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Diversity of diurnal birds and their ecological role in Papua's oil palm plantation landscape, Indonesia

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Abstract. *Affandi R, Santosa Y, Kwatrina RT. 2025. Diversity of diurnal birds and their ecological role in Papua's oil palm plantation landscape, Indonesia. Biodiversitas 26: 799-809.* Oil palm plantations significantly impact biodiversity, particularly in Indonesia, where they play a crucial economic role. However, the ecological consequences remain underexplored in Papua, especially for avian communities. This study examines bird diversity and ecological roles within Papua's oil palm agroecosystem. Observations were conducted in various land cover types in Kaureh Sub-district, Jayapura District, Papua, Indonesia, including oil palm blocks, High Conservation Value (HCV) areas, secondary forests, and shrubs. Using transect surveys, we recorded 46 bird species from 23 families, with the highest species richness in HCV areas. Bird communities contribute vital ecosystem services such as seed dispersal, pollination, and pest control. Granivorous and frugivorous species facilitate habitat regeneration, while insectivorous birds mitigate pest outbreaks, reducing the need for chemical pesticides. Raptors and carnivorous species regulate small mammal populations, enhancing ecological stability. Statistical analysis revealed significant correlations between bird abundance and environmental factors, including vegetation diversity and proximity to HCV areas. Despite their ecological importance, oil palm plantations exhibited lower species richness and evenness than natural habitats. Conservation strategies should integrate bird-friendly management practices, such as maintaining native vegetation, establishing ecological corridors, and minimizing chemical inputs. Enhancing biodiversity in oil palm landscapes can support agricultural productivity and environmental sustainability. This study underscores the need for further research and conservation efforts to balance economic gains with biodiversity preservation in Papua's oil palm agroecosystems.

Keywords: Biodiversity, bird community, *Cacatua galerita*, ecological role, Papua's oil palm plantation

INTRODUCTION

The economic importance and the ecological impact of oil palm plantations on wildlife biodiversity in Indonesia have been significant topics of discussion in recent decades. The palm oil sector plays a crucial role in the Indonesian economy and is a major source of foreign currency (Santosa et al. 2020; Tandra and Suroso 2023; Ditjenbun 2024). However, economic achievements are clouded by heavy reliance on chemical inputs, such as fertilizers and pesticides. The use of chemical fertilizers and pesticides, while necessary for sustaining high production levels, poses considerable long-term environmental risks (Thorat and More 2022) and escalates production expenses (Brunelle et al. 2015). This complex situation highlights the urgent need to reconcile economic benefits and environmental sustainability.

Chemical fertilizers are critical in managing oil palm plantations in Indonesia, particularly for young oil palms that require consistent and balanced fertilization to ensure robust growth and high yield (Adileksana et al. 2020). Similarly, pesticides are extensively utilized to prevent pest outbreaks, which can jeopardize the health of plantations. These pests include caterpillars, *Ganoderma* fungi, and invasive weeds, which can significantly affect agricultural output (Bonning and Chougule 2014). Recent studies have emphasized the potential of bird populations as natural and sustainable replacements for chemical inputs in oil palm plantations (Karp et al. 2013; Maas et al. 2016). Bird populations have been shown to adapt to oil palm plantations, creating alternative habitats within the plantation matrix (Amit et al. 2014). Birds are vital for maintaining ecological harmony; for instance, their droppings can naturally enrich the soil, and reducing dependence on chemical fertilizers (Luneva et al. 2022). This enhances soil fertility and promotes a more organic approach to plantation management. Birds serve as natural pest deterrents by preying on herbivorous insects and small rodents. Predatory birds, including insectivorous and carnivorous species, help regulate pest populations and reduce their dependence on synthetic pesticides (Huffeldt et al. 2012; Oliveira et al. 2022).

The ecological role of birds in oil palm plantations extends beyond pest control. Bird communities provide crucial ecosystem services that are essential for the health of agricultural landscapes (Bernardo 2017; Mohd-Azlan et al. 2019). If oil palm plantations can offer alternative habitats and access to food sources such as insects, caterpillars (Koh and Wilcove 2008; Azhar et al. 2015), rats (Murgianto et al. 2022), and understory vegetation (D'hondt and Hoffmann 2011), they can attract and sustain bird populations. Avian biodiversity can serve as an indicator of environmental health and plays a role in seed dispersal and pollination, aiding in the regeneration of native plant species and enhancing ecosystem resilience (Santosa et al. 2023). Natural pest regulation by birds is a sustainable method that aligns with eco-friendly plantation practices and fosters long-term productivity.

Despite these advantages, research focusing on the role of birds in oil palm plantations in Indonesia has primarily been conducted in Sumatra and Kalimantan, leaving regions such as Papua insufficiently studied (Santosa et al. 2023). Although there are fewer oil palm plantation areas in Papua, they are recognized for their high productivity (BPS 2021). Nevertheless, it is crucial to gather more scientific data regarding the influence of bird communities on the biodiversity and ecological balance in this region. Given Papua's distinctive biodiversity and promise for sustainable agricultural practices, it is essential to conduct thorough research on the significance of birds in these ecosystems. Such studies could provide valuable information for maintaining ecological stability, enhancing plantation productivity, and bolstering conservation efforts in Papua's oil palm.

Recognizing the multifaceted roles of bird populations in oil palm plantations is vital for promoting methods that safeguard economic and environmental interests (Denmead et al. 2017; Kwatrina et al. 2018; Chellappan et al. 2023; Ramlah et al. 2024). Transitioning towards natural alternatives, such as incorporating bird habitat management into plantation practices, can help alleviate the environmental hazards associated with chemical usage. This sustainable strategy has the potential to revolutionize the palm oil industry, ensuring its enduring viability while protecting the rich biodiversity found in Indonesia's landscapes. In-depth research, particularly in less-explored regions such as Papua, is crucial for developing informed strategies that harmonize productivity with ecological protection, benefiting both the industry and the environment.

MATERIALS AND METHODS

Study area

The study was conducted in an oil palm agroecosystem located in Kaureh Sub-district, Jayapura District, Papua Province, Indonesia (2°49'9.509"S, 139°27'43.859"E - 3°19'31.595"S, 140°18'23.083"E) at an elevation of 200-300 m above sea level (Figure 1). Observations were carried out from July to August 2024 across six (6) land types with distinct ecosystem characteristics, namely palm oil blocks, HCV areas, non-HGU forest areas, and shrub areas. In each land type, a single transect line was selected based on its potential to support a diverse range of bird species, with the characteristics of each land type detailed in Table 2.

Data collection and analysis

The data collected in this study were obtained from direct and indirect observations in the field. The data collection focused on three main objectives: (i) analyzing bird species diversity; (ii) analyzing the surrounding environment and plant diversity; (iii) analyzing the correlation of bird species abundance based on ecological roles and environmental factors.

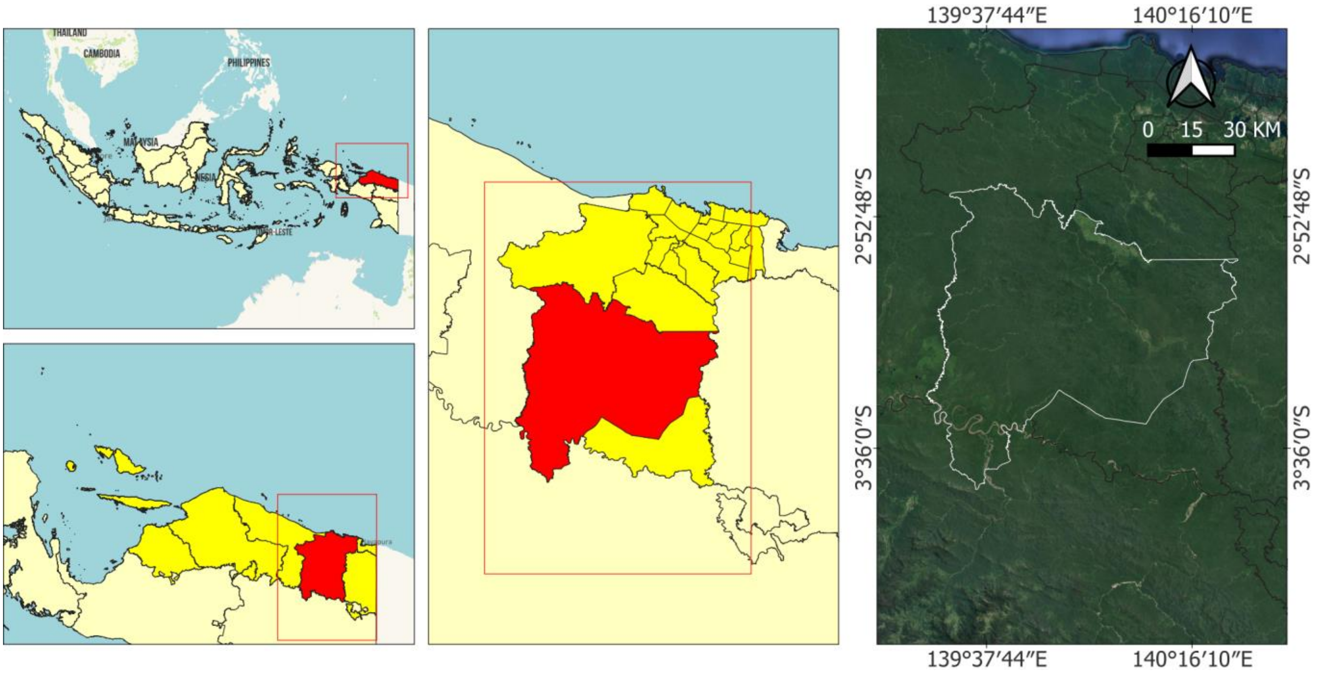

Figure 1. Location of Kaureh Sub-district at Jayapura District, Papua Province, Indonesia

Table 1. Ecological role categories of birds based on feeding guilds

Ecological role	Feeding guild
Seed Dispersal (SD)	Frugivore (FRU), Insectivore (FRU-INS), Frugivore-Nectarivore (FRU-NEC), Granivore-Frugivore (GRA-FRU), Granviore-Nectarivore (GRA-NEC), Omnivores[ǂ] with the criteria of Granivore and Frugivore feeding guild (OMN).
*Water Environment Bioindicator (WEB)	Carnivore (CAR), Carnivore-Insectivore (CAR-INS)
Pollinator (PL)	Nectarivore-Insectivore (NEC-INS), Granivore-Nectarivore (GRA-NEC), Omnivores[ǂ] with criteria of Nectarivore feeding guild (OMN)
Insect Pest Control (IPC)	Aerial Sallying Insectivore (ASI), Fly-catching Insectivore (FCI), Shrub Foliage-gleaning Insectivore (SFGI), Tree-foliage Gleaning Insectivore (TFGI), Carnivores-Insectivore (CAR-INS), Frugivore-Insectivore (FRU-INS), Nectarivore-Insectivore (NEC-INS), Omnivores[ǂ] with the criteria of insectivore feeding guild (OMN)
Predator (PR)	Carnivore-Insectivore (CAR-INS), Carnivore (CAR), Omnivore[ǂ] with criteria of Carnivore feeding guild (OMN)

Note: *indicates habitat/habit in a wetland environment. [ǂ]more than 2 feeding guild (Nugroho et al. 2023)

Data collection to achieve the first objective was conducted through surveys using the line transect method in the morning and evening (Masy'ud et al. 2020; Putri and Santosa 2020; Nugroho et al. 2021; Santosa and Purnamasari 2023) with a time span of morning (06.00-10.00 WIT) and afternoon (14.00-18.00 WIT) with a path length of 1 km and five repetitions of data (Santosa et al. 2018; Ramlah et al. 2021). The data collected included bird species, number of individuals found, and location of discovery. Bird species observed were then identified through visual observation, camera shots, and birdsongs. Furthermore, bird species data that have been identified were sorted based on feeding guilds using literature references (Katuwal et al. 2018; Sastranegara et al. 2020; Panda et al. 2021; Nugroho et al. 2023; Shafie et al. 2023). The data were then analyzed using index analysis (Margalef Species Richness Index (Dmg Index), Shannon-Wiener Species Diversity index (H' Index), Pielou Species Evenness Index (J Index), Simpson Species Dominance Index (D Index), and Sorensen Species Similarity Index (S Index)).

Data collection related to the second objective was conducted through the direct observation of environmental factors such as air temperature and humidity measured with a thermometer. Other environmental factors, including distance from roads, settlements, waterways, palm oil blocks, HCV areas, shrub areas, and non-HGU forest areas, were measured using Google Earth software. Vegetation data were also collected as a part of the environmental factors, covering plant species in oil palm and non-oil palm land (natural vegetation) with variables such as plant species, number of individuals, and location. Vegetation data were collected using the plot method with a purposive sampling technique, using 4×4 m plots in oil palm land (Wulandari 2024) and 20×20 m maximum vegetation plots (Kusmana et al. 2022) in non-oil palm land. Data on the number of vegetation individuals collected were analyzed using the species density approach and index analysis.

To achieve the third objective, the bird species data identified in the first objective were grouped based on the specific ecological roles defined by Santosa et al. (2023) as presented in Table 1. Further analysis included comparisons of the number of bird species and individuals based on specific ecological roles and correlations with the environmental factors analyzed in the second objective. Data related to the ecological roles of bird communities were collected through desk research of bird species found during the data collection period.

RESULTS AND DISCUSSION

Overview of the environmental characteristic and the natural vegetation condition

The data from the observations of environmental characteristic for the six land types are presented in Table 2. The results show differences in the characteristics of the land types studied.

Table 2. Environment characteristic of the study area

Land type	Temperature (ºC)	Humidity (%)	Elevation (m asl)	Distance from (m)						
				Road	Waterway	OP	SFH	HCV	SHR	Settlement
HCV-A	25.485	90.15	290	2	0	214	40	0	10	1,300
HCV-B	26.507	87.62	305	2	1,782	2,000	5,532	0	5,450	135
SFH	26.763	88.463	225	200	300	10	5	4,350	0	2,500
SHR	26.763	88.463	227	180	150	10	0	4,150	5	2,000
OP-A	26.201	90.265	230	7	3	0	10	4,100	10	1,021
OP-B	27.663	72.082	220	6	3	0	700	5,000	1,300	2,000

Note: HCV: High Conservation Value area; SFH: Non-right to cultivate secondary forest; SHR: Shrubs; OP-A: Oil Palm-A block; OP-B: Oil Palm-B block

This table presents an overview of the environmental and spatial characteristics of various land types, including HCV areas (HCV-A and HCV-B), non-right to cultivate secondary forest habitats (SFH), shrubs (SHR), and oil palm plantations (OP-A and OP-B). Temperature ranges from 25°C in HCV-A to 27.7°C in OP-B, while humidity levels fluctuate between 72.1% in OP-B and 90.3% in OP-A. The elevation varies from 220-305 m above sea level. Additionally, the table illustrates the distances to crucial features such as roads, waterways, oil palm plots, forest areas, HCV zones, shrubs, and settlements. For instance, HCV-A was positioned adjacent to a waterway (0 m) and a road (2 m), whereas HCV-B was further away, with a considerable distance from the oil palm blocks (5,532 m). Shrubs and secondary forests are located at intermediate distances from roads, waterways, and adjacent land types, highlighting their role in landscape transition. The oil palm plantations are situated near waterways (3 m) and exhibit varying proximity to settlements, reflecting their integration within agricultural and rural landscapes. Based on the results of the vegetation analysis, there were 101 species found in each land cover type and belonged to 50 different plant families. The HCV-A area has the most plant species (44 species), whereas the OP-B had the least number of species, as presented in Table 3.

The results in Table 3 indicate that non-oil palm land supports vegetation at all growth stages, from seedlings to mature trees, whereas oil palm plantations are limited to seedlings and understory plants. Plant density, calculated as the number of individuals per species in a unit area, reflects species dominance and ecological dynamics, influencing plant sustainability (Nahlunnisa et al. 2022). In HCV areas, SHR, and SFH area, species such as *Urochloa mutica*, *Mimosa pudica*, and *Cyrtococcum patens* exhibited the highest densities at the seedling and understory levels. In non-oil palm areas, *Blumea balsamifera*, *Macaranga* spp., and *Ficus* spp. dominated from sapling to mature tree stages, whereas oil palm plantations only had seedling and understory stages. Additionally, *Imperata cylindrica* and *Diplazium esculentum* were the most abundant species in oil palm plantations, indicating their adaptation to disturbed environments.

Table 3 also highlights significant differences in species diversity across habitat types. HCV-A has the highest total species count (44), followed by HCV-B (30), while OP Blocks have the lowest diversity (17 species in OP-A and 9 in OP-B). Seedling and understory densities are highest in SFH area (386,250 ind/ha) and HCV-B (340,000 ind/ha), whereas OP areas have significantly lower densities (102,500 in OP-A and 36,875 in OP-B). Notably, saplings, poles, and mature trees are absent in oil palm plantations, indicating a lack of higher vegetation growth stages. Diversity indices further emphasize these differences, with HCV-A having the highest species richness and evenness, while oil palm plantations exhibit the lowest values. The H' Index is highest in HCV-A, suggesting a more balanced species composition, whereas oil palm areas have extremely low diversity. Similarly, the J Index is higher in non-oil palm habitats, while the Simpson Species Dominance D Index reveals that a few species dominate oil palm areas. These findings indicate that non-oil palm habitats, particularly HCV areas and SHR, support greater species diversity and structural complexity, whereas oil palm plantations have limited ecological capacity to sustain diverse plant communities.

Table 4 further supports these findings by showing species similarity among habitat types. HCV-A has relatively high species similarity with HCV-B (0.486) but much lower similarity with SFH area (0.190) and SHR area (0.197), and almost no similarity with OP Blocks (0.000 with both OP-A and OP-B). This suggests that while both HCV areas support greater biodiversity, their species compositions remain distinct. Non-right to cultivate secondary forests and shrubs area share more species with each other than with oil palm plantations, indicating a closer ecological relationship. Conversely, oil palm plantation areas exhibit minimal species similarity with all other habitats, with the highest similarity observed between OP-A and OP-B (0.385). These low similarity values reinforce the previous findings that oil palm plantations not only possess significantly lower vegetation diversity but also host a distinctly different plant community compared to natural and semi-natural habitats.

Bird species diversity across different habitat types

The results revealed 473 individual bird species from 46 species belonging to 23 families with the distribution composition as presented in Table 2. Furthermore, data related to the value of diversity presented in Table 3 shows that the HCV-A land type has the highest value of richness and diversity (Dmg: 4.779; H': 2.088; 26 species), while the oil palm-A block has the lowest value of richness and diversity.

Based on Table 5, we identified a variety of bird species present in different land cover types. To assess the diversity of bird communities across these habitats in the study area, we employed several ecological indicators, including the total number of species, individual counts, and various indices of diversity and evenness. These indicators offer valuable insights into the richness, diversity, and dominance of bird species in the various land cover types (Table 3).

Table 3 reveals that HCV-A and HCV-B support more species and greater diversity, highlighting their importance for bird conservation. In contrast, disturbed habitats like SHR and OP-B show less diversity and greater dominance. HCV-A has the highest number of bird species at 26, followed by HCV-B with 20 species, meanwhile in the OP-B has the least species with 10 species. HCV-A also supports the most individual birds at 187, compared to 75 in HCV-B. The Dmg Index shows HCV-A has the highest richness score of 4.779, while SHR and OP-B score lower at 2.594 and 2.207. The H' Index indicates bird diversity is highest in HCV-B (2.577) and SFH (2.424), while SHR (1.926) and OP-B (1.502) show lower diversity. This suggests disturbed habitats have reduced diversity. The J Index indicates species are more evenly distributed in shrubs (0.937) and OP-A (0.604) than in HCV-A (0.641) and HCV-B (0.680). The D Index confirms higher dominance in OP-B (0.394) and SHR (0.103). Based on the similarity values as presented in Table 7, the highest similarity value was between OP-A and OP-B, whereas the lowest similarity value was between HCV-A and SHR. The data in Tables 6 and 7 shows the variety and similarity of bird populations in different habitats.

Bird's ecological role across different habitat types

Based on the results of observations, 13 feeding guilds were found that belong to 5 specific ecological roles that can provide certain roles for the ecosystem. A comparison of the number of species and abundance of individual bird species based on their ecological roles is presented in Figure 2.

Correlation between bird's ecological role and the ecosystem characteristic

Based on the Spearman correlation analysis (Table 8), there was a significant relationship between the abundance of bird species based on ecological roles and environmental variables at several research sites.

The results of the Spearman correlation analysis presented in Table 8 show a significant relationship between the abundance of bird species and their ecological role with respect to various environmental factors in the study landscape. Spearman correlation is a non-parametric method used to measure the strength and direction of the relationship between two ordered variables, particularly useful when data do not meet the assumptions of normality or linearity required for Spearman correlation (Bocianowski et al. 2024). A positive correlation indicates that an increase in one variable tends to be followed by an increase in the other, while a negative correlation indicates the opposite relationship.

Table 3. Diversity of vegetation communities across different habitat types in the study area

Parameter	HCV-A	HCV-B	SFH	SHR	OP-A	OP-B
Species total	44	30	19	27	17	9
Seedlings and Understory Density (ind/ha)	283,750	340,000	100,000	386,250	102,500	36,875
Sapling Density (ind/ha)	3,200	4,800	2,800	4,600	0	0
Pole Density (ind/ha)	1,150	1,550	500	250	0	0
Tree Density (ind/ha)	512.5	500	450	50	0	0
Seedlings and Undestory						
Species Richness Index (Dmg)	5.530	4.103	2.967	3.837	1.387	0.761
Species Diversity Index (H')	2.889	2.528	2.444	2.692	2.322	1.959
Species Evenness Index (J)	0.841	0.795	0.926	0.858	0.819	0.892
Species Dominance Index D	0.091	0.108	0.106	0.087	0.123	0.165
Sapling						
Species Richness Index (Dmg)	2.164	1.259	0.758	1.595	0.000	0.000
Species Diversity Index (H')	1.808	1.547	0.980	1.776	0.000	0.000
Species Evenness Index (J)	0.929	0.961	0.892	0.991	0.000	0.000
Species Dominance Index D	0.180	0.222	0.418	0.172	0.000	0.000
Pole						
Species Richness Index (Dmg)	2.551	0.582	0.869	0.621	0.000	0.000
Species Diversity Index (H')	2.100	0.907	1.030	0.673	0.000	0.000
Species Evenness Index (J)	0.956	0.825	0.937	0.971	0.000	0.000
Species Dominance Index D	0.134	0.451	0.380	0.520	0.000	0.000
Tree						
Species Richness Index (Dmg)	1.885	0.813	0.476	1.443	0.000	0.000
Species Diversity Index (H')	1.763	1.311	1.024	1.040	0.000	0.000
Species Evenness Index (J)	0.848	0.946	0.932	0.946	0.000	0.000
Species Dominance Index D	0.212	0.286	0.578	0.375	0.000	0.000

Note: HCV: High Conservation Value area; SFH: Non-right to cultivate secondary forest; SHR: Shrubs; OP-A: Oil Palm-A block; OP-B: Oil Palm-B block; Dmg: Margalef species richness index; H': Shannon-Wiener species diversity index; J: Pielou species evenness index; D: Simpson species dominance index

Table 4. Vegetation species similarity index value between different habitat types in the study area

Type	HCV-A	HCV-B	SFH	SHR	OP-A	OP-B
High Conservation Value area-A (HCV-A)	1.000	0.486	0.190	0.197	0.000	0.000
High Conservation Value area-B (HCV-B)	-	1.000	0.204	0.316	0.043	0.051
Non-right to cultivate secondary forest (SFH)	-	-	1.000	0.130	0.056	0.071
Shrubs (SHR)	-	-	-	1.000	0.045	0.056
Oil Palm-A Block (OP-A)	-	-	-	-	1.000	0.385
Oil Palm-B Block (OP-B)	-	-	-	-	-	1.000

Note: HCV: High Conservation Value Area; SFH: Non-right to cultivate secondary forest; SHR: Shrubs; OP-A: Oil Palm-A block; OP-B: Oil Palm-B block; Dmg: Margalef Species Richness Index; H': Shannon-Wiener Species Diversity Index; J: Pielou Species Evenness Index; D: Simpson Species Dominance Index

Table 5. Bird species recorded during surveys in the study area

Common name*	**Scientific name****	**Feeding guild**	**Land cover type**					
			HCV-A	**HCV-B**	**SFH**	**SHR**	**OP-A**	**OP-B**
Megapodiidae								
Collared Brush-turkey	*Talegalla jobiensis*	OMN[2]	●	-	●	-	-	-
Columbidae								
Black-billed Cuckoo-dove	*Macropygia nigrirostris*	GRA-FRU[1,2]	●	-	●	-	●	-
Zoe's Imperial-pigeon	*Ducula zoeae*	FRU[2,3]	-	●	-	-	-	-
Dwarf Fruit-dove	*Ptilinopus nainus*	FRU-NEC[1,2]	●	-	-	-	-	-
Orange-bellied Fruit-dove	*Ptilinopus iozonus*	FRU-NEC[2]	●	●	-	-	-	-
Apodidae								
Glossy swiftlet	*Collocalia esculenta*	ASI[2]	-	-	-	-	-	●
Cuculidae								
Ivory-billed Coucal	*Centropus menbeki*	CAR-INS[1,3]	-	-	●	-	●	●
Eastern Koel	*Eudynamys orientalis*	TFGI[2]	●	-	-	-	-	-
Long-billed Cuckoo	*Chalcites megarhynchus*	TFGI[1,2]	●	-	-	-	-	-
Brush Cuckoo	*Cacomantis variolosus*	TFGI[1,2]	-	●	●	●	-	-
Oriental Cuckoo	*Cuculus optatus*	TFGI[2]	-	-	●	-	-	-
Ardeidae								
Great White Egret	*Ardea alba*	CAR[1,2]	-	-	-	-	-	●
Accipitridae								
Pacific Baza	*Aviceda subcristata*	OMN[1,2,3]	-	-	●	-	●	-
Variable Goshawk	*Accipiter hiogaster*	CAR-INS[2]	-	●	●	-	●	●
Brahminy Kite	*Haliastur indus*	CAR-INS[1,2,3]	●	●	●	-	●	●
Bucerotidae								
Papuan Hornbill	*Rhyticeros plicatus*	OMN[1,2,3]	●	-	●	-	-	-
Meropidae								
Rainbow Bee-eater	*Merops ornatus*	FCI[2]	-	●	●	●	●	-
Coraciidae								
Oriental Dollarbird	*Eurystomus orientalis*	ASI[2]	●	●	-	-	-	-
Alcedinidae								
Sacred Kingfisher	*Todiramphus sanctus*	CAR-INS[1,2]	-	-	-	●	-	-
Rufous-bellied Kookaburra	*Dacelo gaudichaud*	CAR[1,2,3]-INS[1,3]	-	●	●	●	●	-
Cacatuidae								
Sulphur-crested Cockatoo	*Cacatua galerita*	GRA[2]-FRU[1,2,3]	●	●	●	-	●	●
Palm Cockatoo	*Probosciger aterrimus*	GRA-FRU[1,2,3]	●	-	-	-	-	-
Psittacidae								
Brown lory	*Chalcopsitta duivenbodei*	FRU-NEC[2]	-	●	-	-	-	-
Coconut Lorikeet	*Trichoglossus haematodus*	OMN[1,2,3]	●	-	-	-	-	-
Salvadori's Fig-parrot	*Psittaculirostris salvadorii*	GRA-NEC[2]	●	-	-	-	-	-
Double-eyed Fig-parrot	*Cyclopsitta diophthalma*	OMN[1,2]	-	●	-	-	-	-
Papuan Eclectus	*Eclectus polychloros*	GRA-FRU[1,2,3]	●	●	●	-	●	●
Maluridae								
Emperor Fairy-wren	*Malurus cyanocephalus*	SFGI[2]	●	-	-	-	-	-
White-shouldered Fairy-wren	*Malurus alboscapulatus*	SFGI[2,3]	-	-	-	●	●	-
Meliphagidae								
Helmeted Friarbird	*Philemon buceroides*	OMN[1,2,3]	●	●	●	-	-	-
Mimic Honeyeater	*Microptilotis analogus*	NEC-INS[1,2]	●	-	-	-	-	-
Oriolidae								
Northern Variable Pitohui	*Pitohui kirhocephalus*	FRU-INS[2]	-	●	-	-	-	-
Brown Oriole	*Oriolus szalayi*	FRU-INS[2]	-	●	-	-	-	-
Campephagidae								
Grey-headed Cicadabird	*Edolisoma schisticeps*	FRU[1,2]-INS[2]	-	●	-	-	-	-
New Guinea Cicadabird	*Edolisoma melas*	FRU-INS[2]	●	-	-	-	-	-
Black-browed Triller	*Lalage atrovirens*	FRU[1,2]-INS[1]	●	●	-	-	-	-
Artamidae								
Black Butcherbird	*Melloria quoyi*	OMN[1,2,3]	●	●	-	-	-	-
Rhipiduridae								
Willie Wagtail	*Rhipidura leucophrys*	ASI[1,2,3]	-	-	-	●	-	●
Paradisaeidae								
Twelve-wired Bird-of-paradise	*Seleucidis melanoleucus*	OMN[1,2]	●	-	-	-	-	-
Pale-billed Sicklebill	*Drepanornis bruijnii*	FRU-INS[1,2]	●	-	-	-	-	-
Lesser Bird-of-paradise	*Paradisaea minor*	FRU-INS[1,2]	●	-	-	-	-	-
Sturnidae								
Yellow-faced Myna	*Mino dumontii*	FRU[1,2,3]-INS[2,3]	●	-	-	-	-	-
Metallic Starling	*Aplonis metallica*	FRU-INS[1,2]	●	●	●	●	●	●
Dicaeidae								
Red-capped Flowerpecker	*Dicaeum geelvinkianum*	FRU-INS[1]	●	●	-	●	●	●
Nectariniidae								
Rand's Sunbird	*Cinnyris idenburgi*	NEC-INS[1]	-	-	-	●	-	-
Estrildidae								
Streak-headed Mannikin	*Lonchura tristissima*	OMN[2,3]	-	-	-	●	-	-

Note: *: Common Name ordering based on HBW and BirdLife International name order (2024); **: Scientific Names for bird species refers to HBW and BirdLife International (2024); HCV: High Conservation Value area; SFH: Non-right to cultivate secondary forest; SHR: Shrubs; OP-A: Oil Palm-A block; OP-B: Oil Palm-B block; 1: Beehler (2001); 2: Pratt and Beehler (2015); 3: van Balen et al. (2005)

Table 6. Diversity of bird communities across habitat types in the study area

Parameter	HCV-A	HCV-B	SFH	SHR	OP-A	OP-B
Species Total	26	20	15	10	12	10
Individual Total	187	75	55	28	69	59
Species Richness Index (Dmg)	4.779	4.401	3.494	2.701	2.598	2.207
Species Diversity Index (H')	2.088	2.577	2.424	1.926	1.502	1.983
Species Evenness Index (J)	0.641	0.860	0.895	0.837	0.604	0.861
Species Dominance Index D	0.258	0.116	0.108	0.188	0.394	0.165

Note: HCV: High Conservation Value area; SFH: Non-right to cultivate secondary forest; SHR: Shrubs; OP-A: Oil Palm-A block; OP-B: Oil Palm-B block; Dmg: Margalef species richness index; H': Shannon-Wiener species diversity index; J: Pielou species evenness index

Table 7. Bird species similarity index value between different habitat types in the study area

Type	HCV-A	HCV-B	SFH	SHR	OP-A	OP-B
High Conservation Value area-A (HCV-A)	1.000	0.435	0.390	0.111	0.316	0.278
High Conservation Value area-B (HCV-B)	-	1.000	0.514	0.333	0.500	0.400
Non-right to cultivate secondary forest (SFH)	-	-	1.000	0.320	0.741	0.480
Shrubs (SHR)	-	-	-	1.000	0.455	0.300
Oil Palm-A Block (OP-A)	-	-	-	-	1.000	0.636
Oil Palm-B Block (OP-B)	-	-	-	-	-	1.000

Note: HCV: High Conservation Value area; SFH: Non-right to cultivate secondary forest; SHR: Shrubs; OP-A: Oil Palm-A block; OP-B: Oil Palm-B block

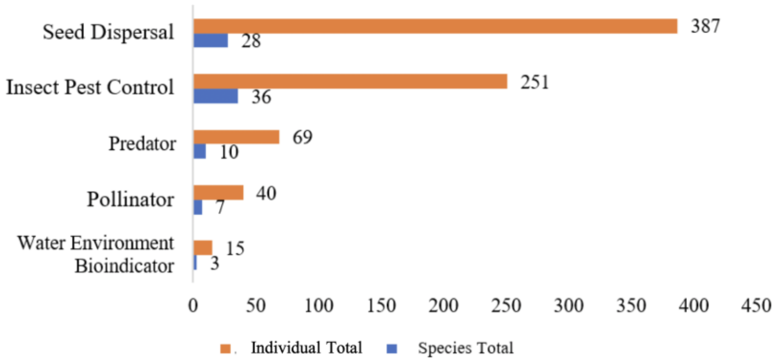

Figure 2. Comparison of the number of bird species and individuals by ecological role

Discussion

Research has shown that bird species richness and diversity are generally higher in HCV lands, which feature diverse vegetation, compared to oil palm areas with lower vegetation complexity (Table 3). This increased diversity in HCV areas results from heterogeneous vegetation structures that create suitable habitats for various animal species, including birds (Santosa and Purnamasari 2023). HCV-A, which has the highest vegetation diversity among surveyed sites, also hosts the most bird species (Table 6). Similar trends have been observed in Sulawesi and Sumatra, where HCV areas support greater bird richness than oil palm blocks (Abdillah et al. 2020; Ramlah et al. 2021). However, in some cases, bird richness and diversity in oil palm areas surpass those in other non-forest land covers, such as shrubs (Bennett et al. 2018; Santosa and Purnamasari 2023).

Vegetation heterogeneity is critical for bird species as it offers diverse food resources and microclimates, with the latter facilitating light penetration to the understory vegetation, thus creating favorable habitats (Kwatrina et al. 2018; Süel et al. 2021). Other environmental factors, such as the availability of water sources (Suri et al. 2017) and minimal human disturbances (Matuoka et al. 2020), further contribute to enhancing bird diversity. In contrast, areas with uniform vegetation often experience reduced bird species richness due to increased competition for limited resources (Nugroho et al. 2023). The bird species similarity analysis presented in Table 7 suggests that the bird compositions in the OP-A and OP-B blocks are more similar to each other than to those in other land types, which can be attributed to both adaptive and non-adaptive species. Adaptive species, such as *Aplonis metallica*, have evolved morphologically and ecologically to thrive in a variety of environments, allowing them to be widespread across all land types (Zuccon et al. 2008; Ayujawi et al. 2021). On the other hand, non-adaptive species, like *Cinnyris idenburgi*, *Todiramphus sanctus*, and etc., are confined to specific habitats, often due to their reliance on certain resources or sensitivity to disturbances (Ayat and Tata 2015; Rohman et al. 2023).

Table 8. Spearman correlation value between the number of bird species found and environmental variables

Parameter	SD	WEB	PL	IPC	PR
Temperature	-0.577	0.539	-0.469	-0.577	-0.161
Sig (2-tailed)	0.231	0.270	0.348	0.231	0.760
Air Humidity	0.406	-0.429	0.358	0.464	0.185
Sig (2-tailed)	0.425	0.396	0.486	0.354	0.726
Elevation	0.657	-0.338	0.677	0.714	-0.152
Sig (2-tailed)	0.156	0.512	0.140	0.111	0.774
Distance from Road	-0.580	0.600	-0.478	-0.406	0.339
Sig (2-tailed)	0.228	0.208	0.338	0.425	0.511
Distance from Waterway	-0.058	0.514	0.090	0.116	0.092
Sig (2-tailed)	0.913	0.296	0.866	0.827	0.862
Distance from Oil Palm Block	0.677	-0.261	**0.939****	**-0.912***	-0.250
Sig (2-tailed)	0.140	0.617	**0.005**	**0.011**	0.633
Distance from Secondary Forest non-HGU	0.486	-0.507	0.177	0.143	-0.030
Sig (2-tailed)	0.329	0.305	0.738	0.787	0.954
Distance from HCV	-0.696	0.429	-0.716	-0.754	0.154
Sig (2-tailed)	0.125	0.396	0.109	0.084	0.771
Distance from Shrubs	0.232	-0.257	0.045	-0.029	-0.277
Sig (2-tailed)	0.658	0.623	0.933	0.957	0.595
Distance from Settlements	-0.406	-0.338	-0.239	-0.261	0.154
Sig (2-tailed)	0.425	0.512	0.649	0.618	0.771
Seedling and Understory Species Total	0.600	-0.338	**0.853***	**0.829***	-0.395
Sig (2-tailed)	0.208	0.512	**0.031**	**0.042**	0.439
Seedling and Understory Density Total	0.029	0.338	0.559	0.486	-0.638
Sig (2-tailed)	0.957	0.512	0.249	0.329	0.173
Sapling Species Total	0.406	-0.171	**0.896***	**0.812***	-0.524
Sig (2-tailed)	0.425	0.745	**0.016**	**0.050**	0.286
Sapling Density Total	0.290	0.171	0.776	0.696	-0.524
Sig (2-tailed)	0.577	0.745	0.070	0.125	0.286
Pole Species Total	0.794	-0.522	**0.955****	**0.971****	0.000
Sig (2-tailed)	0.059	0.288	**0.003**	**0.001**	1.000
Pole Density	0.754	-0.343	**0.925****	**0.928****	-0.092
Sig (2-tailed)	0.084	0.506	**0.008**	**0.008**	0.862
Tree Species Total	0.736	-0.435	**1.000****	**0.971****	-0.250
Sig (2-tailed)	0.096	0.388	**<0.001**	**0.001**	0.633
Tree Species Density	**0.812***	-0.514	**0.985****	**0.986****	-0.092
Sig (2-tailed)	**0.050**	0.296	**<0.001**	**<0.001**	0.862

Note: HCV: High Conservation Value area; SFH: Non-right to cultivate secondary forest; SHR: Shrubs; OP-A: Oil Palm-A block; OP-B: Oil Palm-B block; SD: Seed Dispersal; WEB: Water Environment Bioindicator; PL: Pollinator IPC: Insect Pest Control; PR: Predator *significant effect at 95% confidence level; **significant effect at 99% confidence level

The similarity in bird species composition is also influenced by the comparable vegetation types across different land covers. As seen in Table 4, the OP blocks have a relatively higher vegetation similarity compared to other areas, which likely contributes to the observed similarity in bird assemblages between OP-A and OP-B. Additionally, the low vegetation species richness in oil palm plantations, as shown in Table 3, emphasizes the limited availability of plant-based food resources. This restricted vegetation diversity constrains the variety of food sources available for birds, which could lead to a more homogeneous bird community within oil palm plantations. The combination of limited vegetation richness and similar plant compositions across oil palm areas likely reinforces the convergence of bird species found in OP-A and OP-B.

Birds play a vital ecological role in oil palm plantations, particularly as seed dispersers, the most abundant bird group (Figure 2). Granivorous and frugivorous birds contribute to ecological succession and forest regeneration by consuming fruits and dispersing seeds (Neves et al. 2013; Silva 2022). *Cacatua galerita* is a common seed disperser's species observed in the study area (Table 5). It is frequently seen in groups around oil palm plantations, where it is attracted to fruits (Beehler et al. 2001; Pratt and Beehler 2015), including ripe oil palm fruits. In non-smallholder lands, seed-dispersing birds accelerate habitat recovery by promoting native vegetation growth (Martínez-López et al. 2019). However, their presence in plantations presents challenges, as they can reduce oil palm productivity by consuming Fresh Fruit Bunches (FFB) and spreading Volunteer Oil Palm Seedlings (VOPS), potentially increasing competition and complicating management (Maizatul and Idris 2008).

Besides seed dispersal, birds play a key role in pollination, particularly in forests where they support natural vegetation regrowth (Santosa et al. 2023). Omnivorous birds with nectar-feeding tendencies are primary pollinators, with *Philemon buceroides* commonly found across land types due to its adaptability and social behavior (Beehler et al. 2001; Pratt and Beehler 2015). This species significantly aids plant reproduction in various landscapes. However, pollinator birds are rarely found in oil palm plantations due to the lack of suitable floral resources. Unlike other crops, oil palm is mainly pollinated by insects, particularly *Elaeidobius kamerunicus* (Meléndez and Ponce 2016; Haran et al. 2020; Riley et al. 2022). While insect pollinators enhance oil palm productivity, not all are beneficial. Some, particularly from the Curculionidae family, damage palm trunks, while Scarabaeidae family, such as *Oryctes* spp., feed on palm tissue, causing plant mortality. Other insect species act as defoliators, reducing oil palm yields (Egonyu et al. 2022). To counteract these threats, insectivorous birds play a crucial role in pest control, helping maintain ecosystem balance and support oil palm productivity.

Insectivorous birds are essential for pest management in oil palm plantations, which are vulnerable to insect outbreaks. Studies show that insectivorous and frugivorous birds help control pests by preying on caterpillars, termites, and other harmful insects (de Chenon and Susanto 2005; Koh and Wilcove 2008; Nazaro and Blendinger 2017). Among these natural pest controllers, *A. metallica* is the most abundant, feeding on insect pests and potentially assisting with pollination (Beehler et al. 2001; Pratt and Beehler 2015). Raptors also play an essential role in nutrient cycling and maintaining ecosystem stability by managing populations of pests such as rodents and reptiles (Atmoko et al. 2022; Santosa et al. 2023). In oil palm plantations, key raptor families include Accipitridae (e.g. *Accipiter hiogaster, Haliastur indus*, *Aviceda subcristata*), Ardeidae (*Ardea alba*), Alcedinidae (*T. sanctus*, *Dacelo gaudichaud*), and Cuculidae (*Centropus menbeki*). These birds depend on prey availability, including snakes, rats, and lizards, which thrive in oil palm landscapes.

Beyond terrestrial ecosystems, birds serve as bioindicators in aquatic environments, helping assess land quality and ecosystem health. Aquatic birds from the Alcedinidae and Ardeidae families function as apex predators in water-based ecosystems, where their presence is linked to water quality and food availability (Santosa et al. 2023). Species such as *T. sanctus* and *A. alba* are particularly valuable as bioindicators, reflecting aquatic habitat health (Parsons et al. 2010). Their population trends provide insights into environmental changes, pollution levels, and habitat degradation, highlighting the interconnectedness between avian communities and ecosystem dynamics in oil palm landscapes.

Correlation analysis (Table 8) indicates that seed-dispersing birds are more prevalent in areas with trees and poles, particularly near HCV zones. Tree species such as *Ficus* spp. attract frugivores reliant on these primary food sources (Pradana et al. 2018). The abundance of fruit resources suggests a healthy ecosystem capable of supporting diverse seed-dispersing birds (Santosa et al. 2023).

Conserving bird populations in oil palm agroecosystems is crucial for promoting biodiversity and ecological balance. In the Kaureh Sub-district, conservation measures include, (i) improving vegetation in HCV and non-HCV areas to enhance bird populations while complying with RSPO and ISPO guidelines (Teuscher et al. 2016; Kwatrina et al. 2018; Kissinger et al. 2020); (ii) managing species like *C. galerita* and *A. metallica* that may affect oil palm production through educational initiatives on conservation status, following Indonesian Ministerial regulations, The International Union of Nature (IUCN) Red List, and the Convention on International Trade in Endangered Species (CITES) Checklist; and (iii) conducting regular bird monitoring with community involvement to track population trends (Neate-Clegg et al. 2020).

In summary, bird diversity in oil palm agroecosystems is significantly enhanced in HCV areas with varied vegetation structures. These habitats not only support adaptive birds but also provide crucial environments for non-adaptive species. Additionally, trees such as *Ficus* spp. in HCV areas play a vital role in frugivore and seed disperser sustenance, facilitating natural regeneration. Effective bird conservation in oil palm plantations requires diverse habitat management, species population control, regular monitoring, and collaboration with conservation organizations. These efforts can enhance biodiversity in Kaureh Sub-district's oil palm landscapes, promoting both ecological stability and sustainable production.

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REFERENCES

Abdillah NK, Mulyani YA, Rahman DA. 2020. Frugivorous birds in Taman Hutan Raya Sultan Thaha Syaifuddin Jambi, Jambi. IOP Conf Ser Earth Environ Sci 528: 012028. DOI: 10.1088/1755-1315/528/1/012028.

Adileksana C, Yudono P, Purwanto BH, Wijoyo RB. 2020. Growth performance of oil palm seedlings in pre-nursery and main nursery stages as a response to the substitution of NPK compound fertilizer and organic fertilizer. Caraka Tani 35: 89-97. DOI: 10.20961/carakatani.v35i1.33884.

Amit B, Tuen AA, Haron K, Harun MH. 2014. Diversity of bird species in the oil palm plantation on peat. Oil Palm Bull 69: 1-4.

Atmoko T, Nugroho AW, Mukhlisi. 2022. Bird's species response to the ex-coal mining reclamation stages. IOP Conf Ser Earth Environ Sci 1027: 012009. DOI: 10.1088/1755-1315/1027/1/012009.

Ayat A, Tata HL. 2015. Diversity of birds across land use and habitat gradients in forests, rubber agroforests and rubber plantations of North Sumatra. Indones J For Res 2: 103-120. DOI: 10.20886/ijfr.2015.2.2.829.103-120.

Ayujawi SA, Winarni NL, Pradana DH. 2021. Short communication: Bird correlations with waste in Muara Gembong, West Java, Indonesia. Biodiversitas 22 (9): 3872-3879. DOI: 10.13057/biodiv/d220933.

Azhar B, Puan CL, Aziz N, Sainuddin M, Adila N, Samsuddin S, Asmah S, Syafiq M, Razak SA, Hafizuddin A, Hawa A, Jamian S. 2015. Effects of in situ habitat quality and landscape characteristics in the oil palm agricultural matrix on tropical understory birds, fruit bats and butterflies. Biodivers Conserv 24: 3125-3144. DOI: 10.1007/s10531-015-1005-6.

Badan Pusat Statistik (BPS). 2021. Statistik Kelapa Sawit Indonesia 2021. Badan Pusat Statistik, Jakarta. [Indonesian]

Beehler BM, Pratt TK, Zimmerman DA. 2001. Burung-Burung di Kawasan Papua: Papua, Papua Niugini, dan Pulau-Pulau Satelitnya. Puslitbang LIPI, Jakarta. [Indonesian]

Bennett RE, Leuenberger W, Leja BBB, Caceres AS, Johnson K, Larkin J. 2018. Conservation of neotropical migratory birds in tropical hardwood and oil palm plantations. Plos One 13: 1-18. DOI: 10.1371/journal.pone.0210293.

Bernardo AA. 2017. Disparity in bird communities of oil palm (*Elaeis guineensis*) plantation and adjacent forest in Aborlan, Palawan: implications to avifaunal conservation. J Nat Stud 16 (1): 45-62.

Bocianowski J, Wronska-Pilarek D, Krysztofiak-Kaniewska A, Matusiak K, Wiatrowska B. 2024. Comparison of pearson's and spearman's correlation coefficients for selected traits of *Pinus sylvestris* L. Biom Lett 61 (2): 115-135. DOI: 10.2478/bile-2024-0008.

Bonning BC, Chougule NP. 2014. Delivery of intrahemocoelic peptides for insect pest management. Trends Biotechnol 32 (2): 91-98. DOI: 10.1016/j.tibtech.2013.08.001

Brunelle T, Dumas P, Souty F, Dorin B, Nadaud F. 2015. Evaluating the impact of rising fertilizer prices on crop yields. Agric Econ 46: 653-666. DOI: 10.1111/agec.12161.

Chellappan M, Ranjith MT, Chaudhary V, Sreejeshnath KA. 2023. Bird pests: Damage and ecofriendly management. Ann Arid Zone 62: 361-372. DOI: 10.59512/aaz.2023.62.4.11.

D'hondt B, Hoffmann M. 2011. A reassessment of the role of simple seed traits in mortality following herbivore ingestion. Plant Biol 13: 118-124. DOI: 10.1111/j.1438-8677.2010.00335.x.

Denmead LH, Darras K, Clough Y, Diaz P, Grass I, Hoffmann MP, Nurdiansyah F, Fardiansah R, Tscharntke T. 2017. The role of ants, birds and bats for ecosystem functions and yield in oil palm plantations. Ecology 98: 1945-1946. DOI: 10.1002/ecy.1882.

Direktorat Jenderal Perkebunan (Ditjenbun). 2024. Statistik Perkebunan Jilid I 2022-2024. Kementerian Pertanian Republik Indonesia, Jakarta. [Indonesian]

Egonyu JP, Baguma J, Martinez LC, Priwiratama H, Subramanian S, Tang CM, Anankware JP, Roos N, Niassy S. 2022. Global advances on insect pest management research in oil palm. Sustainability 14: 1-24. DOI: 10.3390/ su142316288.

Haran JM, Beaudoin-Ollivier L, Benoit L, Kuschel G. 2020. Revision of the palm-pollinating weevil genus *Elaeidobius* Kuschel, 1952 (Curculionidae, Curculioninae, Derelomini) with descriptions of two new species. Eur J Taxon 684: 1-32. DOI: 10.5852/ejt.2020.684.

Huffeldt NP, Aggerholm IN, Brandtberg NH, Jørgensen JH, Dichmann K, Sunde P. 2012. Compounding effects on nest-site dispersal of nest-site dispersal of barn owls *Tyto alba*. Bird Stud 3657: 175-181. DOI: 10.1080/00063657.2011.652592.

Karp DS, Mendenhall CD, Sandi RF, Chaumont N, Ehrlich PR, Hadly EA, Daily GC. 2013. Forest bolsters bird abundance, pest control and coffee yield. Ecol Lett 16: 1339-1347. DOI: 10.1111/ele.12173.

Katuwal HB, Pradhan NMB, Thakuri JJ, Bhusal KP, Aryal PC, Thapa I. 2018. Effect of urbanization and seasonality in bird communities of Kathmandu Valley, Nepal. Proc Zool Soc 71: 103-113. DOI: 10.1007/s12595-018-0265-z.

Kissinger, Pitri RMN, Violet. 2020. Vegetation and fauna diversity of high conservation value (HCV) swamp areas in oil palm plantation. IOP Conf Ser Earth Environ Sci 499: 012017. DOI: 10.1088/1755-1315/499/1/012017.

Koh LP, Wilcove DS. 2008. Is oil palm agriculture really destroying tropical biodiversity? Conserv Lett 1: 60-64. DOI: 10.1111/j.1755-263X.2008.00011.x.

Kusmana C, Istomo, Winata B, Hilwan I. 2022 Ekologi Hutan Indonesia. Institut Pertanian Bogor Press, Bogor. [Indonesian]

Kwatrina RT, Santosa Y, Bismark M, Santoso N. 2018. Ecological impacts of oil-palm plantation on butterfly and bird species diversity. Jurnal Manajemen Hutan Tropika 24 (1): 23-31. DOI: 10.7226/jtfm.24.1.23.

Luneva A, Lysenko Y, Gneush A, Lysenko A, Machneva N, Aniskina M. 2022. Bird droppings biodegradation and its use as fertilizer for tomato cultivation. Intl Trans J Eng Manag Appl Sci Technol 13 (5): 1-10. DOI: 10.14456/ITJEMAST.2022.96.

Maas B, Karp DS, Bumrungsri S, Darras K, Gonthier D, Huang JCC, Lindell CA, Maine JJ, Mestre L, Michel NL. 2016. Bird and bat predation services in tropical forests and agroforestry landscapes. Biol Rev 91: 1081-1101. DOI: 10.1111/brv.12211.

Maizatul SM, Idris AS. 2008. Glyphosate Monoammonium for Controlling Volunteer Oil Palm Seedlings. Malaysian Palm Oil Board, Ministry of Plantation Industries and Commodities, Malaysia.

Martínez-López V, Zapata V, De la RP, Robledano F. 2019. Uncovering mechanisms of bird seed dispersal in semiarid environments to help to restore them. Ecosphere 10: 1-12. DOI: 10.1002/ecs2.2673.

Masy'ud B, Santosa Y, Aulia N, Gusnadi FD. 2020. The impact of fire in palm oil estate on the bird and the butterfly species diversity: Case study in RAJ oil palm estate, South Sumatera. IOP Conf Ser Earth Environ Sci 504: 012002. DOI: 10.1088/1755-1315/504/1/012002.

Matuoka MA, Benchimol M, Morante-Filho JC. 2020. Tropical forest loss drives divergent patterns in functional diversity of forest and non-forest birds. Biotropica 52: 738-748. DOI: 10.1111/btp.12795.

Meléndez MR, Ponce WP. 2016. Pollination in the oil palms *Elaeis guineensis*, *E. oleifera* and their hybrids (OxG), in tropical America. Pesquisa Agropecuária Tropical 46: 102-110. DOI: 10.1590/1983-40632016v4638196.

Mohd-Azlan J, Fang VAM, Kaicheen SS, Lok L, Lawes J. 2019. The diversity of understorey birds in forest fragments and oil palm plantation, Sarawak, Borneo. J Oil Palm Res 31: 437-447.

Murgianto F, Edyson, Putra SK, Ardiyanto A. 2022. Role of the barn owl *Tyto alba javanica* as a biological agent for rat pest control in the oil palm plantation of Bumitama Agri Ltd. IOP Conf Ser Earth Environ Sci 985: 012048. DOI: 10.1088/1755-1315/985/1/012048.

Nahlunnisa H, Zuhud EAM, Santosa Y. 2022. Prospek konservasi tumbuhan di areal nilai konservasi tinggi perkebunan kelapa sawit Riau. Jurnal Hutan Tropis 6: 68-79. DOI: 10.32522/ujht.v6i1.6066. [Indonesian]

Nazaro AG, Blendinger PG. 2017. How important are arthropods in the diet of fruit-eating birds? Wilson J Ornithol 129: 520-527. DOI: 10.1676/16-083.1.

Neate-Clegg MHC, Horns JJ, Adler FR, Aytekin MCK, Sekercioglu CH. 2020. Monitoring the world's bird populations with community science data. Biol Conserv 248: 1-7. DOI: 10.1016/j.biocon.2020.108653.

Neves SC, Ribeiro LM, Cunha IRG, Pimenta MAS, Mercadante-Simoes MO, Lopes PSN. 2013. Diaspore structure and germination ecophysiology of the babassu palm (*Attalea vitrivir*). Flora 208: 68-78. DOI: 10.1016/j.flora.2012.12.007.

Nugroho SPA, Mardiastuti A, Mulyani YA, Rahman DA. 2021. Do morning and afternoon bird surveys have the same results? A case of bird survey in Dramaga Campus, IPB University, Indonesia. IOP Conf Ser Earth Environ Sci 771: 012037. DOI: 10.1088/17551315/771/1/012037.

Nugroho SPA, Mardiastuti A, Mulyani YA, Rahman DA. 2023. Bird communities in the tropical peri-urban landscape of Bogor, Indonesia. Biodiversitas 24 (12): 2085-4722. DOI: 10.13057/biodiv/d241260.

Oliveira SL, Flaspohler DJ, Knowlton JL, Wolfe JD. 2022. Do oil palm plantations provide quality habitat for migratory birds? A case study from Mexico. Ecol Indic 139: 1-11. DOI: 10.1016/j.ecolind.2022.108964.

Panda BP, Prusty BAK, Panda B, Pradhan A, Parida SP. 2021. Habitat heterogeneity influences avian feeding guild composition in urban landscapes: Evidence from Bhubaneswar, India. Ecol Process 10: 1-10. DOI: 10.1186/s13717-021-00304-6.

Parsons KC, Mineau P, Renfrew B. 2010. Effects of pesticide use in rice fields on birds. Waterbirds 33: 193-218. DOI: 10.1675/063.033.s115.

Pradana DH, Mardiastuti A, Yasman. 2018. Utilization of *Ficus benjamina* by birds at urban habitat in Depok. Bioma 20: 75-78. DOI: 10.14710/jhp.%v.%i.29-40.

Pratt TK, Beehler BM. 2015. Birds of New Guinea, Second Edition. Princeton University Press, Princeton. DOI: 10.1515/9781400865116.

Putri MM, Santosa Y. 2020. Comparison of bird species diversity between 4th ages burnt and unburnt land in PT Waimusi Agroindah, South Sumatera. IOP Conf Ser Earth Envron Sci 504: 012005. DOI: 10.1088/1755-1315/504/1/012005.

Ramlah S, Ihsan M, Yusran. 2024. Avian species diversity in oil palm plantation in Buol District, Central Sulawesi, Indonesia. Intl J Des Nat Ecodyn 19: 267-273. DOI: 10.18280/ijdne.190129.

Ramlah S, Santosa Y, Santoso N, Rushayati SB. 2021. The variation of bird diversity in various oil palm land cover in North Mamuju, West Sulawesi, Indonesia. Biodiversitas 22 (7): 3068-3074. DOI: 10.13057/biodiv/d220761.

Riley SO, Dery SK, Afreh-Nuamah K, Agyei-Dwarko D, Ayizannon RG. 2022. Pollinators of oil palm and relationship to fruitset and yield in two fruit forms in Ghana. OCL 29: 1-18. DOI: 10.1051/ocl/2022009.

Rohman SN, Mardiastuti A, Mulyani YA. 2023. Bird diversity in several land use types in Boyolali, Central Java. IOP Conf Ser Earth Environ Sci 1220: 012009. DOI: 10.1088/1755-1315/1220/1/012009.

Santosa Y, Kwatrina RT, Erniwati, Purnamasari I, Putri MM. 2023. Karakteristik dan Peran Areal NKT dalam Konservasi Keanekaragaman Jenis Satwa Liar di Kebun Sawit Pulau Sumatera. Institut Pertanian Bogor Press, Bogor. [Indonesian]

Santosa Y, Perdana AY, Sopiyandi S, Yohanna. 2018. Bird diversity in smallholders oil palm plantation in Riau Province. Intl J Oil Palm 1 (1): 28-37. DOI: 10.35876/ijop.v1i1.4.

Santosa Y, Purnamasari I. 2023. Oil palm plantations versus mammals and birds conservation: A case study in two oil palm plantations in West Kalimantan Province. J Nat Resour Environ Manag 13 (3): 475-483. DOI: 10.29244/jpsl.13.3.475-483.

Santosa Y, Sunkar A, Kwatrina RT. 2020. Is it true that oil palm plantations are the main driver of Indonesia's tropical forest deforestation? Intl J Oil Palm 3 (1): 1-10. DOI: 10.35876/ijop.v3i1.37.

Sastranegara H, Mardiastuti A, Mulyani YA. 2020. Guild composition and niche overlap of insectivorous birds in evergreen rainforest. Jurnal Manajemen Hutan Tropika 26 (1): 13-20. DOI: 10.7226/jtfm.26.1.13.

Shafie NJ, Anuar H, David G, Ahmad A, Abdullah MT. 2023. Bird species composition, density and feeding guilds in contrasting lowland dipterocarp forests of Terengganu, Peninsular Malaysia. Trop Ecol 64: 238-248. DOI: 10.1007/s42965-022-00267-5.

Silva LB. 2022. Frugivory and primary seed dispersal of *Elaeis guineensis* by birds of prey. Braz J Biol 84: e256937. DOI: 10.1590/1519-6984.256937.

.

Süel H, Akdemir D, Ertuğrul ET, Özdemir S. 2021. Determining environmental factors affecting bird diversity. Kastamonu Univ J For 21: 244-251. DOI: 10.17475/kastorman.1049336.

Suri J, Anderson PM, Charles-Dominique T, Hellard E, Cumming GS. 2017. More than just a corridor: A suburban river catchment enhances bird functional diversity. Landsc Urban Plan 157: 331-342. DOI: 10.1016/j.landurbplan.2016.07.013.

Tandra H, Suroso AI. 2023. The determinant, efficicency, and potential of Indonesian palm oil downstream export to the global market. Cogent Econ Financ 11: 1-22. DOI: 10.1080/23322039.2023.2189671.

Teuscher M, Gerard A, Brose U, Buchori D, Clough Y, Ehbrecht M, Holscher D, Irawan B, Sundawati L, Wollni M, Kreft H. 2016. Experimental biodiversity enrichment in oil-palm-dominated landscapes in Indonesia. Front Plant Sci 7: 1538. DOI: 10.3389/fpls.2016.01538.

Thorat JC, More AL. 2022. The effect of chemical fertilizers on environment and human health. Intl J Sci Dev Res 7: 99-105.

van Balen B, Mardiastuti A, Husin Y. 2005. Burung-Burung di Mimika Sebuah Pengantar tentang Burung-Burung Dataran Rendah di Wilayah Kontrak Karya PT Freeport Indonesia, Mimika, Papua. PT Hatfindo Prima, Bogor. [Indonesian]

Wulandari DP. 2024. Optimasi Pupuk Hayati untuk Keanekaragaman Tumbuhan Bawah sebagai Pakan Ternak dan Produktivitas Kelapa Sawit. [Thesis]. Institut Pertanian Bogor, Bogor. [Indonesian]

Zuccon D, Pasquet E, Ericson PGP. 2008. Phylogenetic relationships among paleartic-oriental starlings and munas (genera *Sturnus* and *Acridotheres*: Sturnidae). Zool Scr 37: 469-481. DOI: 10.1111/j.1463-6409.2008.00339.x.