Bird community changes across gradient of habitat quality in the urban green open space

A Mardiastuti\textsuperscript{1,2}
\textsuperscript{1} Department of Forest Resources Conservation and Ecotourism
Faculty of Forestry, Bogor Agricultural University (IPB University)
Darmaga Campus, Bogor, West Java, Indonesia
\textsuperscript{2} e-mail: aniipb@indo.net.id; ani_mardiastuti@ipb.ac.id

Abstract. Bird species can be found in almost all habitat types, including urban area. The objective of this research was to investigate the changes in bird community in different habitat quality gradients of urban green open spaces and provide suggestions for indicator species. Five urban green open spaces were selected as study sites, representing gradient from low to high habitat quality: Gunung Gadung cemetery (21 bird sp.), Sentul City (34 sp.), Bogor Botanical Garden (48 sp.), Darmaga Campus (52 sp.), and Darmaga Experimental Forest (35 sp.). Species richness and Jaccard similarity indices were analyzed to discover the pattern reflecting the quality of urban habitat. Bird community in all study sites had low to medium similarity (0.33-0.51), indicating that each site had a distinct bird community. Bird richness was highest in the mid-quality habitat (garden-tree mix), but decreased in the high quality (urban mature forest). Bird that can be used for habitat indicators were babbler (low-medium quality); bulbul, pigeon, flycatchers (medium-quality); pied triller and cuckoo (medium-high quality), and barbet and nuthatch (high quality). Similar research needs to be conducted in other urban areas to reconfirm this pattern, in order to use bird community as an indicator of urban habitat quality.

1. Introduction
Urban area has the most heterogeneous landscapes, creating a mosaic of patches of land use types of various sizes [1, 2]. The land use types can be related to habitat quality for various urban wildlife species, and in turn, can also reflected the quality of environment for human life. Among the urban wildlife species, birds are important because many species of birds are still able to live in urban areas.

In general, a good quality of green open space in an urban area will harbour many bird species [3]. In addition, a good quality of urban green open space also will create a good environment for people who live nearby. The quality of urban green open space and its changes (toward better or worse quality) is important to monitor, for human’s life sake. To detect and monitor the quality of green open space, a simple and relatively fast technique is needed.
Using birds to determine and monitor the quality of green open space is a good option, as birds have been known to respond to habitat changes [4]. In the urban areas where buildings and human activities are intense, bird species is limited, although the number of individuals could be numerous [5].

To understand how bird community responds to different gradient of habitat quality, a comparative study on various habitat types in urban areas was conducted. The objective of this research was to investigate the changes in bird communities in different habitat quality gradients of urban green open spaces and provide suggestions for indicator species. The results can be used to provide management recommendations for similar urban areas in Indonesia.

2. Methods
Five urban green open spaces were selected as study sites, representing different gradients, from low to high habitat quality, i.e Gunung Gadung cemetery complex, Sentul City residential area, Bogor Botanical Garden, Darmaga Campus, and Darmaga Experimental Forest, which are all located in Bogor (West Java, Indonesia), at an elevation of c. 300 m asl. These sites were considered as representing gradients of habitat quality in urban areas, namely open shrubs, ornamental patches, garden-tree mix, tree plantation remnants, and mature urban forest, respectively. The environmental and ecological parameters characterizing the five sites are canopy quality, tree domination, tree story, natural planting, and the wildness of trees/plants. Gunung Gadung cemetery complex represented the lowest environmental-ecological quality, while Darmaga Experimental Forest represented the highest (Figure 1). Size of the sites varies, but still within the range of 35 ha to 60 ha to produce a valid comparison.

Gunung Gadung cemetery complex is the largest public cemetery of 36 ha in the southern Bogor. The cemetery is dominated by Chinese tombs, consisted of open space mixed with several tree species, for example frangipani (*Plumeria* sp.), candle nut (*Aleurites moluccana*), pine (*Pinus merkusii*), umbrella-tree (*Maesopsis eminii*), leucaena (*Leucaena leucocephala*), and mahogany (*Swietenia macrophylla*).

Sentul City residential area is located in the north periphery of Bogor. The whole complex occupied an area of around 2,400 ha, consists of 13 housing complexes, which covers most area, and other facilities including hotels, offices, convention centre, apartment, market, malls, hospital, amusement park, mosques and churches, house-shop complex, schools, bus terminal, and 18-holes golf course. The whole area basically is a landscape of mosaic small patches (size 0.1-0.5 ha) suitable for birds, planted with many ornamental trees such as rain tree (*Samanea saman*), African tulip tree (*Spathodea campanulata*), bottlebrush (*Callistemon sp.*), Madagascar almond (*Terminalia mantaly*), and frangipani (*Plumeria* sp.). The site selected for this study covered only 6 housing complexes.

Bogor Botanical Garden occupies 86 ha, located in the heart of the city of Bogor. It has a massive collection of plants of both native and introduced ones. Inside the Botanical Garden there are streams, a river, i.e Ciliwung River, small lakes, gardens, forest-like tree stands, and lawns. To the north, there is a presidential palace with a big lawn for several hundreds of axis deer (*Axis axis*).

The Bogor Agricultural University campus at Darmaga of 260 ha; hereafter referred to Darmaga Campus, is a mixture of academic buildings, remnants of a rubber plantation, and patches of some forest stands, occupied by pines, and mixed trees in an arborets. The campus area is located in the west of Bogor, surrounded by dense settlements in the east, and two rivers, i.e Ciapus and Cisadane River in the north.

Darmaga Experimental Forest (60 ha) is managed by the Forestry Research, Development and Innovation Agency (FORDIA), Ministry of Environment and Forestry. Located close to Damaga Campus, it basically has a collection of mature tree species from genera *Pinus, Khaya, Terminalia, Agathis, Shorea, Eugenia*, and *Hopea*, creating a dense multi-story forest in most of the area. There are some buildings within the forest i.e. Center for International Forestry Research (CIFOR).
surrounding area are mostly housings and rice fields. There is Cihideung river in the north, and a small lake in the south.

| Sites                  | Habitat Type                      |
|------------------------|-----------------------------------|
| Darmaga Campus         | Tree plantation remnant           |
| Gunung Gadung cemetery | Open shrub                        |

**Figure 1.** Habitat characteristics related to environmental quality for five sites selected for this study

Data of bird species in each site were taken from previous studies, i.e [6] for Gunung Gadung cemetery complex, [7] for Sentul City residential area, [8] for Bogor Botanical Garden, [9] for Darmaga Campus, and [10] for Darmaga Experimental Forest). Parameter used for this study were species richness and analysis of Jaccard similarity indices [11].

Among the bird species found in a specific habitat type, certain species were selected as potential indicators for each of those habitats. The selection was based on a cross reference with previous research on the birds commonly found in urban area of Bogor and the surrounding area (i.e. Greater Jakarta Area) [12].

3. Results

3.1. Species richness and similarity indices

The total number of birds found in all five sites were 80 species (Appendix A). The species richness along the environmental quality gradients increased toward the medium-high quality, but then decreased in the mature urban forest (table 1). The medium-high environment/habitat quality in Darmaga Campus apparently was more appropriate as bird habitat compared to the mature urban forest of Darmaga Experimental Forest.

Similarity indices between the nearest habitat types were relatively low, indicating that each habitat type actually had a relatively distinct bird community. The garden-tree mix habitat type of Bogor Botanical Garden had the most dissimilar bird species composition, as shown by the lowest similarity indices to its closest habitat types i.e. ornamental patches and tree plantation remnants.
Table 1. Bird species richness and similarity indices between the nearest two habitat types.

| Habitat Types                  | Quality | Sites                    | Species Richness | Similarity Index* |
|--------------------------------|---------|--------------------------|------------------|-------------------|
| Open shrub                     | Low     | Gunung Gadung            | 21               | 0.51              |
| Ornamental patches             | Low-medium | Sentul City            | 34               | 0.33              |
| Garden-tree mix                | Medium  | Botanical Garden        | 48               | 0.41              |
| Tree plantation remnants       | Medium-high | Darmaga Campus         | 52               |                   |
| Mature urban forest            | High    | Experimental Forest     | 35               | 0.47              |

*between the nearest habitat types

3.2. Bird species characterized each habitat type

Some bird species inhabited a specific habitat type, and not others (table 2). Open shrub did not have any specific birds. Garden-tree mix, i.e. Bogor Botanical Garden and tree plantation remnants, i.e. Darmaga Campus have several species unique to each habitat type. In the garden-tree mix, some pigeon species were found, indicating that the tree canopy were high and dense. There was also an interesting finding in the garden-tree mixed, namely the existence of some birds that originally are not from Bogor area, e.g Eclectus Parrot, Yellow-crested Cockatoo, and Yellow-throated Hanging Parrot. These birds most likely were feral species of unwanted pets, as most of them originally distributed in the eastern part of Indonesia.

In the tree plantation remnants i.e. Darmaga Campus, specific species inhabit here were a mixture of shrub-specialist and semi-open inhabitants. Meanwhile, in the urban mature forest, many bird species that preferred old growth trees, such as barbets and nuthatch could be found.

As habitat types can be used to indicate environmental quality in the urban area, these habitat-specific birds could be selected as indicators of environment quality for further management, except for the open shrub that did not have any specific species. Bird species that can be used as indicator for a specific habitat type, thus also representing the habitat quality, are shown in bold (see Table 2).

3.3. Generalist species

In contrast to the species that can be found in a specific habitat type, there were some bird species that were able to utilize a wide range of habitat types, usually called generalists. In the five study sites, there were 11 generalist species. These species have been adapted in all habitat due to various reasons (table 3).

The generalist species relied on their adaptation ability to live near human settlements and feed on grains and nectars of plants. Generalists are important for the quality of urban green open space, but due to the ecological nature as generalist, these species cannot be used as an indicator of habitat quality.
Table 2. Bird species found only in a specific habitat type; species written in bold can be used as indicators for each habitat type.

| Habitat Types            | Quality   | Species                                                                 |
|--------------------------|-----------|-------------------------------------------------------------------------|
| Open shrub               | Low       | None                                                                    |
| Ornamental patches       | Low-medium| Chestnut-capped Babbler, Large-tailed Nightjar, White-breasted Woodswallow |
| Garden-tree mix          | Medium    | Oriental Honey-buzzard, Asian Red-eyed Bulbul, Grey-cheeked Bulbul, Black-crested Bulbul, Black-headed Bulbul, Grey-cheeked Green-pigeon, Black-naped Fruit-dove, Island Collared-dove, Blue-winged Leafbird, Coppersmith Barbet, Indigo Flycatcher, Hill Blue Flycatcher, Plain Flowerpecker, Eclectus Parrot*, Yellow-crested Cockatoo*, Yellow-throated Hanging Parrot* |
| Tree plantation remnants | Medium-high| Crested Serpent Eagle, Cinnamon Bittern, Asian Horsfield's Babbler, Pied Triller, Brown Flycatcher, Banded Bay Cuckoo, Chestnut-winged Cuckoo, Barred Buttonquail, Savanna Nightjar |
| Mature urban forest      | High      | Black-banded Barbet, Blue-eared Barbet, Orange-bellied Flowerpecker, Orange-headed Thrush, Velvet-fronted Nuthatch |

*feral species, whose natural distribution is not in West Java

Table 3. List of generalist bird species found in all five habitat types

| Adaptation Capability                                                                 | Species                                      |
|---------------------------------------------------------------------------------------|----------------------------------------------|
| Easily adapted to buildings and human presence, able to feed on various food types     | • Sooty-headed Bulbul                        |
|                                                                                       | • Eurasian Tree Sparrow                      |
|                                                                                       | • Spotted Dove                               |
|                                                                                       | • Bar-winged Prinia                          |
| Nectar-eater, able to utilize flowering plants of natural or ornamental species       | o Scarlet-headed Flowerpecker                |
|                                                                                       | o Olive-backed Sunbird                       |
|                                                                                       | o Olive-backed Tailorbird                    |
| Seed eaters; seeds mostly provided by weedy plants near human settlements             | • Javan Munia                                |
|                                                                                       | • Scaly-breasted Munia                       |
|                                                                                       | • Plaintive Cuckoo                           |
| Aerial feeder, capable of long flight above various habitat types                     | o Cave Swiftlet                              |
4. Discussion

Bird species and community compositions in urban areas have been well documented and described in many parts of the world [3]. Urbanization in Europe and in the US has been known to alter bird communities by changing species richness, relative abundance, and composition [13]. Unfortunately, only few researches have been conducted in Indonesia.

The species richness of birds in the study sites in urban area of Bogor reached the highest in the tree plantation remnants, followed by the garden-tree mix. These are habitats that experiencing mid-disturbances, resulting in a mixture of closed and open canopy, with a variety of vertical canopy thickness, from shrub to emergent trees. Surprisingly, the mature urban forest that experiencing minimum disturbances has less species richness than sites with mid-disturbances. This phenomenon has been known as the intermediate disturbance hypotheses (IDH) [14]. In other parts of Indonesia, the IDH was also detected in natural forests, as mentioned by [15].

Species richness, however, is not the only parameter for bird management in an urban area. As shown in this research, every habitat type has its own distinct bird species. Therefore, it is important to create and maintain various habitat types of different degree of disturbances or successional stages in an urban area. Besides the changes in the species number (or species richness), species composition also changes along different habitat quality, as also noted by previous researchers [3].

Based on this study, some management actions to create a good quality environment for human welfare can be formulated as follows: (a) bird community, i.e. no species and species composition can be used as a good indicator for urban green open space; (b) as the maximum species number happened in the mid-disturbance site, the bird habitat can be managed in such a way to create the mid-disturbance situation; (c) although the sites with mid-disturbance can harbor the maximum species number, a non-disturbance mature forest is still needed, especially as habitat for bird species that prefer old growth, closed canopy forest; (d) some bird species can be selected as habitat indicator, as they select a certain green open space type as their habitat; (e) this indicator can be used as a simple and fast technique to assess the quality of green open space in urban area, as well as to evaluate the success or failure of management intervention.

Many factors may contribute to the species richness. This study provides a proxy only, as the influencing factors were assumed to produce the same effect on all study sites. A more intensive study using various parameters need to be conducted in the future to provide answers to more specific questions.

5. Conclusion

Bird that can be used for habitat indicators were babbler (low-medium quality); bulbul, pigeon, flycatchers (medium-quality); pied triller and cuckoo (medium-high quality), and barbet and nuthatch (high quality). Similar research needs to be conducted in other urban areas to reconfirm this pattern, in order to use bird community as an indicator of urban habitat quality.

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## Appendix A. List of bird species found in each habitat type (0 – absent; 1- present).

| Common Name                  | Scientific Name     | Open Shrub | Ornamental Patches | Garden-tree Mix | Tree plantation Remnant | Mature Urban Forest |
|------------------------------|---------------------|------------|-------------------|-----------------|--------------------------|--------------------|
| 1 Black-crowned Night-heron  | *Nycticorax nycticorax* | 0          | 1                 | 1               | 1                        | 0                  |
| 2 Golden-bellied Gerygone    | *Grygone sulphurea*  | 0          | 1                 | 0               | 1                        | 0                  |
| 3 Cinnamon Bittern           | *Ixobrychus cinnamomeus* | 0          | 0                 | 0               | 1                        | 0                  |
| 4 Oriental Honey-buzzard     | *Pernis ptilorhynchus* | 0          | 0                 | 1               | 0                        | 0                  |
| 5 Crested Serpent Eagle      | *Spilornis cheela*   | 0          | 0                 | 0               | 1                        | 0                  |
| 6 White-breasted Waterhen    | *Amaurornis phoenicurus* | 0          | 1                 | 1               | 1                        | 1                  |
| 7 Barred Buttonquail         | *Turnix suscitator*  | 0          | 0                 | 0               | 1                        | 0                  |
| 8 Grey-cheeked Green-pigeon  | *Treron griseicauda* | 0          | 1                 | 1               | 0                        | 0                  |
| 9 Pink-necked Green-pigeon   | *Treron vernans*     | 0          | 0                 | 1               | 1                        | 0                  |
| 10 Black-naped Fruit-dove    | *Ptilinopus melanospila* | 0          | 1                 | 0               | 0                        | 0                  |
| 11 Island Collared-dove      | *Streptopelia bitorquata* | 0          | 0                 | 1               | 0                        | 0                  |
| 12 Spotted Dove              | *Streptopelia chinensis* | 1          | 1                 | 1               | 1                        | 1                  |
| 13 Zebra Dove                | *Geopelia striata*   | 1          | 1                 | 0               | 0                        | 0                  |
| 14 Red-breasted Parakeet     | *Psittacula alexandri* | 0          | 0                 | 1               | 0                        | 0                  |
| 15 Yellow-crested Cockatoo*  | *Cacatua sulphurea*  | 0          | 0                 | 1               | 0                        | 0                  |
| 16 Yellow-throated Hanging Parrot* | *Loriculus pusillus* | 0          | 0                 | 1               | 0                        | 0                  |
| 17 Eclectus Parrot*          | *Ecclectus roratus*  | 0          | 0                 | 1               | 0                        | 0                  |
| 18 Chestnut-winged Cuckoo    | *Clamator coromandus* | 0          | 0                 | 0               | 0                        | 0                  |
| 19 Banded Bay Cuckoo         | *Cacomantis sonnerati* | 0          | 0                 | 0               | 0                        | 0                  |
| 20 Plaintive Cuckoo          | *Cacomantis merulinus* | 1          | 1                 | 1               | 1                        | 1                  |
| 21 Rusty-breasted Cuckoo     | *Cacomantis sepulcralis* | 0          | 0                 | 0               | 1                        | 1                  |
| 22 Asian Drongo-Cuckoo       | *Surniculus lugubris* | 0          | 0                 | 0               | 0                        | 0                  |
| 23 Lesser Coucal             | *Centropus bengalensis* | 1          | 1                 | 0               | 0                        | 0                  |
| 24 Collared Scopsowl         | *Otus lempiji*       | 0          | 1                 | 1               | 0                        | 0                  |
| 25 Large-tailed Nightjar     | *Caprimulgus macrurus* | 0          | 1                 | 0               | 0                        | 0                  |
| 26 Savanna Nightjar          | *Caprimulgus affinis* | 0          | 0                 | 0               | 0                        | 0                  |
| 27 Edible-nest Swiftlet      | *Collocalia fuciphagus* | 0          | 0                 | 1               | 0                        | 0                  |
| 28 Black-nest Swiftlet       | *Collocalia maximus*  | 0          | 1                 | 0               | 1                        | 0                  |
| 29 Cave Swiftlet             | *Collocalia linchi*  | 1          | 1                 | 1               | 1                        | 1                  |
| 30 House Swift               | *Apus nipalensis*    | 1          | 1                 | 0               | 0                        | 0                  |
| 31 Asian Palm Swift          | *Cypsiurus balasiensis* | 0          | 0                 | 1               | 0                        | 0                  |
| 32 Blue-eared Kingfisher     | *Alcedo meninting*   | 0          | 1                 | 1               | 0                        | 0                  |
| 33 Javan Kingfisher          | *Halcenc cyanonterris* | 1          | 1                 | 0               | 0                        | 0                  |
| 34 Collared Kingfisher       | *Halcen cyanonterris* | 1          | 1                 | 0               | 0                        | 0                  |
| 35 Black-banded Barbet       | *Megalaima javensis* | 0          | 0                 | 0               | 0                        | 0                  |
| 36 Blue-eared Barbet         | *Megalaima australis* | 0          | 0                 | 0               | 0                        | 0                  |
| 37 Coppersmith Barbet        | *Megalaima haemacephala* | 0          | 0                 | 1               | 0                        | 0                  |
| 38 Fulvous-breasted Woodpecker | *Dendrocolpus maecl*  | 1          | 1                 | 1               | 0                        | 0                  |
| 39 Sunda Pygmy Woodpecker    | *Dendrocolpus maecl*  | 1          | 0                 | 1               | 1                        | 0                  |
| 40 Pacific Swallow           | *Hirundo tahitica*   | 0          | 1                 | 0               | 1                        | 0                  |
| 41 Striated Swallow          | *Hirundo striolata*  | 1          | 0                 | 1               | 0                        | 0                  |
| 42 Black-winged Flycatcher-Shrike | *Hemicus hirundinaceus* | 0          | 0                 | 0               | 0                        | 0                  |
| 43 Pied Triller              | *Lalage nigra*       | 0          | 0                 | 0               | 1                        | 0                  |
|   | Species                              | Scientific Name                  | Open shrub | Ornamental patches | Garden-tree mix | Tree plantation remnants | Mature urban forest |
|---|--------------------------------------|----------------------------------|------------|-------------------|------------------|--------------------------|-------------------|
| 44| Small Minivet                        | *Pericrocotus cinnamomeus*       | 0          | 1                 | 0                | 1                        |                   |
| 45| Common Iora                          | *Aegithina tiphia*               | 0          | 1                 | 1                | 1                        |                   |
| 46| Blue-winged Leafbird                 | *Chloropsis cochinchinensis*     | 0          | 0                 | 1                | 0                        |                   |
| 47| Black-headed Bulbul                   | *Pycnonotus atriceps*           | 0          | 0                 | 1                | 0                        |                   |
| 48| Black-crested Bulbul                  | *Pycnonotus melaniceps*         | 0          | 0                 | 1                | 0                        |                   |
| 49| Sooty-headed Bulbul                   | *Pycnonotus aurigaster*         | 1          | 1                 | 1                | 1                        |                   |
| 50| Yellow-vented Bulbul                  | *Pycnonotus goiavier*           | 1          | 1                 | 0                | 0                        |                   |
| 51| Asian Red-eyed Bulbul                 | *Pycnonotus brunneus*           | 0          | 0                 | 1                | 0                        |                   |
| 52| Grey-cheeked Bulbul                    | *Criniger bres*                 | 0          | 0                 | 1                | 0                        |                   |
| 53| Black Drongo                          | *Dicrurus macrocercus*          | 0          | 0                 | 1                | 0                        |                   |
| 54| Ashy Drongo                           | *Dicrurus leucophaeus*          | 0          | 0                 | 1                | 0                        |                   |
| 55| Black-naped Oriole                    | *Oriolus chinensis*             | 0          | 0                 | 1                | 0                        |                   |
| 56| Velvet-fronted Nuthatch               | *Sitta frontalis*               | 0          | 0                 | 0                | 0                        |                   |
| 57| Black-capped Babbler                  | *Pellorneum capistratum*        | 1          | 0                 | 0                | 1                        |                   |
| 58| Horsfield's Babbler                   | *Malacocincla sepiarium*        | 0          | 0                 | 0                | 1                        |                   |
| 59| Chestnut-capped Babbler               | *Timalia pileata*               | 0          | 1                 | 0                | 0                        |                   |
| 60| Orange-headed Thrush                   | *Zoothera citrina*              | 0          | 0                 | 0                | 0                        |                   |
| 61| Common Tailorbird                     | *Orthotomus sutorius*           | 0          | 1                 | 1                | 1                        |                   |
| 62| Olive-backed Tailorbird               | *Orthotomus sepium*             | 1          | 1                 | 1                | 1                        |                   |
| 63| Bar-winged Prinia                     | *Prinia familiaris*             | 1          | 1                 | 1                | 1                        |                   |
| 64| Asian Brown Flycatcher                | *Muscicapa daurica*             | 0          | 0                 | 0                | 0                        |                   |
| 65| Indigo Flycatcher                     | *Eumyias indigo*                | 0          | 0                 | 1                | 0                        |                   |
| 66| Hill Blue Flycatcher                  | *Cynoris banyumas*              | 0          | 0                 | 1                | 0                        |                   |
| 67| Pied Fantail                          | *Rhipidura javanica*            | 0          | 0                 | 1                | 1                        |                   |
| 68| White-breasted Woodswallow            | *Artamus leucorynchus*          | 0          | 1                 | 0                | 1                        |                   |
| 69| Long-tailed Shrike                    | *Lanius schach*                 | 0          | 1                 | 1                | 0                        |                   |
| 70| Plain-throated Sunbird                | *Anthreptes malacensis*         | 0          | 0                 | 1                | 0                        |                   |
| 71| Olive-backed Sunbird                  | *Cinnyris jugularis*            | 1          | 1                 | 1                | 1                        |                   |
| 72| Little Spiderhunter                   | *Arachnothera longirostra*      | 0          | 0                 | 1                | 0                        |                   |
| 73| Orange-bellied Flowerpecker           | *Dicaeum trigonostigma*         | 0          | 0                 | 0                | 0                        |                   |
| 74| Plain Flowerpecker                    | *Dicaeum concolor*              | 0          | 0                 | 1                | 0                        |                   |
| 75| Scarlet-headed Flowerpecker           | *Dicaeum trochileum*            | 1          | 1                 | 1                | 1                        |                   |
| 76| Oriental White-eye                    | *Zosterops palpebrinus*         | 0          | 1                 | 1                | 1                        |                   |
| 77| Eurasian Tree Sparrow                 | *Passer montanus*               | 1          | 1                 | 1                | 1                        |                   |
| 78| Javan Munia                           | *Lonchura leucogasteroides*     | 1          | 1                 | 1                | 1                        |                   |
| 79| Scaly-breasted Munia                  | *Lonchura punctulata*           | 1          | 1                 | 1                | 1                        |                   |
| 80| White-headed Munia                    | *Lonchura maja*                 | 0          | 1                 | 0                | 1                        |                   |

Total number of species: 21 34 48 52 35

*feral species of unwanted released/escaped pets*

**Notes:**
- Open shrub: low quality (Gunung Gadung cemetery complex)
- Ornamental patches: low to medium quality (Sentul City residential area)
- Garden-tree mix: medium quality (Bogor Botanical Garden)
- Tree plantation remnants: medium to high quality (Darmaga Campus)
- Mature urban forest: high quality (Darmaga Experimental Forest)