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**Research Article**

# Bird Diversity and Functional Guilds in Sungai Talibu Forest Reserve, Sabah, Malaysia

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## ABSTRACT

A rapid avifaunal assessment was conducted in Sungai Talibu Forest Reserve, a secondary mixed dipterocarp forest in Telupid, Sabah, Malaysia, to investigate its avian community and ecology as a baseline for future forest management initiatives. The assessment was part of a multi-disciplinary scientific expedition by the Sabah Forestry Department. Using a modified MacKinnon List method, the four-day survey recorded 15 lists, detecting 391 individuals. A total of 107 species from 40 families were identified, with a Shannon Diversity Index of H= 3.88 and Evenness $E_H$= 0.65. Chao1 species richness, estimated via SuperDuplicates®, suggested approximately 138 species, with 31 undetected. The effective number of species ($Num_{eff}$) was 48. Eight Bornean endemics were recorded, including the Borneo Ground Cuckoo (*Carpococcyx radiceus*). The survey also detected species of high conservation concern: Helmeted Hornbill (*Rhinoplax vigil*) and Greater Green Leafbird (*Chloropsis sonnerati*). Pycnonotidae was the most abundant family, with 45 individuals (11.5%) across 10 species. Insectivores dominated feeding guilds, with 174 individuals (44.6%) from 55 species and 20 families, followed by frugivores with 146 individuals (37.3%) from 30 species and 13 families.

**Keywords:** Avifaunal survey; MacKinnon List method; Sungai Talibu Forest Reserve; frugivores; insectivores.

## INTRODUCTION

In 2004, the Sabah Forestry Department (SFD) conducted a forest inventory exercise to ascertain tree density and structure, used to estimate standing timber and forest recovery capacity of Forest Management Unit (FMU) 17A, which includes the Sungai Pinangah Forest Reserve (Class II), Telupid, Sabah, Malaysia. The results were documented in a 10-year forest management plan (SFD, 2009). The first forest management plan was approved by the SFD in 2008. A portion of the Sungai Pinangah FR (Class II) was later degazetted and reconstituted as the Sungai Talibu Forest Reserve (STFR), a Protection Forest Reserve (Class I). From 13–18 May 2024, the SFD, through its Research and Development arm at the Forest Research Centre, Sepilok, conducted a multi-disciplinary scientific expedition to the STFR to study in-depth its ecology and social ecosystem services. The expedition base camp was at the Kun-Kun Riverside Park, situated in the northeast corner of the STFR, accessible from the main gravelled Tangkulap-Deramakot road. This paper documents the outcome of the avifaunal survey conducted during the expedition. The main objective of this survey was to investigate the avian community and ecology within the forest reserve as a baseline for future forest management initiatives.

## METHODS

### Site description

The STFR was gazetted as a forest reserve on 24 December 2014, with an area of 20,881 ha. It was previously gazetted in 1962 as part of Tangkulap Forest Reserve (Class II). As a commercial reserve, it was logged between the early 1970s and 2003. During that time, the issuance of short-term logging licenses at short intervals, as well as poor logging practices, resulted in excessive logging in some areas of the reserve. Currently, the STFR is part of the Tangkulap-Sungai Talibu FMU No. 17A and is managed by the SFD (SFD, 2009). The main focus of the management plan was to intensively restore severely degraded areas. The FMU 17A was certified as well-managed in 2016 by SCS Global Services in accordance with the Forest Stewardship Council's Principles and Criteria (FSC, 2023).

The natural vegetation of the northern portion of the STFR consists of mainly lowland and upland ultramafic forests over the Bidu-Bidu soil association (see Figs. 1 and 2). In the lowland ultramafic forest, the most common tree family is the Dipterocarpaceae, whereas in the upland ultramafic forest non-dipterocarps contribute most of the main canopy layer, namely, *Gymnostoma sumatranum* (Casuarinaceae), *Calophyllum* sp. (Guttiferae) and *Swintonia* cf. *acuta* (Anacardiaceae). In the upland kerangas forest, Dipterocarpaceae are also very common although shorter in stature compared to those growing in lowland mixed dipterocarp forests in the southeast of the reserve (Bower et al., 1975). As mentioned earlier, most of the lowland areas were logged in the past.

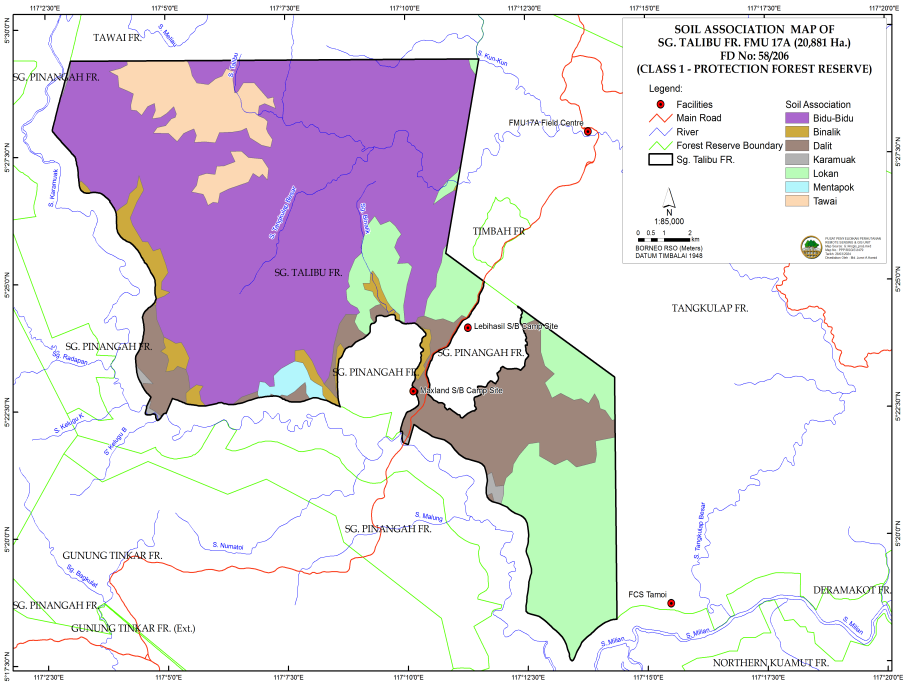


**Figure 2:** Soil association map of Sungai Talibu Forest Reserve, Telupid, Sabah, Malaysia.

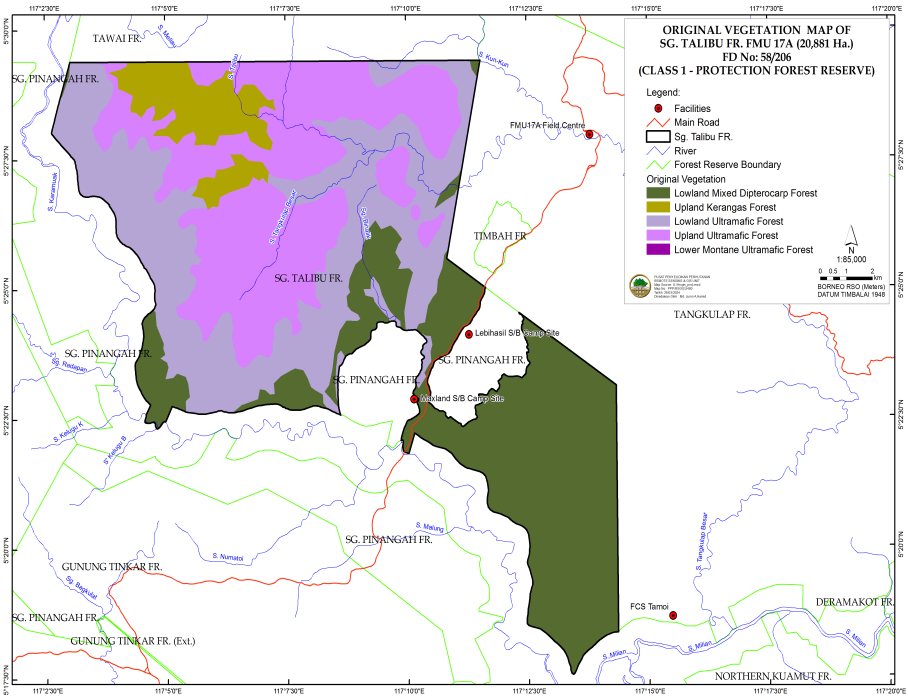


**Figure 1:** Natural vegetation of Sungai Talibu Forest Reserve, Telupid, Sabah, Malaysia.

**Modified MacKinnon List method**

The MacKinnon List (ML) method, introduced by MacKinnon and Phillipps (1993), is a practical and widely used approach for the rapid assessment of species-rich environments, especially when time, manpower, or funding is limited. Unlike more resource-intensive methods such as point counts or mist-netting, ML offers a flexible and non-invasive alternative. It is widely adopted by government agencies, NGOs, and citizen science projects for its simplicity and adaptability to varying observer expertise and field conditions (Poulsen et al., 1997; Yong et al., 2011). MacLeod et al. (2011) demonstrated that species abundance rankings derived from ML closely match those obtained from fixed-radius point counts, while being more robust to variation in detectability and effort. The method's independence from fixed spatial or temporal units also allows for meaningful comparisons across surveys conducted under different conditions (Herzog et al., 2002). Its versatility has extended to other taxa, including mammals and fish (Bach et al., 2020).

In standard ML practice, observers compile sequential lists of species based on the order in which they are detected—visually or aurally—during a survey. Each list contains a fixed number of different species, commonly ten, although Herzog et al. (2002) recommend longer lists (e.g., 15 species) for species-rich tropical systems. Once a species appears in a list, it is excluded from that list and re-enters only when the next list begins. This generates a set of species samples independent of time or space, allowing for a straightforward species accumulation curve.

As with all our assessments, we used a modified version of the ML method developed by our team, in which the number of individuals per species was also recorded within each 15-species list. This adjustment, informed by Herzog et al. (2002) and MacLeod et al. (2011), helps reduce the chance of double-counting and supports more robust estimates of diversity and abundance metrics—such as Shannon diversity (H′), Chao1 richness, and the Effective Number of Species ($Num_{eff}$). Given that our surveys typically span only 3–4 days, reflecting the logistical constraints of rapid assessments by the SFD, this modification improves accuracy for abundance-based comparisons. A species accumulation curve was also generated post-survey to assess sampling completeness. An asymptote in this curve suggests that most of the site's bird diversity was likely detected.

**Survey methods**

Surveys were conducted for 4 days (14–17 May 2024), beginning at 6:30 am and ending after 4 hours. Approximately 5.5 km of the main and secondary earth roads leading into the central portion of the STFR with ultramafic forests, were surveyed. Night surveys to detect nocturnal birds were conducted, weather-permitting, for two hours within 2 km from the base camp as elephants posed a safety risk along the roads.

Every observer had a pair of Nikon binoculars (8 × 42). The reference field guides were Phillipps and Phillipps (2014) and the Merlin Bird ID application (Cornell Lab of Ornithology, 2025). The latest taxonomic changes were determined from the IOC World Bird List (Gill et al., 2025). Whenever possible, a Nikon P1000 mega-zoom camera (3,000 mm equivalent) was used to photograph unfamiliar birds and confirm their identities.

One team member recorded all observations, ensuring no intra-list and inter-list double-counts. Given that approximately half of the individuals were detected aurally, as is standard in tropical forest surveys where dense canopy limits visibility—most birds were first heard and, if the call

was unfamiliar, were then visually sought for confirmation; very common species recognised by call were recorded immediately. Identification by bird vocalisations is widely accepted as equivalent to sight records in established protocols (Ralph et al. 1995; Bibby et al. 2000) and performs comparably to visual counts in estimating richness and composition (Haselmayer & Quinn 2000; Anderson et al. 2015). Our experienced team verified uncertain calls against reference archives (e.g. Xeno-canto Foundation, 2025) to ensure accuracy and consistency. As such, strict care was applied to ascertain the uniqueness of individual bird records, particularly when inputting abundance data within a single 15-species list. The delineation of distinct individuals of the same species hinged upon several criteria: a) the directional origin of their vocalisations; b) the sequential occurrence of two or more calls emanating from a comparable direction to a previously documented individual; and c) the perceived distance from a previously logged individual was deemed sufficient to warrant the classification of a call as originating from a separate individual. This distance refers to the point at which we were confident that the bird could be reliably identified. For common and well-known species, this could be determined quickly through calls alone, whereas for less familiar or uncertain detections, we sought visual confirmation whenever possible. The survey team consisted of experienced birders with over 55 years of cumulative field experience in bird identification in Sabah, ensuring that such judgments were made consistently and with a high degree of reliability. Moreover, in cases where bird species were observed in flocks, photographs were taken and reviewed to estimate the flock's size, with attention given to avoiding double-counting instances. When surveying a secondary road (i.e., smaller branch earth roads that extend from the main road), only bird species not previously recorded along the stretch were documented when returning to the main road.

**Analyses**

From the survey data, we derived basic diversity information, including species richness, number of families, the most speciose family, and the most abundant species. Latest updates on Bornean endemics were obtained from Gill et al. (2025) while conservation status followed the IUCN Red List (IUCN 2025). A species accumulation curve was generated by adding those species not recorded on any of the previous lists to the total species number, which was then plotted as a function of the list number.

For diversity indices, we calculated Shannon diversity index (H'), the effective number of species (exponential of H'), $Num_{eff}$, and Chao1 Estimate. The formula for $Num_{eff}$ is as follows:

$$Num_eff = exp\{-\sum_{i=1}^{s} p_i \ ln(p\_i)\}$$

$Num_{eff}$ accounts for species richness and evenness (Jost, 2006). Chao1 estimates 'true' species richness, including the number of unobserved species. It is calculated using the SuperDuplicates® online calculator (https://chao.shinyapps.io/SuperDuplicates/), developed by Chao et al. (2017). The calculator only requires the total number of species observed and the number of species observed only once, with data type listed as 'abundance data'.

In addition to these metrics, feeding guilds data were used to provide information on how the bird community used specific forest resources (fruits, insects, arthropods, seeds, other resources). Such information may indicate the condition or ecological health of the forest ecosystem at STFR, as

the relative representation of different feeding guilds may reflect habitat quality and resource availability. Species were categorised according to six feeding guilds based on their preferred diet; carnivores, frugivores, insectivores, nectarivores, granivores and generalists. Species were considered generalists if they were known to consume roughly similar amounts of animal- and plant-based food resources. Guild information was determined mainly from Phillipps and Phillipps (2014) and Wells (1999 & 2007). Feeding guilds were then compared among habitat types (e.g., forest, forest edge and open areas) to examine the relative importance of these habitats to different guilds.

## RESULTS

### Avifaunal composition and species richness

The four survey days yielded 15 lists and a total of 391 individuals from a total of 20 survey hours. The avifauna of the STFR was represented by 107 species from 40 families, with a Shannon Diversity Index of H=3.88 and an Evenness, $E_H$=0.65.

The survey documented eight Bornean endemic species (Table 1), of which the Bornean Ground Cuckoo (*Carpococcyx radiceusis*) is the only one classified as Vulnerable on the IUCN Red List, while the Bornean Bristlehead (*Pityriasis gymnocephala*) and Charlotte's Bulbul (*Iole charlottae*) are categorised as Near Threatened. With the exception of the Dusky Munia (*Lonchura fuscans*), all endemic species were strictly dependent on forest habitats. Beyond the endemics, the survey also recorded species with critical conservation statuses: the Helmeted Hornbill (*Rhinoplax vigila*) as Critically Endangered and the Greater Green Leafbird (*Chloropsis sonnerati*) as Endangered. Additionally, five species were identified as Vulnerable: the Bornean Ground Cuckoo (*Carpococcyx radiceusis*), Rhinoceros Hornbill (*Buceros rhinoceros*), Long-tailed Parakeet (*Psittacula longicauda*), Javan Myna (*Acridotheres javanicus*), and Great Slaty Woodpecker (*Mulleripicus pulverulentus*).

**Table 1:** The IUCN conservation statuses of Bornean endemic bird species detected in May 2024 at the Sungai Talibu Forest Reserve, Telupid, Sabah, Malaysia (IUCN, 2025). LC: Least Concern, NT: Near Threatened, VU: Vulenerable.

| Common name | Family | IUCN status |
|---|---|---|
| Bornean Black-capped Babbler | Pellorneidae | LC |
| Bornean Bristlehead | Pityriasidae | NT |
| Bornean Brown Barbet | Megalaimidae | LC |
| Bornean Ground Cuckoo | Cuculidae | VU |
| Charlotte's Bulbul | Pycnonotidae | NT |
| Cream-eyed Bulbul | Pycnonotidae | LC |
| Dusky Munia | Estrildidae | LC |
| White-crowned Shama | Muscicapidae | LC |

Table 2 is a summary of the most commonly represented families and species. The bird family whose members were most commonly encountered in the STFR was Pycnonotidae, with 45 individuals recorded. This family also had the highest species richness with 10 species recorded. The Nectariniidae was the second most common, with 41 individuals and 8 species detected. Other

notable families included Cuculidae and Timaliidae, both contributing 22 individuals, while Pellorneidae exhibited a species richness of seven. Among individual species, the Bold-striped Tit-babbler (*Mixornis bornensis*) and Little Spiderhunter (*Arachnothera longirostra*) were the most frequently observed, with 16 individuals each, followed by the Blue-crowned Hanging Parrot (*Loriculus galgulus*) with 15 individuals. The complete species and family lists are provided in Appendices I and II, respectively.

**Table 2:** Most commonly represented families and species of birds recorded in May 2024 at the Sungai Talibu Forest Reserve, Telupid, Sabah, Malaysia.

| Rank | Family (no. of individuals) | Family (no. of species) | Species (no. of individuals) |
|---|---|---|---|
| 1 | Pycnonotidae (45) | Pycnonotidae (10) | Bold-striped Tit-babbler/ Little Spiderhunter (16) |
| 2 | Nectariniidae (41) | Cuculidae/Nectariniidae (8) | Blue-crowned Hanging Parrot (15) |
| 3 | Cuculidae/Timaliidae (22) | Pellorneidae (7) | Green Iora/ Orange-bellied Flowerpecker (13) |
| 4 | Psittaculidae (19) | Megalaimidae/Picidae (5) | Greater Green Leafbird/ Purple-naped Spiderhunter (12) |
| 5 | Chloropseidae (18) | Alcediniidae/Cisticolidae/ Timaliidae/Muscicapidae (4) | Cream-vented Bulbul/ Spectacled Bulbul (11) |

Apart from observed species richness (107), $Num_{eff}$ was approximately 48 species, and the SuperDuplicates® online calculator estimated the Chao1 estimate there to be approximately 138 total species (Table 3). Thus, the calculator estimated that approximately 31 species were undetected, i.e., the survey detected about 77.5% of the total species in the area. The number of doubletons (species detected only twice) was estimated to be 16, less than the actual number of 27 obtained from the survey. As shown in Figure 3, the species accumulation curve had not reached a plateau, suggesting that additional surveys would likely yield further species. Based on the linear regression line, it estimated that another two lists, or an extra four-survey days, were needed to detect the estimated 138 species of birds predicted by SuperDuplicates®, particularly in the upland ultramafic forests and the logged-over mixed dipterocarp forests in the southeast of the reserve that were not covered during the survey.

**Table 3:** Results from SuperDuplicates®– Chao1 estimation of the bird species recorded in May 2024 at the Sungai Talibu Forest Reserve, Telupid, Sabah, Malaysia.

| Estimated no. of doubletons | Estimated species richness | Standard error | 95% C.I. lower | 95% C.I. upper | No. of undetected species | Undetected percentage (%) |
|---|---|---|---|---|---|---|
| 16.39 | 138.01 | 8.32 | 125.5 | 158.97 | 31.01 | 22.47 |

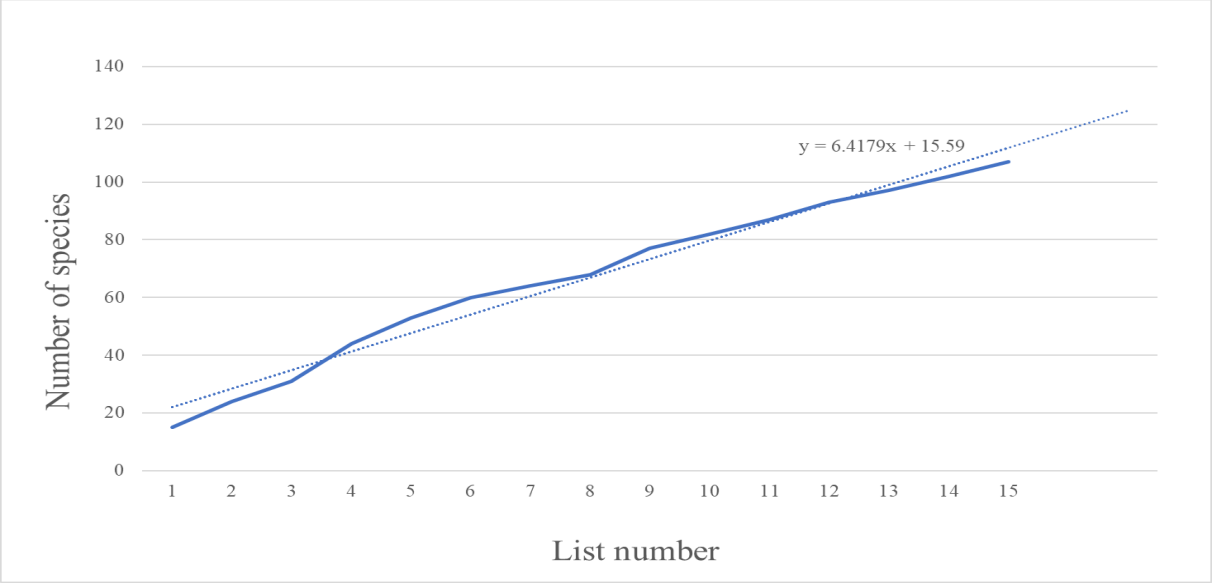


**Figure 3:** Species accumulation curve and linear regression line of birds recorded in May 2024 at the Sungai Talibu Forest Reserve, Telupid, Sabah, Malaysia.

**Preferred habitat types**

Species were categorised based on their preferred habitats (e.g., forest, forest edge, open areas) and feeding guilds (Fig. 4). Of the 107 species detected, 101 (94.4%) were forest-dependent, with 81 (75.7%) classified as strictly forest species. In contrast, only six open-area species (20 individuals) were recorded, mostly near the expedition base camp at Kun-Kun Riverside Park. This low count of open-country birds is likely due to the area's relative isolation; the nearest oil palm plantations lie approximately 2.6 km to the north, limiting edge effects and habitat encroachment from surrounding land use.

**Feeding guilds**

Insectivores and frugivores comprised 80.0 % of the total individuals detected, with insectivores being the most abundant at 174 individuals (44.5%). Among the 55 insectivorous species (spanning 21 families), 45 were strictly forest specialists (Fig. 4). The Bold Striped Tit-babbler and the Green Iora (*Aegithina viridissima*) were the most abundant insectivores detected with 16 and 13 individuals, respectively.

The second most dominant feeding guild was the frugivores, with 146 individuals (37.3%) detected, representing 30 species across 13 families. Among them, the bulbuls (Pycnonotidae) were the most frequently recorded family, with 45 individuals. Both the Cream-vented Bulbul (*Pycnonotus simplex*) and the Spectacled Bulbul (*Ixodia erythropthalmos*) were the most commonly recorded species, each with 11 individuals, followed by Charlotte's Bulbul with seven individuals.

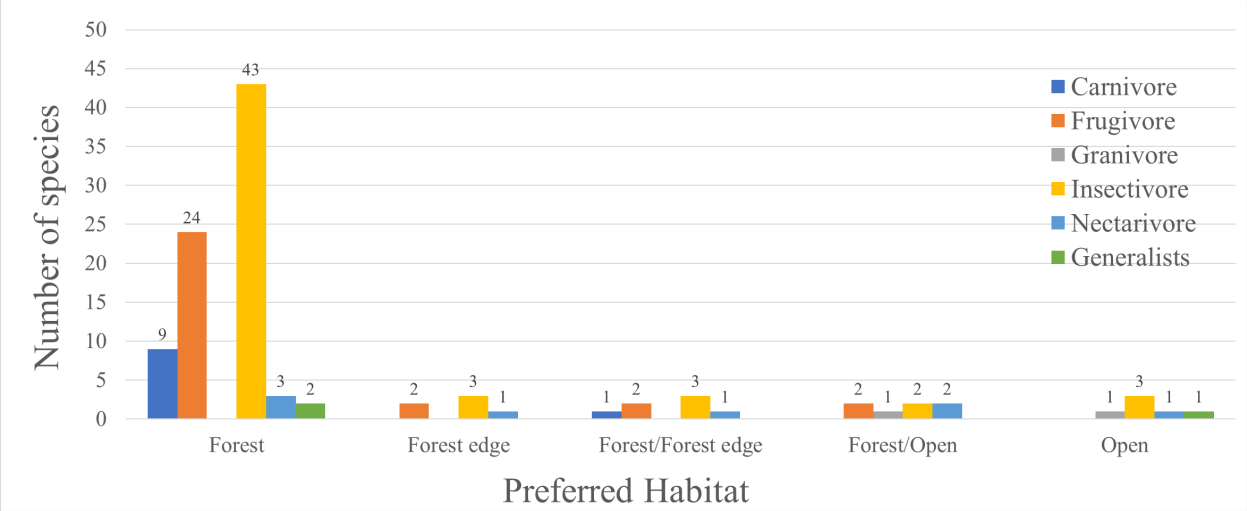


**Figure 4:** Number of bird species according to habitat types and feeding guilds, recorded in May 2024 at the Sungai Talibu Forest Reserve, Telupid, Sabah, Malaysia.

## DISCUSSION

The avifaunal survey conducted at the STFR reveals a robust diversity of bird species, with a Shannon Diversity Index of H=3.88 and a species richness of 107 species across 40 families, reflecting an above-average avifaunal composition for a forest reserve of its type. The large number of forest specialists (101) suggests ecological integrity for the STFR's forest habitats, despite its proximity to disturbance in the surrounding forest reserves and oil palm estates. Notably, the presence of nine Bornean endemics, including the Vulnerable Bornean Ground Cuckoo and the Near Threatened Bornean Bristlehead and Charlotte's Bulbul, highlights the conservation significance of the STFR within the Bornean biodiversity hotspot. The detection of Critically Endangered (Helmeted Hornbill) and Endangered (Greater Green Leafbird) species further elevates the reserve's importance as a refuge for globally threatened avifauna.

However, the species accumulation curve derived from our MacKinnon Lists (Fig. 3) has not reached a plateau, indicating that we conducted too few surveys to truly estimate the number of forest species. This underestimate was suggested by the 31 undetected species predicted by the Chao1 estimate of 138 species. Additional surveys, particularly in the upland ultramafic forests and logged-over mixed dipterocarp forests, could refine our understanding of the reserve's total species pool.

Drawing on a series of surveys conducted by the authors using a consistent modified ML method, we compared bird diversity to other forest reserves that, like the STFR, have experienced varying degrees of logging or disturbance (see Appendix III for a full summary of species and family richness across 22 forest reserves in Sabah). Among those on ultramafic soils, Sapagaya Forest Reserve recorded 114 species from 43 families (Joeman et al., 2020a), while Bukit Hampuan yielded 71 species from 33 families (Petol et al., 2021a). Both sites differ from the STFR in elevation: Sapagaya spans lowland dipterocarp to upland ultramafic forest (~880 m a.s.l.), whereas Bukit Hampuan is a lower montane reserve with surveys reaching 1,100 m a.s.l. Despite being

surveyed primarily in lowland to upland forest, the STFR's richness (107 species, 40 families) closely approaches that of Sapagaya and exceeds that of Bukit Hampuan. The STFR also compares favourably with non-ultramafic reserves. Mensalong, for example, recorded 108 species from 42 families (Joeman et al., 2020b), while Mengilan reported 106 species from 41 families (Petol et al., 2021b). In contrast, lower richness was documented in Mount Mandalom (91 species, 38 families; Joeman et al., 2024) and Sungai Tongod (96 species, 38 families; Joeman et al., 2023). These comparisons suggest that the STFR, despite a history of logging and limited elevational coverage, supports avifaunal diversity on par with Sabah's better-known forest reserves.

These comparisons provide a meaningful reference point for evaluating the STFR's bird diversity. To place these findings in a broader context, species richness at more intensively studied sites such as Danum Valley and Deramakot can be considered. Danum Valley, a largely undisturbed lowland dipterocarp forest on fertile sedimentary soils, has recorded over 275 bird species based on formal research (Adam & Omar, 2002; Sheldon et al., 2001, 2014). In contrast, citizen science platforms report higher numbers, with the Cornell Lab of Ornithology's eBird listing 341 species (Cornell Lab of Ornithology, 2024) and Avibase's Bird Checklist of the World reporting 388 species (Lepage, 2025). Deramakot, a selectively logged but well-managed lowland forest on similar sedimentary substrates, supports over 147 species from formal surveys (Bili, 2013), including all eight Bornean hornbills and the Bornean Bristlehead while eBird lists 296 species (Cornell Lab of Ornithology, 2024). Although these sites differ from STFR in terms of soil type and forest management history, their species richness values, derived from both structured research and birdwatching platforms, provide useful upper-bound benchmarks. These figures highlight the conservation value of STFR's avifauna within the broader context of lowland forest diversity in Sabah.

The prevalence of Pycnonotidae and Nectariniidae as the most abundant and species-rich families aligns with patterns observed in other forest reserves, likely reflecting their vagility and adaptability to a range of forest conditions and resource availability. Feeding guild analysis reveals a clear predominance of insectivores and frugivores, comprising 81.84% of species, a figure consistent with the mean of 77.59±6.15% across surveyed reserves (Table 4). This stability in guild proportions, evidenced by the low coefficient of variation (CV=7.92%) for combined insectivorous and frugivorous species, suggests a predictable ecological structure across forest reserves, irrespective of degradation levels or abiotic variables.

Insectivores, represented by 174 individuals across 55 species, likely benefit from the relatively abundant arthropod prey in the STFR's forest understory. However, only the generalist Malaysian Blue Flycatcher (*Cyornis turcosus*) was detected, while more forest-dependent species such as the Sunda Blue (*C. banyumas*) and Bornean Blue Flycatcher (*C. superbus*) were notably absent. This absence aligns with observations by Wong (1986) that specialist blue flycatchers tend to decline in disturbed or regenerating forests. Similarly, although four species of Timaliidae were recorded, none were strict forest specialists. Wong's study highlighted that habitat disturbance disproportionately affects such understory insectivores, particularly among the babbler guild. The persistence of generalist species, such as the Bold-striped Tit-babbler, coupled with the limited presence of microhabitat specialists, suggests that while the STFR retains some key structural features, it may not yet provide the habitat complexity required to support the full complement of specialist insectivores.

In contrast, the Pellorneidae were better represented in the present study, with seven species (15 individuals), including Bornean Black-capped Babbler (*Pellorneum capistratoides*), Bornean Swamp Babbler (*P. macropterum*), Ferruginous Babbler (*P. bicolor*), and Mourning Babbler (*P. malaccense*). Although specific Pellorneidae taxa were not enumerated by Wong (1986), his study highlighted the vulnerability of ground- and understorey-foraging insectivores to habitat disturbance. The presence of multiple Pellorneidae species in the STFR suggests that certain aspects of forest floor and understorey structure, such as leaf litter and dense vegetation, have been retained or have sufficiently recovered. Nonetheless, the absence of more microhabitat-sensitive Timaliidae and specialist flycatchers further underscores that the STFR may still lack the full structural and microclimatic complexity required to support the most disturbance-sensitive components of the insectivore guild.

Frugivores were the second most prevalent feeding guild in the STFR, with 146 individuals across 30 species and 13 families, markedly led by bulbuls (Pycnonotidae; 45 individuals), especially the Cream-vented and Spectacled Bulbuls (11 each), followed by Charlotte's Bulbul (7 individuals). This pattern is consistent with other studies in Malaysian dipterocarp forests, where Pycnonotidae frequently dominate frugivore assemblages in both primary and logged habitats (Shafie et al*.,* 2023). Seasonal studies on Mount Kinabalu further demonstrated that frugivorous bird activity closely follow fruiting phenology, with fluctuations in abundance corresponding to temporal peaks in fruit availability (Kimura et al*.,* 2001). Although neither Wong (1986) nor Pollock et al*.* (2022) systematically addressed frugivores, other regional studies have noted a similar trend: generalist frugivores such as bulbuls tend to persist in regenerating or structurally simplified forests, while more specialised canopy or fig-associated frugivores may decline.

The presence of additional frugivorous taxa in the STFR—including two species of hornbills (seven individuals), five species of barbets (16 individuals), the Bornean Bristlehead (five individuals), two species of flowerpeckers (17 individuals), and two species of leafbirds (18 individuals)—further supports the conclusion that the forest's vertical vegetation structure and fruit resource availability have recovered to a functionally meaningful extent. While some canopy frugivore specialists may still be underrepresented, the observed diversity and abundance of small- to large-bodied frugivores suggest that the STFR is capable of supporting a broad spectrum of frugivore guilds, especially those associated with fruiting shrubs, mid-storey trees, and light-gap canopy species.

Open-area species were scarce, with only six species and 20 individuals recorded. These included the Barn Swallow (*Hirundo rustica*), Pacific Swallow (*Hirundo tahitica*), Javan Myna (*Acridotheres javanicus*), Dusky Munia (*Lonchura fuscans*), Brown-throated Sunbird (*Anthreptes malacensis borneensis*), and Yellow-bellied Prinia (*Prinia flaviventris latrunculus*)—all typical of disturbed or open habitats. In the STFR, the swallows were observed sallying for insects along gravel and earth roads, while the remaining species were confined to grassy verges along these roads—microhabitats that mimic open-country conditions. Their limited distribution supports the view that the STFR's interior remains largely unaffected by edge effects, likely due to its isolation from nearby oil palm estates.

**Table 4:** Comparison of insectivores/frugivores in Sungai Talibu Forest Reserve and in other selected forest reserves (in alphabetical order).

| Forest reserve/ Site | Total no. of species, S | % of insectivorous + frugivorous species | Insectivores | | | | | Frugivores | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % of total individuals | No. of species | % of total species | No. of families | Biomass (g) | % of total individuals | No. of species | % of total species | No. of families | Biomass (g) |
| Balingkadus | 86 | 82.56 | 53.87 | 42 | 48.84 | 22 | 5009.72 | 26.29 | 29 | 32.56 | 10 | 15337.11 |
| Bkt. Gemok | 69 | 72.46 | 47.83 | 33 | 47.83 | 19 | 4641.50 | 24.64 | 17 | 24.64 | 10 | 19178.22 |
| Bkt. Hampuan | 71 | 81.69 | 53.19 | 36 | 50.70 | 21 | 4717.83 | 15.17 | 22 | 28.17 | 8 | 6931.63 |
| Bkt. Mentapok & Bkt. Monkobo | 89 | 76.40 | 48.10 | 40 | 44.94 | 19 | 6772.69 | 35.31 | 28 | 31.46 | 12 | 40155.60 |
| Gn. Tingkar | 114 | 81.58 | 55.81 | 67 | 58.77 | 23 | 11099.95 | 29.66 | 26 | 22.81 | 11 | 29489.30 |
| Kabili-Sepilok | 159 | 72.96 | 57.27 | 77 | 48.43 | 28 | 36673.21 | 25.57 | 39 | 24.53 | 12 | 92924.35 |
| Kawang | 47 | 76.60 | 38.67 | 22 | 46.81 | 15 | 2215.17 | 28.89 | 14 | 29.79 | 9 | 7791.81 |
| Meliau Range | 90 | 68.89 | 47.83 | 42 | 46.67 | 20 | 4382.02 | 25.47 | 20 | 22.22 | 10 | 15169.52 |
| Menghilan | 75 | 85.33 | 54.73 | 40 | 53.33 | 18 | 6947.05 | 25.72 | 24 | 32.00 | 12 | 30802.57 |
| Mensalong | 101 | 81.19 | 42.76 | 48 | 47.52 | 21 | 5988.00 | 43.46 | 34 | 33.66 | 12 | 48088.58 |
| Mt. Mandalom | 92 | 75.00 | 45.65 | 42 | 45.65 | 21 | 3428.49 | 29.35 | 27 | 29.35 | 11 | 16960.58 |
| Nuluhon-Trusmadi (2023 & 2024) | 124 | 83.06 | 49.89 | 76 | 61.29 | 26 | 12347.45 | 24.31 | 27 | 21.77 | 11 | 47149.66 |
| Ranforest Discovery Centre, Sepilok | 154 | 68.18 | 50.09 | 68 | 44.16 | 25 | 54770.35 | 24.44 | 37 | 24.03 | 12 | 133951.61 |
| Sepagaya | 116 | 80.17 | 61.40 | 60 | 51.72 | 26 | 12696.75 | 25.80 | 33 | 28.45 | 13 | 32466.92 |
| Sg. Pin CA | 65 | 60.00 | 46.25 | 26 | 40.00 | 17 | 5168.70 | 21.32 | 13 | 20.00 | 7 | 61184.81 |

*(Continued to next page)*

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sg. Rawog CA (2018) | 120 | 82.50 | 52.50 | 63 | 52.50 | 21 | 19340.52 | 37.13 | 36 | 30.00 | 12 | 22118.96 |
| Sg. Rawog CA (2023) | 88 | 80.68 | 52.56 | 41 | 46.59 | 16 | 5201.18 | 34.88 | 30 | 34.09 | 11 | 53841.33 |
| Sg. Talibu | 107 | 79.44 | 42.70 | 55 | 51.40 | 20 | 6591.83 | 37.30 | 30 | 28.04 | 13 | 40093.34 |
| Sg. Tindikon & Sg. Tikolod | 79 | 79.75 | 57.19 | 39 | 49.37 | 22 | 4237.60 | 21.10 | 24 | 30.38 | 10 | 20690.51 |
| Sg. Tongod | 85 | 80.00 | 54.68 | 44 | 51.76 | 22 | 4389.91 | 34.21 | 24 | 28.24 | 10 | 41824.19 |
| Tawai | 68 | 80.88 | 54.43 | 38 | 55.88 | 17 | 3411.02 | 32.91 | 17 | 25.00 | 9 | 17570.34 |
| **Mean, μ** | 95.19 | 77.59 | 50.83 | 47.57 | 49.72 | 20.90 | 10477.66 | 28.71 | 26.24 | 27.68 | 10.71 | 37796.24 |
| **SD** | 28.43 | 6.15 | 5.64 | 15.51 | 4.95 | 3.42 | 12710.37 | 6.66 | 7.37 | 4.13 | 1.59 | 30044.75 |
| **CV (%)** | **29.87** | **7.92** | **11.09** | **32.60** | **9.95** | **16.36** | **121.31** | **23.19** | **28.11** | **14.94** | **14.80** | **79.49** |

Table 4 compares insectivore and frugivore figures between STFR and other selected forest reserves surveyed by the authors using the ML method. Notably, the percentage of total insectivorous and frugivorous species across all forest reserves showed the least variation (CV = 7.92%), suggesting that this characteristic remains highly consistent and predictable, regardless of factors such as forest quality, past management history, or abiotic influences like precipitation, elevation, and soil types. However, understanding how these dominant feeding guilds interact with other ecological factors in degraded forest reserves to maintain this stability is beyond the scope of these surveys.

Insectivorous and frugivorous birds were the dominant feeding guilds across all sites. At the STFR, they made up 79.4% of the total species recorded, closely matching the overall mean of 77.6% (±6.2%) across all forest reserves, and just below the peak value of 85.3% observed at Mengilan FR. When examined separately, the proportion of insectivores and frugivores—by species count and individual numbers—varied moderately among sites. However, the number of families within each guild was remarkably consistent. Insectivores averaged 20.9 families per site (±3.4; CV = 16.4%), while frugivores averaged 10.7 families (±1.6; CV = 14.8%). These low coefficients of variation suggest a stable taxonomic breadth across sites, despite differences in overall species richness and forest conditions.

Interestingly, we recorded the Scarlet-breasted Flowerpecker (*Prionochilus thoracicus*) but not the Grey-breasted Babbler (*Malacopteron albogulare*), both of which are rare in Sabah and typically associated with ultramafic or peat swamp forests (Davies & Payne, 1982; Sheldon et al., 2009, 2014). The presence of *P. thoracicus* may reflect the distinctive floristic composition of STFR, which is underlain by ultramafic soils, whereas the absence of *M. albogulare* aligns with its generally low detectability and narrower microhabitat requirements. Both species were previously recorded in the peat swamp forest of Klias Forest Reserve, reinforcing their shared affinity for structurally complex and edaphically distinct habitats. Although ultramafic forests are often floristically simple, they provide critical refugia for habitat specialists and disturbance-sensitive birds. The occurrence of *P. thoracicus* in STFR underscores the conservation value of such forests in maintaining regional avifaunal diversity, while the absence of *M. albogulare* may reflect either its naturally low density, patchy distribution, or more likely, its low detectability due to its skulking behaviour, low vocal activity, and preference for dense understory.

## CONCLUSIONS

The avifaunal survey of STFR reveals a relatively rich and diverse bird community (107 species), comparable to other forest reserves surveyed using the ML method, as discussed above. The high proportion of forest-dependent species, along with the presence of habitat-restricted and rare taxa such as the Scarlet-breasted Flowerpecker, Bornean Ground Cuckoo, and Bornean Bristlehead, underscores the reserve's conservation importance. The dominance of families such as Pycnonotidae and Nectariniidae, and the prevalence of insectivorous and frugivorous guilds, reflect a structurally intact forest consistent with patterns observed in other high-integrity reserves. While the survey accounted for 77.5% of the estimated species pool, additional richness is likely in unsampled microhabitats, suggesting that true avifaunal value of the STFR remains

underrepresented. These results support the case for sustained protection and monitoring to safeguard the ecological integrity of the STFR as a stronghold for Sabah unique ultramafic birdlife.

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## DECLARATIONS

**Research permit(s).** Not applicable because the study was conducted as part of an expedition conducted by the Forest Research Centre, Sabah Forestry Department and all authors are staff of the Centre.
**Ethical approval/statement.** Not applicable.
**Generative AI use.** We declare that Grammarly was used to edit this manuscript prior to submission, and was used in compliance with the JTBC policies. We have reviewed and edited the content after using this tool/service, and I/we take(s) full responsibility for the content of the publication.

## REFERENCES

Adam JH, Omar R (2002) Biodiversity of lowland dipterocarp forest in Danum, Lahad Datu, Sabah, Malaysia. In Omar R, Ali Rahman Z, Latif MT, Lihan T and JH Adam (eds.). Proceedings of the Regional Symposium on Environment and Natural Resources Vol 1, Kuala Lumpur. Pp. 450–458.

Anderson AS, Marques TA, Shoo LP, Williams SE (2015) Detectability in audio-visual surveys of tropical rainforest birds: The influence of species, weather and habitat characteristics. PLoS ONE 10(6): e0128464. https://doi.org/10.1371/journal.pone.0128464.

Bach LL, Bailey DM, Harvey ES, MacLeod R (2020) The MacKinnon List Technique: An efficient new method for rapidly assessing biodiversity and species abundance ranks in the marine environment. PLOS ONE. Vol. 5(4): e0231820. https://doi.org/10.1371/journal.pone.0231820.

Bibby CJ, Burgess ND, Hill DA, Hillis D & Mustoe S (2000). Bird Census Techniques (2nd ed.). Academic Press. 257 pp.

Bili R. (2013). Report on wildlife survey within Deramakot Forest Reserve, Sabah. Unpublished report for Sabah Forestry Department. 28 pp.

Bower RP, Burrough PA, Kalsi MS, Thomas P (1975) The soils of Sabah. Land Resource Study 20, Ministry of Overseas Development, Surrey, England. Pp 76–77.

Chao A, Colwell RK, Chiu CH, Townsend D (2017) Seen once or more than once: Applying Good-Turing theory to estimate species richness using only unique observations and a species list. Methods in Ecology and Evolution, Vol. 8. Pp 1221–1232.

Cornell Lab of Ornithology (2024) Merlin Bird ID (Version 2.1.3) [Mobile application software]. https://apps.apple.com/us/app/merlin-bird-id-by-cornell-lab/id773457673. (Accessed 16 June 2025).

Cornell Lab of Ornithology (2025) eBird: Danum Valley Conservation Area Hotspot Checklist. https://ebird.org/hotspot/L1091515/bird-list (Accessed 16 June 2025).

Davies G & Payne J (1982) A faunal survey of Sabah. IUCN/WWF Project No. 1692. Unpublished report. WWF Malaysia, Kuala Lumpur. 286 pp.

Forest Stewardship Council. (2023). FSC principles and criteria for forest stewardship (FSC-STD-01-001 V5-3 EN). Forest Stewardship Council. https://fsc.org/en/document-centre/documents/resource/392. (Accessed 16 June 2025).

Gill F, Donsker D, Rasmussen P (eds.) (2025) IOC World Bird List (v15.1). International Ornithologists' Union. Retrieved from https://www.worldbirdnames.org. (Accessed 16 June 2025).

Haselmayer J, Quinn, JS (2000) A comparison of point counts and sound recording as bird survey methods in Amazonian Southeast Peru. The Condor: Ornitological Applications. Vol. 102-4. Pp 887-893.

Herzog SK, Kessler M, Cahill TM (2002) Estimating species richness of tropical bird communities from rapid assessment data. Auk. Vol. 119. Pp 749–769.

IUCN (2025) The IUCN Red List of Threatened Species. Version 2021-3. https://www.iucnredlist.org. (Accessed 27 March 2025).

Kimura K, Yumoto T, Kikuzawa K (2001) Fruiting phenology of fleshy-fruited plants and seasonal dynamics of frugivorous birds in four vegetation zones on Mt. Kinabalu, Borneo. Journal of Tropical Ecology. Vol. 17(6). Pp 833–858.

Joeman BD, Petol GH, Rudolf V (2019) Avifaunal survey of Ulu Kalang Forest Reserve in the district of Tenom, Sabah, Malaysia. Sepilok Bulletin. Vol. 28. Pp 69–79.

Joeman BD, Petol GH, Lolin L, Rudolf V, Tingkoi L (2020a) Avifaunal survey of Mt Silam and surrounding areas in the district of Lahad Datu, Sabah, Malaysia. In: Chung, AYC, Nilus R, Sugau JB, Suis MAF & Salleh M (eds.). Compilation of Papers – Mount Silam Scientific Expedition, Lahad Datu, Sabah. Sabah Forestry Department, Sandakan, Sabah. Pp. 87–95.

Joeman BD, Petol GH, Lolin L, Rudolf V (2020b) Avifaunal survey of Mensalong Forest Reserve, Ranau, Sabah, Malaysia. Sepilok Bulletin. Vol. 29. Pp 1–10.

Joeman BD, Petol GH, Lolin, L (2023) A brief description of avian communities in Sungai Tongod Forest Reserve, Tongod, Sabah, Malaysia. Journal of Tropical Biology & Conservation. Vol. 20. Pp 173–191.

Joeman BD, Petol GH. Lolin L, Rudolf V, Juvilis JR, Masum B (2024) A brief description of avian communities at Mount Mandalom Forest Reserve in Tenom, Sabah, Malaysia. Sepilok Bulletin. Vol., 33. Pp 14–29.

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

Lepage D (2025) Avibase – The World Bird Database. https://avibase.bsc-eoc.org/checklist.jsp?region=MYsb03&list=howardmoore. (Accessed 16 June 2025)

MacLeod R, Herzog SK, MacCormick A, Ewing SR, Bryce R, Evans KL (2011) Rapid monitoring of species abundance for biodiversity conservation: consistency and reliability of the MacKinnon Lists Technique. Biological Conservation. Vol. 144(5). Pp 1374–1381.

MacKinnon S, Phillipps K (1993) A Field Guide to the Birds of Borneo, Sumatra, Java and Bali, Oxford University Press. 510 pp.

Petol GH, Rudolf V (2019) Avifaunal survey of Sungai Rawog Conservation Area, Segaliud Lokan Forest Reserve. In Proceedings of the Seminar of Sungai Rawog Conservation Area, Scientific Expedition, Segaliud Lokan Forest Reserve (FMU 19B), Sabah Forestry Department & KTS Plantation Sdn. Bhd., 2019. Pp 191–202.

Petol GH, Lolin L, Rudolf V, Chin, TT (2021a) Avifaunal survey of the lower montane forest of Bukit Hampuan Forest Reserve, Ranau, Sabah, Malaysia. Sepilok Bulletin. Vol. 30. Pp19–31.

Petol GH, Lolin L, Rudolf V, Ardianshah YBB (2021b). Avifaunal survey of Mengilan Forest Reserve and its surrounding areas in Pensiangan, Sabah, Malaysia. Journal of Tropical Biology & Conservation. Vol. 18: Pp 215–228.

Petol GH, Lolin L, Rudolf V, Joel F, Petol MN (2022a) Avifaunal survey of Bukit Balingkadus, a small fragmented forest in Ranau, Sabah, Malaysia. Journal of Tropical Biology & Conservation. Vol. 19: Pp109–123.

Petol GH, Lolin L, Rudolf V, Petol MN, Joel F, Juvilis FR, Khairul AR (2022b) An avifaunal survey of Sg. Tindikon & Sg. Tikolod Forest Reserves in Tambunan, Sabah, Malaysia. Sepilok Bulletin. Vol. 31. Pp 50–63.

Petol GH, Lolin L, Joel F, Khairul AR (2024) The potential of avifaunal tourism in Sungai Rawog Conservation Area, Segaliud Lokan Forest Reserve, Sabah, Malaysia. In Proceedings of the Seminar on Sungai Rawog Conservation Area Scientific Expedition Ver 2.0. 29th February, 2024, Kota Kinabalu. Sabah Forestry Department & KTS Plantation Sdn. Bhd. Pp 255–274.

Pollock HS, Toms JD, Tarwater CE, Benson TJ, Karr JR, Brawn JD (2022) Long-term monitoring reveals widespread and severe declines of understory birds in a protected Neotropical forest. Proceedings of the National Academy of Sciences, Vol. 119:e2108731119.

Poulsen BO, Krabbe N, Frølander A, Hinojosa BM, Quiroga OC (1997) A rapid assessment of Bolivian and Ecuadorian montane avifauna using 20-species lists: efficiency, biases and data gathered. Bird Conservation International. Vol. 7. Pp 53–67.

Phillipps Q, Phillipps K (2014) Phillipps' Field Guide to the Birds of Borneo, 3rd Edition. John Beaufoy Publishing Ltd., Oxford, England. 372 pp.

Ralph CJ, Sauer JR, Droege S (eds.) (1995) Monitoring Bird Populations by Point Counts. USDA Forest Service, PSW-GTR-149. 191 pp.

Sabah Forestry Department (2009) 10-year Forest Management Plan for Tangkulap-Pinangah Forest Management Unit No. 17A. 86 pp.

Shafie NJ, Anuar H, David G (2023) Bird species composition, density and feeding guilds in contrasting lowland dipterocarp forests of Terengganu, Peninsular Malaysia. Tropical Ecology. Vol. 64. Pp 238–248.

Sheldon FH, Moyle RG, Kennard J (2001) Ornithology of Sabah: History, gazetteer, annotated checklist, and bibliography. Ornithological Monographs. Vol. 52. Pp 1–285.

Sheldon FH, Lim HC, Nais J, Lakim M, Tuuga A, Malim P, Majuakim J, Lo A, Schilthuizen M, Hosner PA, Moyle RG (2009) Observations on the ecology, distribution, and biogeography of forest birds in Sabah, Malaysia. Raffles Bulletin of Zoology. Vol 57. Pp 577–586.

Sheldon FH, Davison G, Wong A, Moyle RG (2014) Birds in peatswamp at Klias Forest Reserve and environs, Sabah, Malaysian Borneo. Occasional Papers of the Museum of Natural Science, Louisiana State University. Vol. 83. Pp 1–29.

Wells DR (1999) Birds of the Thai-Malay Peninsula: Volume I: Non-Passerines. Academic Press London, UK. 638 pp.

Wells DR (2007) The birds of the Thai-Malay Peninsula. Volume II: Passerines. Christopher Helm, London. 800 pp.

Wong, M (1986) Trophic organization of understory birds in a Malaysian dipterocarp forest. Auk. Vol. 103. Pp 100–116.

Xeno-canto Foundation. (2025). Xeno-canto: Sharing bird sounds from around the world. https://www.xeno-canto.org (Accessed 13 August 2025).

Yong DL, Sodhi NS, Koh LP, Peh KSH, Lee TM, Lim HC, Lim SLH (2011) Do insectivorous bird communities decline on land-bridge forest islands in Peninsular Malaysia? Journal of Tropical Ecology. Vol. 27(1). Pp 1–14.

## APPENDIX I

### Complete list of bird species recorded in May 2024 at the Sungai Talibu Forest Reserve (Class I), Telupid, Sabah, Malaysia.

Common names are sorted alphabetically. Names in bold denote Bornean endemics. All taxa are according to the classification in Gill et al. (2025) and conservation status is according to IUCN Red List (2025).

| Common name | Species | Family |
|---|---|---|
| Ashy Tailorbird | *Orthotomus ruficeps borneoensis* | Cisticolidae |
| Asian Fairy-bluebird | *Irena puella* | Irenidae |
| Asian Red-eyed Bulbul | *Pycnonotus brunneus brunneus* | Pycnonotidae |
| Banded Bay Cuckoo | *Cacomantis sonneratii* | Cuculidae |
| Banded Broadbill | *Eurylaimus javanicus* | Eurylaimidae |
| Barn Swallow | *Hirundo rustica* | Hirundinidae |
| Black-and-red Broadbill | *Cynbirhynchus macrorhynhos macrorhychus* | Eurylaimidae |
| Black-and-yellow Broadbill | *Eurylaimus ochromalus* | Eurylaimidae |
| Black-bellied Malkoha | *Phaenicophaeus diardi* | Cuculidae |
| Black-eared Barbet | *Psilopogon duvaucelii* | Megalaimidae |
| Black-headed Bulbul | *Brachypodius melanocephalos* | Pycnonotidae |
| Black-naped Monarch | *Hypothymis azurea* | Monarchidae |
| Blue-crowned Hanging Parrot | *Loriculus galgulus* | Psittaculidae |
| Blue-eared Kingfisher | *Alcedo meninting meninting* | Alcedinidae |
| Blyth's Paradise Flycatcher | *Terpsiphone affinis borneensis* | Monarchidae |
| Bold-striped Tit-babbler | *Mixornis bornensis* | Timaliidae |
| **Bornean Black-capped Babbler** | *Pellorneum capistratoides* | Pellorneidae |
| **Bornean Bristlehead** | *Pityriasis gymnocephala* | Pityriasidae |
| **Bornean Brown Barbet** | *Calorhamphus fuliginosus* | Megalaimidae |
| **Bornean Ground Cuckoo** | *Carpococcyx radiceus* | Cuculidae |
| Brown Boobook | *Ninox scutulata borneensis* | Strigidae |
| Brown Fulvetta | *Alcippe brunneicauda* | Alcippeidae |
| Brown-backed Needletail | *Hirundapus giganteus giganteus* | Apodidae |
| Brown-throated Sunbird | *Anthreptes malacensis bornensis* | Nectariniidae |
| Buff-rumped Woodpecker | *Meiglyptes grammithorax* | Picidae |
| Buffy Fish Owl | *Ketupa ketupu pageli* | Strigidae |
| Changeable Hawk-eagle | *Nisaetus cirrhatus* | Accipitridae |
| **Charlotte's Bulbul** | *Iole charlotte* | Pycnonotidae |
| Common Hill Myna | *Gracula religiosa religiosa* | Sturnidae |
| **Cream-eyed Bulbul** | *Pycnonotus pseudosimplex* | Pycnonotidae |
| Cream-vented Bulbul | *Pycnonotus simplex perplexus* | Pycnonotidae |
| Crested Serpent Eagle | *Spilornis cheela* | Accipitridae |
| Dark-necked Tailorbird | *Orthotomus atrogularis humphreysi* | Cisticolidae |
| Diard's Trogon | *Harpactes diardii* | Trogonidae |
| **Dusky Munia** | *Lonchura fuscans* | Estrildidae |
| Everett's White-eye | *Zosterops everetti* | Zosteropidae |
| Ferruginous Babbler | *Pellorneum bicolor* | Pellorneidae |
| Finsch's Bulbul | *Iole finschii* | Pycnonotidae |
| Great Argus | *Argusianus argus grayi* | Phasianidae |
| Great Slaty Woodpecker | *Mulleripicus pulverulentus* | Picidae |
| Greater Green Leafbird | *Chloropsis sonnerati zosterops* | Chloropseidae |
| Greater Racquet-tailed Drongo | *Dicrurus paradiseus* | Dicruridae |

| | | |
|---|---|---|
| Green Broadbill | *Calyptomena viridis gloriosa* | Calyptomenidae |
| Green Iora | *Aegithina viridissima* | Aegithinidae |
| Grey-bellied Bulbul | *Ixodia cyaniventris paroticalis* | Pycnonotidae |
| Grey-hooded Babbler | *Cyanoderma bicolor bicolor* | Timaliidae |
| Grey-rumped Treeswift | *Hemiprocne longipennis harterti* | Hemiprocnidae |
| Hairy-backed Bulbul | *Tricholestes criniger* | Pycnonotidae |
| Helmeted Hornbill | *Rhinoplex vigil* | Bucerotidae |
| Horsfield's Babbler | *Malacocincla sepiaria* | Pellorneidae |
| Indian Cuckoo | *Cuculus micropterus concretus* | Cuculidae |
| Javan Myna | *Acridotheres javanicus* | Sturnidae |
| Lesser Green Leafbird | *Chloropsis cyanopogon cyanopogon* | Chloropseidae |
| Little Green Pigeon | *Treron olax* | Columbidae |
| Little Spiderhunter | *Arachnothera longirostra buettikoferi* | Nectariniidae |
| Long-billed Spiderhunter | *Arachnothera robusta robusta* | Nectariniidae |
| Long-tailed Parakeet | *Psittacula longicauda longicauda* | Psittaculidae |
| Malaysian Blue Flycatcher | *Cyornis turcosus* | Muscicapidae |
| Malaysian Pied Fantail | *Rhipidura javanica longicauda* | Rhipiduridae |
| Orange-backed Woodpecker | *Reinwardtipicus validus xanthopygius* | Picidae |
| Orange-bellied Flowerpecker | *Dicaeum trigonostigma dayakanum* | Dicaeidae |
| Oriental Dollarbird | *Eurystomus orientalis orientalis* | Coraciidae |
| Oriental Dwarf Kingfisher | *Ceyx erithaca motleyi* | Alcedinidae |
| Pacific Swallow | *Hirundo tahitica* | Hirundinidae |
| Plaintive Cuckoo | *Cacomantis merulinus threnodes* | Cuculidae |
| Plume-toed Swiftlet | *Collocalia affinis cyanoptila* | Apodidae |
| Purple-naped Spiderhunter | *Kurochkinegramma hypogrammicum* | Nectariniidae |
| Raffles's Malkoha | *Rhinortha chlorophaea* | Cuculidae |
| Red-bearded Bee-eater | *Nyctyornis amictus* | Meropidae |
| Red-billed Malkoha | *Zanclostomus javanicus pallidus* | Cuculidae |
| Red-crowned Barbet | *Psilopogon rafflesii* | Megalaimidae |
| Red-naped Trogon | *Harpactes kasumba* | Trogonidae |
| Red-throated Barbet | *Psilopogon mystacophanos* | Megalaimidae |
| Rhinoceros Hornbill | *Buceros rhinoceros* | Bucerotidae |
| Rufous Piculet | *Sasia abnormis* | Picidae |
| Rufous-collared Kingfisher | *Actenoides concretus borneanus* | Alcedinidae |
| Rufous-crowned Babbler | *Malacopteron magnum saba* | Pellorneidae |
| Rufous-fronted Babbler | *Cyanoderma rufifrons* | Timaliidae |
| Rufous-tailed Shama | *Copsychus pyrropygus* | Muscicapidae |
| Rufous-tailed Tailorbird | *Orthotomus sericeus sericeus* | Cisticolidae |
| Rufous-winged Philentoma | *Philentoma pyrhoptera pyrhoptera* | Vangidae |
| Scarlet Minivet | *Pericrocotus speciosus insulanus* | Campephagidae |
| Scarlet-breasted Flowerpecker | *Prionochilus thoracicus* | Dicaeidae |
| Scarlet-rumped Trogon | *Harpactes duvaucelii* | Trogonidae |
| Short-tailed Babbler | *Pellorneum malaccense poliogene* | Pellorneidae |
| Silver-rumped Spinetail | *Rhaphidura leucopygialis* | Apodidae |
| Slender-billed Crow | *Corvus enca compilator* | Corvidae |
| Sooty-capped Babbler | *Malacopteron affine phoeniceum* | Pellorneidae |
| Spectacled Bulbul | *Ixodia erythropthalmos* | Pycnonotidae |
| Spectacled Spiderhunter | *Arachnothera flavigaster* | Nectariniidae |
| Spotted Dove | *Spilopelia chinensis tigrina* | Columbidae |
| Square-tailed Drongo-cuckoo | *Surniculus lugubris brachyurus* | Cuculidae |
| Stork-billed Kingfisher | *Pelargopsis capensis inominata* | Alcedinidae |
| Streaked Bulbul | *Ixos malaccensis* | Pycnonotidae |
| Sunda Scimitar-Babbler | *Pomatorhinus bornensis* | Timaliidae |
| Sunda Scops Owl | *Otus lempiji lempiji* | Strigidae |
| Temminck's Sunbird | *Aethopyga temminckii* | Nectariniidae |

| | | |
|---|---|---|
| Thick-billed Spiderhunter | *Arachnothera crassirostris* | Nectariniidae |
| Van Hasselt's Sunbird | *Leptocoma brasiliana brasiliana* | Nectariniidae |
| Ventriloquial Oriole | *Oriolus consobrinus* | Oriolidae |
| Verditer Flycatcher | *Eumyias thalassina* | Muscicapidae |
| Whiskered Treeswift | *Hemiprocne comata comata* | Hemiprocnidae |
| White-bellied Woodpecker | *Dryocopus javensis javensis* | Picidae |
| White-chested Babbler | *Pellorneum rostratum macropterum* | Pellorneidae |
| **White-crowned Shama** | *Copsychus stricklandi* | Muscicapidae |
| Yellow-bellied Prinia | *Prinia flaviventris latrunculus* | Cisticolidae |
| Yellow-crowned Barbet | *Psilopogon henricii brachyrhynchus* | Megalaimidae |

## APPENDIX II

### Bird families recorded in May 2024 at the Sungai Talibu Forest Reserve (Class I), Telupid, Sabah, Malaysia.

The list is sorted according to the highest number of species.

| Family | No. of species | No. of individuals |
|---|---|---|
| Pycnonotidae | 10 | 45 |
| Nectariniidae | 8 | 41 |
| Cuculidae | 8 | 22 |
| Pellorneidae | 7 | 15 |
| Megalaimidae | 5 | 16 |
| Picidae | 5 | 8 |
| Timaliidae | 4 | 22 |
| Cisticolidae | 4 | 14 |
| Muscicapidae | 4 | 9 |
| Alcedinidae | 4 | 5 |
| Apodidae | 3 | 10 |
| Eurylaimidae | 3 | 10 |
| Trogonidae | 3 | 4 |
| Strigidae | 3 | 3 |
| Psittaculidae | 2 | 19 |
| Chloropseidae | 2 | 18 |
| Dicaeidae | 2 | 17 |
| Monarchidae | 2 | 15 |
| Hemiprocnidae | 2 | 8 |
| Bucerotidae | 2 | 7 |
| Sturnidae | 2 | 7 |
| Accipitridae | 2 | 4 |
| Hirundinidae | 2 | 4 |
| Columbidae | 2 | 2 |
| Aegithinidae | 1 | 13 |
| Phasianidae | 1 | 9 |
| Estrildidae | 1 | 8 |
| Zosteropidae | 1 | 7 |
| Pityriasidae | 1 | 5 |
| Oriolidae | 1 | 4 |
| Alcippeidae | 1 | 3 |
| Calyptomenidae | 1 | 2 |
| Campephagidae | 1 | 2 |
| Coraciidae | 1 | 2 |
| Corvidae | 1 | 2 |
| Dicruridae | 1 | 2 |
| Meropidae | 1 | 2 |
| Rhipiduridae | 1 | 2 |
| Vangidae | 1 | 2 |
| Irenidae | 1 | 1 |

# APPENDIX III

## Bird diversity metrics from 22 forest reserves and sites in Sabah, Malaysia.[1]

| Forest Reserve/Site | No. of individuals | H' | $H_{max}$ | $E_H$ | No. of species, S | $Num_{eff}$ | Chao1 est. | No. of families | Habitat type | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Balingkadus | 388 | 3.890 | 4.45 | 0.87 | 86 | 48.91 | 114.00 | 37 | Disturbed upland & montane ultramafic forest | Petol et al., 2022a |
| Bukit Gemok | 273 | 3.870 | 4.23 | 0.91 | 69 | 47.94 | 91.13 | 34 | Isolated, disturbed lowland MDF | Surveyed 2019, unpubl. data |
| Bukit Hampuan | 408 | 3.440 | 4.26 | 0.81 | 71 | 31.19 | 90.50 | 33 | Isolated, heavily disturbed upland & lower montane ultramafic forest | Petol et al., 2021a |
| Bukit Mentapok & Bukit Mongkobo | 422 | 4.016 | 4.49 | 0.89 | 89 | 55.47 | 114.25 | 37 | Lowland to upland MDF & montane | Surveyed 2024 at northern uplands, unpubl. data |
| Gn. Tingkar | 654 | 4.270 | 4.74 | 0.90 | 114 | 71.52 | 135.63 | 38 | Old-growth logged lowland MDF | Surveyed 2020, unpubl. data |
| Kabili-Sepilok* | 1306 | 4.460 | 5.07 | 0.88 | 159 | 86.47 | 195.24 | 53 | Undisturbed lowland MDF | Surveyed 2019, unpubl. Data |
| Kawang | 225 | 3.390 | 3.85 | 0.88 | 47 | 29.67 | 60.02 | 29 | Disturbed lowland to upland MDF | In print |
| Meliau Range | 161 | 4.325 | 4.50 | 0.96 | 90 | 75.57 | 156.18 | 39 | Logged-over lowland to montane ultramafic forest | Surveyed 2025 at northern lowland ultramafic forest, unpubl. Data |
| Menghilan | 486 | 3.860 | 4.32 | 0.89 | 75 | 47.47 | 91.00 | 33 | Logged-over upland MDF & lower montane kerangas forest | Petol et al., 2021b. Surveyed at upland MDF. |
| Mensalong | 566 | 4.180 | 4.62 | 0.91 | 101 | 65.37 | 118.00 | 37 | Logged-over lowland & upland MDF | Joeman et al., 2020b |
| Mt. Mandalom | 242 | 4.250 | 4.52 | 0.94 | 92 | 70.11 | 133.31 | 38 | Logged-over lowland & upland MDF | Joeman et al., 2024 |
| Nuluhon-Trusmadi (cumulative) | 946 | 3.968 | 4.83 | 0.82 | 124 | 52.88 | 163.00 | 45 | Old-growth logged-over montane forest | Surveyed 2023 & 2024, unpubl. data |
| Rainforest Discovery Centre, Sepilok‡ | 2296 | 4.372 | 5.04 | 0.87 | 154 | 79.20 | 169.83 | 45 | Old-growth logged lowland MDF | Surveyed 2020, unpubl. data |
| Sepagaya | 624 | 4.170 | 4.74 | 0.88 | 114 | 64.72 | 146.56 | 43 | Lowland ultramafic & MDF forest | Joeman et al., 2020a |
| Sg. Talibu | 391 | 3.880 | 4.17 | 0.87 | 107 | 37.34 | 138.00 | 40 | Logged-over ultramafic forest | Current publication |
| Sg. Tindikon & Sg. Tikolod | 328 | 3.670 | 4.79 | 0.91 | 79 | 79.04 | 109.26 | 36 | Disturbed upland MDF | Petol et al., 2022b. |
| Sg. Tongod | 342 | 4.070 | 4.48 | 0.92 | 85 | 62.18 | 144.44 | 38 | Logged-over lowland & upland MDF | Joeman et al., 2023 |
| Sg. Pin Conservation Area | 333 | 3.620 | 4.67 | 0.83 | 65 | 48.42 | 83.78 | 33 | Disturbed lowland riverine forest | Surveyed 2025, unpubl. data |
| Sg. Rawog CA (cummulative) | 1072 | 4.490 | 4.94 | 0.91 | 140 | 89.12 | 162.78 | 44 | Logged-over MDF | Petol & Rudolf (2019), Petol et al. (2024), cumulative data unpubl. |
| Tawai | 158 | 3.940 | 4.44 | 0.92 | 68 | 58.56 | 100.43 | 29 | Lowland to montane ultramafic forest | Surveyed 2024, unpubl. data, surveyed at northern lowlands |
| Timbah & Tangkulap | 639 | 3.950 | 4.22 | 0.93 | 92 | 51.42 | 108.24 | 38 | Logged-over lowland & upland MDF | Surveyed 2025, unpubl. data |
| Ulu Kalang | 261 | 4.020 | 4.52 | 0.87 | 85 | 51.94 | 115.18 | 36 | Disturbed upland MDF | Joeman et al., 2019. |
| **Mean, μ** | 569 | 4.005 | 4.54 | 0.89 | 95.73 | 59.29 | 124.58 | 37.95 | | |
| **Std dev** | 486 | 0.301 | 0.30 | 0.04 | 28.90 | 16.67 | 33.03 | 5.58 | | |
| **CV** | 85.42 | 7.524 | 6.61 | 4.24 | 30.19 | 28.12 | 26.51 | 14.69 | | |

‡30-day survey.
* 4-day survey, 2 teams.
[1]For sites without corresponding publications, all species data and diversity metrics are derived from the authors' original field surveys (2018–2025) and remain unpublished.