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# Songbird diversity and poaching pressure in Biha Resort, Bukit Barisan Selatan National Park, Sumatra, Indonesia

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**Abstract.** *Cahyani AF, Master J, Septiadi L, Nurcahyani N, Surya RA, Marthy W. 2025. Songbird diversity and poaching pressure in Biha Resort, Bukit Barisan Selatan National Park, Sumatra, Indonesia. Biodiversitas 26: 6447-6457.* Bird diversity in Sumatra, Indonesia, is increasingly threatened by poaching, yet comprehensive data remain limited, especially in key conservation areas such as Biha Resort within Bukit Barisan Selatan National Park (BBSNP). This study provides a baseline assessment of bird diversity, species composition, and population density across three monitoring sites in Biha Resort, an area previously prone to bird poaching, conducted in July 2024 using the point count method. Analyses included survey completeness, diversity indices (Shannon-Wiener H', Simpson D, Pielou's E), and Hutcheson's *t*-test to compare sites, while distance sampling was used to estimate density. A total of 69 species were recorded, with survey completeness of 73.4%. Diversity indices varied across sites, with significant differences between site A and the others ($p<0.05$). Overall values were H': 3.792, E: 0.896, and D: 0.030, indicating healthy habitat conditions capable of supporting rich variety of bird species. Songbirds dominated the community, and only 12 species had measurable density, with *Arachnothera longirostra* being the most abundant. As a baseline, this survey provides essential reference data for long-term monitoring of bird populations. Continued monitoring is needed to evaluate the effectiveness of an Integrated Prevention Model designed to reduce poaching pressure and support bird conservation in the region.

**Keywords:** Conservation intervention, distance sampling, diversity index, point count method, songbird exploitation

## INTRODUCTION

Poaching and wildlife trade remain among the most serious threats to biodiversity conservation in Southeast Asia, particularly in Indonesia, where the demand for wild-caught birds has led to what is now termed a regional "songbird crisis" (Gill and Prum 2019; Marshall et al. 2020; Chavan et al. 2023; Goboro et al. 2025). The strong cultural preference for keeping caged birds, combined with weak law enforcement, has driven unsustainable extraction of wild populations across many islands (Burivalova et al. 2017; Indraswari et al. 2020; Putri et al. 2024). As a result, large-scale trapping for the bird trade has caused severe population declines, with Sumatra emerging as a major source to supply markets in Java (Chng et al. 2015, 2016, 2018; Harris et al. 2015; Chng and Eaton 2016). Between 2018 and 2021, authorities intercepted the illegal transport of more than 158,000 wild-caught birds from Sumatra to Java (Indonesia) (Guciano et al. 2023), highlighting the scale of the crisis and the urgent need for stronger conservation interventions.

Amid these pressures, Bukit Barisan Selatan National Park (BBSNP), Sumatra, stands as one of the most critical strongholds of biodiversity in Sumatra, harboring approximately 122 mammal species, 450 bird species, 53 fish species, and 91 reptile and amphibian (Surya et al. 2020). As part of the largest remaining lowland tropical rainforest on the island, BBSNP provides essential habitat for numerous forest-dependent species (Pusparini et al. 2018; Allen et al. 2020). The management of BBSNP is implemented through a zoning system, which serves multiple functions including research, scientific development, education, cultivation support, tourism, and recreation (Surya et al. 2020).

Although BBSNP has been the focus of several biodiversity studies, research coverage across its 17 management resorts remains uneven. Among these, Biha Resort, located on the park's southwestern landscape, has received limited attention despite its high ecological importance. Approximately 73% of Biha Resort in BBSNP, is designated as a core conservation zone that serves as critical habitat for flagship species such as the Sumatran tiger (*Panthera tigris sumatrae*), Sumatran rhino (*Dicerorhinus sumatrensis*), and Sumatran elephant (*Elephas maximus sumatranus*). The surrounding buffer areas support agroforestry, agriculture, and resin collection from dammar trees, linking local community livelihoods directly to forest resources (Arimbi et al. 2021; Mardiyanto et al. 2024). In addition to the elongated shape of the BBSNP area facilitating access for anthropogenic activities, this human-forest interface creates both ecological opportunities and conservation challenges, particularly related to wildlife poaching and land encroachment (Gaveau et al. 2009; Pusparini et al. 2018).

Recognizing the significance of the Biha Resort area as a habitat for three rare species of wildlife, an assessment of bird diversity is essential. Birds are one type of wildlife whose diversity can be measures, are relatively easy to observe, and, play a key ecological role as bioindicators sensitive to anthropogenic disturbance, making them valuable for monitoring environmental change and guiding conservation management (Tarjuelo et al. 2015; Kiros et al. 2018; Thongsoulin et al. 2019; Li et al. 2021). Credible information regarding wildlife populations and the threats affecting them is vital for evaluating conservation effectiveness (Pusparini et al. 2018).

Previous assessments by BBSNP and Wildlife Conservation Society-Indonesia Program (WCS-IP) (unpublished) revealed intensive bird poaching (mostly songbird) activity in Biha Resort, identifying three primary poaching hotspots and 26 individuals involved in illegal bird capture. In response, the park authority and local organizations have initiated area and social management interventions through an Integrated Prevention Model that combines law enforcement, community engagement, and livelihood diversification. However, the ecological response of bird communities to these ongoing interventions remains unknown, and baseline data on bird diversity are lacking.

To address this gap, this study provides a baseline assessment of bird diversity, species composition, and population density in Biha Resort. The findings serve as essential reference data for future monitoring to evaluate the effectiveness of ongoing management interventions aimed at reducing poaching pressure and strengthening evidence-based bird conservation strategies in BBSNP.

## MATERIALS AND METHODS

### Study area

This study was conducted in Biha Resort, located within Bukit Barisan Selatan National Park (BBSNP), Sumatra, Indonesia. The resort covers approximately 19,862 ha, with a boundary length of ~28 km and elevations ranging from 70 to 600 m above sea level. Biha Resort holds high conservation value, with 49 recorded species of woody plants and diverse fauna, including endangered primates such as the siamang (*Symphalangus syndactylus*), agile gibbon (*Hylobates agilis*), and southern mitered langur (*Presbytis mitrata*).

Recent monitoring data indicate that at least three individuals of the Sumatran tiger (*P. t. sumatrae*) persist within the Biha landscape, suggesting that the forest ecosystem remains relatively intact. Although large-scale deforestation has been effectively halted in recent years, the area continues to face serious threats from intensive bird poaching, particularly targeting songbirds for the wildlife trade. Evidence of active poaching, including snares, lime sticks, and decoy traps, was documented between 2020 and 2023, and the three priority monitoring sites were determined based on the intensity of these poaching activities (Balai Besar BBSNP and WCS-IP 2023, unpublished). These three sites share similar ecological characteristics, consisting mainly of lowland primary forest dominated by Dipterocarpaceae species. Bird surveys were conducted at 18 fixed point count stations distributed across these monitoring sites (Figure 1).

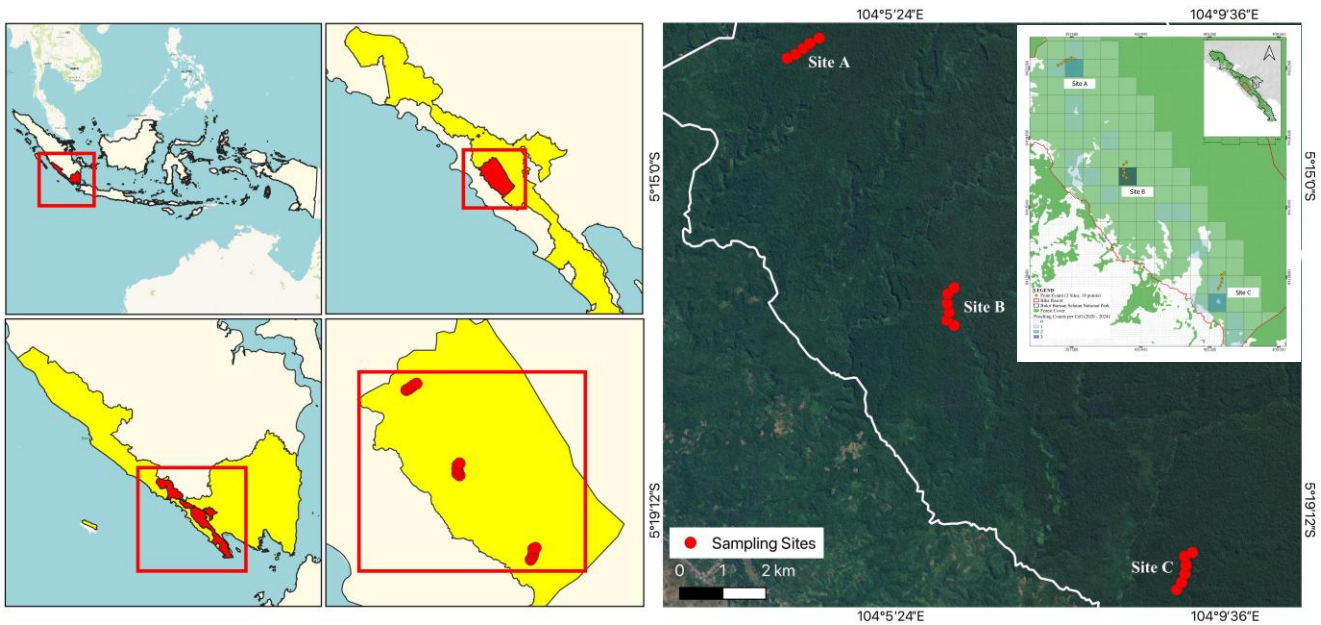


**Figure 1.** Map of the study area showing the three monitoring sites with a total of 18 bird observation points within Biha Resort, Bukit Barisan Selatan National Park (BBSNP), Sumatra, Indonesia. The map also illustrates the spatial distribution of bird poaching records documented between 2020 and 2023, based on data from the BBSNP and Wildlife Conservation-Society Indonesia Program (WCS-IP) (unpublished)

**Sampling**

*Data collection*

Field surveys were conducted in July 2024 across three study sites within Biha Resort. Site selection was based on four criteria: (i) accessibility in the field, (ii) habitat condition, (iii) representation of local ecosystem diversity, and (iv) the presence of signs of bird poaching. At each site, six observation points were established using GPS, spaced 200 m apart to minimize the risk of double counting (Bibby et al. 2000).

Bird observations were carried out between 06:30 and 11:00 a.m., corresponding to peak bird activity and taking into account the challenging terrain. Each point was observed for 15 minutes and revisited twice on separate days along the same route (Nugroho et al. 2023). All birds seen or heard were recorded to maximize species detection.

Vocal identifications were verified by comparing field-recorded calls with reference recordings from online databases (e.g., xeno-canto.org) and through consultation with avian experts. Visual identifications were aided by binoculars, and species names followed the field guide by MacKinnon et al. (2010).

For each observation, the following data were recorded: species name (categorized as songbird or non-songbird), weather condition, time of encounter, detection method (visual or aural), radial distance from observer to bird, and the number of individuals detected.

*Definition of songbird*

Bird identification in this study follows the most current taxonomy based on geographic distribution, as referenced in Avibase: The World Bird Database (Lepage 2025). Songbirds are taxonomically defined as members of the suborder Passeri (Latin: Oscines) within the order Passeriformes. To ensure consistency and avoid categorization bias, all species and families are classified according to the IOC World Bird List version 15.1 (Gill et al. 2024). Oscines, or songbirds, are distinguished from other passerines (suborder Tyranni or suboscines) primarily by the greater number and complexity of their syringeal muscles, which enable the production of more elaborate vocalizations (Catchpole and Slater 2008; Austin et al. 2024). Due to this advanced vocal ability, oscines are commonly referred to as "true songbirds."

In addition to formal taxonomic classification, this study also adopts a broader, culturally relevant definition of songbirds. This includes bird species that are traditionally regarded as songbirds by local bird enthusiasts and are commonly targeted in the songbird trade or for aviculture purposes in the region. This inclusive approach provides a more context-specific understanding of songbird diversity and reflects the conservation relevance of species vulnerable to poaching.

**Data analysis**

All bird species recorded during the survey were compiled into a database that included taxonomic information (family and species) and conservation status based on three references: (i) the International Union for Conservation of Nature (IUCN) Red List, (ii) the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and (iii) national regulations. The latter refers to the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. P.106/MENLHK/SETJEN/KUM.1/12/2018, which is the second amendment to Regulation No. P.20/MENLHK/SETJEN/KUM.1/6/2018 concerning protected plant and animal species. The data analyses involved the following steps.

*Survey completeness*

Data from 18 observation points (each with two replicates) were analyzed to evaluate survey completeness. The analysis followed the method of Marthy et al. (2017), comparing observed species richness ($S_{obs}$) with estimated species richness ($S_{est}$) derived from species abundance data. Four richness estimators were used: Chao1, Jackknife1, Jackknife2, and Bootstrap.

Survey completeness (%) was calculated as the ratio of $S_{obs}$ to the mean $S_{est}$ value. A species accumulation curve with a 95% confidence interval was also generated to visualize detection trends and estimate potential species richness beyond observed data. This analysis provided a quantitative measure of sampling adequacy, the likelihood of undetected species, and the potential for increasing species records with additional sampling effort. All analyses and visualizations were performed using R software (version 4.3.3).

*Shannon-Wiener Diversity Index*

The Shannon-Wiener Diversity Index (H') was calculated using the formula described in Magurran (1988):

$$H' = -\sum_{i=1}^{S} [pi \ln pi]$$

Where, H': Shannon-Wiener Diversity Index, pi: Proportion of individuals of the *i*-th species relative to the total number of individuals (calculated as ni/N), ni: Number of individuals of the *i*-th species, and N: Total number of individuals of all species. Based on the classification proposed by Sidomukti and Wardhana (2021), the criteria for interpreting H' values are as follows: low diversity: H'≤1, moderate diversity: 1<H'<3, high diversity: H'≥3. To assess whether differences in bird diversity among the three priority monitoring sites were statistically significant, Hutcheson's *t*-test was applied (Hutcheson 1970).

*Pielou Evennes Index*

The Pielou evenness index (E) was calculated using the formula provided in Magurran (1988):

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

Where, E: Pielou's evennes index, H': Shannon-Wiener Diversity Index, and S: Total number of species observed. This index measures how evenly individuals are distributed among the recorded species. According to Adelina et al. (2016), the evenness index is interpreted using the following criteria: Stable community: 0.75<E≤1, Unstable

community: 0.5 < E ≤ 0.75, and Depressed community: 0<E≤0.5. A higher E value indicates a more balanced distribution of individuals among species, suggesting better ecological stability.

*Simpson Dominance Index*

The Simpson Dominance Index (D) was calculated following Magurran (1988):

$$D = \sum_{i-1}^{s} \frac{ni}{N}^2$$

Where, D: Simpson Dominance Index, ni: Number of individuals of species *i*, and N: Total number of individuals recorded. This index measures the degree to which a community is dominated by one or a few species. According to Magurran (1988), the index value ranges from 0 to 1. A value close to 0 indicates no dominant species (greater community balance), while a value close to 1 indicates strong dominance by one species, suggesting ecological imbalance or disturbance.

*Composition and population density*

Bird abundance was visualized through a bar graph ranking species from most to least abundant based on the number of individuals. Bird population density was estimated using Distance software (Thomas et al. 2010). Density estimation models included uniform, half-normal, and hazard-rate functions with adjustment terms (cosine, simple polynomial, hermite polynomial) following Buckland et al. (2001) and Buckland (2006). To improve model fit, right truncation and interval grouping were applied when radial distance data showed irregularities, ensuring a monotonic detection curve. The best model was selected using Chi-square goodness-of-fit and the lowest Akaike Information Criterion (AIC) value. When ΔAIC<2, the final model was chosen by comparing detection curves, fit statistics, and the percentage coefficient of variation (% CV) of the density estimate (individuals/hectare±% CV).

Data processing and visualization were performed in RStudio (R Core Team 2021) using packages: dplyr (Wickham et al. 2023), tidyverse (Wickham et al. 2019), ggplot2 (Wickham 2016), vegan (Oksanen et al. 2025), and moonBook (Moon 2015).

## RESULTS AND DISCUSSION

### Species diversity and survey completeness

Surveys conducted across the three primary forest monitoring sites recorded a total of 69 bird species representing 32 families (Table 1). Overall, Biha Resort exhibited high species diversity (H': 3.792), with a high evenness index (E: 0.896) and low dominance (D: 0.030), suggesting relatively stable habitat conditions capable of supporting a rich bird community. However, species diversity varied among sites (Table 2). Hutcheson's *t*-test revealed that Site A had a Shannon-Wiener Diversity Index (H') significantly different from those of Sites B and C, whereas no significant difference was found between Sites B and C (Table 3).

Survey completeness analysis ($S_{obs}$: 69, $S_{est}$: 93.9) indicated that approximately 73.4% of the estimated total species richness was recorded. The species accumulation curve (Figure 2) continued to increase with additional sampling effort, suggesting that several species likely remained undetected. This is further supported by opportunistic observations made outside the standardized survey period, such as the detection of the red-and-black trogon (*Harpactes kasumba*). These results indicate that the reported species list may not yet represent the full avifaunal richness of Biha Resort, BBSNP.

### Composition of birds

The bird community at Biha Resort was dominated by songbirds (41 species) compared to non-songbirds (28 species) (Figure 3). The predominance of songbirds further supports the evidence of intensive songbird poaching observed at the three priority monitoring sites, as spatially illustrated in Figure 2.

### Bird density estimates

Of the total species recorded, only 12 met the criteria for density estimation, indicating low detection rates for the remaining 57 species. Seven of these 12 species yielded reliable density estimates, as reflected by Coefficient of Variation (CV) values below 40% (Ardiantiono et al. 2020). To meet the encounter threshold (≥10 individuals) and accurately estimate detection probability, data from all survey sites were pooled (Marthy et al. 2016). The resulting density estimates (Table 4, Figure 4) provide a robust baseline for statistical comparison with future surveys and are essential for assessing population trends and evaluating the effectiveness of conservation interventions at Biha Resort, BBSNP.

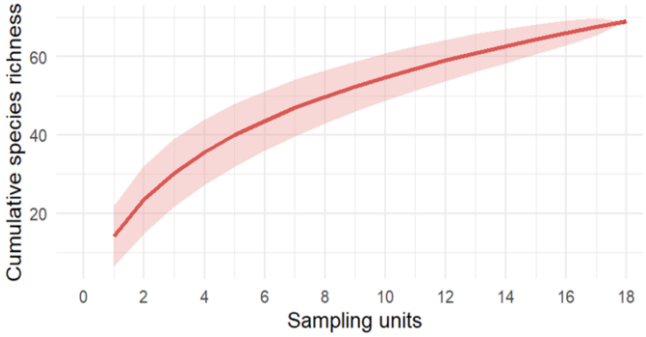


**Figure 2.** Species accumulation curve of birds recorded at three priority monitoring sites in Biha Resort, Bukit Barisan Selatan National Park, Sumatra, Indonesia, based on 18 observation points

**Table 1.** Bird species recorded at three priority monitoring sites in Biha Resort, Bukit Barisan Selatan National Park, Sumatra, Indonesia, including their conservation status based on IUCN Red List, CITES, and Indonesian national regulation (P.106)

| Family | Scientific name | Common name | Species presence | | | Conservation status | | |
|---|---|---|---|---|---|---|---|---|
| | | | Site A | Site B | Site C | IUCN | CITES | P.106 |
| Aegithinidae | *Aegithina viridissima* | Green Iora | ✓ | - | ✓ | NT | NA | NP |
| Alcedinidae | *Ceyx rufidorsa* | Rufous-backed Dwarf Kingfisher | ✓ | - | - | LC | NA | NP |
| Alcippeidae | *Alcippe brunneicauda* | Brown Fulvetta | ✓ | ✓ | ✓ | NT | NA | NP |
| Bucerotidae | *Anorrhinus galeritus* | Bushy-crested Hornbill | - | - | ✓ | NT | II | P |
| | *Buceros rhinoceros* | Rhinoceros Hornbill | - | - | ✓ | VU | II | P |
| | *Rhinoplax vigil* | Helmeted Hornbill | - | ✓ | - | CR | I | P |
| Calyptomenidae | *Calyptomena viridis* | Green Broadbill | ✓ | - | - | NT | NA | NP |
| Chloropseidae | *Chloropsis cyanopogon* | Lesser Green Leafbird | ✓ | ✓ | ✓ | NT | NA | P |
| | *Chloropsis moluccensis* | Blue-winged Leafbird | ✓ | - | ✓ | LC | NA | P |
| Cisticolidae | *Orthotomus atrogularis* | Dark-necked Tailorbird | ✓ | ✓ | ✓ | LC | NA | NP |
| | *Orthotomus sericeus* | Rufous-tailed Tailorbird | - | ✓ | - | LC | NA | NP |
| Columbidae | *Treron capellei* | Large Green Pigeon | ✓ | - | - | VU | NA | NP |
| Corvidae | *Platysmurus leucopterus* | Malayan Black Magpie | - | ✓ | - | LC | NA | P |
| Cuculidae | *Cacomantis merulinus* | Plaintive Cuckoo | ✓ | - | - | LC | NA | NP |
| | *Cacomantis sonneratii* | Banded Bay Cuckoo | ✓ | - | ✓ | LC | NA | NP |
| | *Phaenicophaeus diardi* | Black-bellied Malkoha | ✓ | - | - | NT | NA | NP |
| | *Rhinortha chlorophaea* | Raffles's Malkoha | ✓ | ✓ | ✓ | LC | NA | NP |
| | *Surniculus lugubris* | Square-tailed Drongo-Cuckoo | - | - | ✓ | LC | NA | NP |
| Dicaeidae | *Dicaeum trigonostigma* | Orange-bellied Flowerpecker | ✓ | - | - | LC | NA | NP |
| | *Prionochilus maculatus* | Yellow-breasted Flowerpecker | ✓ | - | ✓ | LC | NA | NP |
| | *Prionochilus percussus* | Crimson-breasted Flowerpecker | - | ✓ | - | LC | NA | NP |
| Dicruridae | *Dicrurus paradiseus* | Greater Racket-tailed Drongo | ✓ | ✓ | ✓ | LC | NA | NP |
| Eupetidae | *Eupetes macrocerus* | Rail-babbler | ✓ | ✓ | ✓ | NT | NA | NP |
| Eurylaimidae | *Eurylaimus javanicus* | Banded Broadbill | ✓ | ✓ | ✓ | LC | NA | NP |
| | *Eurylaimus ochromalus* | Black-and-yellow Broadbill | ✓ | ✓ | - | NT | NA | NP |
| Indicatoridae | *Indicator archipelagicus* | Malaysian Honeyguide | - | ✓ | - | NT | NA | P |
| Irenidae | *Irena puella* | Asian Fairy-bluebird | ✓ | - | ✓ | LC | NA | NP |
| Megalaimidae | *Psilopogon chrysopogon* | Golden-whiskered Barbet | ✓ | - | ✓ | LC | NA | P |
| | *Psilopogon duvaucelii* | Black-eared Barbet | ✓ | ✓ | ✓ | LC | NA | NP |
| Meropidae | *Nyctyornis amictus* | Red-bearded Bee-eater | ✓ | - | ✓ | LC | NA | NP |
| Monarchidae | *Hypothymis azurea* | Black-naped Monarch | - | - | ✓ | LC | NA | NP |
| | *Terpsiphone affinis* | Blyth's Paradise Flycatcher | ✓ | - | - | LC | NA | NP |
| Muscicapidae | *Copsychus pyrropygus* | Rufous-tailed Shama | ✓ | - | - | NT | NA | NP |
| | *Cyornis umbratilis* | Grey-chested Jungle Flycatcher | ✓ | ✓ | - | NT | NA | NP |
| | *Enicurus leschenaulti* | White-crowned Forktail | ✓ | - | ✓ | LC | NA | NP |
| Nectariniidae | *Anthreptes malacensis* | Brown-throated Sunbird | - | - | ✓ | LC | NA | NP |
| | *Arachnothera longirostra* | Little Spiderhunter | ✓ | ✓ | ✓ | LC | NA | NP |
| | *Kurochkinegramma hypogrammicum* | Purple-naped Spiderhunter | ✓ | ✓ | ✓ | LC | NA | NP |
| Oriolidae | *Oriolus xanthonotus* | Dark-throated Oriole | ✓ | ✓ | - | LC | NA | NP |
| Pellorneidae | *Malacopteron cinereum* | Scaly-crowned Babbler | ✓ | - | - | LC | NA | NP |
| | *Malacopteron magnirostre* | Moustached Babbler | ✓ | ✓ | ✓ | LC | NA | NP |
| | *Pellorneum bicolor* | Ferruginous Babbler | ✓ | - | ✓ | LC | NA | NP |
| | *Pellorneum malaccense* | Mourning Babbler | ✓ | ✓ | ✓ | NT | NA | NP |
| | *Pellorneum nigrocapitatum* | Malayan Black-capped Babbler | ✓ | ✓ | ✓ | LC | NA | NP |
| | *Pellorneum rostratum* | Malayan Swamp Babbler | - | - | ✓ | NT | NA | NP |
| Phasianidae | *Argusianus argus* | Great Argus | - | - | ✓ | VU | II | P |
| Picidae | *Chrysophlegma mentale* | Checker-throated Woodpecker | ✓ | ✓ | - | NT | NA | NP |
| | *Chrysophlegma miniaceum* | Banded Woodpecker | ✓ | ✓ | ✓ | LC | NA | NP |
| | *Hemicircus concretus* | Grey-and-buff Woodpecker | - | ✓ | - | LC | NA | NP |
| | *Meiglyptes grammithorax* | Buff-rumped Woodpecker | ✓ | - | ✓ | LC | NA | NP |
| | *Micropternus brachyurus* | Rufous Woodpecker | - | - | ✓ | LC | NA | NP |
| | *Picus puniceus* | Crimson-winged Woodpecker | ✓ | - | ✓ | LC | NA | NP |
| Pittidae | *Hydrornis caeruleus* | Giant Pitta | - | ✓ | - | NT | NA | P |
| Psittaculidae | *Loriculus galgulus* | Blue-crowned Hanging Parrot | ✓ | ✓ | ✓ | LC | II | P |
| Pycnonotidae | *Alophoixus phaeocephalus* | Yellow-bellied Bulbul | ✓ | ✓ | - | LC | NA | NP |
| | *Ixodia erythropthalmos* | Spectacled Bulbul | ✓ | ✓ | ✓ | LC | NA | NP |
| | *Ixodia squamata* | Scaly-breasted Bulbul | ✓ | - | - | NT | NA | NP |
| | *Ixos malaccensis* | Streaked Bulbul | ✓ | - | - | NT | NA | NP |
| | *Pycnonotus brunneus* | Asian Red-eyed Bulbul | ✓ | - | ✓ | LC | NA | NP |
| | *Pycnonotus simplex* | Cream-vented Bulbul | ✓ | ✓ | ✓ | LC | NA | NP |
| | *Tricholestes criniger* | Hairy-backed Bulbul | ✓ | - | - | LC | NA | NP |
| Sturnidae | *Gracula religiosa* | Common Hill Myna | - | ✓ | - | LC | II | P |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Timaliidae | *Cyanoderma erythropterum* | Chestnut-winged Babbler | - | ✓ | - | LC | NA | NP |
| | *Mixornis gularis* | Pin-striped Tit-Babbler | ✓ | ✓ | ✓ | LC | NA | NP |
| | *Pomatorhinus bornensis* | Sunda Scimitar Babbler | ✓ | - | ✓ | LC | NA | NP |
| | *Stachyris maculata* | Chestnut-rumped Babbler | ✓ | ✓ | ✓ | NT | NA | NP |
| Trogonidae | *Harpactes diardii* | Diard's Trogon | - | ✓ | - | NT | NA | P |
| | *Harpactes duvaucelii* | Scarlet-rumped Trogon | - | ✓ | ✓ | NT | NA | P |
| Vangidae | *Philentoma pyrhoptera* | Rufous-winged Philentoma | ✓ | - | - | LC | NA | NP |

Note: IUCN Red List (LC: Least Concern, NT: Near Threatened, VU: Vulnerable, EN: Endangered, CR: Critically Endangered, NE: Not Evaluated), CITES (I: Appendix I, II: Appendix II, NA: Non-Appendix), P.106 MoEF of Indonesia government (P: Protected, NP: Not Protected)

**Table 2.** Ecological indices of bird communities at three priority monitoring sites in Biha Resort, Bukit Barisan Selatan National Park, Sumatra, Indonesia

| Index | Sites | | | All sites |
|---|---|---|---|---|
| | A | B | C | |
| H' | 3.704 | 3.257 | 3.410 | 3.792 |
| E | 0.947 | 0.916 | 0.924 | 0.896 |
| D | 0.029 | 0.051 | 0.041 | 0.030 |

Note: H': Shannon-Wiener Diversity Index, E: Pielou Evennes Index, D: Simpson Dominance Index

**Table 3.** Hutcheson's *t*-test value based on bird diversity index results at three priority monitoring sites in Biha Resort, Bukit Barisan Selatan National Park, Sumatra, Indonesia

| Sites | A | B | C |
|---|---|---|---|
| A | - | - | - |
| B | 4.316* | - | - |
| C | 2.949* | 1.598 | - |

Note: α: 0.05, *: Significant

## Discussion

The presence of intensive bird poaching in Biha Resort adds an urgent real-world dimension to the observed patterns of bird diversity. The high diversity recorded at Site A (Table 2) likely reflects lower poaching pressure compared to other locations, as poaching activity around Site A was last detected in 2021. In contrast, poaching remained active at Sites B and C until 2023, with ongoing poaching still detected at Site B in 2024 (Figure 5).

Such persistent poaching poses a direct threat to avifaunal diversity by reducing population abundance, disrupting genetic structure, and altering the behavioral, physiological, and reproductive traits that influence species persistence (Tarjuelo et al. 2015; Clausen et al. 2017; Brochet et al. 2019; Htay et al. 2023). Information obtained from local communities supports these observations, indicating that birds previously captured using birdlime ("pulut") but managed to escape are rarely encountered again, suggesting behavioral avoidance and decreased tolerance to human presence. Among the most affected taxa are leafbirds (*Chloropsis* spp.), including *C. moluccensis*, *C. cyanopogon*, and *C. sonnerati*.

Our density analysis further reinforces this finding, as only two leafbird species were detected at low frequencies, insufficient for density estimation, while *C. sonnerati* was not recorded at all during the survey. Density analysis shows that the species *Arachnothera longirostra* has the highest density, which may be due to the fact that this species is known to have a high tolerance to habitat disturbance (Susilo and Putri 2018). Research by Marthy et al. (2016), conducted in the degraded Harapan Rainforest Ecosystem Restoration (HRF) in Sumatra, also showed that *A. longirostra* had the highest density at that location. However, when compared to other studies with similarly degraded habitat conditions, the density of *A. longirostra* in HRF was significantly lower. The difference in results with other studies may be due to the diversity of forest conditions damaged by logging, not all degraded forests are the same. Each bird species can respond differently to habitat degradation (Ngila et al. 2024). Our research, along with the findings of Marthy et al. (2016), highlights that some bird species are still able to survive in disturbed habitats. Other bird species whose density cannot be estimated may indicate that disturbance by human activities has an indirect impact on the presence of birds in the forest. This is supported by research from Tarjuelo et al. (2015), which states that high hunting pressure in a location causes steppe birds, as nongame bird species, to experience behavioral and physiological changes, namely becoming more alert and spending more time flying, resulting in higher levels of the stress hormone corticosterone metabolites in their feces. These findings indicate that sustained hunting activities pose the same threat to all bird species.

The strong market demand for songbirds, particularly those valued for their vocal quality, drives continued exploitation. Songbird contests remain a major socioeconomic driver of the trade (Iskandar and Iskandar 2015), as contest-winning birds command high market prices, especially leafbirds (*C. cyanopogon* and *C. moluccensis*), thus perpetuating a lucrative trade network (Mukhlisi et al. 2023). This economic incentive promotes unsustainable harvest rates and contributes to local population declines (Mafaja and Husein 2019).

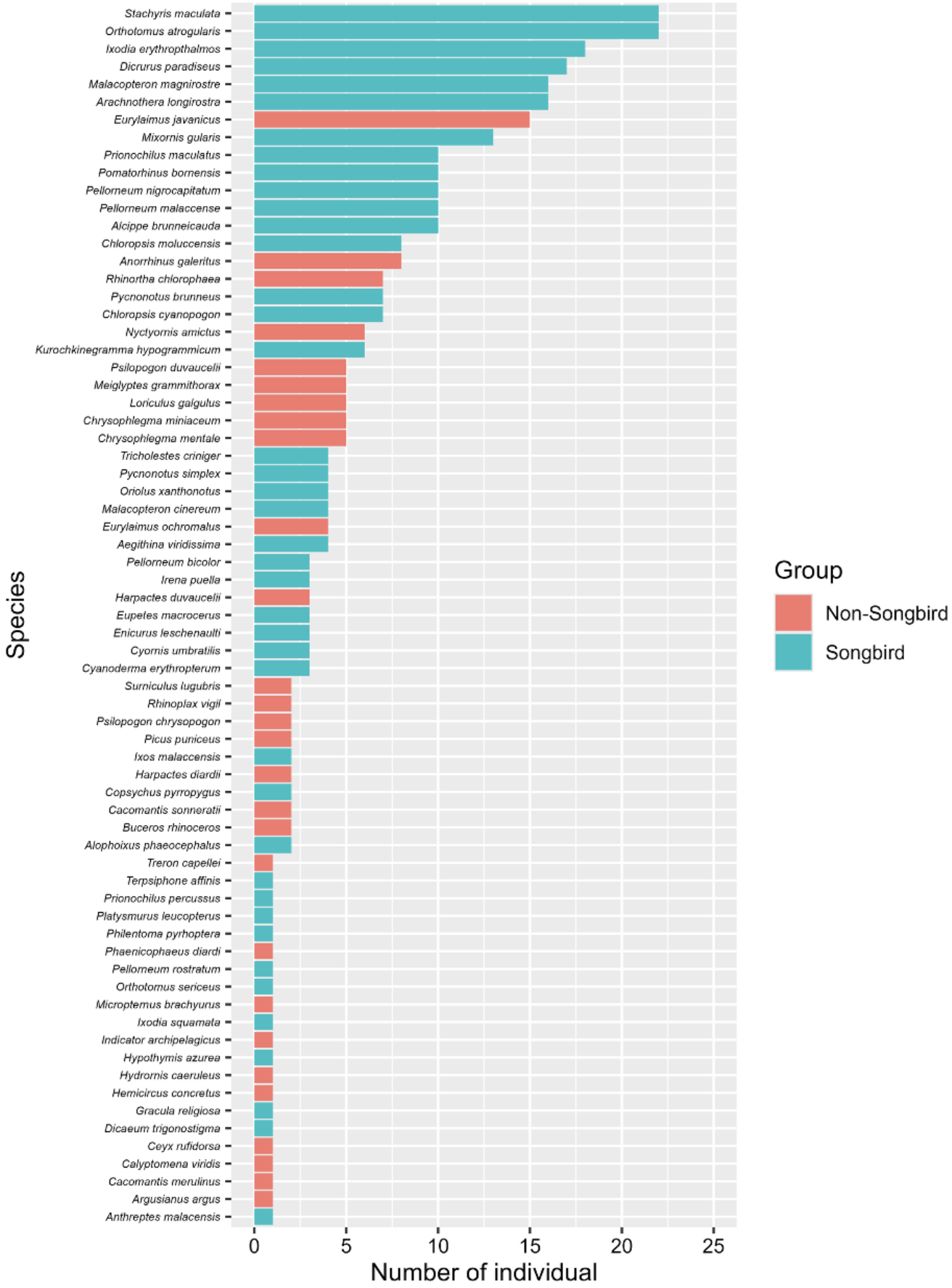


**Figure 3.** Composition of bird individuals recorded at three priority monitoring sites in Biha Resort, Bukit Barisan Selatan National Park, Sumatra, Indonesia, showing the number of individuals encountered for songbird and non-songbird species

**Table 4.** Density estimates of 12 bird species recorded at Biha Resort, Bukit Barisan Selatan National Park, Sumatra, Indonesia, based on point count data from 18 observation points

| Species | No. of detection | Average group size | Probability of detection | Density (ind/ha) | | |
|---|---|---|---|---|---|---|
| | | | | Estimate | Lower-Upper 95% CI | CV (%) |
| *Alcippe brunneicauda* | 10 | 1.00 | 0.39 | 0.46 | 0.20-1.05 | 41 |
| *Arachnothera longirostra* | 15 | 1.07 | 0.31 | 4.50 | 2.41-8.40 | 31 |
| *Dicrurus paradiseus* | 14 | 1.21 | 0.30 | 0.51 | 0.27-0.96 | 32 |
| *Eurylaimus javanicus* | 15 | 1.00 | 0.60 | 0.35 | 0.18-0.67 | 34 |
| *Ixodia erythropthalmos* | 17 | 1.06 | 0.45 | 0.88 | 0.49-1.57 | 29 |
| *Malacopteron magnirostre* | 11 | 1.45 | 0.26 | 1.17 | 0.44-3.15 | 50 |
| *Mixornis gularis* | 13 | 1.00 | 0.45 | 0.26 | 0.12-0.54 | 38 |
| *Orthotomus atrogularis* | 20 | 1.10 | 0.34 | 0.95 | 0.60-1.51 | 23 |
| *Pellorneum nigrocapitatum* | 10 | 1.00 | 0.25 | 0.43 | 0.17-1.11 | 48 |
| *Pomatorhinus bornensis* | 10 | 1.00 | 0.41 | 0.27 | 0.12-0.61 | 42 |
| *Prionochilus maculatus* | 10 | 1.00 | 0.19 | 0.95 | 0.38-2.36 | 46 |
| *Stachyris maculata* | 17 | 1.29 | 0.37 | 0.54 | 0.27-1.06 | 35 |

Note: CI: Confidence interval; CV: Coefficient of Variation

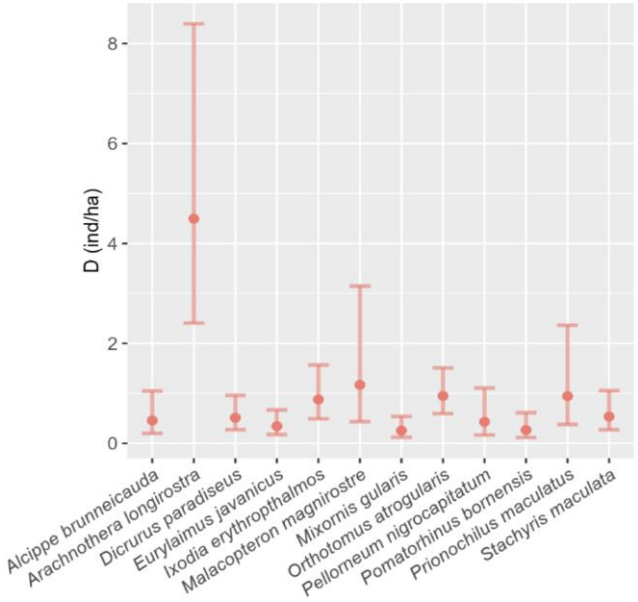


**Figure 4.** Density estimates of 12 bird species recorded across three priority monitoring sites in Biha Resort, Bukit Barisan Selatan National Park, Sumatra, Indonesia. Each circle represents the mean density (individuals per hectare), and vertical lines indicate the 95% Confidence Interval (CI) for each species


**Figure 5.** Evidence of bird poaching using birdlime ("pulut") documented at Site B, Biha Resort, Bukit Barisan Selatan National Park, Sumatra, Indonesia in 2024

Overexploitation of wild bird populations disrupts ecological balance and can trigger cascading effects on forest bird communities (Benítez-López et al. 2017). Many bird species, both songbirds and non-songbirds, form mixed-species flocks to enhance foraging efficiency and predator avoidance (Sridhar et al. 2009; Goodale et al. 2015; Marthy and Farine 2018; Frazier et al. 2025). The loss of key species from such flocks, especially leader species, can destabilize group cohesion and reduce the fitness of follower species (Dolby and Grubb 1998; Goodale et al. 2015; Pagani-Núñez et al. 2018). Consequently, sustained poaching pressure not only threatens targeted songbirds but also indirectly impacts broader community dynamics and ecosystem functioning in Biha Resort.

To date, few studies in Asia have explicitly demonstrated the link between poaching and biodiversity decline. There is research by Benítez-López et al. (2017) reported widespread wildlife depletion across tropical regions, with mammal and bird populations reduced by 83% and 58%, respectively, in hunted compared to unhunted areas. The decline in bird populations in Asia has been studied in China through literature reviews and long-term monitoring data conducted by Kamp et al. (2015), which showed that the population of the yellow-breasted bunting (*Emberiza aureola*), known as a songbird, declined dramatically by 84.3-94.7% between 1980 and 2013. This was caused by illegal trapping along the bird's migration route, especially in eastern China. A more specific case was documented by Andriyani et al. (2022), who found a significant reduction in the relative richness and density of songbirds at the Way Canguk Research Station, BBSNP, as a result of poaching. This pattern highlights the urgent need for greater attention to poaching impacts, particularly in vulnerable areas such as Biha Resort, BBSNP.

Continuous poaching without adequate conservation intervention can lead to the "silent forest syndrome", a condition in which forests lose their characteristic chorus of animal sounds, despite appearing vegetatively intact. Such acoustic emptiness reflects serious ecological degradation and loss of key species interactions (Mukhlisi et al. 2023). Our findings suggest that, although bird diversity in Biha

Resort remains relatively high, the presence of many songbird species under poaching pressure, some with conservation concern, warrants immediate conservation action to prevent future decline.

One promising framework for addressing wildlife crime is the Problem-Oriented Wildlife Protection (POWP) strategy, which applies the SARA model (Scanning, Analysis, Response, and Assessment) (Lemieux and Pickles 2020). The POWP approach has been initiated in Biha Resort, BBSNP, by identifying major poaching drivers through community-based assessments and targeted patrols. Our research contributes to this framework by documenting the current status of bird diversity and identifying species most vulnerable to poaching. These data provide the empirical foundation for designing evidence-based and community-informed conservation responses. The data-driven and behaviorally informed nature of POWP gives it a clear advantage over traditional enforcement-only approaches (Lemieux and Pickles 2020; Risdianto et al. 2025). A similar strategy has been successfully implemented in Way Kambas National Park (WKNP), Indonesia, where focused patrols, livelihood alternatives, and strengthened law awareness collectively reduced illegal snare hunting (Risdianto et al. 2025). To complement these ongoing efforts, periodic re-monitoring of bird diversity at the three priority sites in Biha Resort is essential for evaluating and refining the effectiveness of implemented interventions.

This study also has several limitations that should be acknowledged. First, the surveys may not fully represent the actual species richness of the study area, as indicated by the incomplete survey completeness value. The limited number of observation points and relatively short sampling duration suggest that additional sampling effort may reveal more species. Second, detection bias could have influenced the observed differences in species composition and diversity among sites. Environmental factors, such as weather conditions, vegetation density, and terrain, can reduce the likelihood of visually or aurally detecting certain species (Bibby et al. 2000). For instance, Site B showed the lowest species diversity, likely due to cloudy weather conditions that reduced bird activity during observation. Third, ecological factors such as variation in resource availability and interspecific competition (Ridwan et al. 2015) may also contribute to spatial differences in bird presence and detectability. Therefore, the results presented here should be interpreted as a preliminary baseline that can be refined through extended monitoring and increased sampling intensity.

This study concludes that Biha Resort, BBSNP, supports a remarkably high diversity of bird species, with 69 species recorded and a Shannon-Wiener Diversity Index (H') value of 3.792. Songbirds dominated the community, occurring in greater abundance than non-songbird species. Although the survey likely underestimates the true species richness of the area, the findings indicate that the high abundance of songbirds is a major driver of intensive poaching pressure in Biha Resort. Such persistent poaching threatens bird population dynamics and could lead to broader ecosystem imbalances if left unaddressed. Therefore, conservation measures that deliver tangible reductions in poaching are urgently needed. The density estimates presented here provide essential baseline data to guide future bird monitoring programs and inform management strategies for biodiversity conservation within Balai Besar Bukit Barisan Selatan National Park.

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## REFERENCES

Adelina M, Harianto SP, Nurcahyani N. 2016. Keanekaragaman jenis burung di Hutan Rakyat Pekon Kelungu Kecamatan Kotaagung Kabupaten Tanggamus. J Sylva Lestari 4: 51-60. DOI: 10.23960/jsl2451-60. [Indonesian]

Allen ML, Sibarani MC, Utoyo L, Krofel M. 2020. Terrestrial mammal community richness and temporal overlap between tigers and other carnivores in Bukit Barisan Selatan National Park, Sumatra. Anim Biodivers Conserv 43: 97-107. DOI: 10.32800/abc.2020.43.0097.

Andriyani A, Nurcahyani N, Susanto GN, Sibarani MC, Utoyo L. 2022. The diversity of singing birds at the Way Canguk Research Station, Bukit Barisan Selatan National Park. Jurnal Ilmu Biologi Eksperimen Keanekaragaman Hayati 9: 1-11. DOI: 10.23960/jbek.v9i1.206.

Ardiantiono, Karyadi, Isa M, Hasibuan AK, Kusara I, Arwin, Ibrahim, Supriadi, Marthy W. 2020. Hornbill density estimates and fruit availability in a lowland tropical rainforest site of Leuser Landscape, Indonesia: Preliminary data towards long-term monitoring. Hornbill Nat Hist Conserv 1 (1): 2-11.

Arimbi A, Ardiantono, Rahman F, Wandono H, Muslich M, Surya RA, Widyastuti S, Sugiharti, Anggoro VA. 2021. Menyingkap Kelola 17 Resor. Balai Besar Taman Nasional Bukit Barisan Selatan, Indonesia. [Indonesian]

Austin OL, Gill F, Clench. 2024. Passeriforrm. Encyclopedia Britannica. https://www.britannica.com/animal/passeriform.

Benítez-López A, Alkemade R, Schipper AM, Ingram DJ, Verweij PA, Eikelboom JAJ, Huijbregts MAJ. 2017. The impact of hunting on tropical mammal and bird populations. Science 356: 180-183. DOI: 10.1126/science.aaj1891.

Bibby C, Jones M, Marsden S. 2000. Teknik-Teknik Ekspedisi Lapangan Survei Burung. Birdlife International-Indonesia Programme, Bogor. [Indonesian]

Brochet AL, van den Bossche W, Jones VR, Arnardottir H, Damoc D, Demko M, Driessens G, Flensted K, Gerber M, Ghasabyan M, Gradinaro D, Hansen J, Horvath M, Karlonas M, Krogulec J,

Kuzmenko T, Lachman L, Lehtiniemi T, Lorgé P. 2019. Illegal killing and taking of birds in Europe outside the Mediterranean: Assessing the scope and scale of a complex issue. Bird Conserv Intl 29 (1): 10-40. DOI: 10.1017/ S0959270917000533.

Buckland ST, Anderson DR, Burnhamm KP, Laake JL, Borchers DL, Thomas L. 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford.

Buckland ST. 2006. Point-transect surveys for songbirds: Robust methodologies. Auk 123 (2): 345-357. DOI: 10.1093/auk/123.2.345.

Burivalova Z, Lee TM, Hua F, Lee JS, Prawiradilaga DM, Wilcove DS. 2017. Understanding consumer preferences and demography in order to reduce the domestic trade in wild-caught birds. Biol Conserv 209: 423-431. DOI: 10.1016/j.biocon.2017.03.005.

Catchpole CK, Slater PJB. 2008. Bird Song: Biological Themes and Variations. Cambridge University Press, New York. DOI: 10.1017/CBO9780511754791.

Chavan AS, Muley ED, Naphade SR. 2023. Animal trafficking and poaching: Major threats to the biodiversity. J Entomol Zool Stud 11 (5): 45-49. DOI: 10.22271/j.ento.2023.v11.i5a.9231.

Chng SCL, Eaton JA, Krishnasamy K, Shepherd CR, Nijman V. 2015. In the market for extinction: An inventory of Jakarta's bird markets. Traffic, Petaling Jaya.

Chng SCL, Eaton JA. 2016. In the Market for Extinction: Eastern and Central Java. Traffic, Petaling Jaya.

Chng SCL, Guciano M, Eaton JA. 2016. In the market for extinction: Sukahaji, Bandung, West Java, Indonesia. BirdingASIA 26: 22-28.

Chng SCL, Shepherd CR, Eaton JA. 2018. In the market for extinction: Birds for sale at selected outlets in Sumatra. Traffic Bull 30 (1): 15-22.

CITES. 2025. Convention on Internasional Trade in Endangered Species of Wild Fauna and Flora. https://www.cites.org.

Clausen KK, Christensen TK, Gundersen OM, Madsen J. 2017. Impact of hunting along the migration corridor of pink footed geese *Anser brachyrhynchus*-implications for sustain able harvest management. J Appl Ecol 54 (5): 1563-1570. DOI: 10.1111/1365-2664.12850.

Dolby AS, Grubb TC Jr. 1998. Benefits to satellite members in mixed-species foraging groups: An experimental analysis. Anim Behav 56: 501-509. DOI: 10.1006/anbe.1998.0808.

Frazier EK, Selman ZA, Price CA, Papeş M, Freeberg TM. 2025. Mixed-species flock diversity and habitat density are associated with antipredator behavior in songbirds. Diversity 17 (5): 363. DOI: 10.3390/d17050363.

Gaveau DL, Epting J, Lyne O, Linkie M, Kumara I, Kanninen M, Leader-Williams, N. 2009. Evaluating whether protected areas reduce tropical deforestation in Sumatra. J Biogeogr 36(11): 2165-2175. DOI: 10.1111/j.1365-2699.2009.02147.x.

Gill F, Donsker D, Rasmussen P. 2024. IOC World Bird List. http://www.worldbirdnames.org/.

Gill FB, Prum RO. 2019. Ornithology Fourth Edition. W.H. Freeman and Company, New York.

Goboro EM, Mbise FP, Ngongolo K. 2025. The effects of illegal wildlife activities on biodiversity in few selected African Countries. Afr J Ecol 63: e70055. DOI: 10.1111/aje.70055.

Goodale E, Ding P, Liu X, Martínez A, Si X, Walters M, Robinson SK. 2015. The structure of mixed-species bird flocks, and their response to anthropogenic disturbance, with special reference to East Asia. Avian Res 6: 1-11. DOI: 10.1186/s40657-015-0023-0.

Guciano M, Jumadh M, Muksydayan D, Santoso A, Fatma N, Krishnasamy K, Wong R, Armstrong OH, Pratiwi D, Namaskari N, Chng SCL. 2023. Burung-Burung Sumatera di Bawah Tekanan: Analisa Tindakan Karantina Melalui Penyitaan Burung di Pelabuhan Bakauheni dan Merak dari Januari 2018 hingga Desember 2021. FLIGHT Indonesia, Jakarta. [Indonesian]

Harris JBC, Green JM, Prawiradilaga DM, Giam X, Hikmatullah D, Putra CA, Wilcove DS. 2015. Using market data and expert opinion to identify overexploited species in the wild bird trade. Biol Conserv 187: 51-60. DOI: 10.1016/j.biocon.2015.04.009.

Htay T, Htoo KK, Røskaft E, Ringsby TH, Ranke PS. 2023. Social and ecological drivers of illegal bird hunting in the Indawgyi Wetland ecosystem in Myanmar. Conserv Sci Pract 5: e13029. DOI: 10.1111/csp2.13029.

Hutcheson K. 1970. A test for comparing diversities based on shannon formula. J Theor Biol 29: 151-154. DOI: 10.1016/0022-5193(70)90124-4.

Indraswari K, Friedman RS, Noske R, Shepherd CR, Biggs D, Susilawati C, Wilson C. 2020. It's in the news: Characterising Indonesia's wild bird trade network from media-reported seizure incidents. Biol Conserv 243: 108431. DOI: 10.1016/j.biocon.2020.108431.

Iskandar J, Iskandar BS. 2015. Pemanfaatan aneka ragam burung dalam kontes burung kicau dan dampaknya terhadap konservasi burung di alam: studi kasus di Kota Bandung, Jawa Barat. Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia. Yogyakarta, 31 March 2015. DOI: 10.13057/psnmbi/m010411. [Indonesian]

IUCN. 2025. The IUCN Red List of Threatened Species (Version 2025-1). https://www.iucnredlist.org.

Kamp J, Oppel S, Ananin AA, Durnev YA, Gashev SN, Hölzel N. 2015. Global population collapse in a superabundant migratory bird and illegal trapping in China. Conserv Biol 29 (6): 1684-1694. DOI: 10.1111/cobi.12537.

Kiros S, Afework B, Legese K. 2018. A preliminary study on bird diversity and abundance from Wabe fragmented forests around Gubre subcity and Wolkite town, Southwestern Ethiopia. Intl J Avian Wildl Biol 3: 333-340. DOI: 10.15406/ijawb.2018.03.00116.

Lemieux AM, Pickles RSA. 2020. Problem-Oriented Wildlife Protection. Center for Problem-Oriented Policing, Arizona State University, Phoenix.

Lepage D. 2025. Avibase: The World Bird Database. https://avibase.bsceoc.org/avibase.jsp.

Li X, Anderson CJ, Wang Y, Lei G. 2021. Waterbird diversity and abundance in response to variations in climate in the Liaohe Estuary, China. Ecol Indic 132: 108286. DOI: 10.1016/j.ecolind.2021.108286.

MacKinnon J, Phillips K, Balen BV. 2010. Burung-Burung di Sumatera, Jawa, Bali, dan Kalimantan. Burung Indonesia, Bogor. [Indonesian]

Mafaja K, Husain F. 2019. Kelompok kicau mania, kontes burung dan kesadaran konservasi burung kicau di Kabupaten Blora. J Solidar 8: 601-613. [Indonesian]

Magurran AE. 1988. Ecological Diversity and Its Measurement. Croom Helm Ltd, London. DOI: 10.1007/978-94-015-7358-0.

Mardiyanto A, Riyanto R, Sianipar CP, Shibata S. 2024. Forest ecosystem services and local communities neighboring Biha Resor in Bukit Barisan Selatan National Park, Southern Sumatra, Indonesia. Asian J For 8 (1): 18-30. DOI: 10.13057/asianjfor/r080102.

Marshall H, Collar NJ, Lees AC, Moss A, Yuda P, Marsden SJ. 2020. Spatio-temporal dynamics of consumer demand driving the Asian songbird crisis. Biol Conserv 241: 108237. DOI: 10.1016/j.biocon.2019.108237.

Marthy W, Clough Y, Tscharntke T. 2016. Assessing the biodiversity value of degraded lowland forest in Sumatra, Indonesia. Kukila 19: 1-20.

Marthy W, Clough Y, Tscharntke T. 2017. Assessing the potential for avifauna recovery in degraded forests in Indonesia. Raffles Bull Zool 65: 35-48.

Marthy W, Farine DR. 2018. The potential impacts of the songbird trade on mixed-species flocking. Biol Conserv 222: 222-231. DOI: 10.1016/j.biocon.2018.04.015.

Ministry of Environtment and Forestry. 2018. Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor P. 106/MENLHK/SETJEN/KUM.1/12/2018 tentang Perubahan Kedua atas Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor P.20/MENLHK/SETJEN/KUM.1/6/2018 tentang Jenis Tumbuhan dan Satwa Dilindungi. https://jdih.maritim.go.id/id/peraturat-menteri-lingkungan-hidup-dan-kehutanan-no-p106menlhksetjenkum1122018-tahun-2018. [Indonesian]

Moon K. 2015. R Statistics and Graphs for Medical Papers. Hannarae, Seoul.

Mukhlisi, Atmoko T, Rifqi MA. 2023. Cica daun, burung kicau yang makin sepi nyanyiannya di alam. In: Atmoko T, Gunawan H (eds). Mengenal Lebih Dekat Satwa Langka Indonesia dan Memahami Pelestariannya. Penerbit BRIN, Jakarta. DOI: 10.55981/brin.602.c630. [Indonesian]

Ngila PM, Danmallam BA, Iniunam IA, Kuria A, Trevelyan R. 2024. Impact of forest cover loss on forest dependent avian species in Kenya. Sci Afr 26: e02463. DOI: 10.1016/j.sciaf.2024.e02463.

Nugroho SPA, Mardiastuti A, Mulyani YA, Rahman DA. 2023. Bird communities in the tropical peri-urban landscape of Bogor, Indonesia. Biodiversitas 24 (12): 6988-7000. DOI: 10.13057/biodiv/d241260.

Oksanen J, Simpson G, Blanchet F et al. 2025. Vegan: Community Ecology Package. R Package Version 2.7-0. https://vegandevs.github.io/vegan/.

Pagani-Núñez E, Xia X, Beauchamp G, He R, Husson JHD, Liang D, Goodale E. 2018. Are vocal characteristics related to leadership patterns in mixed-species bird flocks? J. Avian Biol 49: jav-01674. DOI: 10.1111/jav.01674.

Pusparini W, Batubara T, Surahmat F, Ardiantiono, Sugiharti T, Muslich M, Amama F, Marthy W, Andayani N. 2018. A pathway to recovery: The Critically Endangered Sumatran tiger *Panthera tigris sumatrae* in an 'in danger' UNESCO World Heritage Site. Oryx 52: 25-34. DOI: 10.1017/S0030605317001144.

Putri BI, Ummuhany N, Hayati ANS, Fitriyani F, Hidayanti AR, Pramono D. 2024. Pragmatisme dalam perdagangan ilegal satwa liar: Analisis teori philosophy of money george simmel. Sosial 2 (3): 52-66. DOI: 10.62383/sosial.v2i3.286. [Indonesian]

R Core Team. 2021. R: A Language and Environtment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Ridwan M, Choirunnafi A, Sugiyarto SW, Putri RDA. 2015. Hubungan keanekaragaman burung dan komposisi pohon di Kampus Kentingan Universitas Sebelas Maret Surakarta, Jawa Tengah. Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia. Yogyakarta, 31 March 2015. [Indonesian]

Risdianto D, Siregar H, Marthy W. 2025. Reforming Poachers to Reduce Snaring. Ilegal Wildlife Trade Challenge Fund. https://iwt.challengefund.org.uk/news/2025/02/07/reforming-poachers-to-reduce-snaring/.

Sidomukti GC, Wardhana W. 2021. Penerapan metode storet dan indeks diversitas fitoplankton dari Shannon-Wiener sebagai indikator kualitas perairan Situ Rawa Kalong Depok, Jawa Barat. Jurnal Teknologi 14 (1): 28-38. DOI: 10.34151/jurtek.v14i1.3543. [Indonesian]

Sridhar H, Beauchamp G, Shanker K. 2009. Why do birds participate in mixed-species foraging flocks? A large-scale synthesis. Anim Behav 78: 337-347. DOI: 10.1016/j.anbehav.2009.05.008.

Surya RA, Surahmat F, Sibarani MC. 2020. Pendahuluan. In: BBTNBBS, WCS-IP (eds). Stasiun Penelitian Way Canguk: Dua Dekade Riset Ekologi Hutan Hujan Tropis Dataran Rendah Sumatera. BBTNBBS/WCS-IP, Kotaagung. [Indonesian]

Susilo A, Putri IA. 2018. Respons burung bawah tajuk terhadap sistem pengelolaan TPTI dan TPTII/SILIN. Jurnal Penelitian Sosial Ekonomi Kehutanan 15 (2): 91-109. DOI: 10.59465/jphka.15.2.91-109. [Indonesian]

Tarjuelo R, Barja I, Morales MB, Traba J, Benítez-López A, Casas F, Arroyo B, Delgado MP, Mougeot F. 2015. Effects of human activity on physiological and behavioral responses of an endangered steppe bird. Behav Ecol 26: 828-838. DOI: 10.1093/beheco/arv016.

Thomas L, Buckland ST, Rexstad EA, Laake JL, Strindberg S, Hedley SL, Bishop JRB, Marques TA, Burnham KP. 2010. Distance software: Design and analysis of distance sampling surveys for estimating population size. J Appl Ecol 47: 5-14. DOI: 10.1111/j.1365-2664.2009.01737.x.

Thongsoulin P, Phanthuamath V, Islam MS, Thongmanivong S, Kang Y. 2019. The relationship between birds diversity and habitats in Phou Khao Khouay (PKK) National Park of Lao PDR. Open J For 9: 143-158. DOI: 10.4236/ojf.2019.92006.

Wickham H, Averick M, Bryan J, Chang W, McGowan LD, François R, Grolemund G, Hayes A, Henry L, Hester J, Kuhn M, Pedersen TL, Miller E, Bache SM, Müller K, Ooms J, Robinson D, Seidel DP, Spinu V, Takahashi K, Vaughan D, Wilke C, Woo K, Yutani H. 2019. Welcome to the tidyverse. J Open Source Softw 4: 1686. DOI: 10.21105/joss.01686.

Wickham H, François R, Henry L, Müller K, Vaughan D. 2023. dplyr: A Grammar of Data Manipulation. R Package Version 1.1.4. https://dplyr.tidyverse.org.

Wickham H. 2016. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag, New York. DOI: 10.1007/978-3-319-24277-4_9.