Turkish Journal of Zoology

Manuscript 3205

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TÜBİTAK

Turkish Journal of Zoology

http://journals.tubitak.gov.tr/zoology/

Research Article

Turk J Zool
(2024) 48: 675-684
© TÜBİTAK
doi:10.55730/1300-0179.3205

Diversity and evenness of birds during seasonal paddy farming practices in southwestern Sarawak

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Received: 05.04.2024 • **Accepted/Published Online:** 24.08.2024 • **Final Version:** 05.11.2024

Abstract: The influence of seasonal paddy farming activities on the paddy field environment and its composition of birds could be visually observed but has yet to be systematically studied and is still relatively understudied in Malaysian Borneo. Earlier research relied solely on point counts and the failure to use line transects or mist nets for data collection could have resulted in missing and biased findings. Thus, this study aims to evaluate species diversity and evenness of birds in different paddy stages in southwestern Sarawak and compare the data with the findings of previous studies conducted in the region. We obtained higher species richness than previous reports from similar habitats, with 2552 individuals recorded from 94 species of 43 families. Of these, 75.53% and 24.47% were terrestrial birds and waterbirds, respectively. Seven resident taxa are listed as "Near Threatened" or "Vulnerable" according to the 2016–2022 IUCN Red List. The families of Ardeidae and Nectariniidae were most abundant with eight and six species, respectively. The planting and land preparation stages accommodated more diverse and even bird communities in the paddy fields of southwestern Sarawak. Our findings suggest that temporary land-use changes do not necessarily alter paddy field bird diversity and assemblages. Small-patch paddy fields should not be overlooked because they offer additional foraging niches for water-dependent birds and opportunistic feeders, as well as serving as a refuge for migratory waterbirds and vulnerable residents considering their habitat heterogeneity and microhabitat transitions between paddy stages.

Key words: Diversity, indicator species, migratory bird, paddy stages

1. Introduction

Paddy fields host a diverse range of bird species, especially resident and migratory waterbirds. In some regions, paddy fields have become alternative habitats available for wetland birds due to the conversion and degradation of natural wetlands (Rajpar and Zakaria, 2013; Zhang et al., 2024). Large flocks of waterbirds such as those of the families Ardeidae (egrets, herons, storks), Scolopacidae (snipes, sandpipers), and Charadriidae (lapwings) are found frequently in paddy fields around the world and their bird diversity has been studied extensively (Gunathilaka, 2019). In Malaysia, there have been studies on the paddy field bird community in Peninsular Malaysia (Azman et al., 2011, 2019; Amira et al., 2018; Mohd-Taib et al., 2021). However, bird diversity studies in paddy fields are particularly scarce in Malaysian Borneo. This body of literature remains limited to brief reports by Makbul and Wong (2016) in Sabah and Karim et al. (2018) in Sarawak, with few studies focusing on paddy stages (Nur Munira et al., 2014; Mohd-Taib and Kamaruddin, 2018; Putri et al., 2023). The influence of paddy farming activities on the paddy field environment and its composition of birds could be visually observed during different paddy growth stages (Natuhara, 2013) but has yet to be systematically studied. A significant methodological gap was also observed in the literature as most previous studies conducted in the paddy fields did not utilize line transects and mist netting in their data collection, which potentially led to missing data and biased results. The objectives of the present study were to evaluate the diversity and evenness of birds during three different paddy stages (planting, harvest, and land preparation) and compare the diversity findings in paddy fields of southwestern Sarawak with the results of previous studies.

2. Materials and methods

2.1. Study site

The study site encompassed three paddy fields located in southwestern Sarawak, including (i) Kampung Skuduk

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(1°14′57.8″N, 110°25′54.0″E) in Serian Division, (ii) Kampung Baru (1°28′12.5″N, 110°28′42.0″E) in Samarahan Division, and (iii) Kampung Pueh-Siru Dayak (1°49′54.3″N, 109°42′25.3″E) in Kuching Division. The estimated distance from Kampung Skuduk to Kampung Pueh is 134 km, from Kampung Pueh to Kampung Baru is 120 km, and from Kampung Baru to Kampung Skuduk is 34 km (Figure 1). There are approximately 28.4 ha of paddy fields in Kampung Skuduk, 10.7 ha in Kampung Baru, and 85.0 ha in Kampung Pueh-Siru Dayak.

The first planting stage of the annual cycle of the year 2021–2022 started in November 2021 and continued until February 2022. The harvest stage followed in March 2022 and land preparation began in April 2022. The second planting stage of the annual cycle was in May 2022, lasting until July 2022 and followed by harvest in August 2022 and land preparation in September and October 2022, when the cycle was about to start again.

2.2. Data collection

Paddy fields were sampled three times during each paddy stage over the course of 12 months from December 2021 to November 2022. Line transects and mist netting were conducted for 5 days to survey birds in each paddy field. The cumulative effort for line transects and mist netting was 90 h and 10,800 net-hours, respectively.

Eleven line transects of 1 km × 100 m were established twice, back and forth, daily at each site at around 0700 to 0930 hours in the morning and 1600 to 1830 hours in the late evening. Bird sightings and their coordinates were recorded using Nikon Monarch 5 (8 × 42) binoculars (Nikon Corporation, Tokyo, Japan) and the Garmin GPSMAP 78S device (Garmin Ltd., Olathe, KS, USA), respectively. Any birds found throughout the survey were noted and photographed for immediate identification and subsequent confirmation. The Zoom H6 Handy Recorder (Zoom Corporation, Tokyo, Japan), paired with the MKE 600 Shotgun Microphone (Sennheiser, Wedemark, Germany), TELINGA UNIVERSAL Parabolic Sound Dish (Telinga, Tobo, Sweden), and MDR-7506 dynamic stereo headphones (Sony Group Corporation, Tokyo, Japan), was used to identify and record bird songs and calls heard along the line transects. All species that vocalized within acoustic ranges (≤100 m) were recorded. Bird species identification by calls and songs was verified using the accessible global digital archives of Xeno-canto.[1] The recorded audio samples were processed

[1]Planque B, Vellinga WP, Pieterse S, Jongsma J, By R (2005). Xeno-canto. Website https://xeno-canto.org [accessed 31 October 2021].

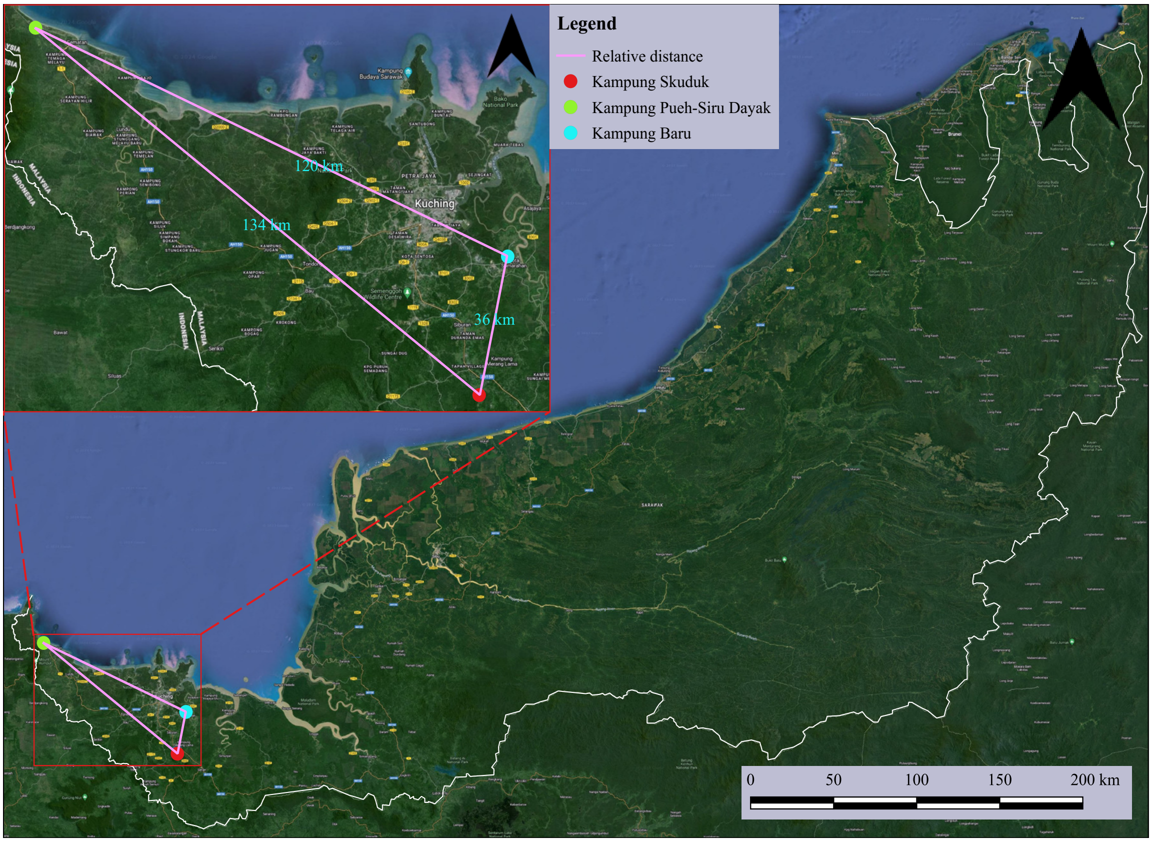

Figure 1. Map showing the three sampled paddy fields (inset) in southwestern Sarawak, Malaysia.

using Audacity (Version 3.4.2)[2] and assessed using Raven Pro (Version 1.6).[3]

Twenty mist nets of 2.5 m × 12 m × 36 mm with three shelves were utilized per sampling. The mist nets were left operational for 12 h between 0600 and 1800 hours and were checked every 1 to 2 h to ensure that the birds caught in the mist nets were disentangled quickly to avoid any casualties. The disentangled birds were put into cloth bags to be taken to a convenient area to be processed. That included bird identification, body measurement, and marking. Species identification was done onsite referring to field guide books by Phillipps and Phillipps (2014) and Lim et al. (2020) and the latest checklist of the birds of Borneo.[4]

2.3. Statistical analysis

A Venn diagram was generated to visualize the number of shared and unique species per paddy stage. To test for statistical differences between species richness during the three different paddy stages (planting, harvest, and land preparation), we applied the Shapiro–Wilk test for normality, one-way analysis of variance (ANOVA), and a subsequent post hoc Tukey honestly significant difference (HSD) test using the 'shapiro.test,' 'aov,' and 'TukeyHSD' functions from the R 'stats' package.[5] The one-way ANOVA results were hypothesized as follows: H_0 - There is no difference in the species richness of birds during different paddy stages; H_A - There is a difference in the species richness of birds during different paddy stages.

Biodiversity assessments were performed using the 'iNEXT.4steps' (Four Steps of Interpolation and Extrapolation) package.[6] This package adopts the Hill number (q = 0, 1, 2) to quantify the species diversity of an assemblage, whereby diversity order 0 (q = 0) refers to species richness, diversity order 1 (q = 1) refers to the Shannon index, and diversity order 2 (q = 2) refers to the Simpson index. The assessment consists of four steps: Step 1, estimation of sample completeness; Step 2 (2a and 2b), empirical and asymptotic estimation of true diversity; Step 3, comparison of diversity for nonasymptotic sample coverage; and Step 4, estimation of evenness profiles across the bird assemblages of different paddy stages. In Step 1, for the estimation of sample completeness, we assessed the level of undetected diversity in the sample. In Step 2, we estimated the true diversity of order q based on the reliability of the data to offer sufficient information. True diversity or the effective number of types is the number of equally abundant types needed for the average proportional abundance of the types to equal that observed in the dataset of interest (Supriatna, 2018). The following general equation was used (Jost, 2006):

$$^{q}D \equiv \left(\sum_{i=1}^{S} p_i^{q}\right)^{1/(1-q)}$$

indicating the qth power sum of species relative abundances. The superscript and exponent of q represent the diversity order for all indices of the functions. In Step 2a, we examined the pattern of each size-based rarefaction and extrapolation sampling curve up to twice the sample size. If the curve stabilized, then the asymptotic estimate could be used to accurately infer the true diversity of the entire assemblage. Otherwise, the asymptotic diversity estimate represented only a lower bound. When the true diversity could be accurately inferred in Step 2a, the extent of undetected diversity within each dataset was obtained by comparing the estimated asymptotic diversity profile and empirical profile in Step 2b. Step 3 entailed nonasymptotic coverage-based rarefaction and extrapolation analysis. When the sampling data did not provide sufficient information to accurately infer true diversity in Step 2, fair comparisons of diversity across multiple assemblages could be made by standardizing the sample coverage based on the integration of coverage-based rarefaction and extrapolation sampling curves up to a maximum coverage value of Cmax, defined as the level of coverage reached by the sample that attained the lowest coverage when all samples were extrapolated to twice the reference sample size (Chao et al., 2020). Step 4 assessed the evenness profiles at the coverage value of Cmax among the compared samples. The Pielou J evenness index was computed for the same coverage value of Cmax.

Indicator values (IndVal) were generated using the 'indicspecies' package[7] to determine which species could potentially be used as bioindicators corresponding to the highest association value between a species and a site

[2] Keary M, Larina Y, Hodgkinson M, Licameli P, Sverchinsky V, Vedenko D, Pickles D, Wattenberg L, Lapysh S, Cinakovs A, Jonas P, Williamson J (2000). Audacity. Website https://www.audacityteam.org [accessed 24 December 2021].

[3] K. Lisa Yang Center for Conservation Bioacoustics (2024). Raven Pro. Website https://www.ravensoundsoftware.com [accessed 1 December 2022].

[4] Lepage, D (2023). Checklist of the birds of Island of Borneo. Avibase, the world bird database. Website https://avibase.bsc-eoc.org/checklist.jsp?lang=EN&region=bor&list=clements&ref=l_asi_my [accessed 24 February 2024]

[5] R Core Team (2024). R: A Language and Environment for Statistical Computing. Website https://www.R-project.org [accessed 9 March 2023].

[6] Chao A, Hu K (2023). Package "iNEXT.4steps: Four Steps of INterpolation and EXTrapolation analysis". Website https://cran.r-project.org/web/packages/iNEXT.3D/index.html [accessed 1 December 2023].

[7] De Cáceres M and Legendre P (2009). Package 'indicspecies': Associations between species and groups of sites: indices and statistical inference. Website https://cran.r-project.org/web/packages/indicspecies/index.html [accessed 1 December 2023]

group. The statistical significance of this relationship was tested by permutation and assessed with the significance level of alpha = 1 to include all potential indicator species in the paddy fields. All calculations were performed using the R program (Version 4.3.2).[8]

3. Results

A total of 2552 birds were recorded, including 94 species from 43 families, 88.30% (83 species) of which were residents while 20.21% (19 species) were migratory birds. While 75.53% (71 species) were terrestrial birds, 24.47% (23 species) were waterbirds, including seven shorebird species (8.51%). Additionally, 27.66% (26 species) were classified as "Protected" under the Sarawak Wild Life Protection Ordinance of 1998. These include taxa of the families Alcedinidae, Apodidae, Ardeidae, Charadriidae, Picidae, Psittacidae, Rostratulidae, Scolopacidae, and Strigidae and songbird species such as common hill myna *Gracula religiosa* and white-rumped shama *Copsychus malabaricus*, which are highly sought in the songbird trade. Moreover, eight species (8.51%) are listed in the 2016–2022 Red List of the International Union for Conservation of Nature (IUCN)[9] as "Near Threatened" or "Vulnerable." Among the taxa found in the paddy fields were two species endemic to Borneo, the dusky munia *Lonchura fuscans* and bold-striped tit-babbler *Mixornis bornensis*. The families Ardeidae and Nectariniidae were the most represented, with eight and six species, respectively. Scaly-breasted munia *Lonchura punctulata* was the most abundant species in this study (310 individuals). Furthermore, 58 species were identified as potential indicators for each stage and combination of stages in paddy fields. Appendix 1 summarizes the assemblages of birds from the selected sites according to families and species.

Figure 2 shows a Venn diagram visualizing the numbers of species shared between paddy stages. This includes 23 species unique to the planting stage, nine species uniquely found in the land preparation stage, and six species uniquely found in the harvest stage. A total of 35 species are shared by all stages, 11 species are shared by planting and harvest, eight species are shared by planting and land preparation, and two species are shared by harvest and land preparation.

We applied the Shapiro–Wilk test for normality ($p = 0.2911$) before conducting one-way ANOVA ($F = 1.786$, $p = 0.246$). The Tukey HSD test (land preparation–harvest: $p = 0.9800$; planting–harvest: $p = 0.3422$; planting–land preparation: $p = 0.2720$) suggested no significant difference in mean species richness during the three paddy stages.

Figure 3 shows the diversity assessment performed using 'iNEXT.4steps.' Numerical values for the procedures are provided in Appendix 2. Figure 3a shows that the

[8] R Core Team (2020). R: Language and Environment for Statistical Computing. R Foundation for Statistical Computing [online]. Website www.R-project.org [accessed 1 October 2023].

[9] The International Union for Conservation of Nature (IUCN) Red List (2016-2022). Website https://www.iucnredlist.org [accessed 24 February 2024].

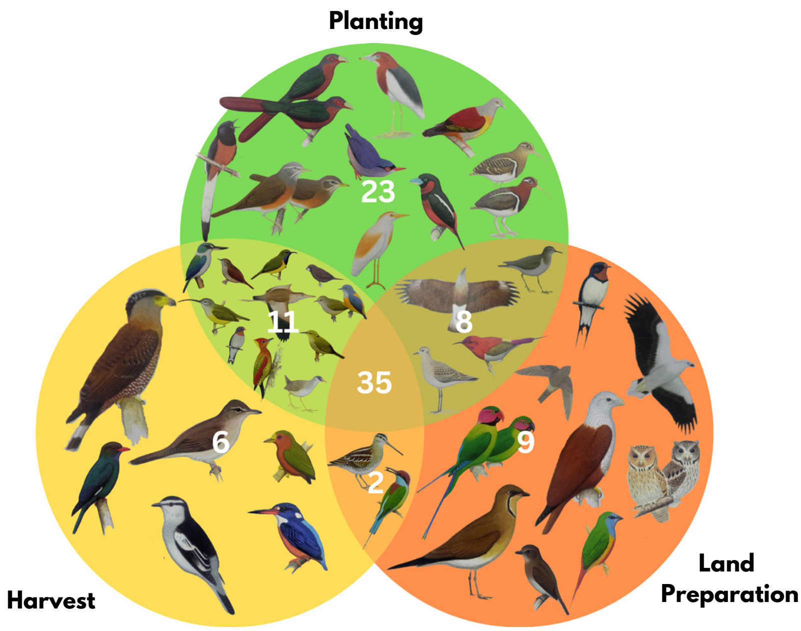

Figure 2. Venn diagram shows that 35 species are shared by all stages, planting has the most exclusive species (23 species), and harvest has the least exclusive species (six species).

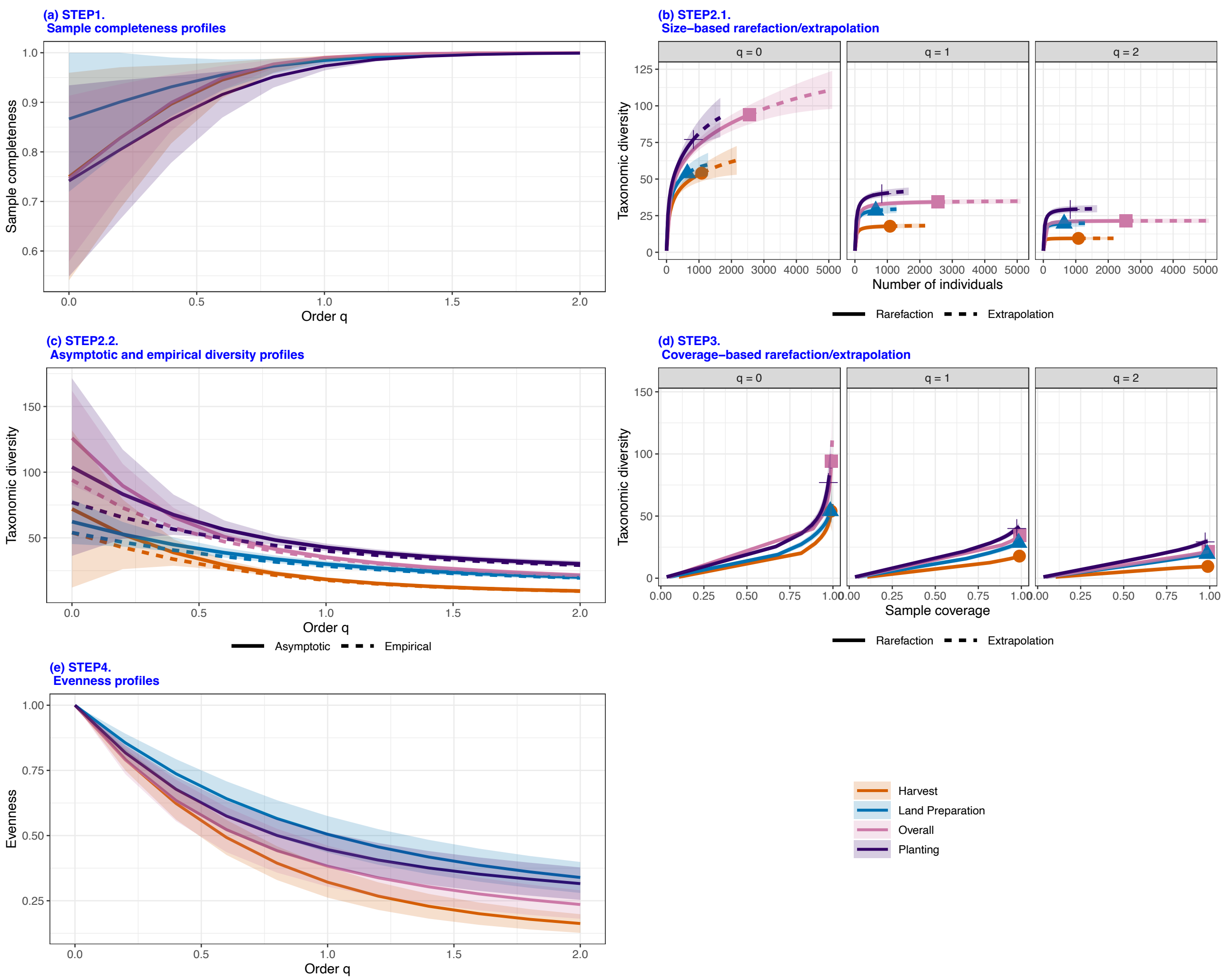

Figure 3. Overview of biodiversity assessments based on Hill numbers (q = 0, 1, 2): a) estimated sample completeness curves; b) size-based rarefaction (solid lines) and extrapolation (dashed lines) curves up to twice the respective sample size; c) asymptotic estimates of diversity profiles (solid lines) and empirical diversity profiles (dashed lines); d) coverage-based rarefaction (solid lines) and extrapolation (dashed lines) curves up to twice the reference sample size; e) evenness profile for q = 0, 1, 2, based on the normalized slope of Hill numbers. Pink lines (overall), purple lines (planting), orange lines (harvest), and blue lines (land preparation) denote observed bird assemblages.

estimated sample completeness profiles increase with diversity order (q = 0, 1, 2), implying undetected diversity within the dataset. The estimated sample completeness for q = 0 for the overall assemblage is 75.0%, with the land preparation stage having the highest completion of species richness and the planting stage having the highest number of undetected species. In contrast, the estimated sample completeness for q = 1 and q = 2 for the overall data is 99.0% and 100.0%, respectively, indicating that almost all species in the studied sites were sampled and detected. Figure 3b reveals that, for each stage, the size-based rarefaction and extrapolation sampling curves for q = 1 and q = 2 stabilize, implying that asymptotic diversity estimates for these two measures work satisfactorily to infer true diversities. The planting stage is significantly more diverse than the other stages for any fraction up to entire assemblages. However, neither of the sampling curves for q = 0 stabilized, extrapolated up to twice the reference sample size, suggesting that our data do not provide sufficient information to accurately estimate true species richness within each assemblage. The asymptotic estimate of species richness (i.e., the Chao1 estimate) thus represents a minimum estimate (lower bound) of species richness. Based on Figure 3c, the undetected species richness (q = 0) within the stages is moderate. However, Figure 3b shows that the degree of difference in true species richness of the entire assemblages cannot be precisely assessed since these estimates are lower bounds. In contrast, the undetected q = 1 and q = 2 within the different paddy stages are small, implying that nearly all highly abundant species were detected. In Figure 3d, for q = 0, although the data are insufficient for inferring the true richness of the entire assemblage, inference and significance testing can be performed up to a standardized coverage value of Cmax = 98.8%. The planting stage shows the highest diversity and all differences in each stage are significant. The diversity value of q = 1 and q = 2 for a standardized coverage value of 98.8% differs very little from that of the entire assemblages. Figure 3e shows the evenness profile for q = 0, 1, 2. Under the coverage value of 98.8%, the Pielou J evenness index shows that the evenness among species occurrences in every stage is relatively similar. Nonetheless, all measures consistently show that the evenness among species abundances in land preparation is higher than that in the planting and harvest stages for a standardized coverage value of 98.8%. Altogether, only true diversities for order q = 1 and q = 2 were achieved with planting observed to have the highest true diversities (^{1}D = 42.75, ^{2}D = 30.25). The highest diversity was still observed during planting (^{0}D = 92.01, ^{1}D = 41.61, ^{2}D = 29.73) in nonasymptotic coverage-based rarefaction and extrapolation. However, evenness was observed to be highest during land preparation (J' = 0.83). In short, our data revealed that the planting stage and land preparation respectively harbor more diverse birds and more even bird communities in the paddy fields of southwestern Sarawak.

4. Discussion

This study recorded a higher number of species compared to most previous studies conducted in paddy fields. Higher bird diversity can be expected in paddy fields if data are sampled using multiple survey methods. Line transects were adopted in this study as that approach offers more practicality in open areas like paddy fields than point counts, which are better suited to large study areas with dense vegetation that obstructs vision (Egli, 2014; Morrison and Peitz, 2021). Conducting point counts in open areas increases the possibility of double-counting the same bird individuals and underestimates the species richness (Egli, 2014; Morrison and Peitz, 2021). Line transects can be supported with bioacoustics equipment and camera capabilities to record more bird species (Carvalho et al., 2023). Moreover, the advantages of the line transect method include the possibility of detecting shy species when complemented with mist netting (Viquerat et al., 2012; Egli, 2014). Mist nets were proven to be effective for secretive, smaller birds or highly mobile species that may be missed and they should be used to complement active surveys (Estades et al., 2006; Tattoni and LaBarbera, 2022; Carvalho et al., 2023). In this study, the pin-tailed parrotfinch *Erythrura prasina*, which is a small and secretive species, was caught in mist nets. Most previous studies relied solely on active surveys and

Table. Diversity indices (richness = number of bird species, ^{1}D/H' = Shannon, ^{2}D/D = Simpson, C = Simpson dominance, J' = Pielou evenness) and sampling methods employed in the studies on paddy fields and associated habitats in the literature.

Habitat	Location	Method	Richness	^{1}D/H'	^{2}D/D/C	J'	Reference
Paddy field	Malaysia	L, M	94	42.75	30.25	0.79	Present study
Multiple habitat	China	L	55, 98	-	-	-	Zhang et al. (2024)
Paddy field	Indonesia	P	14	1.24	0.42	-	Putri et al. (2023)
Multiple habitat	Thailand	L, P	24, 43, 47	1.90, 2.25, 2.50	1.90, 2.25, 2.50	0.87, 0.81, 0.94	Supahan (2022)
Paddy field	Malaysia	P	40	2.47	-	-	Mohd-Taib et al. (2021)
Paddy field	India	L	87	-	-	-	Jayasimhan & Padmanabhan (2019)
Multiple habitat	Malaysia	P, M	438, 129	-	-	-	*Azman et al. (2019)
Paddy field	Malaysia	P	11, 8, 17	-	-	-	Mohd-Taib & Kamaruddin (2018)
Multiple habitat	Malaysia	M	13, 21	3.05, 2.57	0.94, 0.73	-	Karim et al. (2018)
Paddy field	Malaysia	P	46	-	-	-	Amira et al. (2018)
Multiple habitat	Malaysia	P, L, M	37, 46, 18, 11	3.5	-	-	Makbul & Wong (2016)
Paddy field	India	L	42	-	-	-	Rahalker & Patel (2015)
Paddy field	Malaysia	P	67	2.15-3.32	-	-	Nur Munira et al. (2014)
Multiple habitat	Malaysia	P, M	72, 59, 49	3.56, 3.18, 1.04	-	-	Azman et al. (2011)

Abbreviation: Method: L = Line transect, P = Point count, M = Mist netting; *data collection from primary and secondary sources.

did not supplement their data collection with mist netting, which possibly caused missing data (Table). However, mist netting is often considered unnecessary when surveying birds in monoculture agroecosystems such as paddy fields with no obstructions blocking vision for bird detection (Azman et al., 2011, 2019; Munira et al., 2012).

Incomplete diversity detection during the planting stage explains the highest percentage of undetected diversity of singletons recorded over time (Chiu and Chao, 2016). Complete diversity could be achieved if the sampling duration for each of the paddy stages were increased (Grey et al., 2018; Hoffmann et al., 2019). Additionally, flawed partitioning of paddy stages whereby early growing and seedling stages are merged into one stage (planting stage) should be addressed. The northeast monsoon (November to March) and southwest monsoon (May to September) significantly affect the partitioning of paddy stages in southwestern Sarawak, especially for paddy fields without irrigation aid. The northeast monsoon causes substantial rainfall to the west of Sarawak while the southwest monsoon brings drier weather.[10] Local farmers usually engage in planting or land preparation during the northeast monsoon and harvest during the southwest monsoon. Furthermore, the willingness and agreement among farmers to engage in paddy farming practices also affect the partitioning of the stages (Garay-Barayazarra and Puri, 2011). The active paddy stage was identified based on dominant paddy features to avoid common misclassifications due to overlapping paddy stages (Wang et al., 2022).

There were no significant differences in bird diversity between the paddy stages in the present study due to the high numbers of shared species. Resident bird species of the families Ardeidae and Estrildidae were abundantly present in every stage. These birds are found in paddy fields due to spatial mosaics, where houses and nearby forests are interspersed within the matrix of paddy fields, resulting in landscape heterogeneity that provides structural complexity and food resources (Amira et al., 2018). Temporal water fluctuations in the irrigation of paddy fields create microhabitats with various water levels that provide different foraging opportunities for opportunistic feeders (Nam et al., 2015). Additionally, birds may utilize ditches where the drained water concentrates aquatic organisms with a variety of vegetation (Townsend et al., 2006) and may forage on levees rather than in the paddy field matrices (Choi et al., 2022). Other food resources such as insects were continuously available regardless of the paddy stage (Supahan, 2022). Munias were observed opportunistically consuming seeds of various kinds of grass, most notably the leftover paddy that was not harvested, and the nutrient-rich filamentous alga *Spirogyra*, which supplies adequate protein to prepare for breeding (Avery, 1980).

Most indicator species during planting stages belong to Ardeidae and Timaliidae. Ardeidae is synonymous with the paddy fields, especially during planting (Azman et al., 2019). These taxa were observed utilizing most portions of the paddy field, such as flooded paddy, levees, and ditches, to forage for food; they even sought shelter in trees (Pinto et al., 2013). Their habitat use depends on the magnitude of disturbance or contamination in their surrounding environment, thus making Ardeidae taxa useful as bioindicators of the health of an ecosystem (Pinto et al., 2013). Timaliidae feeds on insects and these taxa were observed to dwell in the adjacent forest and grasses to forage for food. These understory insectivore birds can be used as bioindicators and/or umbrella species for conservation as they are particularly sensitive to disturbances related to varying land uses (Sreekar et al., 2015). During harvest, most of the indicator species are carnivorous birds. The water irrigating the paddy matrices is usually drained but these birds can still be seen utilizing the ditches. Ditches are valuable habitats for aquatic and terrestrial animals, supplying food resources and performing connectivity functions within the ecosystem (Herzon and Helenius, 2008). The extensive use of ditches by carnivorous birds suggests that these birds are bioindicators of pollution in aquatic and terrestrial environments. Migratory birds and raptors are indicator species during the land preparation stage. Paddy fields are suitable staging habitats along the route of migratory birds (Masero et al., 2011). Oriental pratincole *Glareola maldivarum* is an uncommon winter visitor that travels through Borneo to Australia and was observed foraging in open land in Kampung Skuduk during land preparation in October (Phillipps and Phillipps, 2014). The response of migratory birds in paddy fields can be used to monitor the carrying capacity of an artificial wetland habitat (Li et al., 2013). Meanwhile, the number of hunting raptors increased during land preparation. Taxa of Strigidae and Accipitridae use rice fields as their preferred sites for hunting prey such as exposed invertebrates, rodents, frogs, and snakes (Fujioka et al., 2010). Migratory raptors make excellent bioindicators and meet most of the criteria for ideal indicators, such as symbiotic associations with other species, connectivity in trophic levels as apex predators, sensitivity to disturbances that become indicative of the cause, and potential for being keystone and umbrella species (Natsukawa and Sergio, 2022).

Paddy fields are important as a refuge for many species of birds, including threatened species (Elphick, 2010;

[10] Malaysian Meteorological Department. (2024). *Weather Phenomena*. Website https://www.met.gov.my/en/pendidikan/fenomena-cuaca/ [assessed 5 March 2024]

Natuhara, 2013). Threatened or rare birds are known to inhabit paddy fields as an alternative to habitat loss (Yoon, 2009; Tadashi et al., 2014). Grey-headed fish eagle *Haliaeetus ichthyaetus* shows an apparent population decline regionally in Southeast Asia due to habitat and food source disturbances (Tingay et al., 2006, 2010). Despite its vulnerability, this species was shown to be able to survive in human-modified landscapes if sufficient food and tall trees for nesting were available (Miron and Chowdhury, 2019). Furthermore, the paddy fields of Kampung Pueh-Siru Dayak are close to the coastal beach, allowing this species to frequent its nesting and foraging areas near permanent water bodies (Tingay et al., 2010).

5. Conclusion

Our study has documented a comprehensive list of birds in the paddy fields of southwestern Sarawak, demonstrating higher species richness compared to previous studies in paddy fields. The identified potential indicator species could help in monitoring the overall quality and health of paddy field ecosystems. Habitat heterogeneity and microhabitat shifts between paddy stages provide additional foraging niches for water-dependent birds and opportunistic feeders. Hence, it is recommended that small-patch paddy fields not be overlooked irrespective of their farming practices, because they provide refuge for threatened residents and migratory waterbirds. Our findings suggest that seasonal changes due to paddy practices do not necessarily alter paddy field bird diversity and assemblages. Nevertheless, seasonal farming practices could vary based on categorization and overlapping paddy stages. Future studies should increase the study duration and sampling visits for each paddy stage while applying distinguishable partitioning of paddy stages with at least four stages (i.e. planting, growing, harvest, and land preparation).

Acknowledgments

The authors are grateful for the support of Shell Chair Research Grant F07/SHC/2073/2021 for funding this project. Appreciation also goes to the Sarawak Forestry Corporation for granting the permit (SFC.810-4/6/1-041) to conduct the research.

References

Amira N, Rinalfi T, Azhar B (2018). Effects of intensive rice production practices on avian biodiversity in Southeast Asian managed wetlands. Wetlands Ecology and Management 26 (5): 865-877. https://doi.org/10.1007/s11273-018-9614-y

Avery ML (1980). Diet and breeding seasonality among a population of Sharp-tailed Munias, Lonchura striata, in Malaysia. The Auk 97 (1): 160-166. https://doi.org/10.1093/auk/97.1.160

Azman NM, Latip NSA, Sah SAM, Akil MAMM, Shafie NJ et al. (2011). Avian diversity and feeding guilds in a secondary forest, an oil palm plantation and a paddy field in riparian areas of the Kerian River Basin, Perak, Malaysia. Tropical Life Sciences Research 22 (2): 45-64.

Azman NM, Sah SAM, Rosely NFN, Ahmad A (2019). Contribution of rice fields to bird diversity in Peninsular Malaysia (Sumbangan sawah padi kepada kepelbagaian burung di Semenanjung Malaysia). Sains Malaysiana 48 (9): 1811-1821. https://doi.org/10.17576/jsm-2019-4809-02

Carvalho WD, Miguel JD, da Silva Xavier B, López-Baucells A, de Castro IJ et al. (2023). Complementarity between mist-netting and low-cost acoustic recorders to sample bats in Amazonian rainforests and savannahs. Community Ecology 24 (1): 47-60. https://doi.org/10.1007/s42974-022-00131-5

Chao A, Kubota Y, Zelený D, Chiu CH, Li CF et al. (2020). Quantifying sample completeness and comparing diversities among assemblages. Ecological Research 35 (2): 292-314. https://doi.org/10.1111/1440-1703.12102

Chiu CH, Chao A (2016). Estimating and comparing microbial diversity in the presence of sequencing errors. PeerJ 4: 1634. https://doi.org/10.7717/peerj.1634

Choi SH, Choi G, Nam HK (2022). Impact of rice paddy agriculture on habitat usage of migratory shorebirds at the rice paddy scale in Korea. Scientific Reports 12 (1): 5762. https://doi.org/10.1038/s41598-022-09708-6

Egli L (2014). Literature review: Monitoring techniques for ungulates in Iran. Technical Report. https://doi.org/10.13140/RG.2.1.4811.6728

Elphick CS (2010). Why study birds in rice fields? Waterbirds 33 (sp1): 181-192. https://doi.org/10.1675/063.033.s101

Estades CF, Escobar MAH, Tomasevic JA, Vukasovic MA, Páez M (2006). Mist-nets versus point counts in the estimation of forest bird abundances in South-Central Chile. Ornitologia Neotropical 17: 203-212.

Fujioka M, Don Lee S, Kurechi M (2010). Bird use of rice fields in Korea and Japan. Waterbirds 33 (sp1): 8-29. https://doi.org/10.1675/063.033.s102

Garay-Barayazarra G, Puri RK (2011). Smelling the monsoon: Senses and traditional weather forecasting knowledge among the Kenyah Badeng farmers of Sarawak. Indian Journal of Traditional Knowledge 10 (1): 21-30.

Grey EK, Bernatchez L, Cassey P, Deiner K, Deveney M et al. (2018). Effects of sampling effort on biodiversity patterns estimated from environmental DNA metabarcoding surveys. Scientific Reports 8 (1): 8843. https://doi.org/10.1038/s41598-018-27048-2

Gunathilaka MDKL (2019). A comparative appraisal of the ecological importance of rice fields for avifaunal species in different regions in the world. International Journal of Fauna and Biological Studies 6 (4): 17-28.

Herzon I, Helenius J (2008). Agricultural drainage ditches, their biological importance and functioning. Biological Conservation 141 (5): 1171-1183. https://doi.org/10.1016/j.biocon.2008.03.005

Hoffmann S, Steiner L, Schweiger AH, Chiarucci A, Beierkuhnlein C (2019). Optimizing sampling effort and information content of biodiversity surveys: a case study of alpine grassland. Ecological Informatics 51: 112-120. https://doi.org/10.1016/J.ECOINF.2019.03.003

Jost L (2006). Entropy and diversity. Oikos 113 (2): 363-375. https://doi.org/10.1111/j.2006.0030-1299.14714.x

Jayasimhan CS, Padmanabhan P (2019). Diversity and temporal variation of the bird community in paddy fields of Kadhiramangalam, Tamil Nadu, India. Journal of Threatened Taxa, 11 (10): 14279-14291.

Karim N, Yee LC, Mohd-Azlan J, Ramji MFS (2018). A survey of understory birds at a rice field and a mixed dipterocarp forest in Kuching, Sarawak. Malaysian Applied Biology 47 (1): 217-222.

Li D, Chen S, Lloyd H, Zhu S, Shan K et al. (2013). The importance of artificial habitats to migratory waterbirds within a natural/artificial wetland mosaic, Yellow River Delta, China. Bird Conservation International 23 (2): 184-198. https://doi.org/10.1017/S0959270913000099

Lim KS, Yong DL, Lim KC, Gardner D (2020). A field guide to the birds of Malaysia & Singapore. John Beaufoy Publishing.

Makbul NS, Wong A (2016). The diversity of birds in Kota Belud Bird Sanctuary, Sabah. Journal of Tropical Biology and Conservation 13: 43-56. https://doi.org/10.51200/jtbc.v13i0.396

Masero JA, Santiago-Quesada F, Sánchez-Guzmán JM, Villegas A, Abad-Gómez JM et al. (2011). Long lengths of stay, large numbers, and trends of the Black-tailed Godwit Limosa limosa in rice fields during spring migration. Bird Conservation International 21 (1): 12-24. https://doi.org/10.1017/S0959270910000092

Miron MK, Chowdhury SU (2019). Breeding density and habitat selection of the Grey-Headed Fish-Eagle in Noakhali District, Bangladesh. Journal of Raptor Research 53 (2): 134. https://doi.org/10.3356/JRR-18-33

Mohd-Taib FS, Kamaruddin HA (2018). The rice-growing cycle influences diversity and species assemblages of birds in the paddy field ecosystem in East Peninsular Malaysia. Pertanika Journal of Tropical Agricultural Science 41 (4): 1669-1683.

Mohd-Taib FS, Mohd-Saleh W, Rosli MZ (2021). Birds diversity at Sabak Bernam granary of West Peninsular Malaysia. Institute of Physics Conference Series: Earth and Environmental Science 736 (1): 12041. https://doi.org/10.1088/1755-1315/736/1/012041

Morrison LW, Peitz DG (2021). Spacing of point counts for grassland bird surveys in small geographical areas: Biases and tradeoffs. The Wilson Journal of Ornithology 132 (4): 810-819. https://doi.org/10.1676/19-00117

Munira AN, Salmi AN, Anuar MS, Juliani SN (2012). Bird communities and feeding guilds from three land use types in Kerian River Basin, Perak. Proceedings of The Annual International Conference, Syiah Kuala University-Life Sciences and Engineering Chapter 2 (1): 115-121.

Nam HK, Choi YS, Choi SH, Yoo JC (2015). Distribution of waterbirds in rice fields and their use of foraging habitats. Waterbirds 38 (2): 173-183. https://doi.org/10.1675/063.038.0206

Natsukawa H, Sergio F (2022). Top predators as biodiversity indicators: A meta-analysis. Ecology Letters 25 (9): 2062-2075. https://doi.org/10.1111/ele.14077

Natuhara Y (2013). Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. Ecological Engineering *56*: 97-106. https://doi.org/10.1016/j.ecoleng.2012.04.026

Nur Munira A, Nurul Salmi AL, Shahrul Anuar MS, Mohd Abdul Muin MA, Amirrudin A et al. (2014). Diversity and temporal distribution of birds in rice-growing landscape, Northern Peninsular Malaysia. Sains Malaysiana 43 (4): 513-520.

Phillipps Q, Phillipps K (2014). Phillipps' Field guide to the birds of Borneo (Third Edition). John Beaufoy Publishing Limited.

Pinto DP, Chivittz CC, Bergmann FB, Tozetti AM (2013). Microhabitat use by three species of egret (Pelecaniformes, Ardeidae) in southern Brazil. Brazilian Journal of Biology 73 (4): 791-796. https://doi.org/10.1590/S1519-69842013000400015

Putri M, Fithri AF, Siregar Z (2023). Bird diversity in paddy field habitats during the paddy ripening hase (Oryza sativa L.) Jurong Peujeura Village, Aceh Besar Regency, Indonesia. The International Journal of Tropical Veterinary and Biomedical Research 8 (1): 43-50. https://doi.org/10.21157/ijtvbr.v8i1.32430

Rahalker S, Patel R (2015). Study on diversity and temporal distribution of avifauna in paddy field during Kharif season of Janjgir-Champa District. International Organization of Scientific Research Journal of Environmental Science, Toxicology and Food Technology 1 (6): 55-61.

Rajpar MN, Zakaria M (2013). Assessing an artificial wetland in Putrajaya, Malaysia, as an alternate habitat for waterbirds. Waterbirds 36 (4): 482-493. https://doi.org/10.1675/063.036.0405

Sreekar R, Srinivasan U, Mammides C, Chen J, Manage Goodale U et al. (2015). The effect of land-use on the diversity and mass-abundance relationships of understory avian insectivores in Sri Lanka and southern India. Scientific Reports 3076 (5): 11569. https://doi.org/10.1038/srep11569

Supahan N (2022). Avian assemblage during the development of rice in organic and inorganic rice paddies and its relation to insect pests. Current Applied Science and Technology 22 (6): 1-34. https://doi.org/10.55003/cast.2022.06.22.005

Supriatna, J. (2018). Biodiversity Indexes: Value and Evaluation Purposes. E3S Web of Conferences, 48. https://doi.org/10.1051/e3sconf/20184801001

Tadashi M, Miyu Y, Masaru HT (2014). Distribution and abundance of organisms in paddy-dominated landscapes with implications for wildlife-friendly farming. Social-Ecological Restoration in Paddy-Dominated Landscapes 45-65. https://doi.org/10.1007/978-4-431-55330-4_4

Tattoni DJ, LaBarbera K (2022). Capture height biases for birds in mist-nets vary by taxon, season, and foraging guild in northern California. Journal of Field Ornithology 93 (1). https://doi.org/10.5751/JFO-00021-930101

Tingay RE, Nicoll MAC, Visal S (2006). Status and distribution of the Grey-headed Fish-Eagle (Ichthyophaga ichthyaetus) in the prek toal core area of Tonle Sap Lake, Cambodia. Journal of Raptor Research 40 (4): 277-283. https://doi.org/10.3356/0892-1016(2006)40[277:sadotg]2.0.co;2

Tingay RE, Nicoll MAC, Whitfield DP, Visal S, McLeod DRA (2010). Nesting ecology of the Grey-headed Fish-eagle at prek Toal, Tonle Sap Lake, Cambodia. Journal of Raptor Research 44 (3): 165-174. https://doi.org/10.3356/JRR-09-04.1

Townsend SE, Pearlstine EV, Mazzotti FJ, Deren CW (2006). Wading birds, shorebirds, and waterfowl in rice field within the Everglades Agricultural Area. Florida Field Naturalist 34 (1): 9-20.

Viquerat SMA, Müller M, Kiffner C, Waltert M, Bobo KS (2012). Estimating forest duiker (Cephalophinae) density in Korup National Park: a case study on the performance of three line transect methods. South African Journal of Wildlife Research 42 (1): 1-10. https://doi.org/10.3957/056.042.0110

Wang X, Fu J, Min Z, Zou D, Liu H et al. (2022). Response of rice with overlapping growth stages to water stress by assimilates accumulation and transport and starch synthesis of superior and inferior grains. International Journal of Molecular Sciences 23: 11157. https://doi.org/10.3390/ijms231911157

Yoon CG (2009). Wise use of paddy rice fields to partially compensate for the loss of natural wetlands. Paddy and Water Environment 7 (4): 357-366. https://doi.org/10.1007/s10333-009-0178-6

Zhang M, Xu Y, Li J, Yang J, Wang Q et al. (2024). Traditional paddy field-supported bird diversity ignored by forest-focused protection of ecosystems in tropical China. Ecology and Evolution 14 (5). https://doi.org/10.1002/ece3.11408

Supplementler Materials

Appendix 1. Bird species recorded and their distribution, protection status, abundance, paddy stages, site and feeding guild. Endemic and potential indicator species were highlighted with symbols.

Family/Common Name	Scientific Name	Distribution	IUCN (2016-2022)	SWLPO	Abundance	Paddy Stage	Sampling Method		Site	Feeding Guild
							Mist netting (Number of individual)	Line transect (Number of sighting)		
ACCIPITRIDAE										
**Brahminy Kite	*Haliastur indus*	CR	LC[1]	-	2	L	0	2	P	CA, IN, PI, CR, SC
**Crested Serpent Eagle	*Spilornis cheela*	CR	LC[1]	-	1	H	0	1	B	CA, IN
**Grey-headed Fish Eagle	*Haliaeetus ichthyaetus*	UR	NT[1]	-	2	P, L	0	2	P	CA, PI, SC
**White-bellied Sea Eagle	*Haliaeetus leucogaster*	CR	LC[4]	-	1	L	0	1	S	CA, PI, SC
ACROCEPHALIDAE										
**Oriental Reed Warbler	*Acrocephalus orientalis*	CWV, M	LC[1]	-	1	H	1	0	B	IN, FR
ALCEDINIDAE										
**Blue-eared Kingfisher	*Alcedo meninting*	CR	LC[1]	P	4	H	4	0	S	IN, PI, CR
**Collared Kingfisher	*Todiramphus chloris*	CR	LC[1]	P	2	L, P	1	1	S, B	CA, IN, PI, CR, VE, MO
APODIDAE										
**White-nest Swiftlet	*Aerodramus fuciphagus*	CR	LC[1]	P	72	L	0	72	P	IN[s]
**Glossy Swiftlet	*Collocalia esculenta*	CR	LC[4]	P	102	P, H, L	0	102	S, B, P	IN[s]

Appendix 1. (Continued.)

ARDEIDAE										
**Cattle Egret	*Bubulcus ibis*	CR, CWV	LC[1]	P	1	P	0	1	P	CA, IN, VE
Great Egret	*Ardea alba*	CNBV	LC[1]	P	100	P, H, L	1	99	S, B, P	CA, IN, PI, CR
Intermediate Egret	*Ardea intermedia*	CWV	LC[4]	P	60	P, H, L	0	60	S, B, P	CA, IN, PI, CR
Little Egret	*Egretta garzetta*	CR, M	LC[1]	P	67	P, H, L	0	67	S, B, P	CA, IN, PI, CR, VE, MO
Cinnamon Bittern	*Ixobrychus cinnamomeus*	CR	LC[1]	P	27	P, H, L	3	24	S, B, P	CA, IN, PI, CR, VE, MO
**Yellow Bittern	*Ixobrychus sinensis*	UR, UWV	LC[1]	P	4	P, H	1	3	S, B	CA, IN, PI, CR, VE, MO
**Chinese Pond-Heron	*Ardeola bacchus*	CWV, M	LC[1]	P	2	P	0	2	P	IN, PI, CR
**Striated Heron	*Butorides striata*	CR, M	LC[3]	P	1	P	0	1	S	PI, CR, MO
ARTAMIDAE										
White-breasted Wood Swallow	*Artamus leucorhynchus*	CR	LC[1]	-	26	P, H, L	2	24	S, B	IN, NE
CAMPEPHAGIDAE										
**Pied Triller	*Lalage nigra*	CR	LC[2]	-	1	H	1	0	P	IN, VE, FR
CAPRIMULGIDAE										
**Large-tailed Nightjar	*Caprimulgus macrurus*	VCR	LC[1]	-	2	P	0	2	S	IN[s]
CHARADRIIDAE										
**Little-ringed Plover	*Charadrius dubius*	CWV, M	LC[1]	P	8	P, L	1	7	S	IN, CR, VE, MO
Pacific Golden Plover	*Pluvialis fulva*	CWV, M	LC[1]	P	36	P, L	1	35	S, B, P	CA, IN, CR, MO, FR, FO, GR

Appendix 1. (Continued.)

CISTICOLIDAE										
Ashy Tailorbird	*Orthotomus ruficeps*	CR	LC[1]	-	46	P, H, L	5	41	S, B, P	IN[s]
Rufous-tailed Tailorbird	*Orthotomus sericeus*	CR	LC[1]	-	38	P, H, L	2	36	S, B, P	IN[s]
Yellow-bellied Prinia	*Prinia flaviventris*	CR	LC[1]	-	120	P, H, L	17	103	S, B, P	IN[s]
COLUMBIDAE										
**Little Green-Pigeon	*Treron olax*	CR	LC[2]	-	1	P	1	0	S	FR, FO
Pink-necked Green-Pigeon	*Treron vernans*	CR	LC[1]	-	32	P, H, L	6	26	S, B, P	FR, GR
Spotted Dove	*Spilopelia chinensis*	CR	LC[1]	-	150	P, H, L	4	146	S, B, P	IN, FR, GR
Zebra Dove	*Geopelia striata*	CR, LCIR	LC[1]	-	19	P, H, L	9	10	S, B, P	IN, GR
CORACIIDAE										
**Dollarbird	*Eurystomus orientalis*	CR, CWV	LC[1]	-	1	H	0	1	P	IN[s]
CORVIDAE										
Black Magpie	*Platysmurus leucopterus*	CR	LC[1]	-	7	P, H, L	0	7	B, P	CA, PI, FR, FO
CUCULIDAE										
**Chestnut-breasted Malkoha	*Phaenicophaeus curvirostris*	CR	LC[1]	-	1	P	0	1	P	CA, IN, FR
**Greater Coucal	*Centropus sinensis*	CR	LC[1]	-	14	P, L	0	14	S, P	CA, IN, MO, FR, GR
Lesser Coucal	*Centropus bengalensis*	CR	LC[1]	-	55	P, H, L	4	51	S, B, P	CA, IN
**Moustache Hawk-Cuckoo	*Hierococcyx vagans*	UR	NT[6]	-	1	P	0	1	S	CA, IN

Appendix 1. (Continued.)

Plaintive Cuckoo	*Cacomantis merulinus*	CR	LC[1]	-	22	P, H, L	2	20	S, B, P	IN, FR
DICAEIDAE										
**Orange-bellied Flowerpecker	*Dicaeum trigonostigma*	CR	LC[1]	-	3	P, H	1	2	S, P	IN, FR, FO, PA, NE, GR
**Scarlet-backed Flowerpecker	*Dicaeum cruentatum*	CR	LC[1]	-	1	P	0	1	S	IN, FR, GR
**Yellow-breasted Flowerpecker	*Prionochilus maculatus*	CR	LC[1]	-	2	P	0	2	S, B	IN, FR, PA, NE, GR
DICRURIDAE										
**Greater Racket-tailed Drongo	*Dicrurus paradiseus*	CR	LC[1]	-	4	P	0	4	S, B	IN, FR
ESTRILDIDAE										
Chestnut Munia	*Lonchura atricapilla*	CR	LC[1]	-	271	P, H, L	56	215	S, B, P	GR[s]
* **Dusky Munia	*Lonchura fuscans*	CR	LC[1]	-	138	P, H, L	92	46	S, B, P	IN, MO, FR, NE, GR, PH
Scaly-breasted Munia	*Lonchura punctulata*	AB	LC[1]	-	301	P, H, L	68	233	S, B, P	IN, FR, GR, PH
**Pin-tailed Parrotfinch	*Erythrura prasina*	RAR	LC[1]	-	1	L	1	0	P	GR[s]
EURYLAMIDAE										
**Black-and-red Broadbill	*Cymbirhynchus macrorhynchos*	CR	LC[1]	-	2	P	1	1	S, B	IN, FR, GR, PH
**Green Broadbill	*Calyptomena viridis*	CR	NT[6]	-	1	P	0	1	S	IN, FR
GLAREOLIDAE										

Appendix 1. (Continued.)

**Oriental Pratincole	*Glareola maldivarum*	UR, UWV	LC[1]	-	1	L	0	1	S	IN, PI
HIRUNDINIDAE										
**Barn Swallow	*Hirundo rustica*	CWV, M	LC[2]	-	9	L	2	7	S	IN, FR, GR
**Pacific Swallow	*Hirundo tahitica*	VCR	LC[1]	-	19	P, H	5	14	S, B, P	IN[s]
LANIIDAE										
Long-tailed Shrike	*Lanius schach nasutus*	RNBV	LC[1]	-	36	P, H, L	18	18	S, B, P	CA, IN, VE
MEGALAIMIDAE										
Red-throated Barbet	*Psilopogon mystacophanos*	CR	NT[6]	-	34	P, H, L	0	34	S, B, P	IN, MO, FR
MEROPIDAE										
**Blue-throated Bee-eater	*Merops viridis*	CR	LC[1]	-	5	H, L	0	5	P	IN, PI
MUSCICAPIDAE										
Oriental Magpie Robin	*Copsychus saularis*	CR	LC[4]	-	20	P, H, L	3	17	S, B, P	IN, PI, VE, FR, NE
**White-rumped Shama	*Copsychus malabaricus*	CR	LC[4]	P	2	P, L	0	6	S	IN, VE, FR, PU
NECTARINIIDAE										
Brown-throated Sunbird	*Anthreptes malacensis*	CR	LC[1]	-	6	P, H, L	1	5	S, P	NE, IN, FR
**Crimson Sunbird	*Aethopyga siparaja*	CR	LC[1]	-	13	P, L	1	12	S, B, P	NE, IN
**Olive-backed Sunbird	*Cinnyris jugularis*	CR	LC[1]	-	6	P, H	2	4	B, P	NE, IN
**Plain Sunbird	*Anthreptes simplex*	CR	LC[1]	-	10	P, L	0	10	S	NE, IN, FR

Appendix 1. (Continued.)

**Little Spiderhunter	*Arachnothera longirostra*	CR	LC[1]	-	4	P, H	2	2	S, B	NE, IN, FR
**Purple-naped Spiderhunter	*Kurochkinegramma hypogrammicum*	CR	LC[1]	-	14	P, H	0	14	S, B, P	NE, IN, FR, GR
PACHYCEPHALIDAE										
**Mangrove Whistler	*Pachycephala cinereal*	UR	LC[1]	-	1	L	0	1	S	IN[s]
PASSERIDAE										
Eurasian Tree Sparrow	*Passer montanus*	VCR	LC[1]	-	57	P, H, L	1	56	S, B, P	IN, FR, FO, GR, SC
PICIDAE										
**Banded Woodpecker	*Chysophlegma miniaceum*	CR	LC[1]	P	5	P, H	3	2	B, P	IN[s]
**Maroon Woodpecker	*Blythipicus rubiginosus*	FCR	LC[1]	P	2	P	0	2	S	IN[s]
**Rufous Piculet	*Sasia abnormis*	FCR	LC[1]	P	1	H	1	0	S	IN, FO
PLOCEIDAE										
Baya Weaver	*Ploceus philippinus*	LCIR (Chupak)	LC[1]	-	37	P, H, L	5	32	S	IN, GR
PSITTACIDAE										
**Long-tailed Parakeet	*Psittacula longicauda*	CR	VU[2]	P	3	L	0	3	P	FR, FO
PYCNONOTIDAE										
**Buff-vented Bulbul	*Iole crypta*	CR	NT[1]	-	1	P	0	1	B	IN, FR
Olive-winged Bulbul	*Pycnonotus plumosus*	CR	LC[1]	-	17	P, H, L	5	12	S, B, P	IN, FR

Appendix 1. (Continued.)

Yellow-vented Bulbul	*Pycnonotus goiavier*	VCR	LC[1]	-	65	P, H, L	20	45	S, B, P	IN, VE, MO, FR, FO, NE, GR, SC
RALLIDAE										
Buff-banded Rail	*Gallirallus philippensis*	RA	LC[1]	-	18	P, H, L	0	18	S, B	VE, MO, FR, FO, GR, SC
Slaty-breasted Rail	*Lewinia striatus*	UR	LC[1]	-	3	P, H, L	2	1	B, P	IN, VE, MO, FR, FO, GR
Eurasian Moorhen	*Gallinula chloropus*	UR, UWV	LC[1]	-	14	P, H, L	1	13	S, P	CA, IN, PI, CR, VE, MO, FR, FO, PH
White-breasted Waterhen	*Amaurornis phoenicurus*	VCR, VCWV	LC[1]	-	115	P, H, L	4	111	S, B, P	IN, PI, VE, MO, FO, GR
**White-browed Crake	*Porzana cinerea*	CR	LC[1]	-	7	P, H	1	6	S, B	CA, IN, MO, FR, FO, GR
RHIPIDURIDAE										
Malaysian Pied-fantail	*Rhipidura javanica*	CR	LC[1]	-	8	P, H, L	2	6	S, P	IN[s]
ROSTRATULIDAE										
**Greater Painted Snipe	*Rostratula benghalensis*	CR	LC[1]	P	1	P	1	0	5	IN, CR, VE, MO, GR
SCOLOPACIDAE										
**Pin-tailed Snipe	*Gallinago stenura*	CWV	LC[4]	P	4	H, L	2	2	B, P	IN, VE, FO
**Swimhoe's Snipe	*Gallinago megala*	UWV	LC[1]	P	8	P, L	4	4	B	IN, VE, NE, GR
**Common Sandpiper	*Actitis hypoleucos*	VCWV, M	LC[1]	P	23	P, L	0	23	S	IN, MO
Wood Sandpiper	*Tringa glareola*	VCWV, M	LC[1]	P	67	P, H, L	16	51	S, B	CA, IN, PI, CR, VE, MO, GR, PH
SITTIDAE										

Appendix 1. (Continued.)

**Velvet-fronted Nuthatch	*Sitta frontalis*	CR	LC[1]	-	1	P	0	1	S	IN[s]
STRIGIDAE										
**Sunda Scops Owl	*Otus lempiji*	CR	LC[1]	P	1	L	1	0	P	CA, IN, PI, FO
STURNIDAE										
Asian Glossy Starling	*Aplonis panayensis*	VCR	LC[1]	-	68	P, H, L	16	52	S, B, P	IN, MO, FR, FO, NE, GR, PU, SC
Common Hill Myna	*Gracula religiosa*	CR	LC[1]	P	26	P, H, L	0	26	S, P	CA, IN, NE
Common Myna	*Acridotheres tristis*	CR	LC[1]	-	34	P, H, L	0	34	S, B, P	IN, CA, FR, FO, SC
TEPHRODORNITHIDAE										
Rufous-winged Philentoma	*Philentoma pyrhopterum*	FCR	LC[1]	-	20	P, H, L	0	20	S, P	IN[s]
TIMALIIDAE										
**Chestnut-winged Babbler	*Cyanoderma erythropterum*	CR	LC[1]	-	3	P	0	3	S, B	IN, FO
**Scaly-crowned Babbler	*Malacopteron magnum*	CR	LC[1]	-	1	P	0	1	B	IN, FR
**Short-tailed Babbler	*Pellorneum malaccense*	CR	NT[5]	-	1	P	0	1	S	IN[s]
* **Bold-Striped Tit-Babbler	*Mixornis bornensis*	CR	LC[2]	-	3	P, H	1	2	P	IN, FR
**Fluffy-backed Tit-babbler	*Macronous ptilosus*	CR	NT[1]	-	3	P	0	3	S	IN[s]
TURDIDAE										IN, VE, FR
**Eyebrowed Thrush	*Turdus obscurus*	UWV, M	LC[1]	-	1	P	0	1	P	IN, VE, FR

Appendix 1. (Continued.)

VIREONIDAE										
**White-bellied Erpornis	*Erpornis zantholeuca*	UR	LC[1]	-	1	P	1	0	S	IN, FR
					2,552		**406**	**2150**		

Abbreviations: IUCN = IUCN Red List: LC = Least Concern, NT = Near Threatened, EN = Endangered, VU = Vulnerable, Year = 2016[1], 2018[2], 2019[3], 2020[4], 2021[5], 2022[6]; SWLPO 1998 = Sarawak Wildlife Protection Ordinance 1998: TP = Totally Protected, P = Protected, - = Not Protected; Distributional Status: VCWV = Very Common Winter Visitor, VCR = Very Common Resident, CR = Common Resident, UR = Uncommon Resident, FCR = Fairly Common Resident, RAR = Rare Resident, SR = Scarce Resident, AB = Absent, CWV = Common Winter Visitor, UWV = Uncommon Winter Visitor, RWV = Rare Winter Visitor, CNBV = Common Non-breeding Visitor, UNBV = Uncommon Non- breeding Visitor, RNBV = Rare Non-breeding Visitor, M = Migrant, N = Native, RA = Rare, VA = Vagrant, LCIR = Locally Common Introduced Resident; Paddy stage: P = Planting, H = Harvest, L = Land preparation; Site: P = Kampung Pueh-Siru Dayak, B = Kampung Baru, S = Kampung Skuduk; Diet Guild: FO = Foliovore, FR = Frugivore, GR = Granivore, NE = Nectarivore, CA = Carnivore, CR = Crustaceovore, IN = Insectivore, MO = Molluscivore, SC = Scavenger, PI = Piscivore, VE = Vermivore, PU = Purgamenovore; Diet Guild[s] = Specialist; *= Endemic.;

**Indicator species

Appendix 2. The numerical values of estimated sample completeness profiles, size-based rarefaction and extrapolation curves, asymptotic and empirical diversity profiles, coverage-based rarefaction and extrapolation curves and the evenness profiles.

Step 1. Sample completeness profiles			
Completeness	**q = 0**	**q = 1**	**q = 2**
Planting	74.0%	97.0%	100.0%
Harvest	75.0%	99.0%	100.0%
Land preparation	87.0%	98.0%	100.0%
Overall	75.0%	99.0%	100.0%
Step 2. Asymptotic analysis			
Diversity	**q = 0**	**q = 1**	**q = 2**
Planting			
Asymptotic	103.86	42.75	30.25
Empirical	77.00	39.98	29.22
Undetected	26.86	2.77	1.03
Harvest			
Asymptotic	71.98	18.40	9.55
Empirical	54.00	17.78	9.48
Undetected	17.98	0.62	0.07
Land preparation			
Asymptotic	62.32	30.00	20.16
Empirical	54.00	28.49	19.58
Undetected	8.32	1.51	0.58
Overall			
Asymptotic	125.99	35.25	21.59
Empirical	94.00	34.34	21.41
Undetected	31.99	0.91	0.18
Step 3. Non-asymptotic coverage-based rarefaction and extrapolation			
Maximum standardises coverage = 98.8%			
Diversity	**q = 0**	**q = 1**	**q = 2**
Planting	92.01	41.61	29.73
Harvest	53.11	17.74	9.47
Land preparation	56.07	28.80	19.69
Overall	87.46	34.08	21.36
Step 4. Evenness among species abundances			
Evenness	**Pielou index, J’**	**q = 1**	**q = 2**
Planting	0.82	0.45	0.32
Harvest	0.72	0.32	0.16
Land preparation	0.83	0.50	0.34
Overall	0.79	0.38	0.24