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Ethno-ornithology and local ecological knowledge of birds in the agroforestry landscapes of Kalibawang, Central Java, Indonesia

FADIL NURSAMI[1], FADILA ARDELIA[1], FARIKHAH LUTFIANA NURAINI[1], FATIHA ALIYAZZAHRA[1], MUCHAMMAD SHOLIQIN[1], JOHAN ISKANDAR[2], BUDIAWATI ISKANDAR[3], DARLINA MD. NAIM[4], AHMAD DWI SETYAWAN[1,5,♥]

[1]Department of Environmental Science, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret. Jl. Ir. Sutami 36A, Surakarta 57126, Central Java, Indonesia. Tel./fax.: +62-271-663375, ♥email: volatileoils@gmail.com
[2]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran. Jl. Raya Bandung Sumedang Km. 21, Hegarmanah, Jatinangor, Sumedang 45363, West Java, Indonesia
[3]Department of Anthropology, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran. Jl. Raya Bandung Sumedang Km. 21, Hegarmanah, Jatinangor, Sumedang 45363, West Java, Indonesia
[4]School of Biological Sciences, Universiti Sains Malaysia. 11800 Penang, Malaysia
[5]Biodiversity Research Group, Universitas Sebelas Maret. Jl. Ir. Sutami 36A, Surakarta 57126, Central Java, Indonesia

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Abstract. *Nursami F, Ardelia F, Nuraini FL, Aliyazzahra F, Sholiqin M, Iskandar J, Iskandar B, Md Naim D, Setyawan AD. 2025. Ethno-ornithology and local ecological knowledge of birds in the agroforestry landscapes of Kalibawang, Central Java, Indonesia. Asian J Ethnobiol 8: 367-389.* Ethno-ornithological knowledge in rural Java provides important insight into how birds are perceived, classified, utilized, and conserved within agroforestry landscapes. This study documents the structure, transmission, and ecological relevance of Local Ecological Knowledge (LEK) among 124 male respondents from four villages in Kalibawang, Central Java. Bird-related knowledge is transmitted predominantly through patrilineal and male-centered networks, reinforced by mentor–apprentice relationships within *lomba kicau* (songbird competition) culture. Respondents recognized 71 bird species organized into flexible folk categories based on vocalization, habitat association, perceived behavior, symbolic meaning, and management context. Songbirds (*burung kicau*) formed the most dominant and culturally salient category, reflecting the central role of acoustic perception in local cognition. Most recorded species (57.7%) were not directly utilized, indicating that bird exploitation is highly selective rather than pervasive. Active use was concentrated on cage birds and pet trade species, supported by specific capture techniques, particularly bird glue (*getah/pulut*) and netting. Cultural taboos and ethical norms contributed to a substantial proportion of non-captured species, especially forest-dependent and symbolically protected birds. LEK showed strong alignment with scientific knowledge regarding habitat use and conspicuous behavior, while partial mismatches in feeding guild perception were primarily driven by visibility and symbolic interpretation rather than ecological misunderstanding. Culturally salient species, including *Copsychus saularis*, *Pycnonotus aurigaster*, *Zosterops* spp., and *Leptocoma* spp., exhibited high Cultural Importance (CI) values and were closely associated with perceived ecological services such as insect control, pollination, and seed dispersal. Overall, LEK in Kalibawang constitutes a coherent socio-ecological system that integrates cultural values, ecological observation, and informal governance. Despite its gendered and cross-sectional scope, this knowledge system offers a culturally grounded foundation for community-based bird conservation in Javanese agroforestry landscapes.

Keywords: Agroforestry conservation, cultural salience, ethno-ornithology, folk taxonomy, local ecological knowledge

INTRODUCTION

Ethno-ornithology, a branch of ethnobiology, offers a key perspective for understanding human–bird relationships, particularly in regions where birds have ecological, economic, and cultural significance. In Southeast Asia, closely linked forest and agroforest livelihoods give birds diverse roles—as seasonal indicators, trade and food resources, symbols of identity, and objects of aesthetic value. While global research highlights the value of Local Ecological Knowledge (LEK) for community-based conservation and tracking long-term ecological change, studies in Indonesia remain limited despite the country's high endemism and cultural diversity (Şekercioglu 2006; Sodhi et al. 2010). Java is a distinctive setting: one of the world's most densely populated islands, yet still supporting rich avifauna embedded in long-standing cultural practices (Whitten et al. 1996). Evidence from Karangwangi, West Java, Indonesia, shows that rural communities hold detailed, structured LEK—including species recognition and folk classifications based on vocal, morphological, behavioral, and ecological cues—and also reports bird declines linked to habitat loss and hunting (Iskandar et al. 2016). These findings highlight the scarcity of ethno-ornithological research in Java and the need for site-specific studies across varied cultural and ecological contexts.

The agroforestry landscapes of Java have long served as interfaces of human–bird interaction. These multifunctional land-use systems—characterized by mixed fruit trees, bamboo groves, shade vegetation, and homegarden mosaics—offer ecological niches for frugivores, insectivores, and nectarivores alike (Michon and de Foresta 1995; Roshetko

et al. 2007). At the same time, these landscapes are social arenas where bird-related knowledge, beliefs, and practices are negotiated daily. Birds are hunted, trapped, traded, reared for song competitions, or protected due to cultural taboos and spiritual values. The contemporary "kicau culture," which has expanded across Java in recent decades, further shapes people's perceptions and utilization of species such as *Zosterops*, *Pycnonotus*, and *Copsychus*. Consequently, agroforestry zones are not merely ecological habitats but living cultural spaces where LEK is accumulated, contested, and transmitted across generations.

A distinctive feature of Javanese ethno-ornithology is its gendered knowledge system. Ethnographic accounts and field observations indicate that manuk (birds) are strongly associated with men, who dominate trapping, bird-keeping, market trade, and forest-based foraging. Women participate more limitedly, mainly through household care and sharing narrative knowledge, but are less involved in species identification or ecological interpretation. This pattern aligns with wider ethnobiological discussions showing that certain taxa can be culturally coded as masculine domains, shaping access to expertise and decision-making. In Kalibawang, the same pattern appeared across all sampled villages, with men as the main holders and intergenerational transmitters of avian local ecological knowledge (LEK). Recognizing these dynamics is important because transmission pathways influence human–bird interactions and should inform conservation strategies.

Despite birds' ecological and cultural importance in Java, research on bird-related LEK remains scarce. Most studies on Javanese avifauna focus on taxonomy (MacKinnon and Phillipps 1993), ecology/biogeography (van Bemmelen 1949; Whitten et al. 1996), and more recently on conservation crises linked to habitat loss and wildlife trade (Sodhi et al. 2010). Few examine how communities classify birds, transmit knowledge, or how traditional practices align with contemporary ecological science. Consequently, understanding of community-scale human–bird relationships—especially within agroforestry systems—remains limited.

This study addresses these gaps by examining ethno-ornithological knowledge in four villages of Kalibawang, Central Java—Dempel, Karangsambung, Kalialang, and Margolangu—an upland, agroforestry-rich landscape with strong cultural ties to birds. We hypothesize that (i) avian LEK is structured as a hierarchical folk taxonomy based on acoustic, morphological, behavioral, and habitat cues, and (ii) culturally salient species show strong agreement between LEK classifications and scientific ecological guilds and habitat associations. Accordingly, we aim to: (i) document the sources, holders, and distribution of avian LEK; (ii) describe folk taxonomic categories at life-form, generic, and specific levels; (iii) characterize bird-use practices (subsistence, cultural roles, and capture methods); (iv) identify culturally salient species and their symbolic meanings; and (v) assess correspondence between LEK and scientific knowledge, particularly for habitat use, feeding guilds, and conservation status.

MATERIALS AND METHODS

Study area

The study was conducted in October 2024 in four villages of Kalibawang Sub-district, Central Java, Indonesia—Dempel, Karangsambung, Kalialang, and Margolangu—representing different parts of the agroforestry landscape in the southern Serayu Mountains foothills (Figure 1). These upland communities rely on mixed tree gardens and diversified farming systems (e.g., coffee, coconut, mango, bamboo, bananas, and seasonal crops), creating complex vegetation mosaics that support diverse bird communities (Michon and de Foresta 1995; Roshetko et al. 2007; BPS Wonosobo 2023).

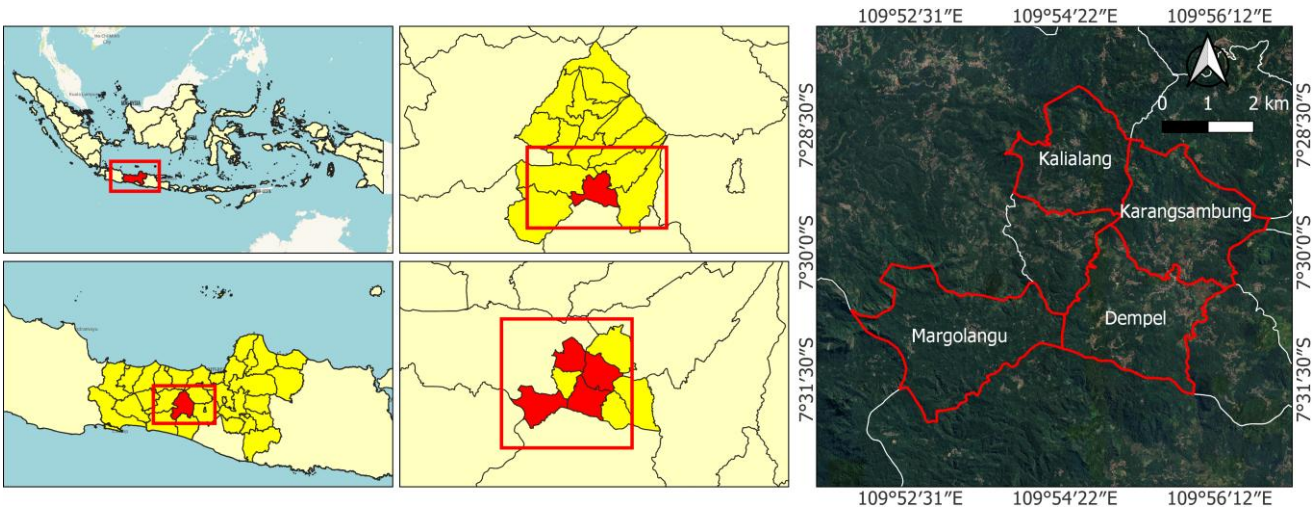

Figure 1. Map of the four study villages (Dempel, Karangsambung, Kalialang, and Margolangu) in the agroforestry landscapes of Kalibawang Sub-district, Wonosobo District, Central Java, Indonesia

The topography is moderately steep, with elevations of 250-550 m above sea level. The area has a tropical monsoonal climate, with a wet season from November to April and a dry season from May to October. Annual rainfall reaches about 2,000-2,500 mm, with average temperatures of 22-28°C and humidity generally above 75% (BMKG 2023). Small rivers and irrigation canals form narrow riparian corridors that connect agroforests with adjacent hillslopes. Although the broader Southern Serayu Mountains landscape has undergone land-use change over the past decades, the agroforestry matrix of Kalibawang remains ecologically important, functioning as a semi-natural buffer zone between settlements, rice fields, and fragmented hill forests. The combination of shaded agroforest, wet-rice paddies, small watercourses, and settlement gardens makes it an ideal setting for examining ethno-ornithological knowledge and human–bird interactions within a culturally embedded agricultural system.

The social–ecological characteristics of Kalibawang further shape human relationships with birds. Most households depend on smallholder agroforestry and paddy agriculture for subsistence, while men actively participate in bird-related practices such as trapping, keeping, and trading. The cultural significance of bird song competitions (*lomba kicau*) is especially prominent, influencing which species are valued, how knowledge is transmitted, and how community members interact with local avifauna. These practices are deeply rooted in Javanese tradition and contribute to the gendered distribution of ecological knowledge observed in this region.

Sampling design and respondent selection

Data collection followed an ethnobiological sampling framework designed to identify individuals who possess extensive and context-specific knowledge of birds within the agroforestry landscapes of Kalibawang. A combined purposive and snowball sampling strategy was employed to reach respondents recognized by the community as "cultural experts," including experienced hunters (*pemburu manuk*), hobbyists involved in bird song competitions, long-term bird keepers, and village elders who have accumulated ecological knowledge through lifelong interaction with agroforests and surrounding forest margins. Purposive sampling enabled the deliberate selection of individuals with specialized knowledge, while snowball sampling allowed respondents to recommend others considered knowledgeable, thereby expanding the network of experts in a culturally grounded manner (Alexiades 1996; Bernard 2017).

A notable characteristic of this study is that all 124 respondents were men, representing an age range from young adults (18-30 years) to older experts (>60 years). This gender distribution is not a sampling bias but a reflection of gendered ecological knowledge in Javanese society, where birds (*manuk*) are culturally coded as a masculine domain. Activities such as trapping, bird-keeping, forest roaming, and participation in *lomba kicau* are overwhelmingly undertaken by men, whereas women rarely engage in species identification, capture practices, or market-related activities. This pattern aligns with broader ethnobiological literature showing that knowledge about certain taxonomic groups—particularly game animals and traded wildlife—is often male-dominated (Pfeiffer and Butz 2005; Jepson and Ladle 2009). Recognizing this gendered context is essential for accurately interpreting how LEK is transmitted and who holds authoritative ecological knowledge within the community.

Interviews, guided walks, and informal discussions were conducted across all four villages, ensuring representation of varied agroforestry contexts and local livelihood backgrounds. Prior to engagement, all respondents were informed of the study objectives, confidentiality procedures, and their right to withdraw from the research at any time. Ethical considerations followed the International Society of Ethnobiology (ISE) (2006) Code of Ethics, including principles of prior informed consent, respect for intellectual sovereignty, and culturally appropriate data handling. This methodological approach ensured that the resulting LEK dataset was both scientifically robust and socially grounded in community-defined expertise.

Ethnobiological interviews and free-listing

Ethno-ornithological data were collected using a combination of semi-structured interviews, free-listing exercises, and in-depth confirmatory interviews to document local knowledge of bird species, habitat associations, and cultural significance. Semi-structured interviews allowed conversations to follow respondents' own narratives while ensuring consistency across participants regarding key themes such as bird names, folk classifications, ecological observations, and historical changes in abundance. This flexible but systematic approach is widely recommended in ethnobiological research because it captures both taxonomic knowledge and contextual cultural meanings (Alexiades 1996; Bernard 2017).

Free-listing was used to elicit the full range of bird taxa known to respondents, including both frequently encountered and rarely observed species. Respondents were asked to spontaneously list all *manuk* they recognized in the agroforestry landscape, enabling the identification of culturally salient species through measures such as frequency of mention, order of recall, and the consistency of naming across villages (Quinlan 2005). This method also helped distinguish between life-form, generic, and specific folk categories, forming the basis for subsequent analysis of folk taxonomy.

To verify the accuracy and depth of recorded knowledge, in-depth interviews were conducted with senior informants—particularly experienced hunters and elders—who were widely regarded as repositories of multigenerational ecological knowledge. These interviews focused on clarifying ambiguous names, validating habitat descriptions, and cross-checking species considered rare or culturally significant. A triangulation approach was employed, comparing statements among multiple experts to ensure the reliability of information and to minimize individual recall bias.

All interviews followed ethical guidelines under the ISE Code of Ethics (2006), including prior informed consent, voluntary participation, and respect for local intellectual property. This combination of interview techniques provided a robust dataset for analyzing how bird knowledge is structured, transmitted, and valued within Kalibawang's agroforestry communities. In total, free-listing and confirmatory interviews resulted in the recognition of 71 bird species across all folk categories in the four study villages.

Folk classification, cultural use, capture techniques, and dominant habitat

Folk ornithological knowledge in Kalibawang was assessed through an integrated analysis of folk classification, cultural utilization, capture techniques, and dominant habitat contexts. Documentation of folk taxonomy followed standard ethnobiological frameworks (Brown 1979; Hunn 1982; Berlin 1992). Birds were grouped into culturally recognized categories based on salient criteria such as vocalization, morphology, behavior, habitat association, and perceived function. Folk categories correspond to life-form and generic levels and include songbirds, rice-field birds, wetland birds, predators, sacred birds, pest birds, settlement-associated birds, and related groups. Consistent with emic classification systems, a species may occur in more than one folk category when justified by cultural meaning or perceived role.

Patterns of bird utilization were analyzed using standardized and mutually exclusive categories derived from local practice. Each species was assigned to a single primary utilization category to avoid overlap, including no direct use, pet bird or cage bird, pet trade, domesticated, occasionally hunted, sacred or culturally protected, edible nest harvested, and ecosystem service (pest control). Although some species have multiple cultural roles, classification was restricted to the dominant use for analytical consistency.

Bird capture techniques were documented and classified into standardized categories, including bird glue trapping (*getah*/*pulut*), netting, snare trapping, cage trapping, projectile hunting, domesticated breeding, nest harvesting, and non-capture due to cultural taboos. Each species was assigned to one dominant capture method based on interview data and field observations, although alternative techniques may be known or occasionally applied. Recorded capture methods reflect traditional practices and do not imply legality.

Dominant habitat was determined based on the primary environment in which each species is most frequently encountered, utilized, or captured according to local knowledge and observation. Habitat categories include agroforestry, forest, forest edge, grassland or open fields, rice fields, settlements, wetlands, riverine areas, and cliffs or rocky habitats. To prevent double-counting, each species was assigned to a single dominant habitat, recognizing that many species occupy multiple habitats ecologically. Habitat classification reflects human–bird interaction contexts rather than exclusive ecological preferences.

Ethnobiological indices (UV, RFC, CI)

To quantify the cultural salience and multidimensional importance of bird species within Kalibawang communities, three widely used ethnobiological indices were calculated: Use Value (UV), Relative Frequency of Citation (RFC), and Cultural Importance Index (CI). These indices provide standardized measures of how frequently and in how many ways a species is recognized, valued, or utilized by local people (Phillips and Gentry 1993; Tardío and Pardo-de-Santayana 2008).

The Use Value (UV) was computed to assess the intensity of cultural knowledge and use associated with each species. UV is defined as:

$$\mathrm{UV} = \frac{\sum U_i}{N}$$

Where, *Ui* represents the number of distinct uses mentioned by each respondent, and *N* is the total number of respondents. Higher UV values indicate species with multiple roles—such as song, symbolism, ecological cues, or economic uses—signifying strong cultural embeddedness.

The Relative Frequency of Citation (RFC) measures how widely known a species is across the community:

$$\mathrm{RFC} = \frac{FC}{N}$$

Where, *FC* is the number of respondents who mention the species. RFC captures species familiarity and general cultural visibility, complementing the more use-oriented UV metric (Tardío and Pardo-de-Santayana 2008).

The Cultural Importance Index (CI) integrates both the diversity of uses and the proportion of informants citing each use category:

$$\mathrm{CI} = \sum_{u=1}^{k} \frac{FC_u}{N}$$

Where, *k* represents the number of use categories. CI is particularly suited for multifunctional taxa, as it reflects both breadth and distribution of knowledge.

These indices were selected because they jointly reveal cultural dependency, knowledge distribution, and species salience, enabling robust interpretation of how birds are valued in the agroforestry-based ethno-ornithological system of Kalibawang.

RESULTS AND DISCUSSION

Socio-cultural profile of respondents and knowledge networks

The 124 respondents interviewed across the four villages of Kalibawang represent a socially diverse yet culturally cohesive community in which bird-related knowledge circulates primarily through male-centered social networks. Most respondents identified their father or grandfather as the earliest and most influential figures who introduced them to bird identification, trapping techniques,

vocal mimicry, and habitat interpretation. This patrilineal pattern reflects the long-standing Javanese norm that birds (*manuk*) are embedded within a masculine cultural domain, where ecological knowledge is transmitted through intergenerational male bonding during farming, forest-edge activities, or shared leisure practices. The centrality of fathers and grandfathers underscores the degree to which LEK is socially inherited rather than independently acquired, forming a stable knowledge base that persists despite environmental change.

Conversely, the role of women in the circulation of bird knowledge was consistently described as minimal or absent. Respondents noted that women rarely participate in trapping, bird keeping, or songbird competitions, and seldom accompany men during agroforest activities where observational learning naturally occurs. This gendered pattern aligns with community norms concerning labor division and symbolic associations between men and bird mastery. As a result, the absence of female participation is not indicative of exclusion but rather reflects a long-standing cultural structure that shapes knowledge accessibility and authority within Kalibawang households.

A distinctive component of knowledge transmission involves mentor–apprentice relationships, particularly among hobbyists engaged in *lomba kicau* (songbird competitions). Younger enthusiasts often learn from more experienced keepers who possess recognized expertise in bird vocalization, diet preparation, conditioning, and species-specific behavior. These learning pathways extend beyond kinship networks, forming horizontal knowledge exchanges that enhance technical specialization and contribute to the diffusion of new techniques, including cage design, lure modification, and acoustic training. Such relationships often transcend village boundaries, supporting a regional knowledge network centered on competitive bird-keeping culture.

Despite shared cultural foundations, knowledge networks show subtle variation across villages. For example, respondents in Karangsambung reported stronger ties to forest-adjacent activities, enabling them to observe a broader range of species and to inherit specialized knowledge related to forest-dwelling taxa. In contrast, Dempel and Kalialang respondents often emphasized knowledge associated with homegardens and rice-field landscapes, reflecting the ecological settings that structure daily encounters with birds. Margolangu displayed a mixed pattern, with both agroforest-influenced and settlement-based knowledge sources.

Table 1 summarizes the distribution of knowledge sources reported by respondents and highlights the predominance of patrilineal and male-centered transmission pathways. The prominence of father-to-son learning, combined with peer apprenticeship networks, illustrates how LEK in Kalibawang is structured through both inheritance and practice-based engagement within agroforestry landscapes.

Folk classification system

The folk classification system documented in Kalibawang reflects a culturally grounded taxonomy in which birds are organized according to locally salient criteria, including vocal characteristics, habitat association, perceived behavior, symbolic meaning, and practical relevance. Based on free-listing and ethnobiological interviews, respondents recognized a set of folk categories that correspond to everyday encounters and cultural interpretations rather than formal scientific taxonomy. As summarized in Table 2, these categories include songbirds, rice-field birds, wetland birds, sacred birds, predators, pest birds, settlement-associated birds, cage birds, game birds, poultry, omen birds, and unclassified species.

Songbirds (*burung kicau*) represent the most dominant folk category, comprising more than half of the recorded species. This category is defined primarily by acoustic qualities, particularly melodious, complex, or trainable vocalizations. Species such as *Copsychus saularis*, *Pycnonotus aurigaster*, *Chloropsis sonnerati*, and *Zosterops* spp. were consistently cited as prototypical songbirds due to their valued calls and suitability for bird keeping or competitions. The prominence of this category highlights the central role of auditory perception in local bird knowledge and reflects the strong influence of songbird culture (*lomba kicau*) in shaping classification criteria.

Rice-field birds (*burung sawah*) form a distinct category associated with open agricultural landscapes, especially paddy fields and field margins. Species included in this group, such as *Mirafra javanica*, *Bubulcus ibis*, *Lonchura leucogastroides*, and *Anthus rufulus* are identified based on frequent encounters during farming activities and their perceived interactions with crops. Classification into this category is closely linked to habitat visibility and seasonal abundance rather than to feeding ecology alone.

Wetland birds (*burung rawa/air*) are recognized as species commonly encountered in marshes, irrigation channels, and flooded fields. Examples include *Amaurornis phoenicurus*, *Gallinula chloropus*, *Porphyrio indicus*, and *Leptoptilos javanicus*. Respondents distinguished these birds primarily by their association with waterlogged habitats and distinctive movement patterns, indicating that spatial context plays a key role in folk categorization.

Table 1. Sources of bird-related knowledge among respondents in Kalibawang Sub-district, Central Java, Indonesia

Source of knowledge	Number of respondents	Percentage (%)
Parents/elders (>30 years)	97	78.22
Friends/peers (≤30 years)	16	12.90
Personal experience	11	8.87
Total	124	100

Note: All respondents (n = 124) were male. This reflects local socio-cultural norms in which bird hunting, bird-keeping, and ecological knowledge of birds are activities primarily practiced by men

Table 2. Folk-based bird categories and associated species in Kalibawang, Central Java, Indonesia

Folk category (English)	Folk category (Indonesia)	No. species	Percentage (%)	Species name
Songbird	*Burung kicau*	41	53.2	*Aegithina tiphia, Aethopyga eximia, Aethopyga siparaja, Anthreptes malacensis, Arachnothera longirostra, Brachypteryx montana crassa, Chloropsis sonnerati, Cinnyris asiaticus, Cinnyris jugularis, Cinnyris solaris, Copsychus malabaricus, Copsychus saularis, Cyanoptila cyanomelana, Cyornis banyumas, Dicaeum trigonostigma, Dicaeum trochileum, Geopelia striata, Gracupica contra, Lanius schach*, Leptocoma calcostetha, Loriculus galgulus, Monticola solitarius, Myophonus glaucinus, Oriolus chinensis, Orthotomus cucullatus, Orthotomus ruficeps, Orthotomus sepium, Orthotomus sutorius, Padda / Lonchura oryzivora, Pericrocotus speciosus, Prinia familiaris, Pycnonotus aurigaster, Pycnonotus goiavier, Pycnonotus simplex, Spilopelia chinensis, Streptopelia risoria, Timalia pileata, Todiramphus chloris, Todiramphus cyanoventris, Zosterops flavus, dan Zosterops palpebrosus*
Rice-field bird	*Burung sawah*	6	7.8	*Mirafra javanica, Bubulcus ibis, Prinia inornata, Lonchura leucogastroides, Anthus rufulus, Acridotheres javanicus*
Wetland bird	*Burung rawa/air*	4	5.2	*Leptoptilos javanicus, Amaurornis phoenicurus, Gallinula chloropus, Porphyrio indicus*
Sacred bird	*Burung mitos/keramat*	3	3.9	*Nisaetus bartelsi*, Surniculus lugubris*, Otus angelinae**
Predator	*Burung pemangsa*	3	3.9	*Lanius schach*, Dicrurus macrocercus*, Otus angelinae**
Pest bird	*Burung hama tanaman*	3	3.9	*Centropus sinensis, Dicrurus macrocercus*, Passer montanus**
Raptor	*Burung pemangsa udara*	2	2.6	*Elanus caeruleus, Nisaetus bartelsi**
Bird of settlement	*Burung permukiman*	2	2.6	*Columba livia, Passer montanus**
Cage bird	*Burung sangkar*	3	3.9	*Serinus canaria domestica, Agapornis sp, Psittacula alexandri*
Game bird	*Burung buruan*	2	2.6	*Gallus gallus bankiva, Gallus varius*
Poultry	*Unggas*	1	1.3	*Columba livia domestica*
Omen	*Burung pertanda*	1	1.3	*Surniculus lugubris**
None	*Tidak diklasifikasikan*	6	7.8	*Collocalia linchi, Collocalia maxima, Corvus enca, Corvus macrorhynchos, Chrysophlegma flavinucha, Dinopium javanense*

Note: This analysis includes 71 unique bird species. The total of 77 folk classification entries reflects six species assigned to multiple categories (*), consistent with emic, community-derived classifications based on cultural meaning and perceived function rather than scientific taxonomy. In the list above, such species are marked with an asterisk. For example, *Passer montanus* is classified both as a rice-field bird and a pest bird, illustrating how a single species can belong to more than one folk category

Several categories are defined primarily by cultural meaning rather than habitat. Sacred birds (*burung mitos/keramat*), such as *Nisaetus bartelsi*, *Otus angelinae*, and *Surniculus lugubris*, are characterized by symbolic attributes, taboo status, or mythological associations. These species are generally avoided and not subjected to capture, illustrating how cultural beliefs directly influence classification and behavior toward birds. Similarly, omen birds (*burung pertanda*), represented by *S. lugubris*, are identified based on perceived associations with misfortune or significant events, demonstrating the role of belief systems in folk taxonomy.

Functional interaction with human activities also shapes classification. Pest birds (*burung hama tanaman*), including *Centropus sinensis* and *Passer montanus*, are identified based on their perceived negative impact on crops, while predator categories encompass birds recognized for hunting behavior or predation on other animals, such as *Elanus caeruleus* and *N. bartelsi*. Settlement-associated birds (*burung permukiman*) are species frequently observed around houses and villages, reflecting patterns of daily human–bird co-occurrence.

Certain categories explicitly reflect management or use contexts, such as cage birds (*burung sangkar*), game birds (*burung buruan*), and poultry (*unggas*). These groups are defined by human intervention, including keeping, hunting, or domestication, rather than by ecological traits alone. In contrast, a small number of species were not assigned to any specific folk category (*tidak diklasifikasikan*), indicating limited cultural salience or ambiguous roles within local knowledge systems.

The folk classification system in Kalibawang is pluralistic and non-exclusive. As shown in Table 2, several species are assigned to more than one folk category, reflecting an emic logic in which classification is shaped by cultural meaning, perceived function, and situational context rather than by rigid taxonomic boundaries. This flexible categorization underscores the dynamic nature of local ecological knowledge and its close integration with daily practices, beliefs, and agroforestry landscapes.

Utilization patterns and capture techniques

Patterns of bird utilization in Kalibawang show that local communities do not directly exploit most recorded species. As summarized in Table 3, more than half of the species (57.7%; 41 species) fall into the category of no direct use, indicating that many birds are primarily perceived as part of the surrounding environment rather than as resources to be actively harvested or managed. These species are typically encountered during daily activities in agroforestry areas, rice fields, wetlands, or forest edges, but are neither intentionally captured nor maintained by local people.

Active utilization is concentrated on a smaller subset of species, mainly those associated with bird keeping and trade. Pet birds or cage birds account for 15.5% of the recorded species, reflecting the strong cultural importance of songbird keeping in Kalibawang. These species are valued primarily for their vocal performance and suitability for captivity. A further 9.9% of species are categorized under the pet trade, indicating targeted capture and exchange of birds with economic value, often driven by demand related to songbird competitions and urban markets. Domesticated species represent 7.0% of the total and consist of birds that are bred and maintained under controlled conditions rather than captured from the wild.

Other forms of utilization occur at much lower frequencies. Occasionally hunted species (4.2%) include birds captured sporadically, mainly for traditional or opportunistic purposes rather than regular consumption. Sacred or culturally protected birds (2.8%) are recognized for their symbolic or spiritual significance and are deliberately avoided, resulting in non-extractive interactions. Highly specific forms of use are represented by single categories, such as edible nest harvesting (1.4%) and ecosystem services in the form of pest control (1.4%), illustrating that these practices are limited to very few species and are not dominant features of local bird utilization.

Table 3. Categories of bird utilization patterns based on local use in Kalibawang, Central Java, Indonesia

Utilization category (English)	Utilization category (Indonesia)	No. species	Percentage (%)	Species name
No direct use	*Tidak dimanfaatkan langsung*	41	57.7	*Aethopyga eximia*, *Aethopyga siparaja*, *Amaurornis phoenicurus*, *Anthreptes malacensis*, *Anthus rufulus*, *Arachnothera longirostra*, *Brachypteryx montana crassa*, *Centropus sinensis*, *Chrysophlegma flavinucha*, *Cinnyris asiaticus*, *Cinnyris jugularis*, *Cinnyris solaris*, *Collocalia linchi*, *Corvus enca*, *Corvus macrorhynchos*, *Cyanoptila cyanomelana*, *Cyornis banyumas*, *Dicaeum trigonostigma*, *Dicaeum trochileum*, *Dicrurus macrocercus*, *Dinopium javanense*, *Elanus caeruleus*, *Leptocoma calcostetha*, *Leptoptilos javanicus*, *Lonchura leucogastroides*, *Monticola solitarius*, *Myophonus glaucinus*, *Oriolus chinensis*, *Orthotomus cucullatus*, *Orthotomus ruficeps*, *Orthotomus sepium*, *Orthotomus sutorius*, *Passer montanus*, *Pericrocotus speciosus*, *Porphyrio indicus*, *Prinia inornata*, *Pycnonotus simplex*, *Surniculus lugubris*, *Timalia pileata*, *Todiramphus chloris*, *Todiramphus cyanoventris*
Pet bird/cage bird	*Burung peliharaan / sangkar*	11	15.5	*Aegithina tiphia*, *Copsychus saularis*, *Geopelia striata*, *Lanius schach*, *Loriculus galgulus*, *Mirafra javanica*, *Prinia familiaris*, *Pycnonotus aurigaster*, *Pycnonotus goiavier*, *Spilopelia chinensis*, *Zosterops palpebrosus*
Pet trade	*Perdagangan burung*	7	9.9	*Acridotheres javanicus*, *Chloropsis sonnerati*, *Copsychus malabaricus*, *Gracupica contra*, *Lonchura oryzivora*, *Psittacula alexandri*, *Zosterops flavus*
Domesticated	*Domestikasi / ternak*	5	7.0	*Agapornis* sp., *Columba livia*, *Columba livia domestica*, *Serinus canaria domestica*, *Streptopelia risoria*
Occasionally hunted	*Diburu sesekali*	3	4.2	*Gallus gallus bankiva*, *Gallus varius*, *Gallinula chloropus*
Sacred / culturally protected	*Sakral / dilindungi secara budaya*	2	2.8	*Nisaetus bartelsi*, *Otus angelinae*
Edible nest harvested	*Pemanenan sarang*	1	1.4	*Collocalia maxima*
Ecosystem service (pest controller)	*Jasa lingkungan (pengendali hama)*	1	1.4	*Bubulcus ibis*

Note: Each bird species was assigned to a single primary human-use category to avoid overlap, although some species have multiple uses. Data were obtained from interviews (N = 124) and field observations, including the use of *getah pulut*, a sticky adhesive made from jackfruit or breadfruit sap applied to twigs or bamboo sticks to trap small birds

Table 4. Standardized methods of bird capture based on local practices

Method of capture (English)	Method of capture (Indonesia)	No. species	Percentage (%)	Species name
Bird glue trapping	*Getah/pulut*	26	36.6	*Aegithina tiphia*, *Aethopyga eximia*, *Aethopyga siparaja*, *Anthreptes malacensis*, *Arachnothera longirostra*, *Chloropsis sonnerati*, *Cinnyris asiaticus*, *Cinnyris jugularis*, *Cinnyris solaris*, *Dicaeum trigonostigma*, *Dicaeum trochileum*, *Lanius schach*, *Leptocoma calcostetha*, *Lonchura oryzivora*, *Orthotomus cucullatus*, *Orthotomus ruficeps*, *Orthotomus sepium*, *Orthotomus sutorius*, *Prinia familiaris*, *Prinia inornata*, *Pycnonotus aurigaster*, *Pycnonotus goiavier*, *Pycnonotus simplex*, *Timalia pileata*, *Zosterops flavus*, *Zosterops palpebrosus*
Netting (mist nets/nets)	*Jaring*	12	16.9	*Brachypteryx montana crassa*, *Columba livia*, *Copsychus malabaricus*, *Copsychus saularis*, *Cyornis banyumas*, *Lonchura leucogastroides*, *Loriculus galgulus*, *Myophonus glaucinus*, *Oriolus chinensis*, *Passer montanus*, *Psittacula alexandri*, *Spilopelia chinensis*
No capture/taboo	*Tidak ditangkap / tabu budaya*	13	18.3	*Chrysophlegma flavinucha*, *Cyanoptila cyanomelana*, *Dicrurus macrocercus*, *Dinopium javanense*, *Elanus caeruleus*, *Leptoptilos javanicus*, *Monticola solitarius*, *Nisaetus bartelsi*, *Otus angelinae*, *Pericrocotus speciosus*, *Surniculus lugubris*, *Todiramphus chloris*, *Todiramphus cyanoventris*
Snare trapping	*jerat*	8	11.3	*Amaurornis phoenicurus*, *Anthus rufulus*, *Centropus sinensis*, *Gallinula chloropus*, *Gallus gallus bankiva*, *Gallus varius*, *Mirafra javanica*, *Porphyrio indicus*
Domesticated breeding	*Domestikasi/ternak*	4	5.6	*Agapornis* sp., *Columba livia domestica*, *Serinus canaria domestica*, *Streptopelia risoria*
Projectile hunting	*Penembakan (senapan angin/ketapel)*	3	4.2	*Bubulcus ibis*, *Corvus enca*, *Corvus macrorhynchos*
Cage trapping	*Perangkap sangkar/bubu*	3	4.2	*Acridotheres javanicus*, *Geopelia striata*, *Gracupica contra*
Nest harvesting	*Pemanenan sarang*	2	2.8	*Collocalia linchi*, *Collocalia maxima*

Note: A total of 71 species (100%) were recorded, with each species assigned to a single dominant capture method for analytical clarity, although multiple techniques may be known or occasionally used in practice; the documented capture methods reflect traditional practices and do not imply legality

Bird capture techniques documented in Kalibawang are similarly uneven in their distribution across species (Table 4). Bird glue trapping (*getah/pulut*) is the most widely applied method, accounting for 36.6% of species. This technique is predominantly used for small to medium-sized passerines and is closely associated with agroforestry settings where birds frequently perch on branches or bamboo stems. Netting (*jaring*), including mist nets and simple nets, represents the second most common method (16.9%) and is applied to species that move along predictable flight paths or forage at lower strata.

A substantial proportion of species (18.3%) are not captured at all due to cultural taboos or deliberate avoidance, particularly those considered sacred, ecologically important, or culturally inappropriate to hunt. Snare trapping (*jerat*) accounts for 11.3% of species and is primarily associated with ground-dwelling or semi-terrestrial birds. Other capture methods occur at lower frequencies, including domesticated breeding (5.6%), projectile hunting using air rifles or slingshots (4.2%), cage trapping (4.2%), and nest harvesting (2.8%).

Bird use in Kalibawang is highly selective and culturally regulated. Only a few species are intensively targeted for keeping or trade using specific capture methods, while most are not used or are protected by cultural norms. As shown in Tables 3 and 4, cultural values, economic interests, and ethical constraints together shape human–bird interactions in this agroforestry landscape.

Alignment between local ecological knowledge and scientific knowledge

To ensure analytical clarity, Table 5 lists selected species for detailed LEK–science comparison, chosen for high cultural salience, well-developed interview narratives, and strong scientific information on ecology or conservation status; species with limited relevance or data were excluded to avoid speculation. Overall, LEK in Kalibawang corresponds closely with scientific knowledge, particularly regarding habitat associations and conspicuous behaviors, especially for frequently encountered and culturally important species (Table 5).

Strong alignment is evident for forest-dependent and culturally protected species. *Nisaetus bartelsi* (Elang Jawa), for example, is locally regarded as a “penjaga alas” (guardian of the forest) and is deliberately avoided by villagers. This perception corresponds well with scientific knowledge identifying the species as an endemic and endangered forest raptor requiring large, intact forest territories. Local practices of avoiding forest clearing near

nesting areas further reinforce this alignment and suggest an implicit form of community-based conservation. Similar congruence is observed for *O. angelinae*, which is culturally protected and scientifically recognized as forest-dependent and sensitive to habitat disturbance.

Culturally salient songbirds also show a high degree of LEK–science convergence. Species such as *Copsychus malabaricus*, *C. saularis*, *P. aurigaster*, and *Zosterops palpebrosus* are valued locally for vocal performance and social behavior. Scientific studies confirm their complex vocal repertoires, territoriality, and, in the case of *Zosterops*, strong flocking tendencies. Local recognition of declining populations in species such as *C. sonnerati* and *Padda oryzivora* is consistent with their documented endangered status and links population decline to trapping pressure and habitat loss.

Alignment is also apparent in habitat-based knowledge. According to Table 6, agroforestry systems represent the dominant habitat context for most recorded species, a pattern that is well recognized by respondents. Local associations of particular species with agroforests, rice fields, wetlands, or forest interiors correspond closely with scientific habitat classifications. For example, rice-field species such as *L. leucogastroides* and *Spilopelia chinensis* are consistently associated with paddy landscapes, while wetland species such as *A. phoenicurus* and *G. chloropus* are linked to flooded fields and marshy areas. These habitat associations demonstrate accurate spatial ecological reasoning derived from repeated daily encounters.

Table 5. Alignment between local ecological knowledge and scientific information for selected bird species in Kalibawang, Central Java, Indonesia

Species name	Local name	Local Ecological Knowledge (LEK)	Scientific knowledge	Alignment/mismatch
Nisaetus bartelsi	Elang Jawa	Considered "penjaga alas" (guardian of forests); never hunted; believed to bring protection	Endemic to Java, endangered, forest raptor requiring a large territory	**Aligned** – habitat and conservation relevance understood by locals
		Locals avoid cutting the forest near nests	Needs an intact forest canopy; sensitive to logging	**Aligned** – supports community-based conservation
Surniculus lugubris	Kedasih	Call signifies misfortune or death; avoided by villagers	Brood parasite cuckoo; known for its melancholic call; not ecologically dangerous	**Partial mismatch** – cultural myth vs. biological neutrality
Copsychus malabaricus	Murai Batu	Excellent songbird; trapped using pulut; high economic value	Known for complex vocal mimicry; overexploited in the bird trade	**Aligned** – locals understand species rarity due to trade
Padda oryzivora	Gelatik Jawa	Rarely seen now, a symbol of Javanese culture	Endemic to Java; endangered due to capture and habitat loss	**Aligned** – local awareness matches scientific decline
Lonchura leucogastroides	Pipit / Bondol	Considered a rice-field pest; hunted during harvest	Primarily granivorous; agricultural pest in Southeast Asia	**Aligned** – perception as pest matches scientific ecology
Gallus gallus bankiva	Ayam Hutan	Used in rituals, cockfighting, and ancestral offerings	Ancestor of the domestic chicken; native to forests and agroforests	**Aligned** – biological and cultural roles consistent
Zosterops palpebrosus	Pleci	Popular singing bird; associated with harmony and togetherness	Known for social flocking behavior and vocal communication	**Aligned** – folk belief reflects ecological behavior
Gracupica contra	Jalak Suren	Believed to bring good luck; mimics human speech	Mimicry confirmed scientifically; now endangered in Java	**Aligned,** but local trade pressure persists
Chloropsis sonnerati	Cucak Ijo	Valued for song; populations are decreasing	Endangered; trapped for the songbird trade; dependent on the forest canopy	**Aligned** – community recognizes decline
Loriculus galgulus	Serindit / Serindit Melayu	Nestlings are sometimes taken from tree hollows	Known cavity nester; vulnerable to nest poaching	**Aligned** – traditional practice impacts conservation

Note*:* Only 10 species are presented because this table focuses on taxa with strong cultural significance, detailed LEK narratives, and well-documented scientific information, allowing robust LEK–science comparison. Other species were excluded due to limited cultural relevance or insufficient comparative data

Table 6. Dominant habitat of birds based on local use in Kalibawang, Central Java, Indonesia

Dominant habitat	No. of species	Percentage (%)	Species names
Agroforestry	30	42.25%	*Aegithina tiphia, Aethopyga eximia, Anthreptes malacensis, Arachnothera longirostra, Centropus sinensis, Chloropsis sonnerati, Cinnyris asiaticus, Cinnyris jugularis, Cinnyris solaris, Copsychus saularis, Dicaeum trigonostigma, Dicaeum trochileum, Dinopium javanense, Geopelia striata, Gracupica contra, Lanius schach, Leptocoma calcostetha, Loriculus galgulus, Oriolus chinensis, Orthotomus ruficeps, Orthotomus sepium, Orthotomus sutorius, Prinia familiaris, Psittacula alexandri, Pycnonotus aurigaster, Pycnonotus goiavier, Pycnonotus simplex, Timalia pileata, Zosterops flavus, Zosterops palpebrosus*
Forest	11	15.49%	*Brachypteryx montana crassa, Chrysophlegma flavinucha, Corvus enca, Cyanoptila cyanomelana, Cyornis banyumas, Gallus varius, Nisaetus bartelsi, Orthotomus cucullatus, Otus angelinae, Pericrocotus speciosus, Surniculus lugubris*
Forest edge	3	4.23%	*Aethopyga siparaja, Copsychus malabaricus, Gallus gallus bankiva*
Grassland / open fields	6	8.45%	*Acridotheres javanicus, Anthus rufulus, Corvus macrorhynchos, Dicrurus macrocercus, Elanus caeruleus, Mirafra javanica*
Rice fields	5	7.04%	*Bubulcus ibis, Lonchura leucogastroides, Lonchura oryzivora, Prinia inornata, Spilopelia chinensis*
Settlements	7	9.86%	*Agapornis* sp.*, Collocalia linchi, Columba livia, Columba livia domestica, Passer montanus, Serinus canaria domestica, Streptopelia risoria*
Wetlands	4	5.63%	*Amaurornis phoenicurus, Gallinula chloropus, Leptoptilos javanicus, Porphyrio indicus*
Riverine	3	4.23%	*Myophonus glaucinus, Todiramphus chloris, Todiramphus cyanoventris*
Cliffs / rocky areas	2	2.82%	*Collocalia maxima, Monticola solitarius*
Total	71	100.00%	

Note: Each species was assigned to one dominant habitat based on local use and observation to avoid double-counting; habitat categories reflect human–bird interaction contexts rather than exclusive ecological preferences

Feeding guild classifications further illustrate areas of convergence and divergence between LEK and scientific knowledge (Table 7). In many cases, local perceptions reflect dominant dietary tendencies, such as the recognition of granivorous species (*Lonchura* spp., *Passer montanus*) and carnivorous raptors (*N. bartelsi*, *Elanus caeruleus*). However, partial mismatches occur where perceptual cues outweigh trophic accuracy. Several insectivorous species observed in rice fields, such as *Dicrurus macrocercus*, are sometimes perceived as crop pests due to their frequent presence during harvest periods, despite scientific evidence that they primarily consume insects and may contribute to pest regulation. These mismatches reflect visibility-based inference rather than a lack of ecological awareness.

Additional divergences are linked to symbolic interpretation rather than ecological misunderstanding. *Surniculus lugubris*, for instance, is widely avoided due to its association with misfortune, while scientific knowledge characterizes the species as a brood-parasitic cuckoo without harmful ecological effects. Such cases represent cultural overlays on ecological knowledge rather than direct contradictions and highlight the role of belief systems in shaping LEK.

LEK in Kalibawang largely aligns with scientific ornithological knowledge, especially regarding habitat use, conspicuous behavior, and culturally important species. Any mismatches mainly reflect perceptual salience, symbolic meanings, or context-dependent interpretations rather than major ecological errors. This highlights LEK as a valuable complementary information source for understanding human–bird interactions in agroforestry landscapes.

Culturally salient bird species

Culturally salient birds in Kalibawang are frequently cited for their aesthetic value, symbolic meaning, direct use, or perceived population trends. Table 8 highlights twelve prominent species that play key roles in local practices, beliefs, and management—through bird keeping and trade, ritual use, avoidance norms, and conservation awareness.

Songbirds with high aesthetic and economic value dominate this group. *Copsychus saularis* and *C. malabaricus* are consistently highlighted as prestigious birds for songbird competitions (*lomba burung*), valued for strong, complex, and aggressive vocal performances. These species are actively kept or traded and command high market prices, particularly *C. malabaricus*, which is widely recognized by locals as increasingly rare due to intensive trapping. Similarly, *C. sonnerati* and *Gracupica contra* are culturally associated with wealth, prestige, and vocal mimicry, and respondents frequently noted declining encounters with these species in the wild, aligning with their protected and endangered status.

Several culturally salient species are valued primarily as cage birds rather than commercial commodities. *Geopelia striata*, *Z. palpebrosus*, *Loriculus galgulus*, and *C. saularis* are commonly kept for companionship, soundscape enrichment, and aesthetic enjoyment. In particular, *Z. palpebrosus* has gained prominence through the recent "pleci mania" trend, while *L. galgulus* is appreciated for its coloration and soft calls. These species are generally perceived as approachable and easy to maintain, reinforcing their popularity among household bird keepers.

Cultural salience in Kalibawang is not limited to use; some species are prominent because they are protected or avoided. *Nisaetus bartelsi* is viewed as a sacred forest

guardian (*penjaga alas*), so people intentionally avoid hunting or disturbing it. *Surniculus lugubris* is associated with misfortune or death; although not used, its call is considered taboo and strongly influences local behavior toward the species.

Table 7. Feeding guild of birds based on local use in Kalibawang, Central Java, Indonesia

Feeding guild	No. of species	Percentage (%)	Species names
Insectivore	27	38.03%	*Aegithina tiphia, Anthus rufulus, Brachypteryx montana crassa, Bubulcus ibis, Centropus sinensis, Chrysophlegma flavinucha, Collocalia linchi, Collocalia maxima, Copsychus malabaricus, Copsychus saularis, Cyanoptila cyanomelana, Cyornis banyumas, Dicrurus macrocercus, Dinopium javanense, Lanius schach, Mirafra javanica, Monticola solitarius, Myophonus glaucinus, Orthotomus cucullatus, Orthotomus ruficeps, Orthotomus sepium, Orthotomus sutorius, Pericrocotus speciosus, Prinia familiaris, Prinia inornata, Surniculus lugubris, Timalia pileata*
Omnivore	8	11.27%	*Acridotheres javanicus, Amaurornis phoenicurus, Corvus enca, Corvus macrorhynchos, Gallinula chloropus, Gallus gallus bankiva, Gallus varius, Gracupica contra*
Granivore	7	9.86%	*Agapornis* sp., *Columba livia, Geopelia striata, Lonchura leucogastroides, Lonchura oryzivora, Passer montanus, Spilopelia chinensis*
Nectarivore	7	9.86%	*Aethopyga eximia, Aethopyga siparaja, Anthreptes malacensis, Cinnyris asiaticus, Cinnyris jugularis, Cinnyris solaris, Leptocoma calcostetha*
Carnivore	5	7.04%	*Elanus caeruleus, Nisaetus bartelsi, Otus angelinae, Todiramphus chloris, Todiramphus cyanoventris*
Frugivore–Insectivore	4	5.63%	*Chloropsis sonnerati, Oriolus chinensis, Pycnonotus aurigaster, Pycnonotus goiavier*
Frugivore	3	4.23%	*Loriculus galgulus, Psittacula alexandri, Pycnonotus simplex*
Nectarivore–Insectivore	3	4.23%	*Arachnothera longirostra, Zosterops flavus, Zosterops palpebrosus*
Domesticated	3	4.23%	*Columba livia domestica, Serinus canaria domestica, Streptopelia risoria*
Frugivore–Nectarivore	2	2.82%	*Dicaeum trigonostigma, Dicaeum trochileum*
Herbivore	1	1.41%	*Porphyrio indicus*
Scavenger	1	1.41%	*Leptoptilos javanicus*
Total	71	100%	

Note: Each species was assigned to one primary feeding guild based on dominant dietary traits to avoid double-counting; guild categories represent general feeding tendencies rather than exclusive or quantitative diets

Table 8. Culturally significant bird species and their perceived ecological roles in Kalibawang, Central Java, Indonesia

Scientific name	Cultural role/meaning	Utilization type	Conservation/ legal status	Notes from local knowledge
Copsychus malabaricus	Prestigious songbird for contests (lomba burung)	Pet trade	Protected (Permen LHK), LC, CITES II	High market price; trapped using pulut or mist nets
Chloropsis sonnerati	Symbol of wealth, high aesthetic value	Pet trade	EN, Protected	Populations are declining; locals say "susah ditemui di alam."
Geopelia striata	Brings tranquility, spiritual harmony	Pet bird / cage bird	Not protected, LC	Believed to bring fortune to households
Nisaetus bartelsi	Sacred forest guardian; omen of protection	Sacred / culturally protected	EN, Protected, CITES II	Locals avoid hunting; called "penjaga alas."
Surniculus lugubris	Believed to predict death or misfortune	No direct use	LC	Its call is taboo to mimic; associated with sorrow
Gallus gallus bankiva	Ritual sacrifices, ancestor offerings	Occasionally hunted	LC, Protected	Used in selametan and traditional rituals
Lonchura leucogastroides	Considered rice pest (hama padi)	No direct use	LC	Trapped using jaring; children hunt with slingshots
Padda oryzivora	Formerly abundant, now rare; cultural icon	Pet trade	EN, Protected	Associated with the rural identity of Java
Zosterops palpebrosus	Popular cage bird, "pleci mania" culture	Pet bird / cage bird	LC	Kept for group singing (ngerumpi), easy to trap
Gracupica contra	Prestige bird; mimics human speech	Pet trade	EN, Protected	Populations are dropping; only a few are spotted in the field
Loriculus galgulus	Kept for beauty and unique soft calls	Pet bird / cage bird	LC, CITES II	Traded locally; nestlings sometimes taken from trees
Copsychus saularis	Songbird in competitions; symbol of virility	Pet bird / cage bird	LC	Valued for aggressive singing style ("tarung gaya")

Note: These 12 species were selected because they represent birds with the highest cultural relevance, direct human use (pet, ritual, trade, pest control), legal or conservation concern, or were reported by locals as declining in the wild

Other species are salient due to their roles in ritual or subsistence-related contexts. *Gallus gallus bankiva* is occasionally hunted and used in traditional rituals, such as *selametan* and ancestral offerings, reflecting its cultural importance despite limited frequency of use. In contrast, *L. leucogastroides* is culturally recognized as a rice-field pest (*hama padi*); although not intensively exploited, its presence during harvest periods makes it salient in agricultural narratives and childhood hunting practices.

Finally, some species are emphasized because of their symbolic and historical significance. *Padda oryzivora*, once abundant and now rarely observed, is widely regarded as a cultural icon of rural Java. Respondents frequently linked its decline to trapping pressure and habitat change, demonstrating local awareness of conservation issues consistent with its endangered status.

Culturally salient birds in Kalibawang reflect diverse relationships—from trade and recreational keeping to symbolic protection and cultural avoidance. Their prominence arises from the overlap of cultural values, livelihoods, and conservation perceptions, showing how local knowledge highlights certain taxa and shapes human–bird interactions in agroforestry landscapes.

Ethnobiological indices (UV, RFC, CI)

Patterns derived from ethnobiological indices—Use Value (UV), Relative Frequency of Citation (RFC), and Cultural Importance (CI)—offer quantitative insight into how bird species are embedded within the socio-cultural and ecological fabric of Kalibawang. Although full numerical outputs are presented in Table S2, several clear trends emerge from the analysis, particularly regarding the top ten species with the highest CI scores. Species that dominate multiple dimensions of cultural relevance include *P. aurigaster*, *C. saularis*, *Zosterops* spp., *C. sonnerati*, *Leptocoma* spp., and a small number of forest-edge insectivores such as *D. macrocercus*. These species appear at the intersection of high visibility, frequent acoustic presence, ease of recognition, and functional roles within agroforestry systems.

Among these, *P. aurigaster* and *C. saularis* consistently exhibited the highest RFC values, reflecting the fact that nearly all respondents mentioned them spontaneously in free-listing exercises. Their ubiquity in agroforestry soundscapes and homegardens makes them cognitively accessible, while their long-standing cultural resonance ensures intergenerational transmission of knowledge. High UV values for these species indicate the breadth of their uses—from recreational keeping and vocal training to symbolic associations and, historically, occasional roles in ritual contexts. Their enduring familiarity explains why they anchor the cognitive structure of Kalibawang's folk ornithology.

The broad distribution of *Zosterops* and *Leptocoma* species across gardens, flowering shrubs, and semi-open agroforest zones also contributes to their elevated CI. Respondents frequently attributed ecological functions to these taxa: pleci (*Zosterops*) as indicators of flowering periods and landscape productivity, and sunbirds (*Leptocoma*) as pollinators whose presence signals healthy homegarden ecosystems. These functional interpretations align with scientific guild classifications, explaining the strong alignment between LEK and ecology-based indices discussed earlier.

The combined behavior of UV, RFC, and CI illustrates not only species salience but also social–ecological dependency: species that are repeatedly encountered, economically relevant, acoustically valued, or symbolically meaningful naturally occupy central positions in local knowledge networks. Conversely, species with low CI scores tend to be either cryptic, transient, difficult to trap, or lacking significance in songbird culture.

Overall, ethnobiological indices reveal a coherent hierarchy of cultural importance, where daily familiarity, ecological function, and aesthetic value intersect to define which birds matter most to agroforestry communities. Numerical details for all species are available in Table S1.

Discussion

Transmission of bird knowledge in the Javanese agroforestry society

The transmission of bird-related knowledge in Kalibawang reflects a deeply rooted patrilineal structure, shaped by cultural norms, labor division, and the historical role of men in agroforestry management. Consistent with Table 1, the majority of the 124 respondents across four villages identified fathers, grandfathers, and older male mentors as their primary sources of bird-related knowledge, a pattern that aligns with ethnobiological observations in rural Southeast Asia where ecological knowledge is strongly gendered (Pfeiffer and Butz 2005; Jepson and Ladle 2009). In Javanese society, manuk (birds) have long been embedded within masculine domains of expertise—hunting, forest roaming, bird keeping, competitive songbird training, and participation in local markets. This cultural framing regulates who has access to experiential learning opportunities and who becomes recognized as a knowledge authority within the community.

Comparative studies across Indonesia reinforce this pattern. In Bali, Sulawesi, and the Lesser Sunda Islands, bird hunting and bird keeping are overwhelmingly practiced by men, resulting in male-dominated knowledge transmission systems (e.g., Katuwal et al. 2021; Plieninger et al. 2025). Similarly, ethnobiological studies among Sundanese and Madurese communities show that women rarely participate in bird-related activities except in supportive roles such as cage cleaning or preparing feed. As documented in Kalibawang, this limited female involvement reflects culturally structured divisions of labor rather than explicit exclusion, resonating with broader global literature on gendered ecological knowledge where mobile wildlife taxa are typically associated with male expertise (Howard 2003; Reyes-García et al. 2009). In Kalibawang, such patterns are reinforced through daily socialization: boys accompany their fathers to agroforest margins, learn to recognize calls, practice setting traps, and gradually build competency in both folk taxonomy and bird behavior interpretation.

The patrilineal structure is further sustained by the cultural prominence of *kicau* (songbird) activities, which

function not only as recreation but also as a form of social capital among men. Participation in lomba *kicau* requires mastery of species identification, vocal variation, conditioning techniques, and ecological cues—skills that are rarely transmitted to daughters or female relatives. Table 1 show that mentor–apprentice relationships among hobbyists constitute an important secondary pathway of knowledge transmission, extending beyond kinship ties. Such networks are characteristic of Indonesian songbird culture, where knowledge circulates through informal peer groups, competition teams, and local market interactions. Studies from Java and Sumatra indicate that these networks act as powerful learning institutions, shaping species preference, trapping pressure, and valuation systems (Chng and Eaton 2016; Marshall et al. 2020). In Kalibawang, these mechanisms explain why younger men increasingly acquire expertise not only from family members but also from experienced bird keepers, thereby diversifying local knowledge channels.

Despite its gendered character, LEK in Kalibawang remains highly adaptive. Respondents reported the incorporation of new learning media, including digital song recordings, acoustic analysis, and online tutorials, reflecting broader transformations in contemporary Indonesian songbird cultures. This adaptive exchange supports the persistence of detailed ecological understanding even as trapping practices and competition standards evolve. Importantly, while most knowledge transmission remains oral and practice-based, the Results demonstrate a high degree of internal consistency in folk taxonomy across villages, indicating strong cultural coherence maintained through repeated observation and shared practice.

Regional comparisons further suggest that Javanese agroforestry landscapes—characterized by mixed fruit gardens, bamboo groves, rice fields, and forest-edge habitats—provide particularly favorable conditions for bird knowledge acquisition. As shown in Table 1, village-level variation in knowledge emphasis corresponds closely with dominant local habitats, with forest-adjacent communities reporting greater familiarity with forest taxa and settlement-based villages emphasizing garden and agricultural species. Such patterns parallel findings from Amazonian and Melanesian contexts, where early and continuous exposure to diverse soundscapes and habitats underpins the development of detailed ornithological knowledge (Berlin 1992; Hunn 2002).

The patrilineal, practice-based, and competition-influenced structure of knowledge transmission in Kalibawang mirrors broader Southeast Asian patterns while retaining distinctively Javanese cultural features. These transmission pathways directly shape which species become culturally salient, how folk classifications are reinforced, and how communities interpret ecological change, providing an essential foundation for understanding human–bird interactions in agroforestry landscapes.

Folk taxonomy and cultural cognition

The folk classification system documented in Kalibawang reflects core cognitive principles widely recognized in ethnobiology, particularly the hierarchical organization of living organisms as described by Brown (1979), Hunn (1982), and Berlin (1992). At the broadest level, respondents recognize a general life-form category equivalent to birds (*manuk*), encompassing all volant vertebrates perceived as avifauna. This life-form category functions as a broad cognitive umbrella rather than a taxonomic unit in the scientific sense. Below this level, birds are organized into a series of culturally meaningful folk categories that correspond to everyday experience, habitat association, symbolic meaning, and practical relevance rather than to formal scientific taxonomy. These categories, summarized in Table 2, include songbirds, rice-field birds, wetland birds, predators, sacred birds, pest birds, settlement-associated birds, game birds, poultry, omen birds, and unclassified species.

Among these, songbirds (*burung kicau*) constitute the most cognitively dominant category, both in terms of species richness and cultural salience. Classification into this group is primarily based on acoustic qualities, particularly melodious, complex, or distinctive vocalizations. Species such as *C. saularis*, *P. aurigaster*, *C. sonnerati*, and *Zosterops* spp. are consistently recognized as prototypical members of this category. The prominence of songbirds reflects the central role of auditory perception in local bird knowledge and the strong influence of songbird keeping and competitive bird contests (*lomba kicau*) on cognitive categorization. Similar sound-based folk groupings have been reported in other Javanese and Sundanese communities, where vocal performance strongly shapes aesthetic and economic valuation of birds (Iskandar et al. 2016).

Habitat-based cognition also plays a major role in structuring folk taxonomy. Rice-field birds (*burung sawah*) and wetland birds (*burung rawa/air*) are defined largely by spatial context and patterns of encounter during agricultural activities. Species associated with paddy fields, irrigation canals, and flooded areas are grouped according to frequent visibility in these environments rather than strict dietary criteria. This spatially grounded classification illustrates how daily livelihood activities—particularly farming—shape perceptual salience and taxonomic grouping, a pattern widely observed in agrarian societies across Southeast Asia.

Several folk categories are primarily defined by cultural meaning and symbolic interpretation rather than ecological traits. Sacred birds (*burung mitos/keramat*), such as *N. bartelsi* and *O. angelinae*, are characterized by taboo status, mythological associations, or perceived spiritual roles, resulting in deliberate avoidance and non-capture. Similarly, omen birds (*burung pertanda*), represented by *S. lugubris*, are classified based on their perceived ability to signal misfortune or significant events. These categories illustrate that belief systems are not peripheral but integral components of folk taxonomic reasoning, influencing both classification and human behavior toward birds.

Functional interaction with human activities further shapes cognitive categorization. Pest birds (*burung hama tanaman*) are identified based on perceived negative impacts on crops, while predator categories include species recognized for hunting behavior or predation. Settlement-associated birds (*burung permukiman*) are grouped according to frequent co-occurrence with humans in residential areas, reflecting patterns of everyday familiarity. Other categories, such as cage birds, game birds, and poultry, are explicitly defined by modes of management, including keeping, hunting, or domestication, underscoring the role of human intervention in shaping folk taxonomic boundaries.

Importantly, the folk taxonomy of Kalibawang is non-exclusive and context dependent. As shown in Table 2, several species are assigned to more than one folk category, reflecting an emic logic in which classification varies according to situation, function, and cultural meaning. For example, a species may simultaneously be recognized as a rice-field bird and a pest bird, or as a songbird and a settlement-associated species. This flexibility is consistent with Hunn's (1982) concept of cultural elaboration, whereby species of high cultural relevance receive more detailed and context-sensitive classification than ecologically marginal taxa.

The degree of correspondence between folk taxonomy and scientific ecology is generally high, particularly with respect to habitat association and conspicuous behavioral traits. However, divergences occur when perceptual salience overrides trophic accuracy, such as when insectivorous species observed in rice fields are perceived as crop pests. These patterns echo findings from other agrarian landscapes, where proximity to crops strongly influences local interpretations of bird behavior (Ntiamoa-Baidu 1995). Rather than indicating misinterpretation, such divergences reflect pragmatic, interaction-based ecological reasoning grounded in everyday experience.

The folk taxonomy of Kalibawang demonstrates a cognitively efficient and culturally embedded system that integrates perceptual cues, functional relationships, and symbolic meaning. This hybrid structure reinforces the analytical value of local ecological knowledge for understanding human–bird interactions in agroforestry landscapes and provides an essential interpretive bridge between cultural cognition and ecological processes.

Dynamics of bird utilization: subsistence, ritual, market, and hobby

Patterns of bird utilization in Kalibawang demonstrate a clear shift from historically diverse forms of interaction toward increasingly selective, culturally mediated use. As shown in Table 3, the majority of recorded bird species (57.7%) are currently not directly utilized, indicating that most birds are perceived primarily as elements of the surrounding agroforestry landscape rather than as consumable resources. This pattern contrasts with earlier subsistence-oriented practices recalled by older respondents, in which small granivorous species, particularly *L. leucogastroides* and related taxa, were occasionally harvested during rice harvest periods, mainly as opportunistic or childhood hunting activities rather than as a primary protein source. Comparable low-intensity subsistence use has been reported from other rural parts of Java and eastern Indonesia (Wadley et al. 1997; Riley 2002).

In contemporary Kalibawang, direct consumption of birds is rare and confined to a very small subset of species categorized as "occasionally hunted" (4.2%; Table 3), such as *G. g. bankiva* and *Gallus varius*. Respondents commonly described bird consumption as outdated, unnecessary, or culturally marginal, attributing its decline to improved food availability, changing dietary norms, and growing awareness of wildlife protection. This pattern mirrors transitions documented in Karangwangi and other Javanese agroforestry communities, where bird use has shifted away from subsistence necessity toward symbolic, recreational, or economic motivations (Iskandar and Iskandar 2015).

Ritual and symbolic uses have likewise diminished in practical importance. Results indicate that ritual use is now limited to a very small number of species and is largely embedded within cultural memory rather than active practice. Older respondents recalled symbolic associations, such as interpreting the presence of *P. aurigaster* as a sign of household harmony or associating the calls of *S. lugubris* with misfortune. While such beliefs persist, Table 3 shows that species linked to ritual or symbolic meaning are currently classified either as "no direct use" or "sacred/culturally protected," rather than as actively exploited taxa. This pattern suggests a broader secularization of ecological symbolism, consistent with trends reported among Javanese and Sundanese communities (Geertz 1960; Ekowati et al. 2024).

The most pronounced transformation in bird utilization is the rise of market-oriented and hobby-driven practices. According to Table 3, pet birds and pet trade together account for more than one-quarter of all utilized species (25.4%), reflecting the strong influence of songbird culture and urban market demand. Species such as *C. saularis*, *C. malabaricus*, *C. sonnerati*, *Z. palpebrosus*, and *Gracupica contra* have acquired heightened cultural and economic value due to their vocal performance, aesthetic traits, and prestige within lomba kicau networks. These findings are consistent with studies showing that Indonesian bird markets and competition circuits shape species preference and intensify selective trapping (Jepson and Ladle 2005; Chng and Eaton 2016; Marshall et al. 2020).

Results from Table 4 further demonstrate that capture techniques are closely aligned with utilization type, with bird glue trapping (*getah*/*pulut*) and netting (*jaring*) dominating methods used for songbirds and trade-targeted species. Hobby-driven capture is highly selective, focusing on individuals with desirable vocal traits rather than indiscriminate harvesting. Mentor–apprentice networks among hobbyists facilitate the transmission of species-specific knowledge related to song quality, conditioning, and capture techniques, reinforcing both cultural cohesion and trapping pressure on favored taxa. Similar dynamics have been documented in Java and Sumatra, where hobby culture reshapes ecological knowledge and contributes to

population declines of heavily targeted species (Harris et al. 2015; Leupen et al. 2020).

Despite increasing commercialization, local ethical norms continue to regulate bird capture and use, albeit unevenly. Respondents frequently referred to aturan ndaru, an unwritten customary rule discouraging capture during nesting periods. This ethic is reflected in Table 4 by the relatively high proportion of species classified as "not captured/taboo" (18.3%), particularly forest-dependent and culturally protected birds such as *N. bartelsi* and *O. angelinae*. While adherence to these norms varies across households and age groups, their persistence indicates that moral considerations still play a role in moderating exploitation, even in the absence of formal enforcement.

Collectively, the Results support a trajectory of change in Kalibawang characterized not by linear replacement, but by selective retention and reconfiguration of bird use. Subsistence and ritual practices have largely receded, while market and hobby-based interactions now dominate extractive use, alongside a broad category of species that remain culturally recognized yet non-utilized. This pattern underscores that bird utilization in Kalibawang is not intensive overall, but highly selective, culturally framed, and mediated by economic opportunity and ethical constraints. These dynamics parallel broader patterns observed in other Javanese agroforestry landscapes and highlight the need for conservation approaches that engage with hobby culture, market demand, and local moral frameworks rather than focusing solely on subsistence hunting reduction.

Cultural salience, guilds, and ecological services

Cultural salience of birds in Kalibawang emerges from the interaction between perceptual prominence (acoustic and visual traits), frequency of encounter, and perceived ecological function within agroforestry landscapes. Species characterized by conspicuous vocalizations or striking plumage—such as *C. saularis*, *Zosterops* spp., and *C. sonnerati*—were consistently identified in the results (Table 8) as culturally prominent taxa. These species are not only aesthetically valued but also highly visible and audible in daily agroforestry activities, reinforcing their cognitive salience. Similar links between perceptual cues and cultural valuation have been widely documented in ethnobiological studies across tropical regions (Berlin 1992; Atran 1990; Hunn 1999).

Local interpretations of bird ecology closely parallel scientific feeding guild classifications. As summarized in Table 7, insectivorous birds constitute the dominant guild (38.03%), and many of these species—such as *C. saularis*, *D. macrocercus*, *Orthotomus* spp., and *Prinia* spp.—are widely perceived as beneficial components of agroforestry systems. Respondents frequently associated these birds with reduced insect abundance in rice fields, homegardens, and mixed-crop plots. Although such benefits are expressed in non-technical terms, they correspond well with ecological evidence demonstrating the role of insectivorous birds in pest regulation within tropical agricultural mosaics (Şekercioglu 2006; Maas et al. 2015).

Nectarivorous and frugivorous guilds are likewise recognized through seasonal and habitat-based observation. Nectarivores, including *Leptocoma* spp. and *Cinnyris* spp., were commonly linked to flowering trees and shrubs in agroforestry and settlement environments (Table 6), while frugivores and frugivore–insectivores such as *P. aurigaster*, *Oriolus chinensis*, and *Zosterops* spp. were associated with fruiting cycles and vegetation regeneration. These observations align with established ecological roles of birds as pollinators and seed dispersers in tropical agroforestry systems (Kissling et al. 2007; Karp et al. 2013). Thus, cultural recognition of these species is grounded not only in aesthetics but also in repeated empirical observation of ecological processes.

The correspondence between folk categories and scientific guilds reflects a vernacular "folk guild" system, in which birds are grouped according to perceived function and behavior rather than taxonomic affinity. Songbirds (burung kicau), which dominate local classification (Table 2), overlap strongly with insectivorous, nectarivorous, and frugivore–insectivore guilds that are acoustically active and visually conspicuous. This pattern supports broader ethnobiological findings that folk taxonomies often converge with functional ecological groupings, particularly in communities with frequent, multisensory interaction with wildlife (Hamzah et al. 2023).

Landscape context further reinforces this alignment. As shown in Table 6, agroforestry habitats account for the largest proportion of recorded species (42.25%), followed by forest, settlement, and rice-field environments. This heterogeneous mosaic provides continuous opportunities for observing bird foraging, movement, and habitat use, allowing ecological knowledge to be built through direct experience rather than abstract inference. The dominance of agroforestry-associated species among culturally salient birds highlights the importance of multifunctional landscapes in sustaining both ecological processes and local knowledge systems.

The results demonstrate that cultural salience in Kalibawang is closely intertwined with feeding guild structure and perceived ecological services. Birds are valued not only for their aesthetic and acoustic qualities but also for their functional roles in agroforestry systems, particularly insect control, pollination, and seed dispersal. This convergence between cultural valuation and ecological function underscores the analytical strength of LEK and supports its relevance for conservation and landscape management in human-dominated tropical environments.

Taken together, the alignment between cultural valuation and ecological function underscores the depth of ecological understanding embedded within Kalibawang's LEK system. Birds are appreciated not only for their aesthetic and acoustic qualities but also for the ecological services they provide to agroforestry systems. This synergy highlights the potential of integrating LEK into conservation planning, particularly in multifunctional landscapes where ecological processes and cultural traditions are mutually reinforcing.

Taken together, these culturally grounded perceptions of ecological function and aesthetic value demonstrate how local knowledge systems actively shape community attitudes toward bird protection. Such intertwined cultural–ecological logics naturally extend into the realm of conservation practice, providing the socio-cultural basis for the management implications discussed in the next section.

Implications for conservation and community-based management

The strong cultural attachment to certain bird species in Kalibawang provides a distinctive foundation for conservation initiatives that resonate with local values and everyday experience. Species with high aesthetic, acoustic, or symbolic significance—such as *C. saularis*, *P. aurigaster*, and *Zosterops* spp.—are more readily subject to informal attention, selective care, or cultural avoidance by residents because they contribute to household identity, community pride, and the familiar soundscape of agroforestry gardens. This pattern parallels findings from other Indonesian and Southeast Asian contexts, where culturally salient species receive varying degrees of informal consideration or protection, even in the absence of formal regulation (Jepson and Ladle 2009; Reyes-García et al. 2013). In Kalibawang, the alignment between cultural valuation and ecological importance creates social conditions that may support conservation-oriented behavior, making protective practices meaningful and locally legitimate.

An important consideration emerging from the documented capture practices (Table 4) concerns their legal status under national wildlife regulations. Several methods recorded in Kalibawang, such as bird glue trapping (*getah*/*pulut*), netting, and nest harvesting, are widely recognized as traditional techniques but may intersect with current conservation laws when applied to protected species or conducted within restricted habitats. Importantly, this study documents these practices as elements of local ecological knowledge and cultural tradition, rather than as an assessment of legal compliance. Legal implications, therefore, depend on species status, spatial context, and scale of use. The coexistence of traditional capture methods and formal conservation regulations highlights a potential gap between statutory frameworks and local practice, underscoring the need for culturally informed outreach, clarification of legal boundaries, and participatory approaches that align conservation objectives with community norms.

Community institutions further shape the social dynamics underlying bird conservation. Village elders, songbird specialists, and leaders of *kicau* groups serve as influential knowledge brokers who mediate norms surrounding trapping, captive care, and ethical conduct. As indicated in the Results, their influence is expressed mainly through advice, customary restraint, and peer regulation rather than formal enforcement. Their endorsement of sustainable behaviors—such as discouraging capture during nesting seasons or favoring captive maintenance over wild capture—plays a role in reinforcing local stewardship. These forms of social authority function similarly to semi-formal governance structures documented elsewhere in Java, where hobby networks and community leaders often exert strong influence over conservation outcomes. Comparable insights arise from Cijambu, West Java, where shifting cultural motivations, local leadership, and evolving norms regulate hunting intensity and species selection, demonstrating that conservation effectiveness is contingent upon localized socio-cultural configurations rather than ecological considerations alone (Suroso et al. 2023). Parallel patterns are also evident in Semarang's traditional markets, where consumer preferences, traders' knowledge systems, and informal ethical norms shape which species are harvested, traded, or avoided, illustrating that market-based socio-cultural dynamics must also be integrated into conservation planning (Azizah et al. 2025).

Urban ethno-ornithological studies likewise highlight the need for culturally anchored strategies. Research from Bandung shows that songbird contests—while enhancing public knowledge of bird care, vocal performance, and breeding—can inadvertently intensify harvesting pressure when left unmanaged (Iskandar and Iskandar 2015). Expanding competition circuits increase demand for wild-caught individuals, demonstrating how culturally valued practices may undermine conservation goals unless supported by governance innovations such as certification of captive-bred birds, ring-marking systems, and community oversight. Although such mechanisms are not yet formalized in Kalibawang, these insights offer practical relevance: integrating similar approaches through *kicau* groups and village leadership could reduce market-driven exploitation while preserving culturally meaningful traditions.

Given these socio-cultural dynamics, conservation strategies in Kalibawang are likely to be most effective when they integrate local logic with ecological objectives. Potential interventions include (i) community agreements regulating trapping intensity and discouraging capture during breeding seasons, (ii) promoting culturally valued but non-threatened species within hobby networks to reduce pressure on vulnerable taxa, (iii) involving *kicau* leaders and respected elders in participatory observation of forest-edge and agroforestry species, and (iv) designing educational initiatives grounded in local terminology, folk categories, and documented Local Ecological Knowledge. Such strategies leverage existing cultural frameworks, ensuring that conservation messages are intelligible, locally relevant, and mediated by trusted social actors.

Ultimately, community-based management in Kalibawang can function synergistically with ecological science when it acknowledges the cultural, economic, and ethical motivations shaping human–bird interactions. By aligning conservation initiatives with cultural salience, local authority structures, and daily agroforestry experience, these approaches support both biodiversity persistence and cultural continuity, fostering conservation practices that are socially embedded and ecologically informed.

Taken together, the dynamics of bird utilization, cultural salience, ecological reasoning, and community institutions reveal an integrated socio-ecological system in

which Local Ecological Knowledge operates not merely as a descriptive framework but also as a context-dependent regulatory and ethical reference. Historical subsistence practices, shifting market forces, and the rise of hobby-based bird culture have reconfigured patterns of use, yet these changes continue to be mediated by perceptual, classificatory, and moral logics grounded in aesthetic appreciation, acoustic recognition, and repeated ecological observation. The convergence between folk categories and scientific ecological roles underscores the depth of local interpretive capacity, while variation in hunting intensity, trade preferences, and ethical norms across Java highlights the importance of place-specific socio-cultural contexts. In this sense, Kalibawang exemplifies how LEK-based conservation can emerge organically when cultural identity, ecological knowledge, and informal governance structures operate in mutually reinforcing ways.

Conclusion, this study documents a socially inherited and culturally embedded system of Local Ecological Knowledge (LEK) on birds in Kalibawang based on interviews with 124 respondents across four villages. Bird knowledge is transmitted mainly through patrilineal and male-centered networks, strengthened by mentor–apprentice learning within *lomba kicau* communities. Respondents apply a flexible folk classification that integrates acoustic traits, habitat context, symbolic meaning, and practical relevance, with songbirds as the most salient category. Although 71 species were recorded, most birds (57.7%) are not directly utilized, while extractive use is highly selective and concentrated on cage birds and trade species. Capture is dominated by getah/pulut and netting, whereas cultural taboos contribute to a substantial proportion of non-captured species. LEK generally aligns with scientific knowledge on habitat association and conspicuous behavior, while mismatches mainly reflect symbolic interpretations or context-based inference. This study is limited by its focus on male respondents and a cross-sectional design that captures LEK at a single time point; future work should include gender-comparative approaches, longitudinal tracking of knowledge change, and population-based ecological surveys to assess how market dynamics and cultural practices influence bird populations over time. Integrating LEK with participatory conservation frameworks and agroforestry management offers strong potential to support culturally appropriate, community-based bird conservation in Java.

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Table S1. Bird species recorded in the agroforestry landscapes of Kalibawang, Central Java, Indonesia, with origin and conservation status, as well as habitat, feeding guilds, folk classification, human uses, and method of capture

Family	Scientific name	Local name	Village presence*	Origin	IUCN	Permen LHK 106/2018	CITES	Folk classification	Human use	Method of capture (local context)	Dominant habitat	Feeding guild
Accipitridae	*Elanus caeruleus*	Alap-alap sapi	DP, KS, KL, ML	Native	LC	–	–	Raptor	No direct use	No capture / taboo	Grassland / open fields	Carnivore
Accipitridae	*Nisaetus bartelsi*	Elang Jawa	DP, KS, KL, ML	Native	EN	✓	II	Sacred bird, raptor	Sacred / culturally protected	No capture / taboo	Forest	Carnivore
Aegithinidae	*Aegithina tiphia*	Sirtu / Cipoh	DP, KS, KL, ML	Native	LC	–	–	Songbird	Pet bird / cage bird	Bird glue trapping	Agroforestry	Insectivore
Alaudidae	*Mirafra javanica*	Branjangan	KL, ML	Native	LC	–	–	Rice-field bird	Pet bird / cage bird	Snare trapping	Grassland / open fields	Insectivore
Alcedinidae	*Todiramphus chloris*	Cekakak sungai	DP, KS, KL, ML	Native	LC	–	–	Songbird	No direct use	No capture / taboo	Riverine	Carnivore
Alcedinidae	*Todiramphus cyanoventris*	Cekakak biru	KS	Native	NT	–	–	Songbird	No direct use	No capture / taboo	Riverine	Carnivore
Apodidae	*Collocalia linchi*	Sriti	DP, KS, KL	Native	LC	–	–	None	No direct use	Nest harvesting	Settlements	Insectivore
Apodidae	*Collocalia maxima*	Walet sarang hitam	DP, KS, ML	Native	LC	–	–	None	Edible nest harvested	Nest harvesting	Cliffs / rocky areas	Insectivore
Ardeidae	*Bubulcus ibis*	Kuntul kerbau	DP, KS, KL	Native	LC	–	–	Rice-field bird	Ecosystem service (pest controller)	Projectile hunting	Rice fields	Insectivore
Campephagidae	*Pericrocotus speciosus*	Sepah merah	DP, KS, KL, ML	Native	LC	–	–	Songbird	No direct use	No capture / taboo	Forest	Insectivore
Chloropseidae	*Chloropsis sonnerati*	Cucak ijo	ML	Native	EN	✓	–	Songbird (prestigious)	Pet trade	Bird glue trapping	Agroforestry	Frugivore–Insectivore
Ciconiidae	*Leptoptilos javanicus*	Bangau tongtong	KL	Native	VU	✓	–	Wetland bird	No direct use	No capture / taboo	Wetlands	Scavenger
Cisticolidae	*Cisticola juncidis*	Cici padi	DP, KS, ML	Native	LC	–	–	Rice-field bird	No direct use	Snare trapping	Grassland / open fields	Insectivore
Cisticolidae	*Orthotomus cucullatus*	Cinenen gunung	ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Forest	Insectivore
Cisticolidae	*Orthotomus ruficeps*	Prenjak kepala merah	KS, ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Insectivore
Cisticolidae	*Orthotomus sepium*	Prenjak jawa	KS	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Insectivore
Cisticolidae	*Orthotomus sutorius*	Cinenen pisang	ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Insectivore
Cisticolidae	*Prinia familiaris*	Ciblek jawa	DP, KL	Native	LC	–	–	Songbird	Pet bird / cage bird	Bird glue trapping	Agroforestry	Insectivore

Cisticolidae	*Prinia inornata*	Ciblek sawah	DP, KS, KL, ML	Native	LC	–	–	Rice-field bird	No direct use	Bird glue trapping	Rice fields	Insectivore
Columbidae	*Columba livia*	Merpati batu	KL	Introduced	LC	–	–	Bird of settlement	Domesticated	Netting	Settlements	Granivore
Columbidae	*Columba livia domestica*	Merpati (peliharaan)	DP, KS, ML	Domesticated	NE	–	NE	Poultry	Domesticated	Domesticated breeding	Settlements	Domesticated
Columbidae	*Geopelia striata*	Perkutut	DP, KS, KL, ML	Native	LC	–	–	Songbird (spiritual)	Pet bird / cage bird	Cage trapping	Agroforestry	Granivore
Columbidae	*Spilopelia chinensis*	Derkuku	DP, KS, KL, ML	Native	LC	–	–	Songbird	Pet bird / cage bird	Netting	Rice fields	Granivore
Columbidae	*Streptopelia risoria*	Puter	DP, KS, KL	Domesticated	NE	–	NE	Songbird	Domesticated	Domesticated breeding	Settlements	Domesticated
Corvidae	*Corvus enca*	Gagak hutan	ML	Native	LC	–	–	None	No direct use	Projectile hunting	Forest	Omnivore
Corvidae	*Corvus macrorhynchos*	Gagak besar	KL	Native	LC	–	–	None	No direct use	Projectile hunting	Grassland / open fields	Omnivore
Cuculidae	*Centropus sinensis*	Bubut	ML	Native	LC	✓	–	Pest bird	No direct use	Snare trapping	Agroforestry	Insectivore
Cuculidae	*Surniculus lugubris*	Kedasih	KS, ML	Native	LC	–	–	Sacred bird, omen	No direct use	No capture / taboo	Forest	Insectivore
Dicaeidae	*Dicaeum trigonostigma*	Kemade	ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Frugivore–Nectarivore
Dicaeidae	*Dicaeum trochileum*	Bangsit	DP	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Frugivore–Nectarivore
Dicruridae	*Dicrurus macrocercus*	Srigunting	KS, KL, ML	Native	LC	–	–	Pest bird, predator	No direct use	No capture / taboo	Grassland / open fields	Insectivore
Estrildidae	*Lonchura leucogastroides*	Bondol jawa	DP, KS, KL, ML	Native	LC	–	–	Rice-field bird	No direct use	Netting	Rice fields	Granivore
Estrildidae	*Padda / Lonchura oryzivora*	Gelatik jawa	KS, ML	Native	EN	✓	II	Songbird	Pet trade	Bird glue trapping	Rice fields	Granivore
Fringillidae	*Serinus canaria domestica*	Kenari	DP, KS, ML	Domesticated	NE	–	NE	Cage bird	Domesticated	Domesticated breeding	Settlements	Domesticated
Laniidae	*Lanius schach*	Cendet	DP, KS	Native	LC	–	–	Songbird, predator	Pet bird / cage bird	Bird glue trapping	Agroforestry	Insectivore
Muscicapidae	*Brachypteryx montana crassa*	Sulingan jawa	ML	Native	LC	✓	–	Songbird	No direct use	Netting	Forest	Insectivore
Muscicapidae	*Copsychus malabaricus*	Murai batu	KS, KL, ML	Native	LC	✓	II	Songbird (prestige)	Pet trade	Netting	Forest edge	Insectivore
Muscicapidae	*Copsychus saularis*	Kacer	KS, ML	Native	LC	–	–	Songbird	Pet bird / cage bird	Netting	Agroforestry	Insectivore
Muscicapidae	*Cyanoptila cyanomelana*	Sulingan biru	KS	Native	LC	–	–	Songbird	No direct use	No capture / taboo	Forest	Insectivore
Muscicapidae	*Cyornis banyumas*	Sikatan cacing	DP, ML	Native	NT	✓	–	Songbird	No direct use	Netting	Forest	Insectivore
Muscicapidae	*Monticola solitarius*	Ciung batu	KS	Native	LC	–	–	Songbird	No direct use	No capture / taboo	Cliffs / rocky areas	Insectivore
Muscicapidae	*Myophonus glaucinus*	Ciung-batu	KS	Native	EN	✓	–	Songbird	No direct use	Netting	Riverine	Insectivore

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Nectariniidae	*Aethopyga eximia*	Kolibri	KS, ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore
Nectariniidae	*Aethopyga siparaja*	Sepah raja	KS	Native	LC	✓	–	Songbird	No direct use	Bird glue trapping	Forest edge	Nectarivore
Nectariniidae	*Anthreptes malacensis*	Burung-madu Kelapa	DP	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore
Nectariniidae	*Arachnothera longirostra*	Madu rimba	DP, KS, ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore–Insectivore
Nectariniidae	*Cinnyris asiaticus*	Kolibri ungu	KL	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore
Nectariniidae	*Cinnyris jugularis*	Sriganti	KS	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore
Nectariniidae	*Cinnyris solaris*	Sriganti dada-api	ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore
Nectariniidae	*Leptocoma calcostetha*	Sogon	KS	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore
Oriolidae	*Oriolus chinensis*	Kepudang kuduk hitam	KL	Native	LC	✓	–	Songbird	No direct use	Netting	Agroforestry	Frugivore–Insectivore
Passeridae	*Passer montanus*	Burung gereja	DP, KS, KL, ML	Native	LC	–	–	Pest bird, settlement bird	No direct use	Netting	Settlements	Granivore
Phasianidae	*Gallus gallus bankiva*	Ayam hutan merah	ML	Native	LC	✓	–	Game bird	Occasionally hunted	Snare trapping	Forest edge	Omnivore
Phasianidae	*Gallus varius*	Ayam hutan hijau	KS, KL	Native	LC	✓	–	Game bird	Occasionally hunted	Snare trapping	Forest	Omnivore
Picidae	*Chrysophlegma flavinucha*	Pelatuk jambul kuning	ML	Native	LC	✓	–	None	No direct use	No capture / taboo	Forest	Insectivore
Picidae	*Dinopium javanense*	Pelatuk bawang	KS	Native	LC	✓	–	None	No direct use	No capture / taboo	Agroforestry	Insectivore
Psittaculidae	*Agapornis* sp.	Lovebird	DP, KS, ML	Domesticated	NE	–	NE	Cage bird	Domesticated	Domesticated breeding	Settlements	Granivore
Psittaculidae	*Loriculus galgulus*	Serindit	ML	Native	LC	✓	II	Songbird	Pet bird / cage bird	Netting	Agroforestry	Frugivore
Psittaculidae	*Psittacula alexandri*	Betet	KL, ML	Native	NT	✓	II	Cage bird	Pet trade	Netting	Agroforestry	Frugivore
Pycnonotidae	*Pycnonotus aurigaster*	Kutilang	DP, KS, KL, ML	Native	LC	–	–	Songbird	Pet bird / cage bird	Bird glue trapping	Agroforestry	Frugivore–Insectivore
Pycnonotidae	*Pycnonotus goiavier*	Trucuk	DP, KS, KL	Native	LC	–	–	Songbird	Pet bird / cage bird	Bird glue trapping	Agroforestry	Frugivore–Insectivore
Pycnonotidae	*Pycnonotus simplex*	Cucak meranti	KS	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Frugivore
Rallidae	*Amaurornis phoenicurus*	Kareo padi	KL	Native	LC	–	–	Wetland bird	No direct use	Snare trapping	Wetlands	Omnivore
Rallidae	*Gallinula chloropus*	Mandar	KL	Native	LC	–	–	Wetland bird	Occasionally hunted	Snare trapping	Wetlands	Omnivore
Rallidae	*Porphyrio indicus*	Mandar besar	DP, KS	Native	LC	–	–	Wetland bird	No direct use	Snare trapping	Wetlands	Herbivore
Strigidae	*Otus angelinae*	Celepuk jawa	DP, KL, ML	Native	NT	✓	–	Predator, sacred bird	Sacred / culturally	No capture / taboo	Forest	Carnivore

Sturnidae	*Acridotheres javanicus*	Jalak kerbau	DP, KS, ML	Native	EN	–	–	Rice-field bird	protected Pet trade	Cage trapping	Grassland / open fields	Omnivore
Sturnidae	*Gracupica contra*	Jalak suren	DP	Native	EN	✓	II	Songbird	Pet trade	Cage trapping	Agroforestry	Omnivore
Timaliidae	*Timalia pileata*	Kaso-kaso	KS	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Insectivore
Zosteropidae	*Zosterops flavus*	Pleci dada kuning	KS	Native	EN	✓	–	Songbird	Pet trade	Bird glue trapping	Agroforestry	Nectarivore–Insectivore
Zosteropidae	*Zosterops palpebrosus*	Pleci	DP, KS, KL, ML	Native	LC	–	–	Songbird	Pet bird / cage bird	Bird glue trapping	Agroforestry	Nectarivore–Insectivore

Note:

1. **Village Codes:** DP: Dempel; KS: Karangsambung; KL: Kalialang; ML: Margolangu.
2. **Origin of Species:** Native: Wild, naturally occurring species in Indonesia; Introduced/domesticated: Non-native or captive species found around settlements.
3. **Conservation status:**
    - **IUCN Red List:** LC: Least Concern; NT: Near Threatened; VU: Vulnerable; EN: Endangered.
    - **National status (RI):** Based on Indonesian Regulation Permen LHK No. 106/2018 (protected species list).
    - **CITES:** Appendix I–III (international trade regulation).
4. **Folk (Emic) classification categories:** songbirds (*burung kicau*), rice-field birds (*burung sawah*), wetland or water birds (*burung rawa/air*), sacred or mythical birds (*burung mitos/keramat*), predators (*burung pemangsa*), pest birds (*burung hama tanaman*), aerial raptors (*burung pemangsa udara*), birds of settlements (*burung permukiman*), cage birds (*burung sangkar*), game birds (*burung buruan*), poultry (*unggas*), omen birds (*burung pertanda*), and species that were not classified under any local category (*tidak diklasifikasikan*).
5. **Human use categories:** no direct use, those kept as pet or cage birds, individuals involved in the pet trade, domesticated species, species that are occasionally hunted, birds regarded as sacred or culturally protected, species whose edible nests are harvested, and birds that provide ecosystem services, particularly as natural pest controllers.
6. **Methods of capture:** Bird glue trapping (*getah/pulut*), netting using mist nets or other nets (*jaring*), practices involving no capture due to cultural taboos (*tidak ditangkap / tabu budaya*), snare trapping (*jerat*), domesticated breeding (*domestikasi/ternak*), projectile hunting such as the use of air rifles or slingshots (*penembakan [senapan angin/ketapel]*), cage trapping (*perangkap sangkar/bubu*), and nest harvesting (*pemanenan sarang*).
7. **Habitat types (observed land-use categories):** Agroforestry systems (mixed fruit trees, coffee, bamboo), natural forest (pine forests etc.), forest edges, grasslands or open fields, rice fields (*sawah*), human settlements, wetlands, riverine environments (riverbanks, riparian vegetation), and cliffs or rocky areas/homegardens (*pekarangan*)
8. **Feeding guild classification:** Insectivores, omnivores, granivores, nectarivores, carnivores, frugivore–insectivores, frugivores, nectarivore–insectivores, domesticated species, frugivore–nectarivores, herbivores, and scavengers
9. **Taxonomic reference and synonym notes:**
   Scientific names follow the IOC World Bird List (v.14.2). Some nomenclature differs from Indonesian Permen LHK 106/2018 but refers to the same taxa. Examples:
    - *Padda oryzivora* = *Lonchura oryzivora* (Java Sparrow)
    - *Myophonus glaucinus* = *Myophonus caeruleus* (Javan Whistling Thrush)
    - *Gracupica contra* is sometimes listed as *Sturnus contra*
    - *Dinopium javanense* = *Picus javanensis*
    - *Chrysophlegma flavinucha* = *Picus flavinucha*
10. **Exclusion criteria:** Only wild bird species were included in richness, guild, and conservation analyses. Domesticated poultry (*Gallus domesticus*, *Anas platyrhynchos domesticus*, *Columba livia domestica*) and fully captive ornamental birds were excluded.

Table S2. Alignment between local ecological knowledge and scientific information for selected bird species in Kalibawang, Central Java, Indonesia

Scientific name	Local name	UV	RFC	CI
Elanus caeruleus	Alap-alap sapi	0.01	0.04	0.01
Nisaetus bartelsi	Elang Jawa	0.02	0.05	0.03
Aegithina tiphia	Cipoh	0.01	0.02	0.01
Mirafra javanica	Branjangan	0.01	0.02	0.01
Todiramphus chloris	Cekakak Sungai	0.01	0.07	0.01
Todiramphus cyanoventris	Cekakak Biru	0.01	0.03	0.01
Collocalia linchi	Walet / Sriti	0.01	0.02	0.01
Collocalia maxima	Walet Sarang Hitam	0.01	0.02	0.01
Bubulcus ibis	Kuntul Kerbau	0.01	0.02	0.01
Pericrocotus speciosus	Sepah Merah	0.01	0.03	0.01
Chloropsis sonnerati	Cucak Ijo	0.08	0.09	0.09
Leptoptilos javanicus	Bangau Tongtong	0.01	0.03	0.01
Orthotomus cucullatus	Cinenen Gunung	0.01	0.02	0.01
Orthotomus ruficeps	Prenjak Kepala Merah	0.03	0.09	0.03
Orthotomus sepium	Prenjak Jawa	0.03	0.08	0.03
Orthotomus sutorius	Cinenen pisang	0.01	0.02	0.01
Prinia familiaris	Prenjak Jawa	0.02	0.05	0.02
Prinia inornata	Ciblek Sawah	0.02	0.07	0.02
Columba livia	Merpati Batu	0.01	0.05	0.01
*Columba livia domestica**	Merpati peliharaan	0.01	0.02	0.01
Geopelia striata	Perkutut	0.04	0.12	0.05
Spilopelia chinensis	Derkuku	0.03	0.08	0.04
*Streptopelia risoria**	Puter	0.01	0.02	0.01
Corvus enca	Gagak Hutan Kecil	0.01	0.02	0.01
Corvus macrorhynchos	Gagak Besar	0.01	0.02	0.01
Centropus sinensis	Bubut	0.01	0.02	0.01
Surniculus lugubris	Kedasih	0.01	0.02	0.01
Dicaeum trigonostigma	Kemade	0.01	0.02	0.01
Dicaeum trochileum	Cabai Jawa Merah	0.01	0.02	0.01
Dicrurus macrocercus	Srigunting Hitam	0.01	0.02	0.01
Lonchura leucogastroides	Bondol Jawa	0.04	0.26	0.06
Lonchura oryzivora	Gelatik Jawa	0.07	0.15	0.08
*Serinus canaria domestica**	Kenari	0.01	0.02	0.01
Lanius schach	Cendet	0.01	0.02	0.01
Cisticola$ juncidis	Cici Padi	0.02	0.10	0.03
Brachypteryx montana crassa	Sulingan Jawa	0.01	0.02	0.01
Copsychus malabaricus	Murai Batu	0.12	0.36	0.15
Copsychus saularis	Kacer	0.10	0.31	0.12
Cyanoptila cyanomelana	Sulingan Biru	0.01	0.03	0.01
Cyornis banyumas	Sikatan Cacing	0.01	0.02	0.01
Monticola solitarius	Ciung Batu	0.01	0.03	0.01
Myophonus glaucinus	Ciung Biru	0.01	0.03	0.01
Aethopyga eximia	Kolibri Jawa	0.02	0.09	0.02
Aethopyga siparaja	Sepah Raja	0.01	0.06	0.01
Anthreptes malacensis	Burung-madu Kelapa	0.02	0.06	0.02
Arachnothera longirostra	Sogon Rimba	0.01	0.02	0.01
Cinnyris asiaticus	Kolibri Ungu	0.01	0.02	0.01
Cinnyris jugularis	Sriganti	0.02	0.11	0.02
Cinnyris solaris	Sriganti dada-api	0.02	0.07	0.02
Leptocoma calcostetha	Sogon	0.01	0.02	0.01
Oriolus chinensis	Kepodang	0.03	0.10	0.03
Passer montanus	Burung Gereja	0.03	0.20	0.05
Gallus gallus bankiva	Ayam Hutan Merah	0.08	0.10	0.09
Gallus varius	Ayam Hutan Hijau	0.05	0.08	0.06
Chrysophlegma flavinucha	Pelatuk Jambul Kuning	0.01	0.02	0.01
Dinopium javanense	Pelatuk Bawang	0.01	0.02	0.01
Agapornis sp.*	Lovebird	0.01	0.02	0.01
Loriculus galgulus	Serindit	0.06	0.07	0.07
Psittacula alexandri	Betet Jawa	0.04	0.06	0.05
Pycnonotus aurigaster	Kutilang	0.05	0.22	0.06
Pycnonotus goiavier	Trucuk	0.04	0.23	0.05
Pycnonotus simplex	Cucak Meranti	0.01	0.05	0.01
Amaurornis phoenicurus	Kareo Padi	0.02	0.07	0.02
Gallinula chloropus	Mandar	0.01	0.05	0.01
Porphyrio indicus	Bluwok	0.01	0.03	0.01
Otus angelinae	Celepuk Jawa	0.01	0.02	0.01
Acridotheres javanicus	Jalak Kerbau	0.06	0.18	0.06
Gracupica contra	Jalak Suren	0.05	0.14	0.06
Timalia pileata	Kaso-kaso	0.01	0.02	0.01
Zosterops flavus	Pleci Dada Kuning	0.01	0.04	0.01
Zosterops palpebrosus	Pleci	0.03	0.12	0.03

Note. *: Domestic. UV: Use Value; RFC: Relative Frequency of Citation; CI: Cultural Importance Index. Values are derived from interview data (N = 124) and field observations. Species with very low mentions were assigned baseline values (UV = 0.01; RFC = 0.02; CI = 0.01). Four domesticated species (*Columba livia domestica*, *Streptopelia risoria*, *Serinus canaria domestica*, *Agapornis* sp.) are listed due to cultural relevance but are not part of the wild avifauna and thus considered Not Evaluated (NE) for conservation analysis