BIOMA
p-ISSN: 0126-3552
e-ISSN: 2580-9032

DOI: 10.21009/bioma.v22i1.66678 Research article

Bird diversity and conservation status in KHDTK Wanadipa research forest, Universitas Diponegoro, Semarang: Ecological buffer implications for Mount Ungaran

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ABSTRAK

Kawasan Hutan Dengan Tujuan Khusus (KHDTK) Wanadipa Universitas Diponegoro di Semarang merupakan habitat penting bagi satwa liar di tengah degradasi lingkungan di Pulau Jawa. Penelitian ini mengkaji jenis burung, kelimpahan, serta status konservasinya di blok penelitian pendidikan dan zona rehabilitasi agroforestri. Survei dilakukan pada Februari 2026 dengan metode point count di lima stasiun, mencatat 133 perjumpaan dari 26 jenis burung. Jenis yang paling melimpah adalah walet linchi (25 individu) dan kutilang (17 individu). Analisis ekologi menunjukkan ekosistem hutan sekunder yang stabil, dengan nilai Indeks Keanekaragaman Shannon-Wiener *sedang (H' = 2,48–2,51), Indeks Dominansi* Simpson *rendah (D = 0,11–0,12), serta Indeks Kemerataan tinggi (E = 0,83–0,87). Lima jenis burung dilindungi berhasil didokumentasikan, termasuk elang jawa yang berstatus terancam punah menurut IUCN, bersama elang ular bido, paok pancawarna jawa, sikep madu asia, dan tangkar cetrong. KHDTK Wanadipa menampung lima jenis burung yang tercatat dalam IUCN dan CITES, jumlah yang sebanding dengan kawasan lebih luas Gunung Ungaran (enam jenis) maupun hutan kota Semarang (enam jenis). Temuan ini menegaskan peran KHDTK Wanadipa sebagai penyangga ekologis yang efektif dalam mendukung konservasi burung langka di Semarang, Jawa Tengah.*

Kata kunci: KHDTK Wanadipa, keanekaragaman hayati burung, konservasi, hutan sekunder

ABSTRACT

The Wanadipa Special Purpose Forest Area (KHDTK) of Diponegoro University in Semarang provides an important refuge for wildlife amid ongoing habitat degradation in Java. This study assessed bird species, abundance, and conservation status in the educational research block and agroforestry rehabilitation zone. Surveys conducted in February 2026 using point count method at five stations recorded 133 encounters of 26 species. The most abundant were the cave swiftlet (25 individuals) and sooty-headed bulbul (17 individuals). Ecological analysis indicated a stable secondary forest ecosystem, with moderate *Shannon-Wiener* Diversity Index values (H' = 2.48–2.51), low *Simpson* Dominance Index (D = 0.11–0.12), and high Evenness Index (E = 0.83–0.87). Five protected species were documented, including the endangered Javan hawk-eagle, alongside the crested serpent-eagle, Javan banded pitta, oriental honey-buzzard, and racquet-tailed treepie. The KHDTK Wanadipa harbors five IUCN and CITES-listed species, comparable to larger Mt. Ungaran (six species) and the Semarang urban forest (six species). These findings highlight the effectiveness of Wanadipa KHDTK as an ecological buffer supporting rare bird conservation in Semarang, Central Java.

Keywords: Wanadipa KHDTK, bird biodiversity, conservation, secondary forest

INTRODUCTION

The current global biodiversity crisis has reached alarming levels, driven primarily by deforestation and the conversion of tropical forests into anthropogenic landscapes such as agricultural land and settlements. On the island of Java, which faces extremely high demographic pressure, the loss of lowland forest cover has led to massive habitat fragmentation, leaving isolated patches of forest vulnerable to local extinction. In the context of this ecological space crisis, protected areas and educational forests hold undeniable urgency (Purnamaningrum et al., 2021). Special Purpose Forest Areas (KHDTK), which are regulated for research and education, now hold a dual ecological mandate as refugia for wildlife displaced from their natural habitats, including various bird species.

Beyond their function as refugia, KHDTK areas may also serve as ecological buffers or stepping-stone habitats within increasingly fragmented landscapes, facilitating species movement and genetic connectivity between larger natural ecosystems and surrounding human-modified environments.

As one such natural laboratory, the KHDTK Wanadipa, managed by Diponegoro University in East Ungaran, Semarang Regency, covers an area of approximately 99.65 hectares (Marsely et al., 2024). This area represents a significant ecosystem restoration effort, having been transformed from a former Perhutani production forest into a sanctuary focused on environmental rehabilitation, forestry research, and community empowerment-based ecotourism (Pinudya et al., 2025).

Geographically, KHDTK Wanadipa occupies a strategic position between the forested slopes of Mt. Ungaran and the increasingly urbanised landscape of Semarang City, thereby forming an intermediate habitat that may function as an ecological buffer connecting these two contrasting environments. Such spatial positioning is particularly relevant for avifauna, as birds possess high mobility and rely on a network of suitable habitats to maintain population connectivity and gene flow across fragmented landscapes.

In terms of spatial planning, the management system of KHDTK Wanadipa applies a specific ecological zoning scheme. The two main areas serving as focal points for ecological interaction are the 35.05 hectares research and education block, characterised by a dense stand of large trees resembling the architecture of a natural secondary forest, and the 20.77 hectares rehabilitation zone. This rehabilitation zone was formerly dry land that has now been engineered through silvicultural interventions in the form of mixed species planting or agroforestry systems. The ecotone or the transition zone between the dense canopy of the secondary forest and the open landscape creates a high degree of ecological niche heterogeneity and an abundance of food sources, making it highly likely to attract a wide variety of bird species. These heterogeneous habitat conditions position the KHDTK Wanadipa as a crucial buffer zone for wildlife conservation. Ecologically, this buffer function may enable birds to move between Mt. Ungaran's montane forest ecosystems and green spaces within Semarang City, including urban parks and riparian corridors that are known to support relatively high avian diversity. By facilitating such movement, KHDTK Wanadipa potentially contributes to maintaining functional

DOI: 10.21009/bioma.v22i1.66678

connectivity and avian gene flow, reducing the risks of population isolation commonly associated with urban expansion and habitat fragmentation.

To evaluate the success of this buffer function, birds act as highly reliable bioindicators in representing the health and stability of the forest ecosystem. The presence of a diverse avifauna community indicates a high environmental carrying capacity in providing good food and shelter (Zaida, 2021). Ecologically, birds perform various ecosystem services through their diverse dietary niches: seed-eaters and nectarivores play a crucial role in pollination and seed dispersal for plant regeneration, whilst insectivores and birds of prey function as biological control agents that suppress pest populations. Therefore, even the slightest change in the structure of the tree canopy within a forest area will have a direct impact on the survival of the birds within it.

In terms of area management, the KHDTK Wanadipa is divided into several areas or blocks. The two most interesting areas for research are the educational research block and the rehabilitation zone (agroforestry). The educational research block 35.05 hectares is a forest area with large, dense trees, resembling a natural forest. In contrast, the rehabilitation zone 20.77 hectares (Pinudya et al., 2025) was once dry land that is now planted with a mixed cropping concept agroforestry (Hidayat et al., 2025) . The meeting between the dense forest area and the open land area creates a highly varied food source, which has the potential to attract various types of birds.

Although the ecological role of the KHDTK Wanadipa is vital, empirical data regarding the level of bird species richness, community structure, and the inventory of birds with endangered status in this area remains extremely limited. Amidst the high threat of poaching in the wild, the compilation of this baseline data is an urgent matter that must be addressed immediately. Therefore, this study aims to address this need through direct observation to assess the level of bird diversity in this area, identify dominant species, evaluate population balance, and assess conservation status based on their legal protection status. It is hoped that the outcomes of this research will serve as scientific evidence for university management and the government in formulating strategies and refining targeted forest protection policies. Therefore, this study aims to address this need through direct observation to assess the level of bird diversity in this area, identify dominant species, evaluate population balance, and assess conservation status based on their legal protection status. It is hypothesised that the highly structured vegetation in the secondary forest block will support a different avifaunal community composition, particularly for forest-specialist species, compared to the agroforestry zone, which is expected to be dominated by generalist species.

METHODOLOGY

Study sites and species sampling

The research was conducted within the KHDTK Wanadipa of Diponegoro University. In terms of village boundaries, this forest stretches between Susukan Village and Mluweh Village, in East Ungaran Subdistrict, Semarang Regency.

The map outlines the KHDTK management zoning system using easy-to-read

DOI: 10.21009/bioma.v22i1.66678

colour indicators (**FIGURE 1**) . Animal sampling in this study focused specifically on two main areas that dominate the map. The first, educational research block, This polygon is identified in yellow on the map, covering an area of 35.05 hectares. Vegetatively, this block represents a Secondary Natural Forest (HAS) structure with a relatively dense and stratified mixed forest canopy architecture. Commercial timber species such as teak, rosewood and mahogany dominate the vertical canopy space, creating a stable and shady microclimate for bird taxa that has an affinity for protected habitats.

The second, agroforestry rehabilitation zone, marked by light green polygons on the map, with an area of 20.77 hectares. This area is open land that was formerly cultivated fields and is managed through polyculture silviculture (agroforestry) interventions. Vegetation enrichment involves shade tree species, Multi-Purpose Tree Species (MPTS), and commercial aromatic plants such as lemongrass. The optimal level of solar radiation exposure in this zone promotes high productivity in terms of flowers, fruits, and pollinating insects, making it a primary foraging ground for nectar-feeding, fruit-eating, and airborne insect guilds.

Research design

The research design was a comparative descriptive study intended to evaluate differences in bird community structures between two distinct habitats. A total of five observation stations were established. These stations were placed from the dense forest area in the educational research block to the more open area in the rehabilitation zone. To reduce the potential for double counting caused by the daily movements of species the distance between stations was set at a constant minimum of 200 metres. This field research was conducted in February 2026. At that time, the trees were beginning to flower and bear fruit, and there were many insects. The abundance of natural food attracted birds to come out and forage, making it easier for us to record them.

Research procedures

This study utilised the point count method, often referred to as the IPA (Indices Ponctuels d'Abondance) method This method is commonly used in forestry research as it is accurate for counting birds in areas where visibility is often obstructed by foliage (Prasetyo & Wulandari, 2021) Observations were conducted in the morning, specifically from 06:00 to 10:00 WIB (Purnamaningrum et al., 2021) The observation procedure was carried out by two trained observers working concurrently in separate zones to minimise temporal bias. Observers were placed at the centre of each station for a constant duration of 15 to 20 minutes per plot. Species documentation included visual identification (beak morphometry, feather pigmentation patterns, flight silhouettes) aided by cameras and binoculars, as well as acoustic detection (song and call repertoires) for cryptic species hidden by dense canopy cover. Acoustic recordings were captured using a directional microphone and cross-referenced with the Xeno-canto database for verification. To mitigate abundance overestimation bias from acoustic data, vocalising individuals were only recorded as one encounter unless multiple distinct calls of the same species were

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heard simultaneously from different directions within the 50-metre radius of the station. Scientific nomenclature validation is strictly aligned using field identification guides for birds in Sumatra, Java and Bali (MacKinnon et al., 2010).

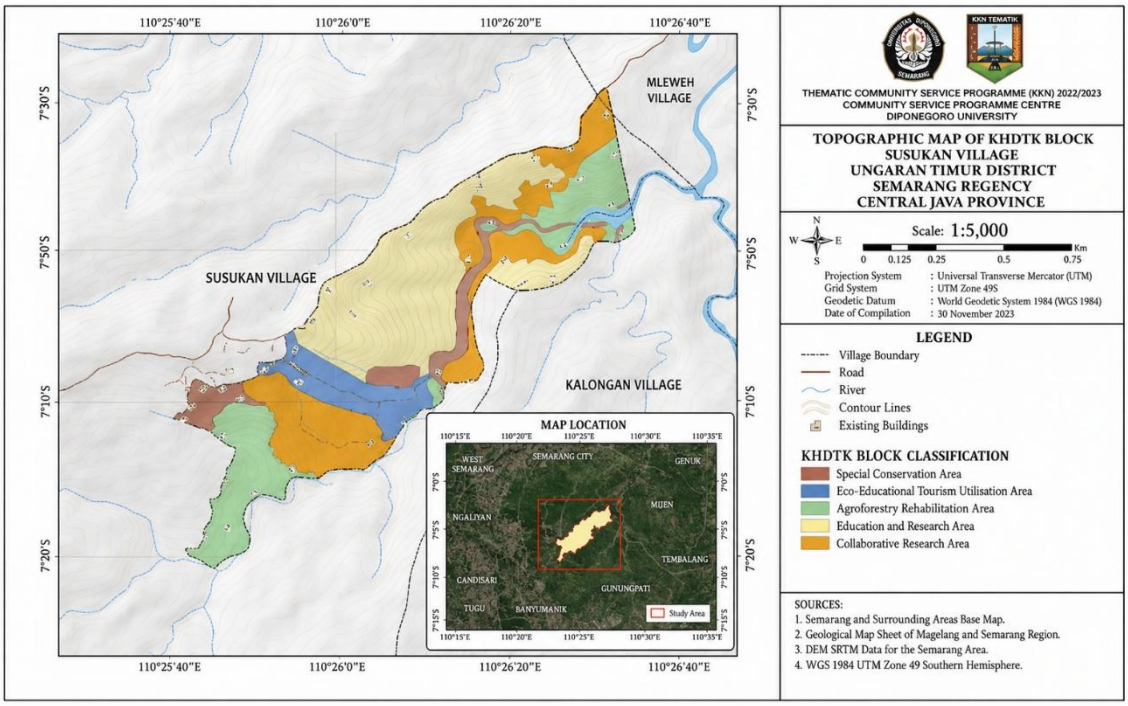

FIGURE 1. Map of the Wanadipa Semarang KHDTK block division (Source: KHDTK.undip.ac.id)

Data analysis techniques

The data collected was analysed quantitatively, including species names and number of individuals. Analysis of the bird community structure used the following ecological indices

Shannon-Wiener Diversity Index (H'): Used to determine the level of bird species diversity at the study site (Nolan & Callahan., 2006).

$$H' = \sum_{I=1}^{S} Pi.Ln(Pi)$$

Where S is the total number of species, and pi is the proportion of individuals of species i (pi = ni/N). Interpretation: H' < 1 (low diversity), 1 < H' < 3 (moderate diversity), and H' > 3 (high diversity).

Simpson's Dominance Index (D): Calculated to determine whether or not there is dominance by a particular bird species. The value of D ranges from 0 to 1. If the value is close to 0, then no species is dominant (low dominance).

$$H' = \sum_{i=1}^{S} \frac{ni(ni-1)}{N(N-1)}$$

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Where ni is the number of individuals of species i and N is the total number of individuals. If the value is close to 1, it indicates strong dominance (low diversity). A value close to 0 indicates low dominance (high diversity).

Evenness Index (E): Used to determine the level of evenness of individuals between species. The E value ranges from 0 to 1. A value close to 1 indicates that the number of individuals between species is evenly distributed (stable community).

$$E = \frac{H'}{H'max} = \frac{H'}{Ln(S)}$$

Conservation Status: The conservation status of bird species is evaluated based on the Regulation of the Minister of Environment and Forestry (PERMENLHK, 2018) No. P.106/MENLHK/SETJEN/KUM.1/12/2018. Global threat status refers to the International Union for Conservation of Nature (IUCN) Red List, as well as trade status according to the CITES convention.

The data were described in tables and figures, without inferential statistical test. The comparison of species conservation status within our study site was compared to those neighbouring Mt. Ungaran (Huril'in et al., 2025) and Semarang Urban Forest (Naim et al., 2019).

RESULTS AND DISCUSSION

Bird diversity and abundance

Based on observations conducted at the five stations in the Wanadipa Forest Management Unit in February, 26 bird species from various families were found, with a total of 133 individuals encountered. Complete data on bird species, number of individuals, proportions, and diversity index calculations are presented in **TABLE 1.** The abundance analysis results in **TABLE 1** show that the dominant bird species at the study site was the cave swiftlet *(Collocalia linchi)* with 25 individuals, followed by the sooty-headed bulbul *(Pycnonotus aurigaster)* with 17 individuals, the small minivet *(Pericrocotus cinnamomeus)* with 14 individuals, and the scarlet-headed flowerpecker *(Dicaeum trochileum)* with 14 individuals. The high number of encounters with aerial insectivores, such as the cave swiftlet, was recorded as they actively foraged within the open airspace and canopy gaps of the agroforestry rehabilitation zone, rather than merely passing high above the canopy. While the river flow provides an abundant source of flying insects, the presence of swiftlets is also strongly driven by this open habitat structure, which accommodates species tolerant of modified or edge habitats. On the other hand, the presence of nectarivorous and frugivorous species indicates that the mixed vegetation in the agroforestry area and forest edge is able to provide food in the form of nectar and fruit.

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TABLE 1. Summary of species diversity data and individual proportions at the Wanadipa Forest Management Unit in Semarang

No.	Scientific name	English name	Abundance
1	*Artamus leucorynchus*	White-breasted woodswallow	11
2	*Cacomantis merulinus*	Plaintive cuckoo	1
3	*Cacomantis sonneratii*	Banded bay cuckoo	1
4	*Cecropis daurica*	Red-rumped swallow	1
5	*Centropus bengalensis*	Lesser coucal	2
6	*Collocalia linchi*	Cave swiftlet	25
7	*Crypsirina temia*	Racquet-tailed treepie	1
8	*Cynniris ornatus*	Ornate sunbird	4
9	*Dicaeum trochileum*	Scarlet-headed flowerpecker	14
10	*Halcyon cyanoventris*	Javan kingfisher	6
11	*Hemiprocne longipennis*	Grey-rumped treeswift	10
12	*Hemipus hirundinaceus*	Black-winged flycatcher-shrike	1
13	*Hirundo javanica*	House swallow	1
14	*Hydrornis guajanus*	Javan banded pitta	1
15	*Lonchura leucogastroides*	Javan munia	3
16	*Malacocincla sepiaria*	Horsfield's babbler	1
17	*Nisaetus bartelsi*	Javan hawk-eagle	1
18	*Orthotomus sutorius*	Common tailorbird	5
19	*Pellorneum capistratum*	Rufous-browed babbler	2
20	*Pericrocotus cinnamomeus*	Small minivet	14
21	*Pernis ptilorhynchus*	Oriental honey-buzzard	3
22	*Pycnonotus aurigaster*	Sooty-headed bulbul	17
23	*Pycnonotus goiavier*	Yellow-vented bulbul	1
24	*Rubigula dispar*	Ruby-throated bulbul	3
25	*Spilornis cheela*	Crested serpent-eagle	3
26	*Todiramphus chloris*	Collared kingfisher	1
		Total	**133**

This is supported by Firmansyah et al. (2025) and Hutami et al. (2022) who state that complex habitats characterised by a wide variety of vegetation are directly proportional to the high availability of food and habitat niches, thereby increasing the carrying capacity of the environment for the survival of various bird species. Furthermore, the presence of the sooty-headed bulbul group in this area confirms the ecological role (food guild) of birds as natural seed dispersers, which are essential for the regeneration of secondary forest vegetation.

TABLE 2. Ecological parameters of avifauna in the wanadipa protected forest area

Ecological parameter	Research education block	Agroforestry rehabilitation zone
Total Individual Abundance (N)	85	48
Diversity Index (H')	2.48	2.51
Dominance Index (D)	0.12	0.11
Evenness Index (E)	0.83	0.87

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This study also recorded 11 bird species that were only encountered once (1 individual) during the observation period. These species include the Javan banded pitta, racquet-tailed treepie, and Javan hawk-eagle. The low encounter rate for these species is related to their specific ecological and behavioural characteristics, such as the cryptic nature of the pittas in dense understory shrubbery, as well as the vast territorial range requirements for apex predators like the Javan hawk-eagle.

Diversity and abundance of the area's avifauna

Based on field observations in the KHDTK Wanadipa, the structure of the avifaunal community was analysed to evaluate the effectiveness of the area's zoning. A comparison of ecological parameters is presented in **TABLE 2**.

Analysis of ecosystem factors on diversity levels

Based on the calculations, the level of bird diversity in both blocks falls into the medium category (H' 24.8 and 2.51). From an ecosystem perspective, this medium level of diversity arises from the interaction of four main factors: geography, climate, vegetation, and human activity. Geographically, the KHDTK Wanadipa is situated on the slopes of Mt. Ungaran, creating topographical variation and providing a diverse gradient of microhabitats. Climatically, the data collection carried out in February coincided with the peak of the tropical rainy season, which physiologically triggers mass flowering and fruiting in the vegetation, resulting in an abundance of energy available for the avifauna.

In terms of vegetation, the presence of a multi-layered canopy in the research block (dominated by mahogany and rosewood) provides vertical niches for forest- specialist birds, whilst Multi-Purpose Tree Species (MPTS) such as guava and trengguli in the rehabilitation zone provide sources of nectar and fruit. As for human activities, Wanadipa's status as an educational forest limits large-scale exploitation and disturbance. However, silvicultural interventions involving land clearing in the agroforestry zone have transformed this area into a secondary forest ecosystem and a modified landscape, rather than a primary forest with climax succession. Consequently, the resulting habitat heterogeneity supports a stable, moderate level of bird diversity, as the species present comprise a mix of open-habitat-tolerant species and secondary-forest-adapted species. This is supported by a study by (Purnamaningrum et al., 2021), which states that the fragmented landscape in the Mt. Ungaran area is highly dependent on secondary vegetation cover to maintain animal diversity at a stable level.

Species composition and absence of dominance

One of the most crucial ecological findings in this study is the very low Simpson's Dominance Index values in both zones (D = 0.11 and 0.12). When analysed using descriptive statistical methods, certain bird species were encountered with very high frequencies, such as the cave swiftlet *(Collocalia linchi)* with 25 individuals and the golden-cheeked bulbul *(Pycnonotus aurigaster)* with 17 individuals. Although these two

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species were abundant in terms of numbers, they did not dominate the community structure ecologically.

This lack of dominance occurs because *Collocalia linchi* and *Pycnonotus aurigaster* do not monopolise spatial and food resources (competitive exclusion). The cave swiftlet is an exclusive aerial insectivore in open airspace due to human activities that create canopy-free areas within the agroforestry zone. On the other hand, the brown-eared bulbul exploits fruits within the canopy of the MPTS. These specific ecological niches leave other niches vacant and open to being occupied by species of significant numbers, such as the small minivet *(Pericrocotus cinnamomeu*s), which forages for caterpillars on branches, and the ornate sunbird *(Cinnyris ornatus),* which feeds on nectar. This is supported by research by (Surur & Purnamaningrum, 2020), which confirms that the absence of dominance reflects an excellent ecosystem equilibrium, where variations in food and vegetation structure allow for the proportional utilisation of natural resources by various taxa.

Species evenness

The stability of the avifaunal community in the KHDTK Wanadipa is validated by the high Evenness Index (E = 0.83 – 0.87). By definition, evenness in this context refers to the distribution of individuals being proportionately and evenly distributed amongst the 26 species found. This high evenness value is likely rooted in the high availability of niche partitioning resulting from the presence of the ecotone phenomenon (the interface between dense secondary forest and open agroforestry).

This mechanism of evenness can be explained through the functional composition (feeding groups/guilds) of birds within the Wanadipa ecosystem. This complex habitat provides energy for many functional groups simultaneously. Apex predator species such as the Javan hawk-eagle utilise the dense canopy of mahogany to monitor prey; nectarivorous and frugivorous species exploit guava in agroforestry areas; whilst cryptic insectivores such as the five-coloured Javan banded pitta hunt in the damp forest floor litter. This view is strongly supported by the study by (Hutami et al., 2022), which demonstrates that habitats with varied vegetation cover and managed landscape modifications are directly proportional to the abundance of food variety. These conditions prevent detrimental interspecific competition, thereby maintaining the stability of food webs and ensuring that community evenness remains at a highly optimal level. Further support is provided by (Aryanti et al., 2021), who confirm that the dense canopy structure of secondary forests constitutes an absolute niche that ensures the survival of top-level predator groups, which ultimately contributes to the evenness of the food pyramid in the area.

Conservation status

The analysis of bird presence in the KHDTK Wanadipa was integrated with legal and conservation status to support protection policies. Based on the data obtained, there are nine bird species that are protected under Regulation of the Minister of Environment

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and Forestry No. P.106 of 2018. Details of the conservation status of each species are presented in **TABLE 3**.

TABLE 3. Conservation Status of Bird Species in the Wanadipa Forest Management Unit Based on PermenLHK P.106/2018, the IUCN Red List, and CITES

No	Scientific name	English name	P.106/2018 Status	IUCN Status	CITES Status
1	*Artamus leucorynchus*	white-breasted woodswallow	-	LC	-
2	*Cacomantis merulinus*	plaintive cuckoo	-	LC	-
3	*Cacomantis sonneratii*	banded bay cuckoo	-	LC	-
4	*Cecropis daurica*	red-rumped swallow	-	LC	-
5	*Centropus bengalensis*	lesser coucal	-	LC	-
6	*Collocalia linchi*	cave swiftlet	-	LC	-
7	*Crypsirina temia*	racquet-tailed treepie	Protected	LC	-
8	*Cinnyris ornatus*	ornate sunbird	-	LC	-
9	*Dicaeum trochileum*	scarlet-headed flowerpecker	-	LC	-
10	*Halcyon cyanoventris*	Javan kingfisher	-	LC	-
11	*Hemiprocne longipennis*	grey-rumped treeswift	-	LC	-
12	*Hemipus hirundinaceus*	black-winged lycatcher-shrike	-	LC	-
13	*Hirundo javanica*	house swallow	-	LC	-
14	*Hydrornis guajanus*	Javan banded pitta	Protected	LC	-
15	*Lonchura leucogastroides*	Javan munia	-	LC	-
16	*Malacocincla sepiaria*	Horsfield's babbler	-	LC	-
17	*Nisaetus bartelsi*	Javan hawk-eagle	Protected	EN	Appendix II
18	*Orthotomus sutorius*	common tailorbird	-	LC	-
19	*Pellorneum capistratum*	rufous-browed babbler	-	LC	-
20	*Pericrocotus cinnamomeus*	small minivet	-	LC	-
21	*Pernis ptilorhynchus*	oriental honey-buzzard	Protected	LC	Appendix II
22	*Pycnonotus aurigaster*	sooty-headed bulbul	-	LC	-
23	*Pycnonotus goiavier*	yellow-vented bulbul	-	LC	-
24	*Rubigula dispar*	ruby-throated bulbul	-	VU	-
25	*Spilornis cheela*	crested serpent-eagle	Protected	LC	Appendix II
26	*Todiramphus chloris*	collared kingfisher	-	LC	-

(Note: LC = Least Concern; VU = Vulnerable; EN = Endangered).

On **TABLE 3**, the five bird species protected by PermenLHK P.106/2018 consist of predatory birds (Javan hawk-eagle, crested serpent-eagle, oriental honey- buzzard), as well as other species such as the five-coloured Javan banded pitta and the racquet-tailed treepie. In addition to being protected nationally, the Javan hawk-eagle (*Nisaetus bartelsi*) is also classified as endangered according to the IUCN status. Although not a protected

DOI: 10.21009/bioma.v22i1.66678

species under national law, the ruby-throated bulbul (*Rubigula dispar*) is classified as vulnerable due to high pressure from illegal hunting for the pet bird trade. The presence of these bird species with important conservation status shows that the research education block and rehabilitation zone in the KHDTK Wanadipa play a crucial role in providing a suitable corridor and habitat for rare fauna in the ecological Semarang region in Central Java. Specifically for the conservation of apex predators, this is supported by various scientific studies (Luthfi et al., 2020; Aryanti et al., 2021; Febryan et al., 2024), proving that the Javan hawk-eagle species is highly dependent on the availability of dense canopy cover in primary and secondary forest habitats as a place to hide, build nests on high branches, and as a lookout post to support its hunting activities.

(a) (b) (c)

FIGURE 2. Visual documentation of species encounters; (a) *Nisaetus bartelsi*; (b) *Spilornis cheela*; (c) *Pernis ptilorhynchus*

FIGURE 2 shows empirical evidence that successfully recorded the soaring activity of one individual apex raptor, namely the Javan hawk-eagle (*Nisaetus bartelsi*) above the canopy of the KHDTK Wanadipa. The presence of this endangered bird is crucial for the balance of the forest food chain. This is supported by a study (Aryanti et al., 2021) which states that the Javan hawk-eagle uses both primary and secondary forest landscapes as habitats to facilitate its hunting activities.

Global conservation value and ecological buffer function

To further contextualise the conservation urgency of the KHDTK Wanadipa as a ecological buffer zone, it is essential to compare its avifaunal composition with adjacent landscapes across an urbanisation and elevation gradient. **FIGURE 3** illustrates the comparison of total species richness and the number of globally threatened or CITES-regulated species between highly modified urban forests in Semarang City (Naim et al., 2019), the transitional habitat of the KHDTK Wanadipa, and the natural primary forest edges of Mt. Ungaran (Huril et al., 2025). KHDTK Wanadipa records 26 bird species, a value intermediate between the urban forests of Semarang City (48 species) and the larger forest complex of Mt. Ungaran (34 species), reflecting its transitional position along both spatial and ecological gradients. Despite its smaller area, Wanadipa supports four conservation-important species, a proportion that is notably closer to Mt. Ungaran (six species) than to the urban forest landscape, suggesting stronger ecological affinity with montane forest systems.

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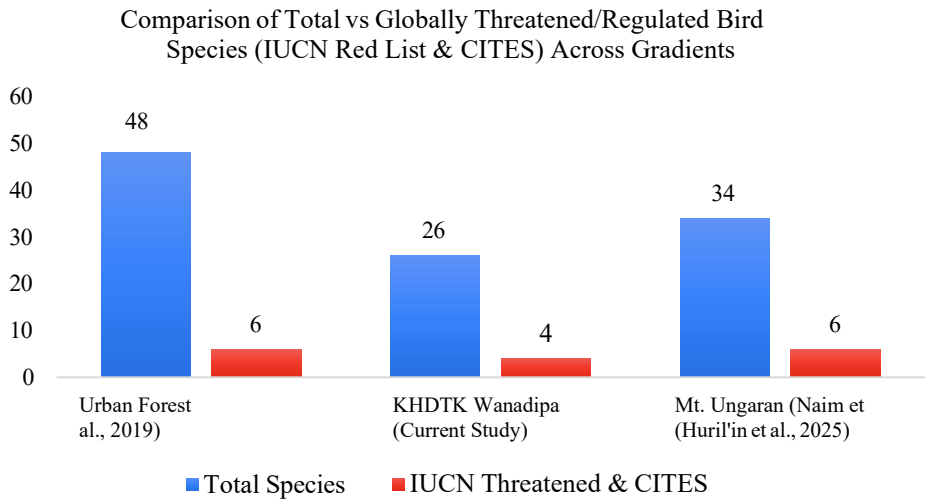

FIGURE 3. Comparison of total species and globally threatened/regulated bird species (IUCN & CITES)

As seen in **FIGURE 3**, urban forests naturally exhibit the highest total species richness (48 species) as they are influenced by a wide variety of vegetation and human-modified open spaces (Naim et al., 2019). However, an in-depth ecological review reveals that this high number in the urban area is heavily inflated by generalist wetland birds exploiting river basins and escaped cage birds, such as the critically endangered Bali myna (*Leucopsar rothschildi*), which do not establish functional wild populations in such areas. In contrast, the lower but more structurally representative species richness of KHDTK Wanadipa reflects a filtering effect typical of buffer habitats, where only species capable of utilising semi-natural forest mosaics persist. This filtering process reinforces the role of Wanadipa as a selective dispersal stepping-stone rather than a biodiversity sink dominated by opportunistic urban exploiters.

In contrast, the globally threatened and CITES-regulated species found in the KHDTK Wanadipa (4 species) and the natural forests of Mt. Ungaran (6 species) (Huril et al., 2025) portray an authentic, self-sustaining terrestrial forest ecosystem. The protected fraction in KHDTK Wanadipa consists exclusively of naturally occurring apex forest predators, such as the Javan hawk-eagle (*Nisaetus bartelsi*) and oriental honey-buzzard (*Pernis ptilorhynchus*), alongside the vulnerable ruby-throated bulbul (*Rubigula dispar*).

The close similarity in conservation-important species composition between Wanadipa and Mount Ungaran is likely facilitated by their geographical proximity, enabling repeated dispersal events and functional connectivity between the two forested landscapes. Such proximity enhances the role of KHDTK Wanadipa in maintaining avian gene flow, particularly for forest-dependent and low-density species whose long-term persistence depends on connected habitat networks.

Therefore, the presence of these authentic globally threatened species definitively proves Wanadipa's success as an ecological buffer. It does not merely serve as an isolated

DOI: 10.21009/bioma.v22i1.66678

green space, but functions actively as a vital sanctuary and ecological corridor. It provides sufficient carrying capacity to safely buffer the rich biodiversity stronghold of Mt. Ungaran from the expanding anthropogenic pressures of the heavily urbanised lowlands below. In this context, KHDTK Wanadipa acts as a biological interface between the montane ecosystems of Mount Ungaran and the fragmented green spaces of Semarang City, mitigating isolation effects and sustaining landscape-scale avian connectivity across the urban–forest continuum.

CONCLUSIONS

Twenty six bird species with a total abundance of 133 individuals were recorded in the KHDTK Wanadipa. The ecological indices indicate a stable and balanced avifaunal community, characterised by a moderate diversity index in both the research education block (H' = 2.48) and the agroforestry rehabilitation zone (H' = 2.51), accompanied by very low dominance (D = 0.11 - 0.12) and high species evenness (E = 0.83 - 0.87). From a conservation perspective, the area successfully supports five legally protected species under Indonesian law, including globally threatened and CITES- regulated apex predators such as the endangered Javan hawk-eagle *(Nisaetus bartelsi)* and the oriental honey-buzzard *(Pernis ptilorhynchus).* The ability of this relatively small secondary forest to sustain such authentic, high- value conservation species confirms its critical function as an ecological buffer. The KHDTK Wanadipa does not merely serve as an isolated green space, but actively operates as a vital sanctuary and transitional corridor. It effectively bridges the ecological gap and safely buffers the rich biodiversity stronghold of Mt. Ungaran from the expanding anthropogenic pressures of the heavily urbanised lowlands of Semarang.

AUTHOR CONTRIBUTIONS

M.L.M , F.M., J.W.H.: project conception; M.L.M., F.M.: methodology; M.L.M., J.W.H..: data analyses; M.L.M.: original manuscript draft; J.W.H., S.P., K.: manuscript review and editing.

ACKNOWLEDGMENTS

The author would like to thank the leadership of Diponegoro University and the management of KHDTK Wanadipa for granting permission and providing facilities for the research, as well as the communities of Susukan and Mluweh villages for supporting the smooth collection of data in the field.

CONFLICTS OF INTEREST STATEMENT

There are no conflicts to declare.

ETHICAL COMPLIANCE

This research was conducted objectively based on field data without any financial or commercial conflicts of interest with any party. The process of collecting bird

DOI: 10.21009/bioma.v22i1.66678

population data was carried out using remote observation (non-invasive) methods that fully complied with the principles of wildlife conservation ethics.

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