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Avian Communities in Forest Patches of Mount Halimun-Salak National Park, Bogor

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Abstract

Habitat fragmentation due to human activities has affected the existence of bird communities in conservation areas, including the Gunung Halimun-Salak National Park (TNGHS). This study aims to evaluate the structure of bird communities in three main forest patches (Purasari, Garehong, and Kendeng) as well as one fragmented open area in the TNGHS area. Data collection was carried out between March and September 2023 using the Index Point Abundance (IPA) method, and the data was analyzed with indices of diversity, dominance, and community similarity. A total of 81 species of birds with 1,531 individuals were successfully recorded. The Kendeng forest patch shows the highest level of diversity (H' = 3.23; R = 8.98), while open areas recorded the lowest values (H' = 2.67; R = 5.97). The dominant species include Pycnonotus aurigaster, Orthotomus sutorius, Collocalia linchi, and Lonchura leucogastroides. The Kruskal-Wallis analysis showed that there was no significant difference in the number of species between sites (P > 0.05). The highest similarity index was found between Kendeng and Garehong (69.42%). The results of this study confirm the importance of protecting forest patches in maintaining bird diversity and highlight the real threat of habitat fragmentation to avifauna communities.

Keywords: *Avian Ecology, Similarity Index, Forest Patches, Mount Halimun-Salak National Park.*

Introduction

In the field of ecology, birds play a crucial role in everyday human life. They serve as indicators of environmental quality within ecosystems and act as natural controllers of insects, some of which are classified as pests. Additionally, birds indirectly contribute to the dispersal of seeds from forest plants in the wild. Birds are also recognized as pollinators for certain flowering plant species. Furthermore, they hold unique appeal for tourists as objects of birdwatching activities, although this practice is not yet widely popularized in Indonesia. [1].

One of the remaining montane rainforest ecosystems in West Java Province, home to a diverse array of bird species, is the Mount Halimun-Salak National Park (MHSNP) in Bogor and Sukabumi. The forested area of MHSNP Bogor has been recorded as a habitat for 97 forest bird species, occupying strata ranging from the forest floor to the tree canopy. Among these are 23 migratory species and 32 restricted-range species (Prawiradilaga, Marakarmah & Wijamukti, 2003). However, the presence of such bird species in MHSNP Bogor is highly vulnerable to habitat changes. This is evident in the declining bird community diversity observed in parts of

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the lower montane and submontane regions of Mount Halimun-Salak National Park, where 54 species were recorded in 2017 [2]. Additionally, [3] inventoried 49 bird species in the Malasari Halimun Ecotourism Area.

The diversity of bird fauna in MHSNP, spanning the Bogor and Sukabumi regions, has shown a decline over the past 20 years, from 2003 to 2023. This decline is not limited to a reduction in species numbers but is also suspected to involve decreases in population size, composition and structure, and other ecological values. This condition may be attributed to the utilization of forests, which serve as bird habitats and natural forest boundaries within the MHSNP area, for various purposes, one of which is regional development.

This development is closely linked to the increasing population, which necessitates new alternative roads and transportation infrastructure to connect several regional governments, including Bogor, Sukabumi, and Lebak (Banten), or vice versa. Such measures aim to alleviate traffic congestion in the region.

Regional development can also reduce the extent of forested areas, which serve as critical habitats for birds to engage in activities such as foraging, breeding, and seeking shelter as they move between the forest core and its edges. According to [4] Several endemic bird species with restricted distributions that can be found in this area include the Javan Hawk-Eagle (Nisaetus bartelsi), the Sumatran Trogon (Harpactes reinwardtii), and the Rufoustailed Fantail (Rhipidura phoenicura).

Additionally, certain bird species are known to exhibit positive symbiotic relationships within the forest habitats of MHSNP. For instance, members of the Nectariniidae family, such as the Olive-backed Sunbird (Cinnyris jugularis) and the Javan Sunbird (Aethopyga mystacalis), play essential roles as pollinators for flowering forest plants. However, some forest bird species are highly dependent on others for breeding. For example, the Plaintive Cuckoo (Cacomantis merulinus) relies on brood parasitism, targeting species from the Sylviidae and Timaliidae families, while the Brush Cuckoo (Cacomantis sepulcralis) parasitizes songbirds such as the Longtailed Shrike (Lanius schach) and the Striated Grassbird (Megalurus palustris).

The reduction of natural forest areas due to various human activities in MHSNP has also resulted in fragmented forest landscapes. This condition, where natural forests are broken and separated into distinct sections, is commonly referred to as forest patches. The distances between these forest patches vary, with some being relatively close to each other and others significantly farther apart. For highly mobile bird species, it is possible to forage in distant feeding locations that are relatively safe from disturbances. However, bird species with lower mobility levels are likely to remain confined to limited areas, making them more vulnerable to habitat fragmentation.

Dri et al., (2021) Emphasize that the continuous loss of a habitat can lead to the disappearance of species from that location. Meanwhile, the most immediate threats to global biodiversity, including avian fauna, are habitat loss, fragmentation, and the impacts of land degradation.

Other factors threatening bird communities in MHSNP include wild hunting, predation by top carnivores, and the risk of landslides in forested areas. These threats are often exacerbated by activities such as the collection of leaves for livestock feed and the harvesting of wood for fuel, including from trees like Maeopsis eminii, whose seeds are an essential food source for birds. Additionally, commercial and traditional agricultural practices near the forest corridor pose significant risks. These include the use of pesticides and land-clearing methods involving burning, which contribute to forest deforestation and further habitat loss.

The previous research was done by Hardina, K., Mulyani, Y. A., & Mardiastuti, A. (2019), "Bird communities in the lower and sub-mountains in Mount Halimun Salak National Park" Researchers found a decline in the number of bird species due to habitat degradation. The study recorded 54 species of birds found in the submontana region of TNGHS, highlighting the importance of preserving montana ecosystems as a key habitat for endemic and migratory birds. This study is in line with your findings regarding the vulnerability of birds to habitat fragmentation.

Widiya, Y., et al. (2023) "Inventory of Avifauna in the Ecotourism Area of Malasari Village, Mount Halimun Salak National Park": This study recorded 49 species of birds in one of the TNGHS ecotourism areas. The focus of the research is to identify bird species as potential for the development of biodiversity-based ecotourism. These results show differences in species distribution that may be caused by human activity pressures, in line with your research on the effects of fragmentation and land change on bird distribution.

Based on the issues outlined above, a study on bird communities in several forest patches within the MHSNP corridor in Bogor and Sukabumi was conducted with a focus on the ecological value of these birds. The research locations were selected in the forest patches of Purasari,

Garehong, and the mainland Cipeuteuy (Kendeng). This selection was based on the fact that the Kendeng resort area serves as a corridor within MHSNP, forming a boundary where the ecosystems of Mount Halimun and Mount Salak meet. This corridor spans approximately 9 km and functions as a bridge connecting the two ecosystems.

Additionally, the Kendeng corridor is critically important as a genetic exchange channel among faunal species, especially for wide-ranging animals such as leopards and Javan hawkeagles. However, one-third of the corridor has been converted into shrublands, and parts of it have been lost entirely. This degradation has negatively impacted the ecosystem, causing disturbances to wildlife. [6].

The research findings are expected to provide fundamental scientific data on avian biodiversity and other ecological values about environmental management studies. This will serve as a basis for management recommendations to relevant stakeholders, aiming to achieve a sustainable and well-preserved Mount Halimun-Salak National Park (MHSNP).

Materials and Methods

Before conducting the study in the forested areas of Mount Halimun-Salak National Park (MHSNP), a preliminary field survey was carried out. Based on the survey, the first research site (I) was designated in the Purasari patch and the forest corridor area near the Bukit Cianten tea plantation boundary (Leuwiliang District, Bogor). The geographical coordinates of this area range from 06º 40′ 45.6′′ to 06º 42′ 22.5′′ S (South Latitude) and 106º 37′ 07.5′′ to 106º 36′ 31.5′′ E (East Longitude), with an elevation spanning 876–1167 meters above sea level.

The second research site was located in the Garehong patch, specifically in the forested area along the Garehong-Cipicung route. Geographically, Site II is positioned at approximately 06º 45′ 53.6′′ S (South Latitude) and 106º 36′ 31.5′′ E (East Longitude), with an elevation of around 1,049 meters above sea level.

The third research site was the mainland Cipeuteuy (Kendeng forest area), including approximately 500 meters of its buffer zone in the Cimapag forest. This area encompasses the Kendeng forest patch and serves as the boundary between Bogor and Sukabumi regencies.

Geographically, Site III is situated at around 06° 44' 55.0" S and 106° 36' 46.2" E, with an elevation of about 1,010 meters above sea level.

The fourth research site consisted of a fragmented area extending from Cianten to the border with Garehong and just before Kendeng forest. This area includes a landscape of tea plantations, vegetable farms, fields, rice paddies, and settlements.

The overall characterization of natural vegetation in the research locations includes Puspa (Schima wallichii), Saninten (Castanopsis argentea), Rasamala (Altingia excelsa), Pine (Pinus spp.), Damaran (Agathis dammara), Rattan (Calamus spp.), Manii (Maesopsis eminii), African Mahogany (Khaya senegalensis), and Harendong (Melastoma malabathricum).

Administratively, the research sites are situated in three subdistricts: Purasari (Leuwiliang District, Bogor), Garehong (Pamijahan District, Bogor), and Cisarua and Cipeuteuy (Kabandungan District, Sukabumi). The research location map is presented in Figure 1.

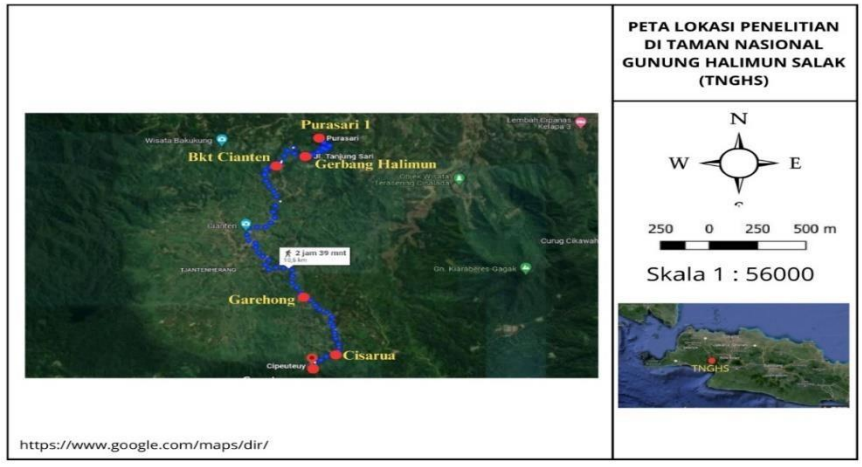

Figure 1. Map of the Research Locations

Research Procedure

Field data collection was conducted using research tools, including Nikon binoculars (8 x 35 mm), a wristwatch or timer, GPS, raffia rope, measuring tape, camera, mobile phone, location maps, data tabulations, and notebooks with writing instruments. Bird species identification in the field relied on reference books, specifically those by [4].

The research materials consisted of various bird species and their counts observed directly within the three forest patches of Mount Halimun-Salak National Park, along with their surrounding landscapes.

Data Collection Method

The research data was collected using the Index Point Abundance (IPA) method. [7]. The procedure involved determining observation points to record bird species and individual counts

in each habitat. These observation points were assigned IPA numbers corresponding to locations within the study area. The distance between IPA points was set at 100 meters.

At each IPA point, bird observations were conducted for 9–15 minutes. This time frame was based on preliminary observations, which indicated that the average observation period at each point ranged from 9 to 15 minutes. During this time, any bird species that could be seen or heard within the observer's range of vision (or through binoculars, approximately 35–40 meters) was recorded, noting the species name and the number of individuals. To avoid redundancy, only birds present within the specific IPA point were recorded. Birds flying over without perching within the observation point were excluded, except for certain species such as raptors, swifts, or bee-eaters that hover and forage within the IPA area.

Once the observation time at the first IPA point was completed, data collection proceeded to the next IPA point, following the same procedure. The transition time between IPA points averaged 4–5 minutes, depending on terrain conditions. According to [7], minimizing observation time at each point allows for data collection from a larger number of points. The scientific nomenclature for bird species followed Sukmantoro et al. (2007).

Bird observations were prioritized during the morning hours (07:00–11:00) and the afternoon to early evening (13:00–16:00). Observations were temporarily halted in cases of fog or rain and resumed when the weather conditions improved. Data recording was conducted in four bird observation blocks: three forest patches—Purasari (PRS), Garehong (GRH), and Kendeng (KDG)—and one fragmented area (open area, OPA) around Bukit Cianten-Garehong/Kendeng. Observations in each block were repeated three times, with the species names and the number of individuals recorded. This approach enabled the determination of the total number of bird species and individuals in each observation block.

Subsequently, the data were analyzed to calculate various indices, including bird abundance (Pi), bird diversity index (H'), bird species richness index (R), bird evenness index (E), relative dominance (DR), relative frequency (FR), the Importance Value Index (INP) for birds, and the bird similarity index (IS). These indices provided a comprehensive ecological assessment of the bird communities across the study sites.

Data Analysis

Based on the recorded bird species and the number of individuals across all observation blocks, the ecological values of birds utilized in this study were measured and calculated using the formulas provided by [8].

a. Bird Diversity Index (H’)

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

b. Margalef Richness Index (R)

$$R = \frac{S-1}{}$$

$\ln(N)$

c. Species Evenness Index (E)

H'

$E = \frac{}{\ln S}$

d. Species Dominance Index (C)

$C = \Sigma \left[\frac{ni}{N}\right]^2$ (Odum 1993).

e. Relative Dominance Index (DR)

The relative dominance index represents the ratio of the dominance of a particular bird species to the total dominance of all bird species within a community, expressed as a percentage:

$$\text{Relative Dominance (DR)} = \frac{\text{Dominance of a Species}}{\text{Total Dominance}} x100\% \quad [9]$$

f. Species Frequency (F)

The species frequency (F) was calculated using the formula by Hermadhiyanti et al., (2015):

$$\text{Species Frequency (F)} = \frac{\text{Number of plots where a species was found}}{\text{Total number of sample plots}}$$

The relative frequency (FR) was calculated as:

$$\text{Relative Frequency } (FR) = \frac{\text{Frequency of a Species}}{\text{Total Frequency of all Species}} x100\%$$

g. Bird Species Similarity Index (IS)

The similarity index (IS) was used to assess the degree of similarity between bird communities in different forest patches and identify potential clustering or separation of their affiliations:

$$IS = \frac{2C}{A+B}$$

Design of Analysis and Statistical Formula

A statistical test was employed to determine differences in the number of bird species across various habitat patches using the one-way Kruskal-Wallis analysis of variance approach. [11]; [12]. The Kruskal-Wallis analysis is used in comparative studies to assess differences between two or more independent groups (groups derived from different subjects).

The Kruskal-Wallis test model has previously been applied by [13] A study on edge effects on bird communities between *Agathis* and *Puspa* stands in the Gunung Walat Educational Forest, Sukabumi, West Java.

The formula for the Kruskal-Wallis test is as follows:

$$H = \frac{12}{N(N+1)} \{(\Sigma Rk)^2 | nk)\} - 3(N+1)$$

If the result is significant, with $P \leq 0.05P$, it indicates that the two tested groups are different at a 5% significance level. Conversely, if the result is not significant, with $P \geq 0.05P$, it suggests that the two tested groups do not differ at the 5% significance level.

Results and Discussion

Diversity, Species Dominance Index, and Bird Individual Counts

The study recorded a total of 81 bird species comprising 1,531 individuals (see Appendix 1). These birds were distributed across the following areas: 49 species in the Purasari forest patch, 46 species in the Garehong patch, 55 species in Kendeng, which serves as a corridor within the Mount Halimun-Salak National Park (MHSNP), and 34 species in the fragmented area near residential zones. The bird species diversity observed in this study was greater compared to previous studies conducted by [2] and [3] Other parts of MHSNP recorded 54 and 49 bird species, respectively.

Several dominant bird species from the three forest patches and the fragmented area are presented in Figure 2. Most birds exhibited a low dominance index (Di<2%), accounting for approximately 62.20% of all species. The remaining species were categorized as moderate (Di=2−5%) or high (Di>5%) dominance.

Bird species with moderate dominance (Di=2−5%) in the three forest patches included *Dicaeum trigonostigma* (Di=2.23%), *Halcyon chloris* (Di=2.71%), *Stachyris melanothorax* (Di=2.83%), *Dicaeum trochileum* (Di=3.32%), *Hirundo tahitica* (Di=3.56%), *Cacomantis merulinus*

(Di=3.62%), and *Pteruthius aenobarbus* (Di=3.79%).

Bird species with high dominance (Di>5%) in the three forest patches included *Lonchura leucogastroides* (Di=8.81%), *Collocalia linchi* (Di=9.22%), *Orthotomus sutorius* (Di=13.8%), and *Pycnonotus aurigaster* (Di=15.97%).

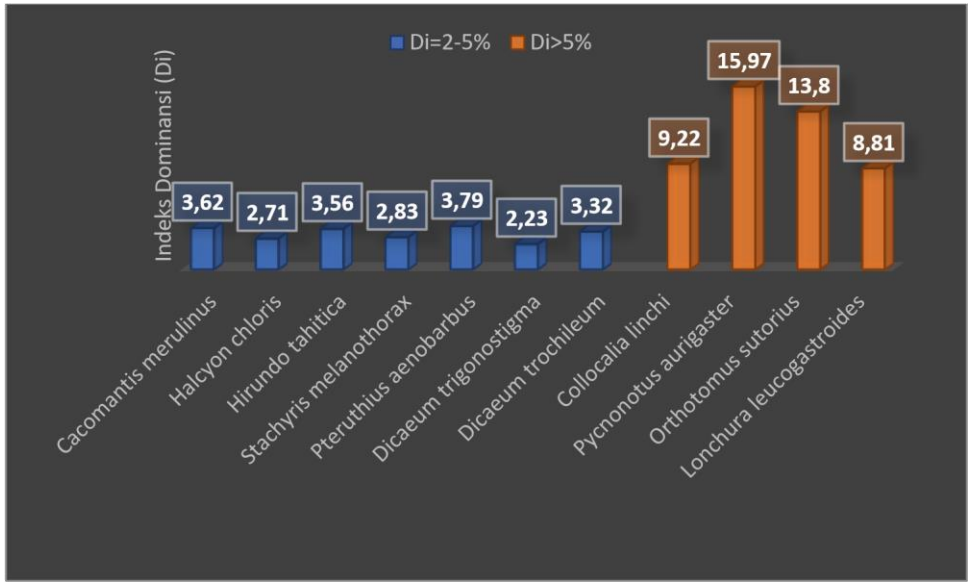

Figure 2 Species Dominance Index of Birds with Moderate (Di=2−5%) and High (Di>5%) Levels in Mount Halimun-Salak National Park (MHSNP)

The four bird species with high dominance indices—Pycnonotus aurigaster, Orthotomus sutorius, Collocalia linchi, and Lonchura leucogastroides—were abundant during the study period. These species were not previously recorded in the Kendeng forest corridor patches. [14]. These birds belong to species closely associated with human activity and are capable of thriving in open habitats. The findings indicate that birds from non-patch habitats have begun to spread into the forest patches of MHSNP. These species exhibit adaptive traits, enabling them to persist in forest patches that are becoming increasingly open.

The ability of bird species to adapt to new environmental conditions reflects their capacity to cope with changing surroundings and utilize available natural resources to sustain their survival within their ecological niches. Collocalia linchi is commonly found across all altitudes, while Lonchura leucogastroides has a wide distribution up to 1,800 meters, and Pycnonotus aurigaster is among the most widely distributed species, commonly found up to an altitude of 1,600 meters. [15].

When compared to the observations conducted 20 years ago by Prawiradilaga, Marakarmah, and Wijamukti (2003), 54 bird species were not rediscovered within the MHSNP forest corridor during this study. A portion of the species not observed were nocturnal birds, as this research did not include nighttime observations. Among the nocturnal birds were members of the family Strigidae (Otus rufescens, Otus brookii, Otus lempiji), Caprimulgidae (Caprimulgus pulchellus), and Podargidae (Batrachostomus javensis, Batrachostomus cornutus).

Additionally, not all migratory bird species previously recorded could be covered during this

study. These include Accipiter gularis, Erithacus cyane, Rhinomyias brunneata, Muscicapa ferruginea, and Motacilla cinerea. However, some migratory birds were successfully observed, such as Dicrurus annectans, Ficedula mugimaki, and Locustella certhiola.

Other forest birds that were also not recorded during this study in 2023 include three major families: *Timaliidae* (*Pellorneum pyrrogenys*, *Malacocincla sepiarium*, *Pomatorhinus montanus*, *Napothera macrodactyla*, *Stachyris grammiceps*, *Stachyris thoracica*), *Turdidae* (*Erithacus cyane*, *Cinclidium diana*, *Enicurus velatus*, *Myiophoneus glaucinus*, *Myiophoneus caeruleus*, *Zoothera andromedae*), and *Muscicapidae* (*Rhinomyias brunneata*, *Rhinomyias olivacea*, *Muscicapa ferruginea*, *Ficedula dumetoria*, *Ficedula hyperythra*, *Culicicapa ceylonensis*, *Cyornis banyumas*, *Cyornis unicolor*). [8]These three bird families were documented to be distributed within the Kendeng forest corridor at elevations ranging from 1,000 to 1,400 meters above sea level (Prawiradilaga, Marakarmah & Wijamukti, 2003).

The Kendeng forest corridor has undergone significant changes compared to its condition before 2023. Many trees in the forested areas between Purasari and Cisarua (Kendeng) have been removed to facilitate the construction of roads connecting Cianten and Cipeuteuy. This situation has likely reduced the habitat available for bird activities in the area, potentially prompting birds to shift their distribution toward safer, undisturbed forest areas within the interior of MHSNP.

The changes in the MHSNP corridor are also influenced by various environmental and societal factors, reflecting the increasingly dynamic nature of local communities. To meet their daily needs, residents around the forest have opened agricultural areas, cultivating a variety of vegetables such as chili, bok choy, scallions, eggplant, long beans, green beans, tomatoes, and more. Some farmers were observed clearing forested areas for farming through slash-and-burn practices. This method negatively impacts the environment, with the heat and smoke from the fires causing forest birds to flee to other areas.

Similarly, the creation of rice paddies has had comparable effects to those seen in the clearing of forest land for vegetable farming. When birds are disturbed due to an unsafe habitat, they tend to move to safer locations. [16]. This situation not only impacts bird species but also other wildlife, such as *Hylobates moloch* (Javan gibbon) and *Presbytis comata* (surili). These primates, which once roamed freely between trees and foraged in the MHSNP forest corridor, now exhibited reduced activity during this study. [17]. One of the suspected factors is the fragmentation of the forest into patches due to land clearing activities.

The disruption of tree vegetation within the forest for various purposes has led to the displacement of forest birds and other wildlife. This shift is evident in the findings of the study. Meanwhile, several resident forest bird species were recorded, including *Stachyris melanothorax*, *Napothera epilepidota*, *Rhipidura phoenicura*, and *Pycnonotus bimaculatus*. These remaining forest birds were observed in dense undergrowth layers dominated by rattan vegetation within the forest patches.

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Among the bird species identified in this study, several are protected predators, including *Accipiter trivirgatus*, *Ictinaetus malayensis*, *Spilornis cheela*, and *Spizaetus cirrhatus*. Other species are categorized as endemic, such as *Loriculus pusillus*, *Harpactes reinwardtii*, *Halcyon cyanoventris*, *Rhipidura phoenicura*, *Megalaima armillaris*, *Dicaeum sanguinolentum*, and *Aethopyga eximia*. Additionally, some bird species are not only protected and endemic but also classified as endangered, such as *Spizaetus (Nizaetus) bartelsi*.

These findings indicate that the three forest patches studied possess significant conservation value. At least 15% of the bird species in MHSNP are categorized as protected, endangered, or endemic. The total number of individual birds (NN) observed in the various forest patches and the surrounding fragmented areas is presented in Figure 3.

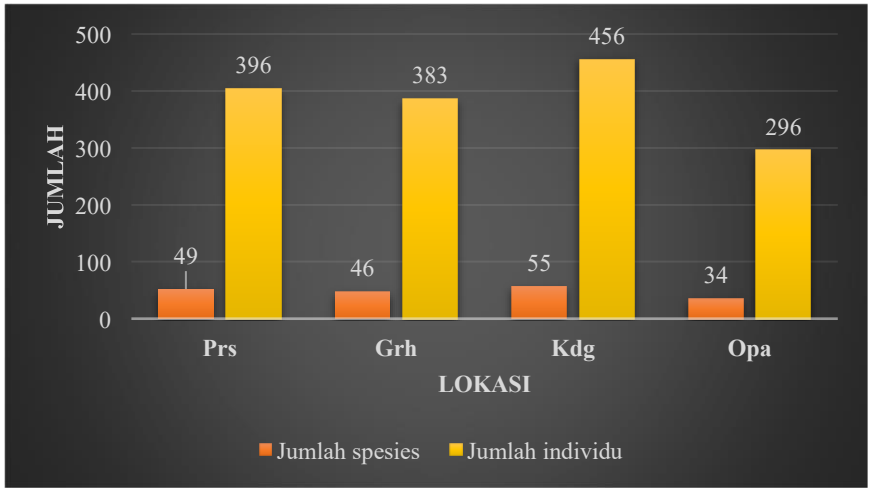

Figure 3 Number of Bird Species and Individuals in Various Forest Patches and Fragmented Areas in MHSNP

Based on Figure 3, the highest number of individual birds was recorded in the Kendeng forest patch (Kdg), with 456 individuals from 55 species, followed by the Purasari forest patch (Prs) with 396 individuals from 49 species. The lowest numbers were found in the Garehong forest patch (Grh), with 383 individuals from 46 species, and the fragmented area/open area (Opa), with 296 individuals from 34 species.

The relatively high number of bird species and individuals in the Purasari and Kendeng forest patches is likely linked to the well-preserved condition of *Puspa* (*Schima wallichii*) vegetation in these locations. *Puspa* trees grow dominantly, reaching tall heights with dense foliage that serves as a vital food source for various bird species. During the study, the *Puspa* trees were in bloom, attracting numerous insects, which in turn provided food for insectivorous birds such as

swifts (*Collocalia linchi*), bulbuls (*Pycnonotus aurigaster*), drongos (*Dicrurus leucophaeus*), and white-eyes (*Zosterops palpebrosus*).

Around the *Puspa* community, water streams were also present, extending to the edge of the MHSNP forest corridor near Bukit Cianten. The forest floor under the *Puspa* vegetation was particularly characteristic, hosting bird species such as *Enicurus leschenaulti* and *Stachyris melanothorax*. [13] Note that *Puspa* stands are associated with specialist species like *Enicurus leschenaulti* and *Stachyris melanothorax*.

Habitats with higher vegetation diversity tend to support a greater number of bird species compared to habitats with poorer vegetation diversity (Dewi, Mulyani & Santosa, 2007). Differences in the number of bird species and individuals are also influenced by habitat conditions, food resource availability, and vegetation structure [18]. In relatively well-preserved habitats, the entirety of tree vegetation species can be utilized by birds as nesting sites, perching areas, and food sources. [19].

Species Richness, Diversity, and Evenness Indices

The species richness index (R), Shannon-Wiener diversity index (H'), and evenness index (E) of birds in the study areas are presented in Figure 4.

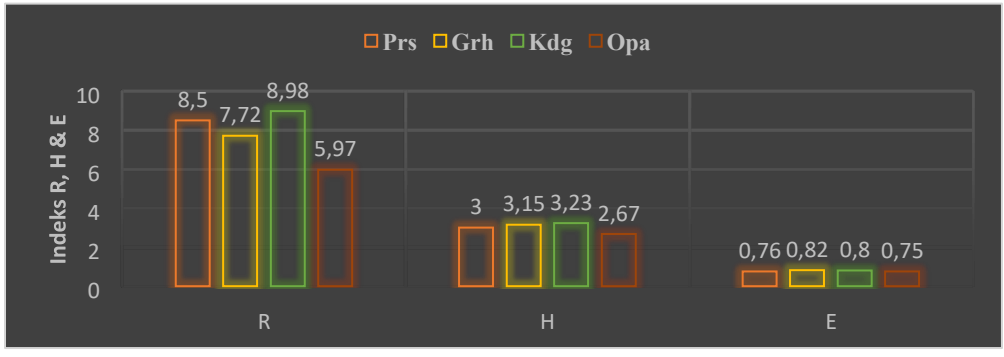

Figure 4. Species Richness (R), Diversity (H'), and Evenness (E) Indices of Birds in MHSNP

Observing Figure 4 reveals that the average values of the three bird ecological indices— species richness (R), Shannon-Wiener diversity (H'), and evenness (E)—are highest in the Kendeng forest patch (Kdg), with R=8.98, H'=3.23, and E=0.80. Meanwhile, the Purasari forest patch (Prs) shows values of R=8.50, H'=3.0, and E=0.76.

According to [3]A high species richness index (R>5) indicates significant bird species richness, reflecting a large variety of species within the habitat. This highlights that the Kendeng and Purasari forest patches are home to a high diversity of bird species. Higher species richness (R) signifies a greater number of species present in the habitat. The species richness in Kendeng (R=8.98) and Purasari (R=8.50) is notably higher compared to the bird species richness observed in the restoration area of Mount Gede Pangrango National Park, which recorded an R value of 4.695 (Ario et al., 2020).

Meanwhile, the value of H′=3.23 in the Kendeng patch indicates that the bird community in this location exhibits a high overall species diversity. This aligns with [3] The assertion that H′>3 is categorized as high diversity. Moreover, the value of H′ is directly proportional to the evenness index (E). The high H′ values observed in the study areas are accompanied by correspondingly

large E values, such as 0.80 in Kendeng, which is close to 1. This indicates that the high bird diversity in the area is complemented by a relatively uniform distribution of individuals across different species.

Based on the parameters R and H′, the Kendeng and Purasari forest patches can be categorized as having the highest criteria. This is supported by their bird species richness index (R) values, which range between 8.50 and 8.98, indicating an almost even distribution, and their diversity index (H′) values, which range between 3.0 and 3.23, reflecting high diversity. These conditions suggest that the ecosystems in these patches are highly productive, relatively free from ecological pressure, and exhibit environmental balance.

Another contributing factor to the richness of bird species in an area is the availability of food sources and the well-maintained condition of the habitat (Sumardika, Ginantra & Suaskara, 2017). Bird species diversity indices are influenced by various factors, including habitat quality and variability. Different vegetation types can result in varying bird diversity (Ridwan et al., 2015). Diverse vegetation not only provides a wider range of food sources but also ensures that birds have more feeding options available.

The high bird diversity index (H′) values in the Purasari and Kendeng forest patches indicate that these ecosystems are balanced in terms of food availability and bird populations. [19].

The conditions in the Garehong area differ slightly. Despite the forest patch being affected by the operations of a geothermal power company, the bird diversity index remains at H′=3.15. This indicates that bird species diversity in Garehong is still categorized as high. Emphasizes that a bird diversity index of H′>3 signifies high diversity, and the bird species richness (R=7.72) in Garehong also reflects significant diversity, even though the area has been impacted.

Meanwhile, the lowest ecological values for birds were found in fragmented or open areas near settlements. These areas have undergone various land-use changes, with forested land converted into monoculture plantations, gardens, rice fields, and residential zones. Additionally, remnants of motor trail tracks used for local tourism attractions and the extraction of forest resources further contribute to the degradation. As a result, fragmented areas are relatively more impacted and disturbed by human activities.

When compared to studies conducted in other regions of West Java, the average bird species diversity index at Halimun is slightly lower. In the forests of Mount Ciremai National Park and the Kamojang Geothermal Plant area, despite the forests being impacted, the H′ values are higher, recorded at 3.55 and 3.67, respectively. [20]; [21].

According to Kartikasari et al., (2018)Disturbances to bird communities in the Kamojang conservation area are largely attributed to the reduction of natural forest vegetation, which serves as bird habitats. Additionally, tree felling, forest fires, encroachment, and illegal hunting using snares, adhesives, or air rifles have further exacerbated the situation.

The bird evenness index (E) indicates that bird species in the three forest patches of MHSNP tend to be distributed relatively evenly. According to Ludwig & Reynolds (1988), the evenness index ranges from 0 to 1. The results of this study show E values between 0.75 and 0.82, which are closer to 1. This suggests that the birds in the study areas are distributed almost evenly.

The evenness index (E) is directly proportional to the diversity index (H′) and is influenced by both the number of bird species and the number of individuals. In a habitat where several bird species are present with individual counts distributed relatively evenly and no single species

dominates in terms of population, the evenness of bird distribution in that location is categorized as high.

Species diversity is one of the most fundamental aspects of ecology, and birds are among the fauna whose diversity can be measured due to their sensitivity to environmental changes. [22]. Birds can be found in various habitat types, and their primary habitat type is closely related to their daily needs and activities. [23]. Habitats with higher vegetation diversity tend to support greater bird species diversity. Bird species diversity is strongly influenced by the variety of plant species and the structure of the vegetation. Furthermore, high bird species diversity indicates a broader distribution of individuals among species, which contributes to greater community stability. [24].

Based on the study results, there are four rankings of bird species counts across the forest patches and surrounding open areas, with slightly different proportions. As previously mentioned, the highest ranking is found in the Kendeng patch, with 55 species. The second rank is held by the Purasari patch with 49 species, followed by the Garehong patch with 46 species in third place. The lowest rank, with the fewest number of bird species, is the open habitat with 34 species, including tea plantations, vegetable gardens, rice fields, and residential areas. The scores and rankings for each category, with three replications, are presented in Table 1.

Number of Bird Species (S) in 4 Research Blocks/Locations							
Purasari (Psr)		Garehong (Grh)		Kendeng (Kdg)		Fragmented Area (Opa)	
Score	Rank	Score	Rank	Score	Rank	Score	Rank
17	1	19	2	20	4,5	20	4,5
29	6	24	5	32	8	13	1
31	7	38	9	22	4	23	7
n_1=3	R_1=14	n_2=3	R_2=16	n_3=3	R_3=16,5	n_4=3	R_4=12,5

Table 1

Results of H Test Analysis (Kruskal-Wallis)

Notes: The score referred to is the number of species observed in the four research blocks during the first, second, and third rounds of observations.

The results of the H test analysis indicate that the rankings of bird species count in the research locations are not significantly different (Kruskal-Wallis test with $H_{calculated} = 1.80 < X^2\ 0_{,05;\ 3} = 7,815$). Although there is no significant difference in species rankings, it can be observed that forest patches with greater plant diversity tend to have the highest number of bird species compared to fragmented habitats.

Birds Similarity Index

The similarity in bird species composition between observation blocks in the various forest

patches and open areas was determined using the similarity index (IS) formula, with the results expressed as percentages (%). To examine the clustering of bird species similarity percentages among the three forest patches and the fragmented area, cluster analysis was performed using the software application BioPro (Biodiversity Professional) version 2.0 (2016 edition). The results of this analysis are presented in the dendrogram shown in Figure 5.

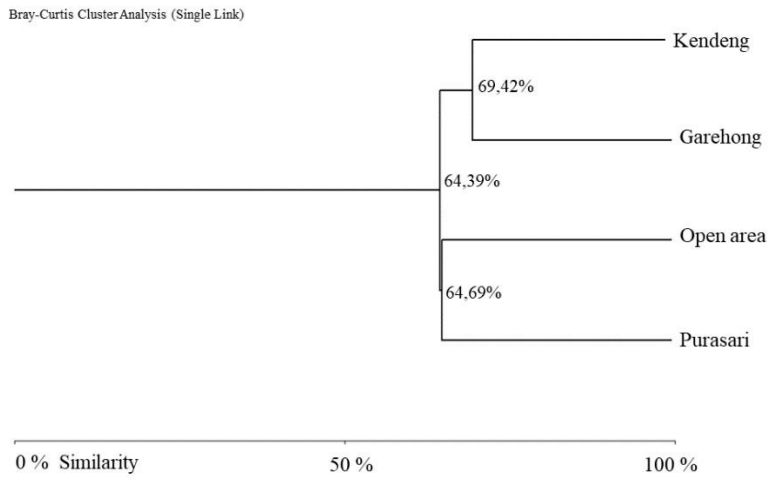

Figure 5. Dendrogram of Bird Clustering Based on Similarity Across Three Forest Patches and the Fragmented Area in MHSNP

Using the BioPro (Biodiversity Professional) version 2.0 (2016 edition), the analysis showed that the bird species composition across the four observation blocks exhibited a relatively high similarity, approximately 64.39%. The closest similarity grouping was observed between the bird communities in the Kendeng (KDG) and Garehong (GRH) forest patches, with a similarity of 69.42%. Meanwhile, the bird community in the Purasari forest patch showed a closer similarity to the bird community in the open area/residential habitat, with a similarity of 64.69%.

The relatively high bird species similarity (>65%) between the Kendeng and Garehong patches can be understood through the historical development of the Mount Halimun-Salak National Park (MHSNP). Initially, Halimun was designated as a protected forest before being converted into a nature reserve from 1979 to 1992. This area remained near the forest of Mount Gede Pangrango. Meanwhile, the Mount Salak area was managed as a protected forest under Perhutani. The integration of the Mount Halimun and Mount Salak forests into the Mount Halimun-Salak National Park, covering an area of 113,357 hectares, was officially established in 2003 (Minister of Forestry Decree No. 175/Kpts-II/2003).

The integration of Halimun's natural forest, characterized by native trees such as *Saninten*, with the production forest of Mount Salak, managed by Perhutani and dominated by production trees such as *Rasamala* and *Puspa*, is likely to have influenced the current bird communities in MHSNP. Observed species in areas such as Purasari and Kendeng include members of the Nectariniidae family (nectarivores) such as *Aethopyga mystacalis*, *Arachnothera longirostra*,

and *Cinnyris jugularis*, as well as Dicaeidae (mistletoe fruit eaters) such as *Dicaeum trochileum*, *Dicaeum trigonostigma*, and *Dicaeum sanguinolentum*. Insectivores include the Apodidae family (*Collocalia linchi*), Timaliidae (*Stachyris melanothorax*), Turdidae (*Brachypteryx leucophrys* and *Enicurus leschenaulti*), Pycnonotidae (*Pycnonotus aurigaster*), Hirundinidae (*Hirundo tahitica*), Sylviidae (*Orthotomus sutorius*), and Artamidae (*Artamus leucorhynchus*). Fish-eating species (fishivores) observed include the Alcedinidae family (*Halcyon chloris* and *Halcyon cyanoventris*), while seed-eating species (granivores) include the Estrildidae family (*Lonchura leucogastroides*).

When grouped by their food sources, the bird species mentioned above can be categorized as insectivores (insect eaters), nectarivores (nectar eaters), granivores (seed eaters), and fishivores (fish eaters). The high similarity of bird species between Kendeng and the surrounding forest patches may be attributed to the similar environment and habitat, which serve as feeding grounds for birds in both patches.

This is evident from the presence of several dominant plant species, including *Puspa* (*Schima wallichii*), *Rasamala* (*Altingia excelsa*), and *Saninten* (*Castanopsis argentea*). During the study, the *Puspa* trees were in bloom, attracting various types of insects. These insects serve as food sources for insectivorous birds such as *Orthotomus sutorius*, *Zosterops palpebrosus*, and *Pycnonotus aurigaster*, as well as for *Collocalia linchi*, which were observed flying through the open areas nearby.

Within the Purasari and Kendeng forest patches, there are also river streams that serve as habitats for fish and aquatic insects, providing food sources for kingfisher species (*Ceyx rufidorsa*, *Halcyon chloris*, and *Halcyon cyanoventris*) as well as *Enicurus leschenaulti*. Additionally, plants such as cardamom (*Amomum* spp.), *Caliandra* (*Calliandra calothyrsus*), and guava (*Syzygium* spp.) were observed in both patches. The nectar from their flowers was noted to be consumed by members of the Nectariniidae family, including *Arachnothera longirostra* and *Aethopyga mystacalis*.

On the other hand, between the Purasari forest patch and the disturbed surrounding open areas, the bird similarity index dropped to approximately 64.69%. This indicates a relatively larger difference in the bird communities between these habitats. In natural forest vegetation, forest bird species such as *Rhipidura phoenicura*, *Napothera epilepidota*, *Pachycephala pectoralis*, *Cissa thalassina*, *Ficedula mugimaki*, and *Pitta guajana* were observed. Meanwhile, in disturbed or fragmented areas, species like *Passer montanus*, which are not found in forest patches or natural forests, were recorded.

The disturbed areas in the study are forests surrounded by tea plantations, vegetable gardens, and settlements near the Cianten region. According to the study by Dewi et al., (2007)The lowest similarity index was observed between bird communities in primary forests and gardens, with a similarity index value of only 13%. [25] Further noted that a high species similarity index may be attributed to the proximity of two forests and the ability of birds in both forests to adapt to various habitat types and share similar spatial use within forest habitats. Conversely, a low similarity index is due to significant differences between the two habitats, leading to distinct bird species compositions.

Adaptation is the ability of an individual to cope with environmental conditions and utilize natural resources more effectively to sustain life within its ecological niche. Thus, adaptation is often defined as the capability of an individual to adjust to environmental changes. Disturbances

in a habitat can alter its components, potentially rendering it unsuitable for the birds inhabiting it. If habitat conditions change beyond the minimum and maximum thresholds (outside the ecological range) required by organisms, those organisms may either die or migrate elsewhere. During this process, they must adapt to their new environment.

This situation highlights the presence of certain bird species observed in the study that are categorized as uncommon, distinct, or found only in a single forest patch. This is particularly true for birds with low mobility. Examples include *Cissa thalassina*, *Apalharpactes reinwardtii*, and *Eurylaimus javanicus*.

On the other hand, birds with high mobility and extensive roaming ranges may adapt to environmental changes by flying to suitable areas. This is especially evident among members of the Accipitridae family (raptors), such as the Javan hawk-eagle (*Spizaetus/Nisaetus bartelsi*), changeable hawk-eagle (*Spizaetus cirrhatus*), crested serpent eagle (*Spilornis cheela*), and black eagle (*Ictinaetus malayensis*).

Conclusion

Based on the study, 81 bird species were identified in the Mount Halimun-Salak National Park (MHSNP). The birds were distributed as follows: 52 species (404 individuals) in the Purasari forest patch, 56 species (456 individuals) in Kendeng, and 47 species (386 individuals) in the Garehong forest patch. In the fragmented habitat, 34 bird species comprising 296 individuals were recorded.

Birds classified as abundant (Di>5%) include the Javan munia (Lonchura leucogastroides), a granivore; the linchi swiftlet (Collocalia linchi) and the common tailorbird (Orthotomus sutorius), both insectivores; and the sooty-headed bulbul (Pycnonotus aurigaster), which is both an insectivore and frugivore.

The highest ecological values for bird communities, particularly the diversity index, were observed in the Kendeng forest patch with H′=3.23, R=8.98, and E=0.80. These were followed by the Purasari forest patch (H′=3.0, R=8.5, E=0.76) and Garehong forest patch (H′=3.15, R=7.72,

E=0.82). The lowest values were found in the fragmented area (H′=2.67, R=5.97, E=0.75). Statistical analysis using the Kruskal-Wallis test showed no significant differences in species rankings (P>0.05), with H=1.8, which is smaller than the critical value $X^2_{0.05;\,3}$ = 7,815.

Species with the highest Importance Value Index (INP > 10%) included the sooty-headed bulbul (Pycnonotus aurigaster), Javan munia (Lonchura leucogastroides), linchi swiftlet (Collocalia linchi), common tailorbird (Orthotomus sutorius), plaintive cuckoo (Cacomantis merulinus), chestnut-backed scimitar babbler (Stachyris melanothorax), chestnut-winged cuckoo (Pteruthius aenobarbus), and scarlet-backed flowerpecker (Dicaeum trochileum).

The highest similarity grouping occurred between bird communities in the Kendeng (KDG) and Garehong (GRH) forest patches, with a similarity of 69.42%. Meanwhile, the bird community in the Purasari forest patch showed closer similarity to the bird community in the open areas near settlements, tea plantations, fields, or rice paddies, with a similarity of 64.69%.

Suggestions

Overall, the ecological value of birds in several forest patches serving as corridors for the

Mount Halimun-Salak National Park, particularly in Purasari and Kendeng, is still relatively good.

This is reflected in the bird diversity index (H′>3), which remains significantly high, according to the study results. It is recommended that ongoing management efforts, such as habitat management through reforestation programs with native Halimun plants, continue and be regularly monitored for progress. In-situ conservation efforts for endemic species, such as ensuring the availability of nesting trees and food sources for the Javan hawk-eagle (*Nisaetus bartelsi*) in its breeding locations, must be maintained. The increasing popularity of ecotourism programs in the future must be carefully managed to prevent adverse impacts on natural resources, including fauna, flora, water sources, and the well-being of the local community.

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