

Assessing the bird and tree species diversity in the north of Badung, Bali, Indonesia

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Abstract. Yuni LPEK, Wijaya IMS, Sari IAEP. 2022. Assessing the bird and tree species diversity in the north of Badung, Bali, Indonesia. *Biodiversitas* 23: 4482-4489. Bird diversity is related to tree diversity, which is influenced by landscape heterogeneity. Here, we reported the bird diversity of Jempanang, Bali, Indonesia, in riparian, plantation, and forest edge habitats estimated through a point count survey undertaken in June 2021, and related to patterns of tree diversity. Overall, Jempanang had a high diversity of bird and tree species, with 54 bird species and 18 tree species recorded in total. Among habitats, bird diversity was highest in the riparian area, whereas the plantation and forest edges had moderate bird diversity. The plantation had the lowest absolute tree diversity, but all sites had a moderate level of tree diversity. The wide range of land uses in Jempanang provides a diverse composition of plant species, thereby increasing the number of environmental niches and driving higher diversity of bird species. The presence of apex raptor species indicates that Jempanang can be considered an area with good environmental quality. Considering the high diversity of bird and tree species in the area, birdwatching activities could be promoted as an agent for community-based conservation, potentially providing local incentives for preserving the area's biodiversity.

Keywords: Bird, diversity, point count, tree, vegetation analysis

INTRODUCTION

Jempanang, a sub-village of Bilok Sidan village, is situated in the northernmost area of Badung Regency, Bali, Indonesia. It is a mountainous highland area, and forest and plantation areas are the dominant land cover types (BPS-Statistics of Badung Regency 2022). Jempanang is in the upstream area of the Ayung River. The Ayung River basin is the largest watershed in the Bali Penida River Region, and it flows through four regencies (Bangli, Badung, Gianyar, and Denpasar) (Eryani and Jayantari 2019). According to the Badung Regency Regional Regulation Number 26 of the Year 2013 on Spatial Planning for the Badung Regency 2013-2033, this area plays an important role as one of the main water catchment areas in Bali (BPS-Statistics of Badung Regency 2022). Therefore, it is essential to carry out regular biodiversity monitoring to assist with environmental planning in the area.

Biodiversity conservation is an important component of preserving natural resources since the state of a region's flora and fauna greatly affects the balance of ecosystems and, ultimately, the sustainability of human life (Chu and Karr 2017). To carry out biodiversity management activities, it is necessary to have a basic knowledge of local biodiversity. Such knowledge can be obtained through a field survey that can be used as baseline knowledge for biodiversity planning and on-ground management (Mäkeläinen and Lehtikoinen 2021). Birds are acknowledged as excellent ecological indicators to measure

ecosystem change (Alexandrino et al. 2016) because, in many cases, their life histories are well-known, they are widely distributed in most ecosystems, they forage on a wide range of food sources. They, therefore, occupy many niches, and they are relatively easy to observe, identify and survey during the day (BirdLife International 2013). Moreover, as a diverse class, birds are known to be sensitive to ecological changes (Keten et al. 2020). By conducting regular monitoring of birds, a baseline can be established against which changes in the future can be measured.

In this study, we report the bird and tree diversity of Jempanang. Previous studies have shown that bird diversity is related to several factors, including tree diversity (Sudaryanto et al. 2019; Villaseñor et al. 2021). This is because woody vegetation provides opportunities for shelter, nesting, and foraging (Dyson 2020). Bird diversity is also influenced by landscape heterogeneity, demonstrated by the increasing number of bird species along a gradient of increasing landscape heterogeneity (Lee and Martin 2017; Basile et al. 2021). Besides acting as ecological indicators, birds carry out important ecosystem functions, for example, as seed dispersers and pollinators, as part of predator-prey relationships, controlling pest species, and as scavengers (Kazama 2015). Birds also provide recreational services to humans through birdwatching activities, an international industry employing guides that can be a significant source of income (Şekercioğlu 2002; Ocampo-Peñuela and Winton 2017).

Unfortunately, previously there are no studies on bird and tree diversity have been conducted in Jempanang. Unlike the southern area of Badung Regency, where the tourism facilities have been majorly developed over decades, less economic development occurred on the northern side of the regency. Recently, the local government has discussed agrotourism and agroindustry development plans to reduce economic inequality between the southern and northern areas of Badung Regency. The results of this study may, therefore, benefit the local community of Bilok Sidan village if they help promote birdwatching as a potential source of income through a professionally managed agrotourism program enriched with birdwatching activities.

MATERIALS AND METHODS

Study area

The study was conducted in June 2021 in the northernmost village of Badung Regency, Bali Province ($8^{\circ}15'6''$ S, $115^{\circ}12'57''$ E; Figure 1). Specifically, the study area was Jempanang, a sub-village (2.22 km^2) of Bilok Sidan village (3.226 km^2). This is a highland area (1310 m asl) with a mountainous landscape and slopes of $30\text{--}70^{\circ}$, and it is located in the upstream area of the Ayung River, which is the longest river (68.5 km) in Bali (BPS-Statistics of Badung Regency 2022). Three land cover types were included in the survey: a riparian area (site 1), plantation (site 2), and forest edge (site 3). The edge of the forest is bordered by a plantation area. The plantation area covers approximately 60% of land use in Jempanang, where locals predominantly grow coffee, oranges, and some vegetables. The riparian site covers open habitats

with a fairly steep slope, with some tree species that have a high tolerance to high soil humidity and fern species as the ground cover. On the forest edge, locals mostly grow tree species for Balinese ceremonies purposes and for land conservation. At the forest side, the tree heights range from 10–15 m, and the canopy cover ranges from 50–80%.

Procedures

At each site, we surveyed birds at three point counts (Bibby et al. 1998) for 15 mins within 50 m from each point, twice per week in June 2021, from 06:00 to 17:00 hours. Due to the pandemic, visit access to the village was restricted in the matter of time and number of people. Each point count was visited eight times, and in total 1080 minutes of observation time was collected. The distance between points was approximately 500 m. Three observers were equipped with binoculars (Nikon Prostaff 8×42 6.3 $^{\circ}$) and a camera (Nikon B700 60 \times optical zoom 4.3–258 mm and Canon 60D Sigma 70–300 mm) if photos were needed to aid identification. We recorded the bird species and the number of individuals seen. The bird species recorded were those that perched on or moved among branches within site or flew over the observation point. The species identification aid we used was Atlas Burung Indonesia (2020). The conservation status of birds follows the Ministry of Environment and Forestry of the Republic of Indonesia Regulation Number P.106/MENLHK/SETJEN/KUM.1/12/2018 and the IUCN Red List of Threatened Species. Therefore, the conservation status of the birds on the national and international levels was checked.

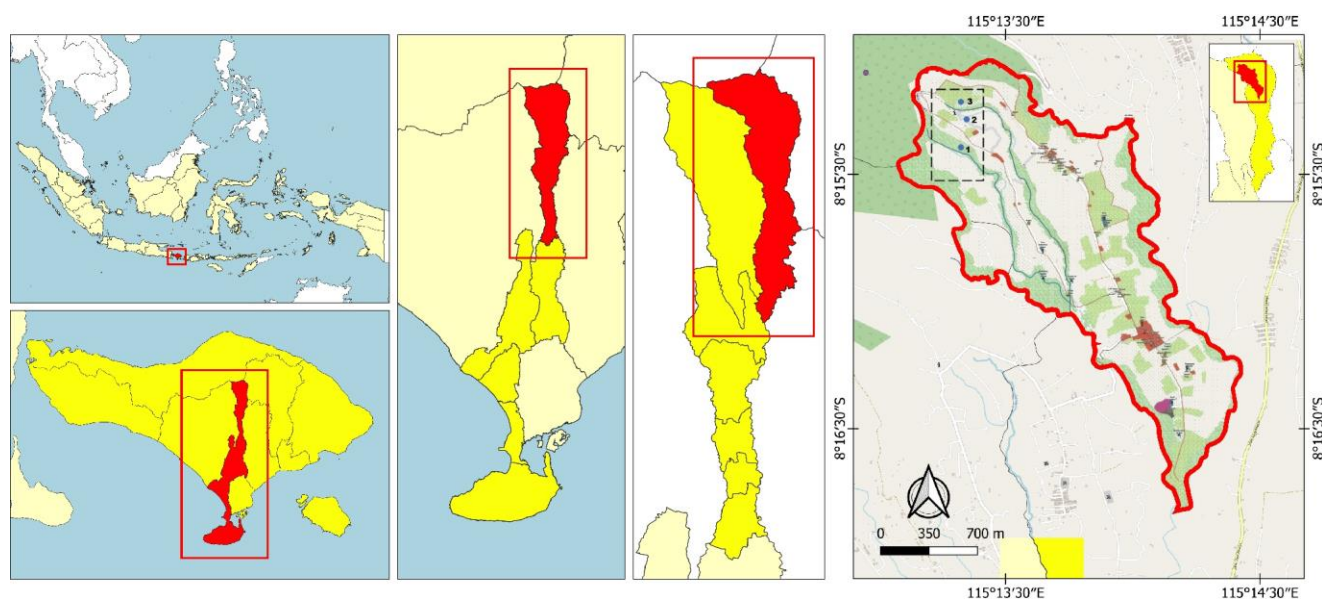


Figure 1. Study sites at Jempanang sub-village, Bilok Sidan village, Petang District, Badung Regency, Bali, Indonesia (Source of Map: Bilok Sidan Village Office 2022)

To determine habitat conditions in each land cover type, we conducted a vegetation analysis in three sampling plots using a 20×20 m². In each plot, we recorded the tree species present, stem diameter at breast height, and the number of each tree species. A plant was classified as a tree if its main stem's diameter ³ 20 cm or the stem circumference ³ 62 cm (Silvianingsih et al. 2021). Tree identification was based on field observation and identification key (Backer and van den Brink 1963, 1965, 1968; Partomihardjo et al. 2014).

Data analysis

Bird diversity was calculated based on the Shannon-Wiener Diversity Index (H') = $-\sum (n_i/N) \ln (n_i/N)$. The diversity is categorized as relatively low if $H' \leq 1$, moderate if $1 < H' < 3$, and high if $H' \geq 3$ (Ludwig and Reynolds 1988). To determine the evenness of bird species at each study site, we calculated the Index of Evenness (E) = $H'/\ln S$, where S is the total number of species in the samples. The evenness is categorized as low if $0 < E \leq 0.4$, as moderate if $0.4 < E \leq 0.6$, and as high if $0.6 < E \leq 1.0$ (Ludwig and Reynolds 1988). The bird species dominance in each site was calculated by using Dominance (D_i) = $(n_i/N) \times 100\%$, where n_i is the number of individuals of species i and N is the total number of individuals of all species. The level of dominance was determined following Sudaryanto et al. (2019), in which non-dominant species had D_i : 0-2%, sub-dominant species had D_i : 2-5%, and dominant species had $D_i > 5\%$. The calculation was made for the entire site, as well as for each site.

For the vegetation analysis, the parameters calculated were the Importance Value (IV) and Diversity Index (H'). The IV was calculated by using density (D), relative density (DR), frequency (F), relative frequency (FR), dominance (Do), and relative dominance (DoR). The diversity Index was calculated by using the Shannon-Wiener Diversity Index (H'). The IV parameters were calculated using the following formulae (Krebs 1999):

$$\text{Density (individu/400m}^2\text{)} = \frac{\text{Number of individu of a species}}{\text{Area}}$$

$$\text{Relative density (\%)} = \frac{\text{Density of a species}}{\text{Total density}} \times 100\%$$

$$\text{Frequency (\%)} = \frac{\text{Number of plots in which species occur}}{\text{Total of plots}}$$

$$\text{Relative frequency (\%)} = \frac{\text{Frequency of a species}}{\text{Total frequency}} \times 100\%$$

$$\text{Dominancy (species/m}^2\text{)} = \frac{\text{Average of Basal Area of a species}}{\text{Area sampled}}$$

$$\text{Relative dominancy (\%)} = \frac{\text{Dominancy of a species}}{\text{Total dominancy}} \times 100\%$$

$$\text{Importance value index (IV)} = \text{Relative Density} + \text{Relative Frequency} + \text{Relative Dominancy}$$

$$\text{Shannon - Wiener Diversity Index (H')} = - \sum_{i=1}^s \left(\frac{n_i}{N} \right) \left(\ln \frac{n_i}{N} \right)$$

Where, n_i : number of individuals of species i ; N : total number of individuals of all species; H' : Shannon-Weiner diversity index

RESULTS AND DISCUSSION

Bird diversity

There were 54 bird species, consisted of 45 genus, 29 families, and 10 orders, recorded at Jempanang, Bilok Sidan village (Table 1), with 50, 23 and 24 species recorded at riparian (Site 1), plantation (Site 2), and forest edge (Site 3), respectively. Among those 54 bird species, 34 species were passerines and 20 species were non-passerines, as well as five forest bird species with population trend declining according to IUCN Red List. Four species afforded legal protection under the Ministry of Forestry and Environment of Republic Indonesia Regulation Number P.106/MENLHK/SETJEN/KUM.1/12/2018 were recorded during the survey. These were the Sunda Pied Fantail *Rhipidura javanica* and three raptor species-the Black Eagle *Ictinaetus malayensis*, Crested-serpent Eagle *Spilornis cheela*, and Black-thighed Falconet *Microhierax fringillarius*. We also recorded Javan Myna *Acridotheres javanicus* and Brown-cheeked Bulbul *Alophoixus bres*, which are included on the IUCN Red List as Vulnerable (VU) and Endangered (EN) species, respectively.

The bird diversity (H') for Jempanang was 3.27, which is considered a high bird diversity. With regard to the Evenness Index, the bird species recorded were distributed evenly among sites (0.82). For each site, the H' calculation yielded values of 3.64 for riparian (site 1), 2.59 for plantation (site 2), and 2.57 for forest edge (site 3). Therefore, it can be stated that site 1 has high bird diversity, whereas sites 2 and 3 have moderate and quite similar levels of bird diversity. Despite the presence of some dominant bird species in each site, the bird species' evenness was high at each site, with values of 0.81 for both site 1 and site 2, and 0.9 for site 3 (Table 1). Dominant species in site 1 were the Cave Swiftlet *Collocalia linchi*, Scaly-breasted Munia *Lonchura punctulata*, Eastern Spotted Dove *Spilopelia chinensis*, and Pink-necked Green-pigeon *Treron vernans*. In site 2, the dominant bird species were the Cave Swiftlet, Pacific Swallow *Hirundo tahitica*, Olive-backed Tailorbird *Orthotomus sepium*, and Sunda Pied Fantail. Finally, in site 3 the dominant species were the Cave Swiftlet, Pacific Swallow, and Long-tailed Shrike *Lanius schach*.

Vegetation analysis

The vegetation analysis of the tree community in Jempanang is presented in Table 2. In total, 18 tree species were recorded at all sites. In site 1, the tree species with the highest IV was *Pterospermum javanicum* (126.16%), followed by *Bischofia javanica* (68.34%) and *Homalanthus populneus* (58.65%). In site 2, the tree species with the highest IV was *Melia azedarach* (90.69%), followed by *Arenga pinnata* (75.35%) and *Persea americana* (71.97%). In site 3, the dominant species with the highest IV was *Swietenia mahagoni* (92.91%), followed by *Albizia chinensis* (49.29%) and *Artocarpus heterophyllus* (34.48%).

The Shannon-Wiener Index (H') value for Jempanang was 3.08, indicating the area has high tree species diversity. Site 1, site 2 and site 3 had H' values of 2.47, 1.60, and 2.12, respectively. Based on those values, the tree diversity index per site is moderate.

Table 1. Bird species recorded at Jempanang, Bilok Sidan village in June 2021

| Scientific name | Common name | Dominance (%) | | | IUCN |
|---|-----------------------------------|---------------|--------|--------|------|
| | | Site 1 | Site 2 | Site 3 | |
| <i>Acridotheres javanicus</i> | Javan Myna | 1.32 | 0.00 | 0.00 | VU |
| <i>Aegithina tiphia</i> | Common Iora | 1.32 | 0.00 | 0.00 | LC |
| <i>Alophoixus bres</i> | Brown-cheeked Bulbul | 1.32 | 0.00 | 0.00 | EN |
| <i>Aplonis panayensis</i> | Asian Glossy Starling | 1.32 | 0.00 | 0.00 | LC |
| <i>Arachnothera longirostra</i> | Little Spider Hunter | 1.32 | 0.00 | 0.00 | LC |
| <i>Ardeola speciosa</i> | Javan Pond-heron | 1.32 | 0.00 | 0.00 | LC |
| <i>Cacomantis merulinus</i> | Plaintive Cuckoo | 1.32 | 1.64 | 0.00 | LC |
| <i>Cacomantis sepulchralis</i> | Rusty-breasted Cuckoo | 1.32 | 0.00 | 1.72 | LC |
| <i>Centropus bengalensis</i> | Lesser Coucal | 1.32 | 1.64 | 1.72 | LC |
| <i>Collocalia linchi</i> | Cave Swiftlet | 13.16 | 32.79 | 36.21 | LC |
| <i>Coracina javensis</i> | Javan Cuckooshrike | 1.32 | 0.00 | 0.00 | LC |
| <i>Cuculus saturatus</i> | Oriental Cuckoo | 1.32 | 0.00 | 0.00 | LC |
| <i>Culicicapa ceylonensis</i> [#] | Grey-headed Canary-flycatcher | 1.32 | 1.64 | 0.00 | LC |
| <i>Cyornis olivacea</i> | Fulvous-chested Jungle-flycatcher | 1.32 | 0.00 | 0.00 | LC |
| <i>Dendrocopos moluccensis</i> [#] | Sunda Pygmy Woodpecker | 1.32 | 0.00 | 3.45 | LC |
| <i>Dicaeum trigonostigma</i> [#] | Orange-bellied Flowerpecker | 1.32 | 0.00 | 0.00 | LC |
| <i>Dicaeum trochileum</i> [#] | Scarlet-headed Flowerpecker | 1.32 | 0.00 | 3.45 | LC |
| <i>Dicrurus macrocercus</i> | Black Drongo | 0.00 | 1.64 | 0.00 | LC |
| <i>Enicurus leschenaulti</i> | White-crowned Forktail | 1.32 | 0.00 | 0.00 | LC |
| <i>Ficedula westermanni</i> [#] | Little Pied Flycatcher | 1.32 | 1.64 | 1.72 | LC |
| <i>Gallus gallus</i> | Red Junglefowl | 0.00 | 0.00 | 1.72 | LC |
| <i>Gallus varius</i> | Green Junglefowl | 1.32 | 3.28 | 0.00 | LC |
| <i>Halcyon cyanoventris</i> | Javan Kingfisher | 1.32 | 0.00 | 0.00 | LC |
| <i>Hemipus hirundinaceus</i> | Black-winged Flycatcher-shrike | 1.32 | 0.00 | 0.00 | LC |
| <i>Hirundo tahitica</i> | Pacific Swallow | 3.95 | 6.56 | 8.62 | LC |
| <i>Ictinaetus malaiensis</i> * | Black Eagle | 0.00 | 0.00 | 1.72 | LC |
| <i>Lanius schach</i> | Long-tailed Shrike | 2.63 | 3.28 | 5.17 | LC |
| <i>Lonchura punctulata</i> | Scaly-breasted Munia | 5.26 | 4.92 | 3.45 | LC |
| <i>Lophozosterops javanicus</i> | Javan Grey-throated White-eye | 1.32 | 0.00 | 1.72 | LC |
| <i>Megalaima armillaris</i> * | Flame-fronted Barbet | 1.32 | 4.92 | 1.72 | LC |
| <i>Megalaima haematocephala</i> | Coppersmith Barbet | 1.32 | 3.28 | 1.72 | LC |
| <i>Megalaima lineata</i> * | Lineated Barbet | 1.32 | 0.00 | 0.00 | LC |
| <i>Megalurys palustris</i> | Striated Grassbird | 1.32 | 0.00 | 0.00 | LC |
| <i>Microhierax fringillarius</i> * | Black-thighed Falconet | 1.32 | 0.00 | 0.00 | LC |
| <i>Nectarinia jugularis</i> | Olive-backed Sunbird | 2.63 | 1.64 | 1.72 | LC |
| <i>Orthotomus ruficeps</i> | Ashy Tailorbird | 1.32 | 0.00 | 0.00 | LC |
| <i>Orthotomus sepium</i> | Olive-backed Tailorbird | 1.32 | 6.56 | 3.45 | LC |
| <i>Pachycephala mentalis</i> | Black-chinned Whistler | 1.32 | 0.00 | 0.00 | LC |
| <i>Passer montanus</i> | Eurasian Tree Sparrow | 0.00 | 1.64 | 3.45 | LC |
| <i>Pericrocotus cinnamomeus</i> | Small Minivet | 1.32 | 0.00 | 1.72 | LC |
| <i>Pericrocotus flammeus</i> | Scarlet Minivet | 1.32 | 0.00 | 1.72 | LC |
| <i>Phaenicophaeus curvirostris</i> | Chestnut-breasted Malkoha | 1.32 | 3.28 | 1.72 | LC |
| <i>Phylloscopus trivirgatus</i> | Mountain Warbler | 1.32 | 0.00 | 0.00 | LC |
| <i>Pitta guajana</i> | Javan Banded Pita | 1.32 | 0.00 | 0.00 | LC |
| <i>Pycnonotus aurigaster</i> | Sooty-headed Bulbul | 2.63 | 1.64 | 3.45 | LC |
| <i>Pycnonotus goiavier</i> | Yellow-vented Bulbul | 2.63 | 3.28 | 3.45 | LC |
| <i>Pycnonotus melanicterus</i> | Black-crested Bulbul | 1.32 | 0.00 | 1.72 | LC |
| <i>Rhipidura javanica</i> * | Sunda Pied Fantail | 1.32 | 8.20 | 3.45 | LC |
| <i>Saxicola caprata</i> | Pied Bushcat | 1.32 | 0.00 | 0.00 | LC |
| <i>Spilopelia chinensis</i> | Eastern Spotted Dove | 5.26 | 1.64 | 0.00 | LC |
| <i>Spilornis cheela</i> * | Crested-serpent Eagle | 1.32 | 1.64 | 0.00 | LC |
| <i>Todiramphus chloris</i> | Collared Kingfisher | 2.63 | 0.00 | 0.00 | LC |
| <i>Treron vernans</i> | Pink-necked Green-pigeon | 6.58 | 1.64 | 0.00 | LC |
| <i>Zosterops chloris</i> | Lemon-bellied White-eye | 1.32 | 1.64 | 0.00 | LC |

Note: EN: Endangered; VU: Vulnerable; LC: Least Concern; *: protected species based on Minister of Environment and Forestry Republic of Indonesia Regulation Number P.106/MENLHK/SETJEN/KUM.1/12/2018; IUCN: Conservation status based on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species; #: Forest bird species with population trend declining according to IUCN Red List

Table 2. Vegetation analysis of tree community in Jempanang, Bilok Sidan Village in June 2021

| Species | Family | DR (%) | FR (%) | DoR (%) | IV (%) |
|---------------------------------|----------------|---------------|---------------|---------------|---------------|
| Site 1 (Riparian area) | | | | | |
| <i>Arenga pinnata</i> | Arecaceae | 9.09 | 12.50 | 10.54 | 32.13 |
| <i>Bischofia javanica</i> | Phyllanthaceae | 18.18 | 25.00 | 25.16 | 68.34 |
| <i>Commersonia bartramia</i> | Malvaceae | 9.09 | 12.50 | 29.28 | 50.87 |
| <i>Dendrocnide</i> sp. | Urticaceae | 18.18 | 12.50 | 5.49 | 36.17 |
| <i>Erythrina subumbrans</i> | Fabaceae | 18.18 | 12.50 | 13.14 | 43.83 |
| <i>Hibiscus</i> sp. | Malvaceae | 9.09 | 12.50 | 13.61 | 35.20 |
| <i>Homalanthus populneus</i> | Euphorbiaceae | 18.18 | 25.00 | 15.47 | 58.65 |
| <i>Pterospermum javanicum</i> | Sterculiaceae | 36.36 | 37.50 | 52.29 | 126.16 |
| Total | | 100.00 | 100.00 | 100.00 | 300.00 |
| Site 2 (Plantation area) | | | | | |
| <i>Aleurites moluccanus</i> | Euphorbiaceae | 5.88 | 11.11 | 3.78 | 20.77 |
| <i>Arenga pinnata</i> | Arecaceae | 17.65 | 22.22 | 35.48 | 75.35 |
| <i>Artocarpus heterophyllus</i> | Moraceae | 5.88 | 11.11 | 3.95 | 20.94 |
| <i>Melia azedarach</i> | Meliaceae | 41.18 | 22.22 | 27.29 | 90.69 |
| <i>Persea americana</i> | Lauraceae | 23.53 | 22.22 | 26.22 | 71.97 |
| <i>Trema orientale</i> | Cannabaceae | 5.88 | 11.11 | 3.29 | 20.28 |
| Total | | 100.00 | 100.00 | 100.00 | 300.00 |
| Site 3 (Forest edge) | | | | | |
| <i>Albizia chinensis</i> | Fabaceae | 12.50 | 11.11 | 25.68 | 49.29 |
| <i>Arenga pinnata</i> | Arecaceae | 4.17 | 11.11 | 10.05 | 25.33 |
| <i>Artocarpus heterophyllus</i> | Moraceae | 12.50 | 11.11 | 10.86 | 34.48 |
| <i>Hibiscus</i> sp. | Malvaceae | 4.17 | 11.11 | 4.15 | 19.43 |
| <i>Leucaena leucocephala</i> | Fabaceae | 4.17 | 11.11 | 3.06 | 18.34 |
| <i>Magnolia champaca</i> | Magnoliaceae | 4.17 | 11.11 | 4.07 | 19.35 |
| <i>Swietenia mahagoni</i> | Meliaceae | 45.83 | 11.11 | 35.96 | 92.91 |
| <i>Syzygium polycephalum</i> | Myrtaceae | 4.17 | 11.11 | 2.51 | 17.79 |
| <i>Trema orientale</i> | Cannabaceae | 8.33 | 11.11 | 3.64 | 23.08 |
| Total | | 100.00 | 100.00 | 100.00 | 300.00 |

Discussion

Bird diversity is known to be strongly related to vegetation structure in an ecosystem (Jankowski et al. 2013). Our study found that both bird and vegetation index diversity (H') in Jempanang were high. The different land cover types in Jempanang provide a diverse plant community, thereby increasing the number of niches available and subsequently increasing the diversity of bird species in the area. We recorded a total of 54 bird species, including Javan Myna (*Acridotheres javanicus*: globally Vulnerable) and Brown-cheeked Bulbul (Endangered) species, according to the IUCN Red List at site 1. The Javan Myna is endemic to Java and Bali, and its Vulnerable status is due to the rapid population decrease owing to illegal trapping for the cagebird trade (BirdLife International 2022). Likewise, the Brown-cheeked Bulbul is restricted to Java and Bali and is one of the most traded birds in Java, which has led to a considerable population decline (Squires et al. 2020). There were also five forest bird species with a declining population trend according to IUCN Red List, although their current ecological status is considered as Least Concern.

Of the three sites included, the riparian area (site 1) had the highest bird diversity. This was in line with findings from Cubley et al. (2020), where it was reported that riparian areas support a high bird diversity compared to

surrounding upland areas. Riparian areas provide cover and food sources for birds to utilize and act as corridors for dispersal to more favorable habitats (Litteral and Shocat 2017). The riparian area also had the highest tree species diversity compared to the other two sites. The tree species with the highest IV at site 1 were *Pterospermum javanicum* followed by *Bischofia javanica* and *Homalanthus populneus*. These species are reported to be abundant in Bali's riparian ecosystem (Wijaya et al. 2021). *Bischofia javanica* is a source of food for various animals, including squirrels and birds (Rohman et al. 2019). The riparian area is considered critical vegetation that can be disturbed easily by anthropogenic activity or natural disasters (Keten et al. 2020; Riis et al. 2020). The existence of these species can help indicate the stability of a riparian ecosystem.

With regard to the bird species recorded, the dominant species found in the riparian area were the Cave Swiftlet, Scaly-breasted Munia, Eastern Spotted Dove, and Pink-necked Green-pigeon. The Cave Swiftlet is an insectivore (Anonymous 2022a), the Scaly-breasted Munia and Eastern Spotted Dove are granivores, and the Pink-necked Green-pigeon is a frugivore (Anonymous 2022b). The Javan Myna is an omnivore and feeds on fruits, nectar, insects, and other animal matter (Craig and Feare 2020). The Brown-cheeked Bulbul is an insectivore that feeds on insects including beetles, bugs, dragonflies, damselflies,

and termites (BirdLife International 2022). The presence of these species indicates that the riparian area is capable of supporting a diverse range of bird feeding guilds.

The plantation area (site 2) had the lowest tree species diversity. However, the bird diversity index was similar to the forest edge area (site 3) and is considered moderate. Site 2 had the lowest value because it is a plantation and the tree species planted were relatively uniform. Agricultural intensification has led a pattern of landscape homogenization, which is considered a crucial process was influencing biodiversity (Salek et al. 2001; Gámez-Virués et al. 2015). In the plantation area the tree species with the highest IV was *Melia azedarach* (90.69%), followed by *Arenga pinnata* (75.35%) and *Persea americana* (71.97%). The existence of *M. azedarach* in site 2 has a vital role for frugivores. Among other tree species, *M. azedarach* is able to provide more fruits. This species also produces nectar from various parts, which can simplify as floral nectar and extrafloral nectar that is primarily produced in the leaves (Tilney et al. 2018). The presence of nectar can maintain the stability of the bird community. The nectarivore bird can directly utilize the nectar as its food, while the insectivore bird can utilize the nectar source as its feeding ground.

The dominant bird species in site 2 were the Cave Swiftlet, Pacific Swallow, Olive-backed Tailorbird, and Sunda Pied Fantail, the latter being legally protected under the Ministry of Forestry and Environment of Republic Indonesia Regulation Number P.106/MENLHK/SETJEN/KUM.1/12/2018. The Sunda Pied Fantail was found at all sites but was far more dominant in the plantation area (Di: 8.20) compared to the riparian (Di: 1.32) and forest edge (Di: 3.45) areas. Animals may respond differently toward new anthropogenic habitats, playing the role of an adapter, exploiter, or avoider (Tryjanowski et al. 2020). The Sunda Pied Fantail, in this circumstance, might act as an exploiter, benefitting by utilizing the anthropogenic habitat and exceeding its population size in more natural habitats. In this study, the birds were mostly seen moving, either hopping or flying on *Persea americana* branches. The same pattern was observed for the Olive-backed Tailorbird, which was seen most in the plantation area.

We recorded three raptor species during this study, including the Black Eagle, Crested-serpent Eagle, and Black-thighed Falconet. Raptors are apex predators that have a significant role in balancing the ecosystem through preying on other species (Rectenwald et al. 2021). In Indonesia, all raptor species are protected under the Ministry of Forestry and Environment of Republic Indonesia Regulation Number P.106/MENLHK/SETJEN/KUM.1/12/2018. All the raptor species were recorded in the forest edge area (site 3), and this area was bordered by the plantation. This is in line with findings from Rohman et al. (2019), who studied habitat use by three raptor species at Buyan Lake and Tamblingan Lake Natural Park in Bali and found that the Crested-serpent Eagle prefers primary forest, plantations and human settlements. The Buyan Lake and Tamblingan Lake Natural Park and Jempanang are both located in the highland

central-north region of Bali. According to Widiana (2007), the Black Eagle, in particular, is a raptor species that has a relatively high tolerance to forest shrinkage and is able to occupy forest remnants.

The presence of raptor species can also be used as an indicator of environmental quality. A study by Sergio et al. (2005) on five raptor species that differ widely in terms of diet and habitat use revealed that their presence is consistently associated with high avian and plant biodiversity. In the forest edge area, the bird and vegetation diversity was considered to be moderate. The tree species with the highest IV were *Swietenia mahagoni* (92.91%), *Albizia chinensis* (49.29%), and *Artocarpus heterophyllus* (34.48%). Locals commonly plant these tree species to provide shade for their coffee plants and timber. The Black Eagle and Black-thighed Falconet were found perching on the upper and mid-level branches of *Albizia chinensis* when they were recorded, respectively, whereas the Crested-serpent Eagle was seen flying over the site. We presume that the raptor species live inside the forest for shelter and utilize the edge of the forest as a foraging ground. *Albizia chinensis* can reach 40 m in height and its canopy can provide shelter to many other animals, with some feeding on its leaves, flowers, and seeds, and its branches providing a microhabitat for insects (Galetti and Rodrigues 1992; Setyawan et al. 2018). Therefore, this species supports potential prey species for raptors. The dominant bird species in the forest edge were the Cave Swiftlet, Pacific Swallow, and Long-tailed Shrike. The Cave Swiftlet and Pacific Swallow are widely distributed from the lowlands to the highlands, are always found in flocks and frequently form mixed species flocks (Atlas Burung Indonesia 2020). These species performed aerial hawking in flocks above *Albizia chinensis* trees, where small aerial insects feed. These small birds are also potential prey species for raptors. The Black-thighed Falconet has been observed feeding on small birds, including the Cave Swiftlet, munias, and honeyeaters at Baluran National Park in East Java (Setiyono et al. 2014). Tall trees in relatively open areas provide good vantage points for raptors to apply their sit-and-wait foraging strategy (Anonymous 2022c).

The results of this study can be used to form a baseline for biodiversity monitoring in Jempanang, that subsequently will preserve the area as the main water catchment in Bali. The protection of interior habitats (e.g., preserving forest integrity) is essential in order to preserve high levels of biodiversity (Jin et al. 2021). The plantation area should be arranged with native tree species in mixed arrangements to provide better connectivity with the adjacent native forest (Castaño-Villa et al. 2019). Regular monitoring is ultimately required in the area, and this would ideally be achieved through the involvement of the local community. Jempanang is one of the focal areas of PT Tirta Investama-Mambal's conservation program through the Jempanang Lestari program. Capturing the aspirations and desires of the local community regarding the management of biodiversity in their area should enhance their motivation to preserve the valuable biodiversity independently. Considering the high bird and tree diversity found in the area, one activity that could be

promoted is ecotourism, especially birdwatching. Ecotourism can act as an agent for community-based conservation when it is conducted by emphasizing the well-being of local ecosystems and human communities (Şekercioğlu 2002). Birdwatching, the act of observing birds in their habitats with an unaided eye or using tools such as telescopes and binoculars (Kurnia et al. 2021), has a high potential to create local and national incentives for the protection and preservation of natural areas (Şekercioğlu 2002; Ocampo-Peñuela and Winton 2017).

In conclusion, the Jempanang sub-village of Bilok Sidan village has high bird and tree diversity. The diverse land cover types in Jempanang provide a variety of plant species which increases the number of niches and results in an increased diversity of bird species. Using the presence of apex predators (raptors) as a biological indicator of environmental quality, Jempanang can be considered an area with good environmental quality. Considering the high diversity in bird and tree species possessed by this area, birdwatching activity can be applied as an agent for community-based conservation as it potentially provides incentives for the protection and preservation of the area.

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