Chiroptera population as bioindicators of urbanization and fragmented habitat in West Java

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Abstract. One of the threats to the natural ecosystem is urbanization. The deforestation and development of settlements have caused fragmented natural habitat, vegetation cover reduction, and decline of biodiversity. In urban, one of the mammalian groups that can adapt to the presence of settlement is the Chiroptera group or commonly known as bats. One of the areas that have experienced rapid urbanization was located in West Java. Considering this condition, this study aims to study the impact of urbanization and the potential use of Chiroptera as an urbanization bioindicator. The method used was line transect across the landscape mosaic located in 2 urbanized areas in West Java, i.e., Bekasi and Depok. There was 3 line transects in each area. Three locations were selected from each transect and sampled with 3 replications. The density of Chiroptera and the percentage of vegetation covers were observed along transects. In total, there were 18 observations. The study confirms the presence of fragmented landscape with vegetation cover mean ranged from 39.8%/100 m² (95% CI: 20.4% to 59.2%), to 65.3%/100 m² (95% CI: 52.5% to 78.1%). While the density of Chiroptera mean ranges were 2.18 inds./100 m² (95% CI: 1.44 to 2.92)-2.85 inds./100 m² (95% CI: 0.98 to 4.72). There was a significant positive correlation (p = 0.004, r² = 0.630) between vegetation cover and Chiroptera abundance. Based on the correlation, the less fragmented landscape was indicated by high Chiroptera abundance.

1. Introduction
Chiroptera is a mammalian group commonly known as bats. The Chiroptera group consists of more than 1300 species, and this number covers almost 25% of the Mammalia class[1]. While in Indonesia, there are approximately 215 bats species[2]. Chiroptera has a wide variety of feeding guilds, including frugivores, pollinivores/nectarivores, carnivores, omnivores, insectivores, piscivores, and hematophages[3]. This great foraging diversity enables Chiroptera to have various many ecological roles including seed dispersal and natural insect control. Hence, Chiroptera population is very important for ecosystems[4].

Chiroptera is also known as valuable bioindicators of ecosystem health and habitat quality. This is related to the Chiroptera’s responses to a range of environmental alterations, including deforestation, urbanization, and fragmented habitats[5]. Environmental alteration is a driving force of biodiversity loss in terrestrial ecosystems, including Chiroptera biodiversity. For several decades, human-induced environmental transformation in the form of urbanization has accelerated the habitat fragmentation and biodiversity loss of Chiroptera. This situation is significant, especially in tropical landscapes[6].
To date, the impacts of these urbanizations upon Chiroptera populations have been reported by a large body of literature. There are extensive reports of apparent impacts of urbanization on Chiroptera communities in altered ecosystems, including urbanization impacts on the decline of Chiroptera species richness and abundance in fragmented areas [7, 8, 9]. While the reports on how the Chiroptera respond and can indicate the urbanization and habitat fragmentation especially in South East Asia are still limited. Considering that the natural landscape and wildlife habitat in West Java, Indonesia have experienced urbanization and habitat fragmentation, while in other hands, Chiroptera are very important in natural environments. Therefore the aims of this study are to estimate the magnitude of habitat fragmentation in the form of vegetation covers, Chiroptera abundances, and to develop a correlation between habitat fragmentation and Chiroptera abundance in the urbanized ecosystem in West Java. By knowing the correlations between vegetation cover and Chiroptera abundance, hence the Chiroptera can be used as bioindicators of habitat fragmentation in urban ecosystems.

2. Methods

2.1. Study areas
The study areas were located in 2 urbanized areas in West Java, Indonesia, i.e. Bekasi and Depok (Figure 1). In each urban area, 3 transects were located. Each transect was divided into 3 sampling locations. There were 9 sampling locations to conduct the observations (1-9) in each urban area. In total 18 observations in 2 study areas were conducted in July 2020.

![Figure 1](image-url). Map of sampling locations in urban Bekasi (left: B1-B9) and Depok (right: D1-D9) in West Java, Indonesia (aerial photo courtesy of Google Earth).

2.2. Chiroptera observations
Chiroptera abundance observations were conducted following methods as described by several authors [10, 11, 12, 13]. The observations were conducted at noon from 17.00 to 19.00 following Chiroptera activity times within 10 m x 10 m grid in each sampling location (Figure 1). Chiroptera abundances were recorded and denoted as individuals/100 m².
2.3. Fragmentation analysis
The fragmentation analysis was based on the measurement of vegetation and tree canopy covers [14, 15]. In each sampling location along the transect, the area of the tree canopy was measured within 10 m x 10 m grid. The cover was denoted as the ratio of tree canopy area to 100 m² grid multiplied by 100% to convert it to the percentage of covers. The vegetation canopy cover is indicated as %/100 m².

2.4. Data and statistical analyses
The descriptive statistics of vegetation cover and Chiroptera abundance data in Bekasi and Depok were presented as mean and 95% CI (Confidence Interval). The trends of vegetation cover and Chiroptera abundance data in Bekasi and Depok were analyzed using Pearson correlation with vegetation cover as an independent variable and Chiroptera abundance as a dependent variable. The correlation is significant at p < 0.05.

3. Results and discussion

3.1. Vegetation canopy cover
Table 1 reports the vegetation cover both in Bekasi and Depok areas. The covers in both areas were not closed to 100% and this condition indicates that the intact previous vegetation has been fragmented. The intact trees have been deforested and replaced by the development of settlements. The vegetation cover mean in Bekasi was 65.27%/100 m² (95% CI: 52.5% to 78.1%) and in Depok was 39.77%/100 m² (95% CI: 20.4% to 59.2%). Percentages of vegetation covers affected by fragmentations due to urbanization have been reported worldwide [16, 17]. The vegetation covers in urban cities in the United States were reported to range from 3% to 86% [18]. In urban cities in Asia like Bangkok, Thailand, the tree covers were estimated at 8.6%, with approximately 27 trees/ha [19]. Tree covers were related to the urban development where the developed sites generally had lower tree covers, and urbanization events lead to the rapid tree cover loss [20]. Urbanization and other driving forces, including historic development patterns and age of development, also are likely to influence urban vegetation, and tree canopy covers [21].

Table 1. Mean and CI (95%) of vegetation cover (%/100 m²) and Chiroptera abundance (inds./100 m²) in sampling locations in urban Bekasi and Depok in West Java, Indonesia

| Factors             | Sampling locations | Mean  | 95%CI     |
|---------------------|--------------------|-------|-----------|
|                     |                    | Lower | Upper     |
| Vegetation cover    | Bekasi (n=9)       | 65.27 | 52.5      |
| (%/100 m²)          | Depok (n=9)        | 39.77 | 20.4      |
| Chiroptera abundance| Bekasi (n=9)       | 2.18  | 1.44      |
| (inds./100 m²)      | Depok (n=9)        | 2.85  | 0.31      |
|                     |                    |       | 2.92      |

3.2. Chiroptera abundance
Figure 2 shows the Chiroptera abundance mean in Bekasi and Depok urban areas. The solid line indicates the change of abundance over sampling locations. The shaded area illustrates the abundance with 95% confidence intervals. The figure clearly shows a variation of Chiroptera abundance, as can be seen both in Bekasi and Depok. Those variations were related to the vegetation canopy covers in each sampling location.
Figure 2. Mean and 95% CI lower and upper bands (shaded areas) of Chiroptera abundance (inds./100 m$^2$) in sampling locations in urban Bekasi (left: B1-B9) and Depok (right: D1-D9) in West Java, Indonesia.

The Vertical (y) axis is Chiroptera abundance (inds./100 m$^2$), and the horizontal (x) axis is sampling locations. The data shows a trend of Chiroptera abundance follows the canopy cover, as can be seen in Figure 3. In Bekasi, the canopy covers were observed high in locations B1, B2, B3, B6, B7, and B8. In locations B4, B5, and B9, the tree covers were declining. The Chiroptera abundances were observed following that canopy trends. As can be seen, the Chiroptera abundance was high in B2, B3, B4, B6, B7, and B8 sampling locations while low in B1, B5, and B9. The sampling locations B2 and B3 were closed to the parks and have preserved vegetation, including trees (Figure 1). While the sampling locations B7 and B8 were along a river that has vegetation along the banks. In contrast, the B5 and B9 locations were located near the settlements where most landscapes were dominated by the settlements, and the hardwood vegetation has been replaced by houses and settlement amenities.

Figure 3. Trends of vegetation canopy cover (%/100 m$^2$) (left y axis) and Chiroptera abundance (inds./100 m$^2$) (right y axis) in sampling locations in urban Bekasi (left: B1-B9) and Depok (right: D1-D9) in West Java, Indonesia.

The same pattern was also observed in the Depok urban areas. The vegetation canopy covers were only high in particular locations and low in certain locations. As observed, the Chiroptera abundances in Depok were observed following the canopy tree patterns. The highest tree covers and Chiroptera abundances in Depok were observed in locations D1, D2, and D3. Those locations were located near the Ciliwung river. This river is a big river that has a width equal to 14 m. Correspondingly, this river also has a wide catchment area. Those areas were inhabited by various vegetation, including trees. The
presence of a tree community along river banks has provided habitats for various animals, including Chiroptera. While the other locations were located in the middle of settlements (Figure 1). In these areas and compared to the Bekasi urban areas, the settlements have a low number of trees. This situation has caused the tree covers, and Chiroptera abundances were low.

The results and trends of Chiroptera in this study were comparable to other results. Similar to findings in this study, other studies [22, 23] have reported that the vegetation remnants in urban areas can provide habitats for Chiroptera, and their abundance in these remnants was observed high. It was reported that the Chiroptera abundance was high in urban forest and settlements that have vegetation in their yards. While the Chiroptera abundances were low in bushes and built-up area dominated landscapes. In this study, those landscapes were comparable to some locations in Bekasi and in Depok.

3.3. Chiroptera responses to fragmentation
The Chiroptera abundances that follow the vegetation covers indicate Chiroptera responses and correlations to fragmentations. The statistical tests show a significant positive correlation (p = 0.004, r = 0.630) between vegetation cover and Chiroptera abundance (Figure 4). The Chiroptera assemblages that have been reported can be used to indicate the percentage of vegetation covers. Those assemblages include species richness and abundance. In Mexico, for example, the Chiroptera abundance was positively correlated with the covers [11]. This finding has proven the hypothesis that if urbanization and fragmentation increase, the Chiroptera abundance will decrease. Since the correlation was significant, then the Chiroptera abundance can be used to provide insight regarding the ongoing urbanization and fragmentation. In fact, Chiroptera has been used as a bioindicator ranging from heavy metal contents [12] to ecosystem health. In Brazil, the Chiroptera presence has been considered good indicators for habitat disturbance [13].

![Figure 4](image)

**Figure 4.** Correlation of vegetation cover (%/100 m$^2$) and Chiroptera abundance (inds./100 m$^2$) in sampling locations in urban Bekasi and Depok in West Java, Indonesia

4. Conclusions
The study confirms fragmentation in the designated urban landscape with measured vegetation covers were less than 100%/100 m$^2$. The Chiroptera abundances were observed following the vegetation cover trends. The statistical test shows a significant positive correlation between vegetation cover and Chiroptera abundance. To conclude, the fragmented urban landscape was indicated by low Chiroptera abundance. Respectively, the Chiroptera abundance can be used as an urbanization and fragmentation bioindicator in the urban landscape.

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References
[1] Fenton M B 1992 Biol. J. Linn. Soc. 47 161
[2] Nurfitrianto H, Budijastuti W and Faizah U 2013 LenteraBio 2 143
[3] Norberg U M and Rayner J M V 1987 Philos. Trans. R. Soc. Lon. 316 335
[4] Reis N R, Fregonezi M N, Peracchi A L and Shibatta A O 2013 Morcegos do Brasil: Guia de Campo Technical Books p 252.
[5] Jones G, Jacobs D S and Kunz T H 2009 Endanger Spec. Res. 8 93
[6] Lee T M, Jetz W 2008 Proc. R. Soc. B 275 1261
[7] Cosson J F, Pons J M and Masson D 1999 J. Trop. Ecol. 15 515
[8] Medellin R A, Equihua M and Amin M A 2000 Conserv. Biol. 14 1666
[9] Muylaert R L, Stevens R D and Ribeiro M C 2016 Ecol. Appl. 26 1854
[10] Krebs C J 2017. Estimating abundance: line transects and distance methods.
[11] García-Morales R, Moreno C E, Badano E I, Zuria I, Galindo-González J and Rojas-Martínez A E 2016 PLoS ONE 11 12
[12] Zukal J, Pikula J and Bandouchova H 2015 Mamm. Biol. 80 3 220
[13] Oliveira H F M, Camargo N F, Gager Y, Aguiar L MS . 2017 Trop. Conserv. Sci. 10
[14] Schulz B K, Bechtold W A and Zarnoch S J 2009 Sampling and Estimation Procedures for the Vegetation Diversity and Structure Indicator
[15] Korhonen L, Korhonen K,  Rautiainen M and Stenberg P 2006 Silva Fenn. 40 577
[16] Jim C Y 1989 Geoforum 20 1 57
[17] Nowak D J, Rowntree R A, McPherson E G, Sisinni S M, Kerkmann E R, Stevens J C 1996 Landsc. Urban Plan. 36 1
[18] Schwarz K, Fragkias M, Boone CG, Zhou W, McHale M, Grove JM 2015 PLoS ONE 10 4
[19] Montri I, Hauer RJ, Werner LP, Larsen E 2016 J. Sustain. For.
[20] Berland A 2012 Urban Ecosyst. 15 3
[21] Heynen N and Lindsey G 2003. Public Work. Manag. Policy 8 33
[22] Mustari A H, Zulkarnain and Rinaldi D 2014 Media Konservasi 19 117
[23] Trecyana L, Dewantara I and Erianto 2019 Jurnal Hutan Lestari 7 198