. Dev.* **31**(1): 63-72.
### Appendix I

List of bird species recorded in each urbanization gradient in Sentul City residential area. Sequence and nomenclature follow [7]; ● present, ○ absent.

| No | Common Name                  | Latin Name                        | Urbanization Gradient (Low; Rural – High; Urban) |
|----|-------------------------------|-----------------------------------|-----------------------------------------------|
|    |                               |                                   | I    | II   | III  | IV   | V    |
| 1  | Black-crowned Night-heron     | Nycticorax nycticorax             | ●    | ○    | ○    | ○    | ○    |
| 2  | Barred Buttonquail           | Turnix suscitator                 | ○    | ●    | ○    | ○    | ○    |
| 3  | White-breasted Waterhen      | Amaurornis phoenicurus            | ●    | ○    | ○    | ○    | ○    |
| 4  | Zebra-Dove                   | Geopelia striata                 | ●    | ●    | ●    | ●    | ●    |
| 5  | Spotted-Dove                 | Streptopelia chinensis           | ●    | ●    | ●    | ●    | ●    |
| 6  | Pink-necked Green-Pigeon     | Treron vernans                   | ●    | ○    | ○    | ○    | ○    |
| 7  | Plaintive Cuckoo             | Cacomantis merulinus             | ●    | ●    | ●    | ●    | ●    |
| 8  | Banded Bay Cuckoo            | Cacomantis sonneratii            | ●    | ○    | ○    | ○    | ○    |
| 9  | Rusty-breasted Cuckoo        | Cacomantis sepulcralis           | ●    | ○    | ○    | ○    | ○    |
| 10 | Lesser Coucal                | Centropus bengalensis            | ●    | ○    | ○    | ○    | ○    |
| 11 | Cave-Swiftlet                | Collocalia linchi                | ●    | ●    | ●    | ●    | ●    |
| 12 | Little Swift                 | Apus affinis                     | ○    | ○    | ●    | ●    | ●    |
| 13 | Black-nest Swiftlet          | Collocalia maxima                | ○    | ○    | ●    | ●    | ●    |
| 14 | Javan Kingfisher             | Halcyon cyanoventris             | ●    | ○    | ○    | ○    | ○    |
| 15 | Collared Kingfisher          | Todiramphus chloris              | ●    | ●    | ●    | ●    | ●    |
| 16 | Blue-eared Kingfisher        | Alcedo meninting                 | ●    | ○    | ○    | ○    | ○    |
| 17 | Fulvous-breasted Woodpecker  | Dendrocopos macei                | ●    | ●    | ●    | ●    | ●    |
| 18 | Pacific Swallow              | Hirundo tahitica                 | ●    | ●    | ●    | ●    | ●    |
| 19 | Striated Swallow             | Hirundo striolata                | ●    | ●    | ●    | ●    | ●    |
| 20 | Small Minivet                | Pericrocotus cinnamomeus         | ●    | ●    | ○    | ○    | ○    |
| 21 | Common Iora                  | Aegithina tithia                 | ●    | ○    | ○    | ○    | ○    |
| 22 | Sooty-headed Bulbul          | Pycnonotus aurigaster            | ●    | ●    | ●    | ●    | ●    |
| 23 | Yellow-vented Bulbul         | Pycnonotus goiavier              | ●    | ○    | ○    | ○    | ○    |
| 24 | Long-tailed Shrike           | Lanius schach                    | ●    | ○    | ○    | ○    | ○    |
| 25 | White-breasted Wood-swallow  | Artamus leucorynchus             | ●    | ○    | ○    | ○    | ○    |
| 26 | Black-capped Babbler         | Pellorneum capistratum           | ●    | ○    | ○    | ○    | ○    |
| 27 | Horsfield’s Babbler          | Malacocincla sepiarium           | ●    | ○    | ○    | ○    | ○    |
| 28 | Olive-backed Tailorbird      | Orthotomus sepium                | ●    | ●    | ●    | ●    | ●    |
| 29 | Common Tailorbird            | Orthotomus sutorius              | ●    | ●    | ●    | ●    | ●    |
| 30 | Bar-winged Prinia            | Prinia familiaris                | ○    | ○    | ○    | ○    | ○    |
| 31 | Golden-bellied Gerygone      | Gerygone sulphurea               | ●    | ●    | ○    | ○    | ○    |
| 32 | Scarlet-headed Flowerpecker  | Dicaeum trochileum               | ●    | ●    | ●    | ●    | ●    |
| 33 | Olive-backed Sunbird         | Nectarinia jugularis             | ●    | ●    | ●    | ●    | ●    |
| 34 | Oriental White-eye           | Zosterops palpebrosus            | ●    | ●    | ○    | ○    | ○    |
| 35 | White-headed Munia           | Lonchura maja                    | ○    | ○    | ○    | ○    | ○    |
| 36 | Javan Munia                  | Lonchura leucogastroides         | ●    | ●    | ●    | ●    | ●    |
| 37 | Scaly-breasted Munia         | Lonchura punctulata              | ●    | ●    | ●    | ●    | ●    |
| 38 | Eurasian Tree Sparrow        | Passer montanus                  | ●    | ●    | ●    | ●    | ●    |

Number of species: 33 19 19 17 15