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Source: Bulletin of the British Ornithologists' Club, 138(1) : 45-66

Published By: British Ornithologists' Club

URL: https://doi.org/10.25226/bboc.v138i1.2018.a6

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Preliminary assessment of community composition and phylogeographic relationships of the birds of the Meratus Mountains, south-east Borneo, Indonesia

by Subir B. Shakya, Tri Haryoko, Ryan C. Burner, Dewi M. Prawiradilaga & Frederick H. Sheldon

Received 4 December 2017; revised 9 January 2018; published 22 March 2018

http://zoobank.org/urn:lsid:zoobank.org:pub:C28ADC34-7917-4413-8CE8-084480AA9E19

Summary.—The Meratus Mountains of south-east Borneo are biogeographically interesting due to their isolation and potential endemicity. However, Meratus' birds have never been quantitatively surveyed or collected, so we know little of their community structure or taxonomy. In May 2017, we visited Mt. Besar in the Meratus range to assess its avifauna and collect specimens for phylogeographic study. Here, we report on Mt. Besar's avifauna and provide preliminary ND2-sequence assessments of their relationships. We recorded 89 species, of which we collected 68 species; 17 represented distributional extensions. Mt. Besar's avian community is depauperate compared to Borneo's main mountains, and several of its species exhibit unusual elevational abundance patterns. We attribute these findings to the range's small area, low elevation, isolation from other mountains, depleted surrounding native lowland forest, and exploitation for food and pet-trading. ND2 comparisons indicate that at least 12 Meratus species exhibit population structure that merits additional phylogeographic study.

The island of Borneo is well known for its impressive avian diversity, which includes at least 373 breeding landbird and 52 endemic species, depending on classification (Dickinson & Remsen 2013, Dickinson & Christidis 2014, Sheldon *et al*. 2015, Eaton *et al*. 2016c, Clements *et al*. 2017). This remarkable diversity hinges on the island's wide range of habitats, from low-elevation mixed-dipterocarp, peatswamp and kerangas forests to montane moss forests and ericaceous heath. Although most of Borneo's avian diversity inhabits the lowlands, the island's montane forests are particularly important in terms of biogeographic history, not only of the island itself but the Greater Sundas as a whole (de Bruyn *et al*. 2014, Sheldon *et al*. 2015). Borneo's mountains include the main central range, which runs north-east to south-west across most of the island and features several peaks above 2,000 m in elevation, one of which, Mt. Kinabalu, reaches 4,095 m (Fig. 1). There are also numerous smaller ranges and peaks that are isolated from the main range by areas of low elevation. As a group, Borneo's mountains—especially those on the eastern side of the island—are thought to have played a key role in fomenting and preserving much of South-East Asia's avian diversity (de Bruyn *et al*. 2014, Sheldon *et al*. 2015). The mountains supported rainforest continuously during dramatic climatic changes in the Oligocene, Pliocene and Pleistocene, when colder temperatures extirpated rainforest over much of the rest of Sundaland in favour of seasonal forest and even grasslands (Bird *et al*. 2005, Morley 2012, Sheldon *et al*. 2015). However, despite the biogeographic importance of Borneo's mountains, remarkably little is known concerning the evolution and ecology of birds there, especially those occurring in mountains outside the Malaysian states of Sarawak and Sabah. This is particularly true of birds in the Meratus range of south-east Borneo. These mountains have rarely been visited by ornithologists or birdwatchers (Davison 1997, Eaton *et al*. 2016a), and their birds have

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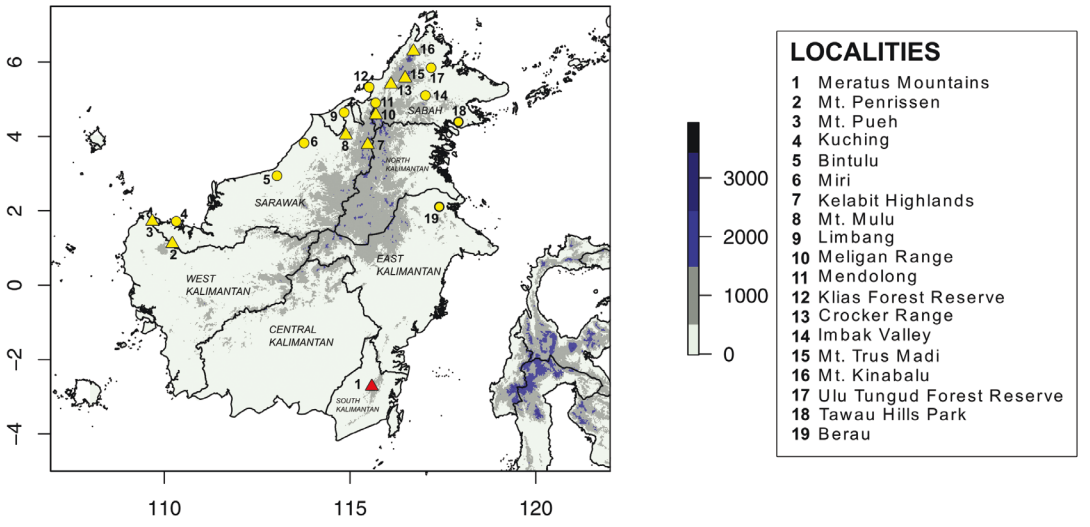


Figure 1. Map of Borneo showing the location of the Meratus and other mountain ranges.

never been surveyed quantitatively or collected for taxonomic study. As a result, we know little concerning the biogeographic relationships or community composition of the Meratus avifauna.

The Meratus Mountains are a low-elevation range skirting the south-east corner of Borneo in the Indonesian province of South Kalimantan (Fig. 1). They run north-northeast and are *c*.300 km in length and 65 km wide (Witts *et al*. 2012), with a highest point at Mt. Besar (1,901 m). The mountains consist mainly of an early Cretaceous volcanic arc and ophiolite sequence (Moss & Wilson 1998) but, like Mt. Kinabalu, they are relatively young, having arisen in the middle to late Miocene as a result of collision and subduction of continental plates on Borneo's south-eastern side (Witts *et al*. 2012). Their potential as a Pleistocene refugium and area of high endemicity has long been appreciated (MacKinnon *et al*. 1996, Gathorne-Hardy *et al*. 2002, Quek *et al*. 2007, Raes *et al*. 2009). Most forest in the Meratus Mountains is intact compared to the surrounding lowlands, but it is largely unprotected from logging and development, except the southern section, which lies within the Martapura-Pleihari Reserve (Holmes & Burton 1987, Davison 1997).

To date, only two surveys of Meratus birds have been published. Davison (1997) visited these mountains between 30 September and 10 October 1996. He identified 80 species above 800 m, expanding the known range of 21 montane specialists (*sensu* Wells 1985). Eaton *et al*. (2016a) visited the mountains on 7–10 July 2016. They observed, audio-recorded and photographed birds, identified 91 species, expanded the known range of several species, and discovered what they believed to be new species of *Cyornis* and *Zosterops*. Both expeditions approached the range from the west via Loksado (*c*.200 m) and the village of Kadayang (*c*.500 m). Davison (1997) reached close to the top of Mt. Karokangan (1,686 m), while Eaton *et al*. (2016a) reached the peak of Mt. Besar (1,901 m). Both noted that forest was heavily disturbed below 900 m, where rugged limestone outcrops appear (Davison 1997), and mildly disturbed above this elevation. The discoveries made by these two expeditions highlight the potential importance of the Meratus Mountains to understanding the evolution of avian diversity on Borneo.

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Louisiana State University Museum of Natural Science (LSUMNS) and the Museum Zoologicum Bogoriense, Indonesian Institute of Sciences (MZB), conducted a joint expedition to Mt. Besar on 1–19 May 2017. The primary purpose was to obtain molecular and morphological specimens for use in ongoing studies of Sundaic avian biogeography (e.g., Lim *et al*. 2011, Lim & Sheldon 2011, Chua *et al*. 2017, Lim *et al*. 2017, Moyle *et al*. 2017). We were also interested in the elevational distribution of birds in the Meratus Mountains, and how this distribution compares with montane communities examined elsewhere on Borneo (e.g., Harris *et al*. 2012, Burner *et al*. 2016). Here, we report on the expedition, approximate distribution of birds in the Mt. Besar region, and findings of preliminary molecular phylogeographic comparisons.

Methods

Expedition.—Our team comprised three researchers from LSUMNS (SBS, RCB, FHS), a researcher (TH) and field technician from MZB (Suparno), and a variety of local guides and porters. Like Davison (1997) and Eaton *et al*. (2016a), we approached Mt. Besar from Loksado in the Hulu Sungai Selatan regency of South Kalimantan province. We travelled from Loksado to the village of Kadayang (02°44′47″S, 115°33′20″E; 500 m), where we mist-netted birds on 1–6 May 2017. Near Kadayang, virtually all forest had been converted to (mostly overgrown) rubber, plots of hill rice, and gardens. On 6 May, we established camp on the Mt. Besar summit trail at a site known locally as 'Matupa' (02°43′30″S, 115°35′11″E; 1,150 m). We remained at this site until 19 May, setting mist-nets along the main ridge at 1,100–1,200 m and along another ridge at 1,350 m (02°43′22″S, 115°35′35″E). As noted by earlier expeditions, rubber plantation and shifting cultivation gave way to less disturbed forest at *c*.900–1,000 m. The forest above 1,000 m was largely intact, although there were some cleared areas of varying age, and footpaths were heavily trafficked by hunters armed with air guns (pellet guns) and persons seeking forest products.

Elevational records.—Avian species were sampled using mist-nets and by opportunistic observation based on visual and aural detections. Team members noted all species heard or seen during the trip, but most of our effort was directed towards mist-netting and specimen preparation.

Comparative analysis.—For morphometric comparisons we measured bill length, width and depth (all at the rear of the nares), as well as tail length, diagonal tarsus and flat wing-chord length.

We compared mitochondrial ND2 sequences of 41 species from Mt. Besar with sequences from populations in other parts of South-East Asia as available (Appendices 1–2). ND2 was used because it is the most commonly sequenced avian gene and numerous sequences were available in GenBank. When possible, we compared two individuals from each population, and included outgroups for perspective. Total genomic DNA from preserved tissues was extracted using DNEasy® Blood and Tissue Kit (Qiagen) following the manufacturers' protocol. PCR amplifications were performed in 25 µl reactions using Taq DNA Polymerase (New England BioLabs Inc.) and ND2 primers L5215 (Hackett 1996) and HTrpC (STRI). Amplification consisted of 34 cycles at a denaturing temperature of 95°C, an annealing temperature of 54°C and an extension temperature of 72°C. We visualised the PCR products in 1.5% agarose gel stained with SYBR® Safe DNA Gel Stain (Invitrogen). Samples were sequenced at Macrogen USA (Rockville, MD). The ND2 sequences were assembled in Geneious 8.1.9 (Biomatters) and aligned using MUSCLE (Edgar 2004) implemented in Geneious. We generated mitochondrial gene trees using the maximum likelihood (ML) framework in RAxML 8 (Stamatakis 2014), with 1,000 bootstrap replicates, through the CIPRES Science Gateway (Miller *et al*. 2010).

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Results

Expedition.—We recorded 89 species on Mt. Besar (Appendix 1), of which 68 were collected. Of the species recorded, 17 were new for the Meratus Mountains (marked with double asterisks in Appendix 1). Most notable among these was Bornean Spiderhunter *Arachnothera everetti*, the first record of this species outside Borneo's main mountain chain (Mann 2008, Brickle *et al*. 2010, Burner *et al*. 2016, Moyle *et al*. 2017). Its occurrence in the Meratus Mountains mirrors Bornean Leafbird *Chloropsis kinabaluensis*, which until it was discovered in the Meratus Mountains by Eaton *et al*. (2016a) was also thought to be restricted to Borneo's main mountain chain (Mann 2008, Moyle *et al*. 2011, 2017). Two of our 'new' Meratus records, Black-backed Dwarf Kingfisher *Ceyx erithaca* and Pin-tailed Parrotfinch *Erythrura prasina*, were anticipated by Davison (1997) from discussions with villagers. Some usually easily detected species recorded by Davison (1997) were not found by us or by Eaton *et al.* (2016a), most notably Helmeted Hornbill *Buceros vigil*, Oriental Magpie-Robin *Copsychus saularis*, White-rumped Shama *C. malabaricus* and Grey-cheeked Bulbul *Alophoixus bres.* These species are highly sought by hunters and pet traders (Eaton *et al*. 2016b), and probably have been extirpated from the area we visited.

Elevational records.—Elevational ranges of most species detected on Mt. Besar were within the limits known from other parts of Borneo. However, some patterns of species occurrence appeared unusual. Several species that are common at the same elevations in similar forest in other parts of Borneo were absent or found in low numbers on Mt. Besar. These include species that are generally common and conspicuous at 500 m, such as Grey-bellied Bulbul *Pycnonotus cyaniventris*, Spectacled Bulbul *P. erythropthalmos*, Yellow-bellied Bulbul *Alophoixus phaeocephalus*, Fluffy-backed Tit-Babbler *Macronus ptilosus*, Rufous-fronted Babbler *Cyanoderma rufifrons*, Rufous-crowned Babbler *Malacopteron magnum* and Short-tailed Babbler *Pellorneum malaccense*. Other 'missing' species were Rufous-winged Philentoma *Philentoma pyrhoptera*, Green Iora *Aegithina viridissima*, Blyth's Paradise Flycatcher *Terpsiphone affinis* and Pale Blue Flycatcher *Cyornis unicolor*. Another unusual feature of the bird community at 500–1,200 m was that its commonest species (based on capture and incidental observations) was Hill Blue Flycatcher *Cyornis banyumas*, which is generally uncommon and restricted to a narrow submontane elevational band in other parts of Borneo. Other slope specialists that are principally montane elsewhere in Borneo but occurred in unusually large numbers at 500 m on Mt. Besar were Grey-throated Babbler *Stachyris nigriceps* and Temminck's Babbler *Pellorneum pyrrogenys.* Their abundance near Kadayang was remarkable. At higher elevation, *c*.1,300–1,400 m, some usually scarce species were remarkably common, e.g., Bornean Stubtail *Urosphena whiteheadi*. In contrast, a species that is generally common and easy to mist-net in the main Bornean mountain range, Chestnut-hooded Laughingthrush *Ianthocincla treacheri*, was rarely seen and only occasionally heard (see Discussion).

Genetic and morphological comparisons.—Of the 41 Meratus species whose ND2 we compared, 23 were not obviously distinct from populations sampled elsewhere on Borneo, i.e., their phylogeographic trees had little branching structure, and their ND2 divergence values averaged less than 1%: Plaintive Cuckoo *Cacomantis merulinus*, Rufous Piculet *Sasia abnormis*, Malaysian Pied Fantail *Rhipidura javanica*, White-throated Fantail *R. albicollis*, Spotted Fantail *R. perlata*, Ashy Drongo *Dicrurus leucophaeus*, Bornean Treepie *Dendrocitta cinerascens*, Ashy Bulbul *Hemixos flavala*, Mountain Leaf Warbler *Phylloscopus trivirgatus*, Yellow-breasted Warbler *Seicercus montis*, Rufous-tailed Tailorbird *Orthotomus sericeus*, Scaly-crowned Babbler *Malacopteron cinereum*, Brown Fulvetta *Alcippe brunneicauda*, *Pellorneum pyrrogenys*, *Ianthocincla treacheri*, Rufous-chested Flycatcher *Ficedula dumetoria*,

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Little Pied Flycatcher *F. westermanni*, Eyebrowed Jungle Flycatcher *Vauriella gularis*, *Chloropsis kinabaluensis*, Chestnut-crested Yuhina *Yuhina everetti*, *Arachnothera everetti*, Little Spiderhunter *A. longirostra* and Purple-naped Spiderhunter *A. hypogrammicum.* In six cases, we did not possess an adequate number of specimens or sequences to speculate on patterns of population structure: Bornean Barbet *Psilopogon eximius*, Grey-chinned Minivet *Pericrocotus solaris*, Blyth's Shrike-Babbler *Pteruthius aeralatus*, *Urosphena whiteheadi*, Mountain Tailorbird *Phyllergates cucullatus* and Indigo Flycatcher *Eumyias indigo*. However, the remaining 12 species exhibited phylogeographic patterns worthy of further work. We depict these patterns in Fig. 2 and describe them briefly below, but caution that population genetic parameters have not been examined in detail. Also, note that mitochondrial trees sometimes indicate incorrect population structure (see Bornean examples in Lim *et al*. 2017, Manthey *et al*. 2017). The rooted trees in Fig. 2, therefore, are intended only as preliminary guides for future investigation.

Bornean Whistler *Pachycephala hypoxantha*.—Meratus individuals form a clade separate from other Bornean individuals, but divergence between the populations is not large (*c*.1%).

Ochraceous Bulbul *Alophoixus ochraceus*.—The Meratus population differs by 4.5% from both *A. o. ruficrissus* (Sabah specimens) and *A. o. fowleri* (Sarawak specimens), which are also distinct genetically from each other (Chua *et al*. 2017). All three populations differ in plumage (Table 1). The Sabah and Sarawak populations lack yellow pigment in their plumage, causing them to appear distinct from other populations of *A. ochraceus*. Indeed, the Meratus individuals look more like Sumatran than northern Bornean birds, raising the possibility of multiple invasions of Borneo. Confusion is also wrought by paraphyly of *A. ochraceus* and Grey-cheeked Bulbul *A. bres* as traditionally constituted; *A. ochraceus* of Sabah is sister to *A. bres* of Java (Fuchs *et al*. 2015, Collar 2017). *A. ochraceus* and *A. bres* populations among all of the Greater Sundas and the Malay Peninsula should be compared before their scientific names are revised.

Lemon-bellied White-eye *Zosterops chloris*.—This is one of the taxa identified as a new species by Eaton *et al*. (2016a). ND2 comparisons with 45 other species of white-eyes, including the genera *Zosterops*, *Lophozosterops*, *Speirops* and *Chlorocharis* (mostly from Moyle *et al*. 2009), reveal the Meratus population to be most closely related to *Z. chloris* (ND2 divergence 2.69%). This finding makes general biogeographic sense, because *Z. chloris* occurs from Wallacea west across some islands of the Java Sea to Karimata and Belitung (van Balen 2017). The occupied islands include Kalambau and Solombo Besar near the south-east corner of Borneo (Clements *et al*. 2017). However, *Z. chloris* generally occurs at low elevations and in coastal habitats, whereas the Meratus population is montane. As such, the Meratus population appears to fill a potential ecological gap left by the absence of montane white-eye species that occupy mountains in other parts of Borneo: Black-capped White-eye *Z. atricapilla*, Mountain Black-eye *Chlorocharis emiliae* and Pygmy White-eye *Oculocincta squamifrons*. None of these species seems to occur in the Meratus range, leaving the high-elevation forest open for invasion and occupation by *Z. chloris*. We have not yet performed a morphological analysis for lack of specimens from other populations, but plumage of the Meratus birds appears much like that in photographs of other populations (Fig. 3). Given the large number of *Z. chloris* populations across the Java Sea and Wallacea, extensive study will be required to determine more precise phylogeographic relationships of the Meratus birds.

Bold-striped Tit-Babbler *Mixornis bornensis*.—Genetic comparisons of the Meratus population indicate it is closest to individuals from Sarawak and western Sabah (Meligan range) (ND2 divergence 0.55%) than to those in the rest of Sabah and mid-eastern Kalimantan (Berau) (ND2 divergence 3.33%). However, this species displays greater mtDNA

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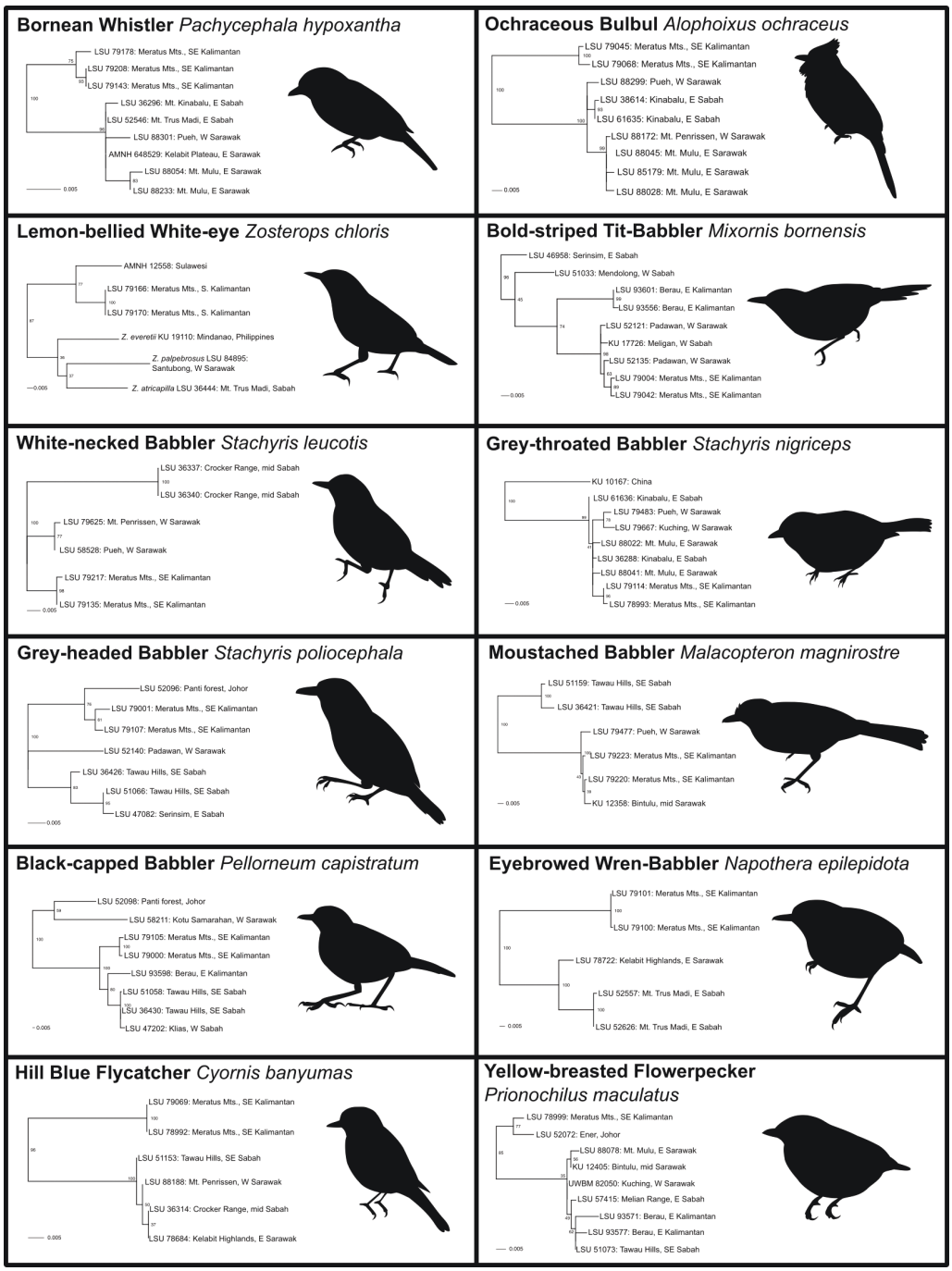


Figure 2. Rooted maximum likelihood trees indicating mtDNA-ND2 relationships between Meratus and other populations (in some cases species) for 12 species exhibiting marked genetic patterns. Bootstrap values are reported next to respective nodes.

than nuclear DNA structure on Borneo (Lim *et al*. 2017). It also has complex relationships with Pin-striped Tit-Babbler *M. gularis* (Cros & Rheindt 2017), its closest relative outside of

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TABLE 1
Plumage colour variation in Ochraceous Bulbul *Alophoixus ochraceus* and Grey-cheeked Bulbul *A. bres* from the Meratus Mountains and other parts of Borneo.

Plumage tract	***A. ochraceus* (Meratus)**	***A. ochraceus ruficrissus*/ *fowleri* (Sabah and Sarawak)**	***Alophoixus bres* (Sabah and Sarawak)**
Crown and nape	Grey	Greyish brown	Rufous-brown
Back and rump	Olive-green	Olive-brown	Olive-green
Tail	Dark reddish brown	Dark reddish brown	Dark reddish brown
Wings	Brown with green edges	Dark reddish brown	Dark reddish brown
Throat	White	White	White
Breast and flanks	Bright olive-green	Greyish brown	Pinkish brown
Belly	Lemon-yellow	Pale yellowish brown	Pale yellow
Vent	Yellowish brown	Rufous	Yellowish brown

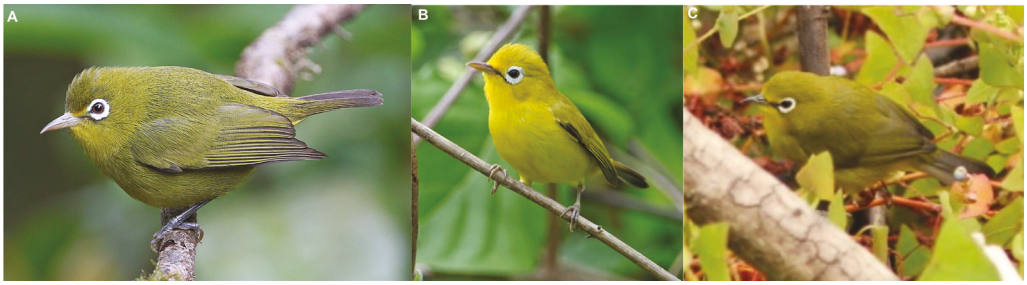


Figure 3. Lemon-bellied White-eyes *Zosterops chloris* from: (A) the Meratus Mountains (J. C. Eaton); (B) Tukangbesi Islands, south-east Sulawesi, *Z. c. flavissimus* (J. C. Eaton); and (C) Lore Lindu National Park, central Sulawesi, *Z. c. mentalis* (D. Beadle)

Borneo, decreasing the reliability of conclusions based on a few mtDNA comparisons of a limited sample of specimens.

White-necked Babbler *Stachyris leucotis*.—The Meratus, Sarawak and Sabah populations appear to form distinct clades. ND2 distances are: Meratus–Sarawak 1%, Meratus–Sabah 3% and Sabah–Sarawak 3%. The substantial divergence separating Sabah's population from the others is consistent with many other species (Lim *et al*. 2010, 2011, Lim & Sheldon 2011, Lim *et al*. 2017).

Grey-throated Babbler *Stachyris nigriceps*.—The Meratus population appears distinct from western Sarawak and north-eastern populations (ND2 divergence 4%; also see Chua *et al*. 2017).

Grey-headed Babbler *Stachyris poliocephala*.—Like White-necked Babbler *S. leucotis*, this lowland species exhibits marked divergence among Meratus, Sarawak and Sabah populations (ND2 divergence 2.3%) (Lim *et al*. 2011).

Moustached Babbler *Malacopteron magnirostre*.—The population-genetic structure of Borneo's *Malacopteron* species has never been assessed. Meratus and Sarawak populations appear to be closely related and quite distinct from birds in eastern Sabah (ND2 divergence 5.81%). The pattern in this species suggests a connection between western and southern Bornean populations and, again, a distinct history for the north-east population (Lim *et al*. 2010, 2011, Lim & Sheldon 2011, Lim *et al*. 2017).

Black-capped Babbler *Pellorneum capistratum*.—The Meratus population is distinct from others in Borneo (average ND2 divergence 7.2%), and Sabah and Sarawak populations are distinct from one another as well (ND2 divergence 11.2%) (Lim *et al*. 2011).

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Eyebrowed Wren-Babbler *Napothera epilepidota*.—Few tissues of this species are available for genetic assessment. However, the three Bornean populations we compared are remarkably different from one another genetically, in the order of 7%. We did not obtain sufficient specimen material to judge morphological differences.

Hill Blue Flycatcher *Cyornis banyumas*.—This taxon is one of two possibly new species mentioned by Eaton *et al*. (2016a). ND2 comparisons indicate that the Meratus population is monophyletic with *C. banyumas* and divergent by 3.27% from other Bornean populations that have been sampled (i.e., in Sabah and on Mt. Mulu in eastern Sarawak). Morphometric comparisons indicate that Meratus individuals are larger overall in size and have larger bills than those from Borneo's central mountain chain (Table 2). The orange breast of Meratus males also grades into a whiter belly and their black chin is much reduced compared to male *C. banyumas* from Mt. Mulu and Sabah. As with *Z. chloris*, thorough phylogeographic comparisons across the entirety of Sundaland will be required to establish the phylogeographic position of the Meratus population.

Yellow-breasted Flowerpecker *Prionochilus maculatus*.—Our single Meratus specimen is relatively distinct genetically from other Bornean populations and closer to a Peninsular Malaysian bird. Better sampling will be required to tell if this unexpected relationship is well supported and what it implies for Bornean populations.

Discussion

Avifaunal characteristics.—Compared to Borneo's central mountain chain, the Meratus forest bird community has distinctive features. At 500 m, some common lowland species are absent (e.g., *Pycnonotus erythropthalmos*, *Macronus ptilosus* and *Pellorneum malaccense*), whereas species normally uncommon at this elevation are abundant (e.g., *Stachyris nigriceps*, *Pellorneum pyrrogenys* and *Cyornis banyumas*). At higher elevations, 1,100–1,400 m, some species that are usually common are uncommon (e.g., *Ianthocincla treacheri*), and others that are typically uncommon are remarkably common (e.g., *C. banyumas*, *Urosphena whiteheadi*). Moreover, at this higher elevation, many montane species are completely absent, including numerous Bornean endemics such as Whitehead's Trogon *Harpactes whiteheadi*, Whitehead's Broadbill *Calyptomena whiteheadi* and Whitehead's Spiderhunter *Arachnothera juliae*.

Several interacting factors probably contribute to these patterns. First, the Meratus range is relatively small in area, low in elevation and isolated from other mountain ranges. Simply as a function of size, elevation and location, i.e., by the expectations of island biogeography, the Meratus Mountains should lack a complete montane avifauna. Second,

TABLE 2
Size comparison between six specimens of Meratus and five specimens of Sabah and Sarawak populations of Hill Blue Flycatcher *Cyornis banyumas*, including males and females. T-test values show significance of differences between the two groups. All measurements in mm.

Population	Culmen length	Culmen width	Culmen depth	Tail	Tarsus	Wing
Meratus (mean)	10.63	5.87	4.53	64.78	20.48	78.83
Meratus (s.d.)	0.37	0.25	0.35	2.86	1.24	2.19
Sabah and Sarawak (mean)	9.68	5.48	3.86	61.20	17.98	72.80
Sabah and Sarawak (s.d.)	0.22	0.31	0.14	1.43	1.32	1.60
T-test *P* value	0.001	0.038	0.003	0.024	0.009	0.001

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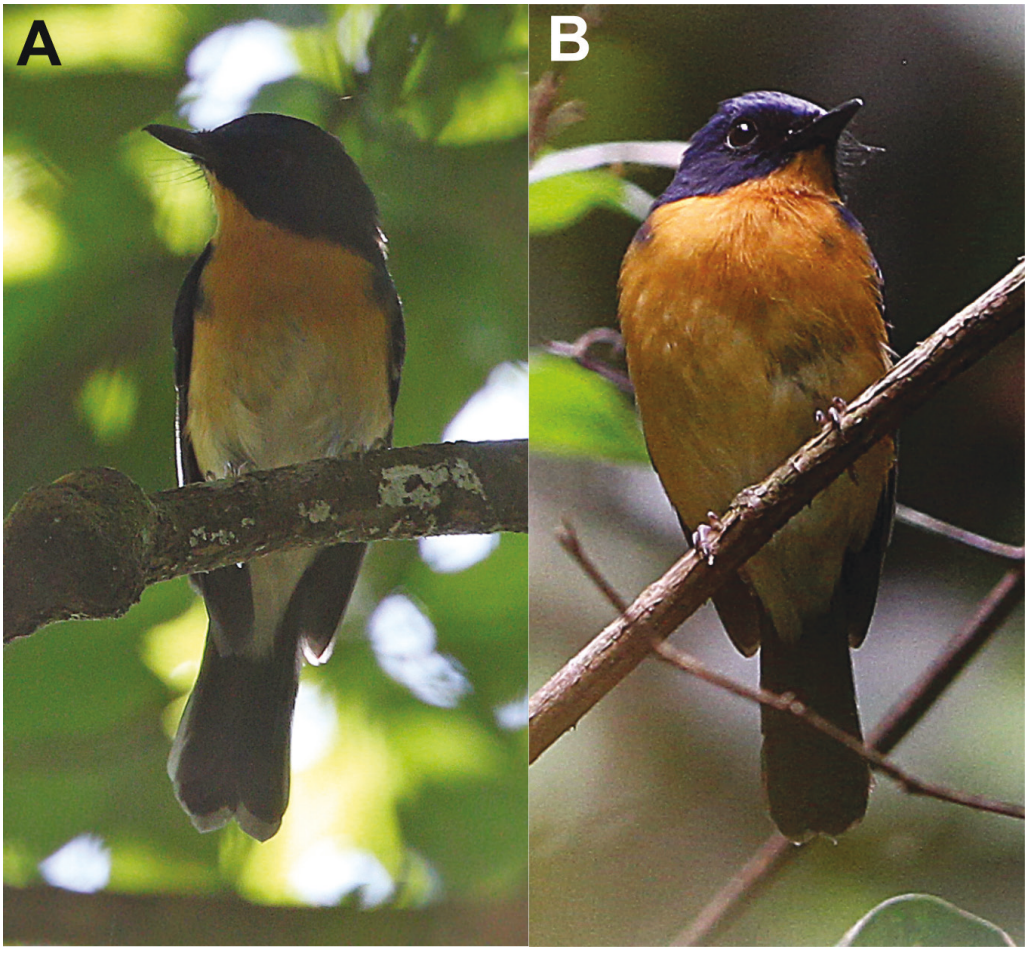


Figure 4. Male Hill Blue Flycatchers (*Cyornis banyumas*) from: (A) the Meratus Mountains (J. C. Eaton) and (B) Poring, Sabah, *C. b. montanus* (J. C. Eaton)

native lowland forest surrounding the Meratus Mountains has been replaced mostly by plantations: oil palm at low elevation, rubber and mixed-use forest at higher elevation (up to 900 m). Thus, the lowland forest avifauna that would normally contribute to the Meratus community at 500 m and above has largely been depleted. Montane species such as *Stachyris nigriceps* and *Cyornis banyumas* may be filling this low-elevation species void. There may also be a Massenerhebung effect driving montane species to lower elevation (Bruijnzeel *et al*. 1993). Third, the local human population appears to depend heavily on small birds for protein. Virtually every villager we encountered in the forest was carrying an air gun (pellet gun) and was shooting small birds and mammals for food. Unlike shotgun ammunition, air gun ammunition is inexpensive and, thus, these guns can be used economically to hunt animals that individually yield small amounts of food. The guns are also quiet when fired, and do not disturb wildlife. We observed hunters climbing fruiting fig trees and shooting numerous barbets at a sitting. This type of hunting pressure might explain the paucity of pigeons, trogons, laughingthrushes, drongos, *Alophoixus* bulbuls and other mid-sized species in the area we visited. Finally, hornbill-ivory hunters and pet traders appear to have extirpated *Buceros vigil*, *Copsychus saularis*, *C. malabaricus* and *Alophoixus bres* in the

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Kadayang area, and may be influencing numbers of other popular cagebird species (e.g., laughingthrushes and leafbirds).

Biogeographic issues.—Knowledge of Sundaic rainforest bird phylogeography is confined mainly to studies of populations in Malaysian Borneo (Sabah and Sarawak). Although restricted geographically, these studies provide hypotheses against which to judge the results of our preliminary genetic comparisons of Meratus bird populations. Studies in Malaysian Borneo indicate that lowland populations of birds in Sarawak are often more closely related to those in western Sundaland (Malay Peninsula and Sumatra) than to populations in Sabah (Sheldon *et al*. 2009, Lim *et al*. 2010, 2011, Lim & Sheldon 2011, Lim *et al*. 2017). This pattern, combined with molecular estimates of divergence dates, suggests that Sabah's lowland birds were isolated (one or more times) from populations in western Sundaland, probably in rainforest refugia during global glacial events early in the Pleistocene (e.g., 1–2 million years ago) when most of central Sundaland was subaerial and covered by dry or seasonal forest (Sheldon *et al*. 2015). Similarly, studies suggest that Bornean populations of montane taxa, such as *Chloropsis kinabaluensis*, Bornean Forktail *Enicurus leschenaulti borneensis* and *Arachnothera everetti*, were isolated in rainforest refuges in north-east Borneo from congeneric populations in western Sundaland early in the Pleistocene (Moyle *et al*. 2005, 2011, 2017). During the more recent Pleistocene, glaciation events apparently had a different effect on Sundaic habitats; instead of reducing rainforest cover in Sundaland, they increased it, causing greater habitat connectivity among islands and the mainland (Cannon *et al*. 2009, Raes *et al*. 2014). Genetic comparisons suggest that, concomitant with this recent increase in rainforest coverage, several western Sundaic bird populations invaded Borneo and occupied the western lowlands, pushing or restricting endemic Bornean populations to the east or into the mountains. These dynamics caused the marked parapatry witnessed today between populations in the lowlands of Sarawak and Sabah (e.g., between White-rumped Shama *Copsychus malabaricus suavis* in Sarawak and White-crowned Shama *C. m. stricklandii* in Sabah) and between populations in the lowlands and mountains of Borneo (e.g., White-crowned Forktail *Enicurus leschenaulti frontalis* in the lowlands and Bornean Forktail *E. l. borneensis* at higher elevation) (Sheldon *et al*. 2015, Moyle *et al*. 2017). Using these biogeographic scenarios as a foundation, we can put our preliminary phylogeographic comparisons of Meratus birds into context and identify the requirements of future investigations.

One of the most interesting discoveries of this study is the occurrence of *Chloropsis kinabaluensis* and *Arachnothera everetti* in the Meratus Mountains (also see Eaton *et al*. 2016a). Previously these species were known only from north-eastern portions of the main Bornean mountain range, e.g., Mulu, Crocker Range and Menyapa Mountains (Mann 2008, Brickle *et al*. 2010, Burner *et al*. 2016, Moyle *et al*. 2017). Their presence in the Meratus Mountains suggests that early Bornean Pleistocene rainforest refuges occurred not just in Sabah (Sheldon 2016) but also in mountains and adjacent lowlands near the coast across much of eastern Borneo. This hypothesis is supported by paleo-habitat data (Morley 2012), paleo-habitat modelling (Cannon *et al*. 2009, Lim *et al*. 2011, Manthey *et al*. 2017) and phylogeographic studies (Quek *et al*. 2007, Chua *et al*. 2015).

Some of our preliminary ND2 comparisons suggest that lowland species in the Meratus Mountains are more closely related to western Sarawak or even western Sundaic populations than to north-east Bornean populations (e.g., *Malacopteron magnirostre*, *Stachyris leucotis* and *Prionochilus maculatus*). This pattern could result from the same phenomenon causing similarity between Sarawak and western Sundaic populations: invasion of Borneo from the west during recent global glacial events when the islands and mainland were connected by suitable habitat. Recent invasion of Borneo might also explain the genetic

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difference between montane birds in the Meratus Mountains and those in northern Borneo (e.g., *Alophoixus ochraceus*, *Pellorneum pyrrogenys*, *Napothera epilepidota* and *Cyornis banyumas*). Invasion from Sumatra is possible for all four of these species; the last three could have arrived from Java. A faunal connection between Java and south-east Borneo is especially likely, given proximity. Several open- or dry-habitat taxa are shared between Java and Borneo, e.g., Red-breasted Parakeet *Psittacula alexandri*, Savanna Nightjar *Caprimulgus affinis*, *Copsychus saularis* and Scarlet-headed Flowerpecker *Dicaeum trochileum* (e.g., Mees 1996, Phillipps & Phillipps 2014). More importantly for Meratus populations, preliminary genetic comparisons of some taxa from Borneo's central mountain chain, e.g., swiftlets (*Collocalia*), spiderhunters (*Arachnothera*) and forktails (*Enicurus*), suggest they are closest to Javan populations (Moyle *et al*. 2005, 2008, 2011). Thus, it is reasonable to expect that some birds in the Meratus Mountains will have at least as much, or greater, affinity with Javan populations than with other Bornean populations.

Overall, understanding the biogeographic significance of genetic and morphological divergence in both lowland and montane populations of the Meratus Mountains will require phylogeographic comparisons with populations of Java, Sumatra and even Peninsular Malaysia, as well as the rest of Borneo. For *Zosterops chloris*, it will require comparisons with populations across the Java Sea and Wallacea.

Acknowledgements

We thank the State Ministry of Research and Technology (RISTEK research license numbers 388/SIP/FRP/E5/Dit.KI/XI/2016 and 389/SIP/FRP/E5/Dit.KI/XI/2016) and the Ministry of Forestry for permission to undertake research in south-east Kalimantan. We also thank the Research Center for Biology, Indonesian Institute of Science (RCB-LIPI), and the Museum Zoologicum Bogoriense for their invaluable support; and MZB technician Suparno, Lindsay Burner and the people of Kadayang village for much assistance in the field. John Klicka helped with specimen identification. David Wells, Geoffrey Davison and James Eaton commented on the manuscript, and James Eaton kindly provided photographs of *Cyornis banyumas* and *Zosterops chloris*. David Beadle permitted us to use his Internet Bird Collection photo of *Zosterops chloris*. The project protocol was approved by LSU's Institutional Animal Care and Use Committee (#16-039). Financial support was provided by the US National Science Foundation grant 1241059 and Louisiana State University Museum of Natural Science. All sequences generated from this project have been deposited in GenBank (accession numbers: MG546332–MG546514; MG590020–MG590022).

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Appendix 1: List of bird species recorded in the Meratus Mountains

Scientific name[a]	English name[a]	Elevation, this study[b]			Davison (1997)[c]	Eaton *et al.* (2017)
		500 m	1,150 m	1,350 m		
Rollulus rouloul	Crested Partridge					x
Spilornis cheela	Crested Serpent Eagle	x			x	x
Nisaetus alboniger	Blyth's Hawk-Eagle					x
Lophotriorchis kienerii	Rufous-bellied Eagle					x
Macropygia ruficeps	Little Cuckoo-Dove		x		x	x
Chalcophaps indica	Asian Emerald Dove	x			x	
*Treron olax***	Little Green Pigeon		x			
Ducula badia	Mountain Imperial Pigeon				x	
Centropus sinensis	Greater Coucal	x			x	
Centropus bengalensis	Lesser Coucal				x	
Phaenicophaeus curvirostris	Chestnut-breasted Malkoha	s				
*Cacomantis merulinus**	Plaintive Cuckoo	s			x	
Cacomantis variolosus	Brush Cuckoo					x

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Scientific name[a]	English name[a]	Elevation, this study[b]			Davison (1997)[c]	Eaton *et al.* (2017)
		500 m	1,150 m	1,350 m		
Surniculus lugubris	Square-tailed Drongo-Cuckoo		x		x	
Cuculus micropterus	Indian Cuckoo		x		x	
Cuculus lepidus	Sunda Cuckoo		x	s	x	x
Otus spilocephalus	Mountain Scops Owl					x
Bubo sumatranus	Barred Eagle-Owl					x
Glaucidium brodiei	Collared Owlet		s			x
Batrachostomus poliolophus	Short-tailed Frogmouth				x	x
Lyncornis temminckii	Malaysian Nightjar				x	
Rhaphidura leucopygialis	Silver-rumped Needletail				x	
Collocalia affinis	Plume-toed Swiftlet				x	
Aerodramus sp.	swiftlet sp.	x			x	x
Cypsiurus balasiensis	Asian Palm Swift	x				x
Harpactes diardii	Diard's Trogon	s				x
*Harpactes oreskios***	Orange-breasted Trogon		s			
*Berenicornis comatus***	White-crowned Hornbill		x			
Buceros vigil	Helmeted Hornbill				x	
Buceros rhinoceros	Rhinoceros Hornbill		x		x	x
Anorrhinus galeritus	Bushy-crested Hornbill		x		x	x
Rhyticeros undulatus	Wreathed Hornbill		x		x	x
*Alcedo euryzona***	Blue-banded Kingfisher	s				
*Ceyx erithaca***	Black-backed Dwarf Kingfisher	s				
Lacedo pulchella	Banded Kingfisher				x	x
Actenoides concretus	Rufous-collared Kingfisher				x	
Nyctyornis amictus	Red-bearded Bee-eater	s			x	
Merops viridis	Blue-throated Bee-eater				x	
Psilopogon duvaucelii	Blue-eared Barbet				x	x
Psilopogon eximius	Bornean Barbet		s			x
Psilopogon mystacophanos	Red-throated Barbet	s			x	
Psilopogon monticola	Mountain Barbet		s	x	x	x
Psilopogon chrysopogon	Gold-whiskered Barbet				x	x
*Sasia abnormis**	Rufous Piculet	s	s	x	x	x
Dendrocopos moluccensis	Sunda Woodpecker				x	
Dendrocopos canicapillus	Grey-capped Woodpecker				x	x
Picus miniaceus	Banded Woodpecker					x
Picus puniceus	Crimson-winged Woodpecker					x
Picus mentalis	Checker-throated Woodpecker		s			x
*Meiglyptes tristis***	Buff-rumped Woodpecker		s			
Blythipicus rubiginosus	Maroon Woodpecker		s		x	x
Loriculus galgulus	Blue-crowned Hanging Parrot					x
Calyptomena viridis	Green Broadbill		x		x	x
*Psarisomus dalhousiae***	Long-tailed Broadbill		s			
Eurylaimus javanicus	Banded Broadbill		x		x	
Eurylaimus ochromalus	Black-and-yellow Broadbill	x			x	x
Hydrornis schwaneri	Bornean Banded Pitta				x	x
Gerygone sulphurea	Golden-bellied Gerygone	x			x	x
Hemipus picatus	Bar-winged Flycatcher-Shrike				x	x
*Pericrocotus solaris**	Grey-chinned Minivet		s			x
*Pachycephala hypoxantha**	Bornean Whistler		s	s		x
*Pteruthius aeralatus**	Blyth's Shrike-Babbler		s	s	x	x

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Scientific name[a]	English name[a]	Elevation, this study[b]			Davison (1997)[c]	Eaton *et al.* (2017)
		500 m	1,150 m	1,350 m		
Erpornis zantholeuca	White-bellied Erpornis					x
*Dicrurus leucophaeus**	Ashy Drongo		s	s		x
*Rhipidura perlata**	Spotted Fantail		s		x	x
*Rhipidura javanica** **	Malaysian Pied Fantail	s				
*Rhipidura albicollis**	White-throated Fantail		s	s	x	x
Hypothymis azurea	Black-naped Monarch					x
Platylophus galericulatus	Crested Jay		x		x	x
*Dendrocitta cinerascens**	Bornean Treepie		s	x		x
Corvus enca	Slender-billed Crow				x	
Hirundo tahitica	Pacific Swallow				x	
Culicicapa ceylonensis	Grey-headed Canary-Flycatcher		s			x
Sitta frontalis	Velvet-fronted Nuthatch			s		x
Pycnonotus atriceps	Black-headed Bulbul	x			x	x
Pycnonotus squamatus	Scaly-breasted Bulbul				x	x
Pycnonotus goiavier	Yellow-vented Bulbul	s			x	
Pycnonotus brunneus	Red-eyed Bulbul				x	
*Alophoixus ochraceus**	Ochraceous Bulbul	s	s		x	x
Alophoixus bres	Grey-cheeked Bulbul				x	
*Hemixos flavala**	Ashy Bulbul		x	s	x	x
Ixos malaccensis	Streaked Bulbul					x
*Urosphena whiteheadi**	Bornean Stubtail			s		x
Abroscopus superciliaris	Yellow-bellied Warbler	s	s		x	x
*Phyllergates cucullatus**	Mountain Tailorbird			s	x	x
*Phylloscopus trivirgatus**	Mountain Leaf Warbler			s	x	x
*Seicercus montis**	Yellow-breasted Warbler		x	s	x	x
Orthotomus atrogularis	Dark-necked Tailorbird					x
Orthotomus ruficeps	Ashy Tailorbird	s			x	x
*Orthotomus sericeus**	Rufous-tailed Tailorbird	s			x	x
Prinia flaviventris	Yellow-bellied Prinia	s			x	
*Yuhina everetti**	Chestnut-crested Yuhina		s	s		x
Zosterops palpebrosus	Oriental White-eye					x
Zosterops everetti	Everett's White-eye				x[d]	
*Zosterops chloris**	Meratus White-eye			s	x[e]	x
*Mixornis bornensis**	Bold-striped Tit-Babbler	s			x	x
*Cyanoderma erythropterum***	Chestnut-winged Babbler		x			
Pomatorhinus montanus	Chestnut-backed Scimitar Babbler	s	s	s	x	x
*Stachyris nigriceps**	Grey-throated Babbler	s	s	x	x	x
*Stachyris poliocephala**	Grey-headed Babbler	s			x	
*Stachyris leucotis** **	White-necked Babbler			s		
*Malacopteron magnirostre**	Moustached Babbler	s				x
*Malacopteron cinereum** **	Scaly-crowned Babbler	s				
*Pellorneum capistratum** **	Black-capped Babbler	s				
*Pellorneum pyrrogenys**	Temminck's Babbler	s	s	x	x	x
*Napothera epilepidota** **	Eyebrowed Wren-Babbler		s			
*Alcippe brunneicauda**	Brown Fulvetta		s			x
*Ianthocincla treacheri**	Chestnut-hooded Laughingthrush		s		x	x
Irena puella	Asian Fairy Bluebird		s		x	x
Copsychus saularis	Oriental Magpie-Robin				x	
Copsychus malabaricus	White-rumped Shama				x	

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Scientific name[a]	English name[a]	Elevation, this study[b]			Davison (1997)[c]	Eaton *et al.* (2017)
		500 m	1,150 m	1,350 m		
*Cyornis banyumas**	Meratus Flycatcher	s	s	x	x	x
Cyornis superbus	Bornean Blue Flycatcher					x
*Eumyias indigo**	Indigo Flycatcher		s			x
Eumyias thalassinus	Verditer Flycatcher					x
*Vauriella gularis**	Eyebrowed Jungle Flycatcher		s	s	x	x
Brachypteryx montana	White-browed Shortwing					x
Enicurus leschenaulti	White-crowned Forktail	x			x	
Enicurus ruficapillus	Chestnut-naped Forktail				x	
*Ficedula westermanni**	Little Pied Flycatcher		s		x	x
*Ficedula dumetoria** **	Rufous-chested Flycatcher		s			
Chlamydochaera jefferyi	Fruit-hunter					x
Gracula religiosa	Common Hill Myna				x	
*Chloropsis kinabaluensis**	Bornean Leafbird		s			x
*Prionochilus maculatus**	Yellow-breasted Flowerpecker	s				x
Prionochilus xanthopygius	Yellow-rumped Flowerpecker					x
Dicaeum trigonostigma	Orange-bellied Flowerpecker	s			x	x
Dicaeum monticolum	Black-sided Flowerpecker				x	x
Chalcoparia singalensis	Ruby-cheeked Sunbird					x
Anthreptes malacensis	Plain-throated Sunbird				x	x
Leptocoma brasiliana	Van Hasselt's Sunbird					x
Aethopyga temminckii	Temminck's Sunbird		s	s	x	x
Aethopyga siparaja	Crimson Sunbird				x	
*Arachnothera longirostra**	Little Spiderhunter	s			x	x
*Arachnothera hypogrammicum**	Purple-naped Spiderhunter	s				x
*Arachnothera flavigaster***	Spectacled Spiderhunter			s		
Arachnothera modesta	Grey-breasted Spiderhunter					x
*Arachnothera everetti** **	Bornean Spiderhunter	s	s	x		
*Erythrura prasina***	Pin-tailed Parrotfinch	s				
Lonchura fuscans	Dusky Munia	s			x	x

[a] = Classification follows Clements *et al*. (2017).
[b] = s: specimen records, x: other records.
[c] = Migrants recorded by Davison (1997) have been omitted.
[d] = Identified as *Zosterops everetti* or perhaps *Z. palpebrosa* by Davison (1997)
[e] = Identified as *Z. atricapilla* by Davison (1997).
* = Species for which ND2 was sequenced in this study.
** = New records for the Meratus Mountains.

Appendix 2: List of ND2 sequence-samples compared for this study, classified according to Clements *et al*. (2017).

Tissue No.*	Genus	Species	Locality	GenBank No.
LSUMNS B-51117 / AMNH DOT 15123	*Cacomantis*	*sonneratii*	Tawau Hills Park, Sabah	KJ455342
LSUMNS B-79648	*Cacomantis*	*sonneratii*	Kuching, Sarawak	MG546353
LSUMNS B-47009	*Cacomantis*	*merulinus*	Mt. Kinabalu, Sabah	MG546349
LSUMNS B-47049	*Cacomantis*	*merulinus*	Mt. Kinabalu, Sabah	MG546350
LSUMNS B-58630	*Cacomantis*	*merulinus*	Mt. Pueh, Sarawak	MG546351
LSUMNS B-79020	*Cacomantis*	*merulinus*	Meratus Mountains, South Kalimantan	MG546352
UWBM 67474	*Cacomantis*	*merulinus*	Sumatra, Indonesia	KJ455341
LSUMNS B-51190	*Psilopogon*	*eximius*	Tawau Hills Park, Sabah	MG546418
LSUMNS B-79082	*Psilopogon*	*eximius*	Meratus Mountains, South Kalimantan	MG546419

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Tissue No.*	Genus	Species	Locality	GenBank No.
LSUMNS B-79194	*Psilopogon*	*eximius*	Meratus Mountains, South Kalimantan	MG546420
LSUMNS B-36374	*Sasia*	*abnormis*	Tawau Hills Park, Sabah	MG546474
LSUMNS B-36380	*Sasia*	*abnormis*	Tawau Hills Park, Sabah	DQ479158
LSUMNS B-36428	*Sasia*	*abnormis*	Tawau Hills Park, Sabah	DQ188163
LSUMNS B-52131	*Sasia*	*abnormis*	Padawan, Sarawak	MG546475
LSUMNS B-58509	*Sasia*	*abnormis*	Mt. Pueh, Sarawak	MG546476
LSUMNS B-79019	*Sasia*	*abnormis*	Meratus Mountains, South Kalimantan	MG546477
LSUMNS B-79061	*Sasia*	*abnormis*	Meratus Mountains, South Kalimantan	MG546478
LSUMNS B-88097	*Sasia*	*abnormis*	Mt. Mulu, Sarawak	MG546479
LSUMNS B-88107	*Sasia*	*abnormis*	Mt. Mulu, Sarawak	MG546480
LSUMNS B-93562	*Sasia*	*abnormis*	Berau, East Kalimantan	MG546481
LSUMNS B-93600	*Sasia*	*abnormis*	Berau, East Kalimantan	MG546482
LSUMNS B-51210	*Pericrocotus*	*solaris*	Guangdong, China	JQ864472
LSUMNS B-52683	*Pericrocotus*	*solaris*	Mt. Trus Madi, Sabah	MG590020
LSUMNS B-79096	*Pericrocotus*	*solaris*	Meratus Mountains, South Kalimantan	MG590021
LSUMNS B-79142	*Pericrocotus*	*solaris*	Meratus Mountains, South Kalimantan	MG590022
AMNH 648529	*Pachycephala*	*hypoxantha*	Kelabit Highlands, Sarawak	GQ494105
LSUMNS B-36296	*Pachycephala*	*hypoxantha*	Mt. Kinabalu, Sabah	MG546431
LSUMNS B-52546	*Pachycephala*	*hypoxantha*	Mt. Trus Madi, Sabah	MG546432
LSUMNS B-79143	*Pachycephala*	*hypoxantha*	Meratus Mountains, South Kalimantan	MG546433
LSUMNS B-79178	*Pachycephala*	*hypoxantha*	Meratus Mountains, South Kalimantan	MG546434
LSUMNS B-79208	*Pachycephala*	*hypoxantha*	Meratus Mountains, South Kalimantan	MG546435
LSUMNS B-88054	*Pachycephala*	*hypoxantha*	Mt. Mulu, Sarawak	MG546436
LSUMNS B-88233	*Pachycephala*	*hypoxantha*	Mt. Mulu, Sarawak	MG546437
LSUMNS B-88301	*Pachycephala*	*hypoxantha*	Mt. Pueh, Sarawak	MG546438
LSUMNS B-52675	*Pteruthius*	*aeralatus*	Mt. Trus Madi, Sabah	MG546454
LSUMNS B-79081	*Pteruthius*	*aeralatus*	Meratus Mountains, South Kalimantan	MG546455
LSUMNS B-79214	*Pteruthius*	*aeralatus*	Meratus Mountains, South Kalimantan	MG546456
LSUMNS B-36475	*Dicrurus*	*leucophaeus*	Mt. Trus Madi, Sabah	MG546371
LSUMNS B-52560	*Dicrurus*	*leucophaeus*	Mt. Trus Madi, Sabah	MG546372
LSUMNS B-79080	*Dicrurus*	*leucophaeus*	Meratus Mountains, South Kalimantan	MG546373
LSUMNS B-79134	*Dicrurus*	*leucophaeus*	Meratus Mountains, South Kalimantan	MG546374
LSUMNS B-79564	*Dicrurus*	*leucophaeus*	Kuching, Sarawak	MG546375
LSUMNS B-88044	*Dicrurus*	*leucophaeus*	Mt. Mulu, Sarawak	MG546376
LSUMNS B-88295	*Dicrurus*	*leucophaeus*	Mt. Pueh, Sarawak	MG546377
LSUMNS B-38596	*Rhipidura*	*perlata*	Imbak Valley, Sabah	MG546468
LSUMNS B-57451	*Rhipidura*	*perlata*	Ulu Tungud Forest Reserve, Sabah	GQ145409
LSUMNS B-74749	*Rhipidura*	*perlata*	Mt. Mulu, Sarawak	MG546469
LSUMNS B-79054	*Rhipidura*	*perlata*	Meratus Mountains, South Kalimantan	MG546470
LSUMNS B-79070	*Rhipidura*	*perlata*	Meratus Mountains, South Kalimantan	MG546471
LSUMNS B-79480	*Rhipidura*	*perlata*	Kuching, Sarawak	MG546472
LSUMNS B-88071	*Rhipidura*	*perlata*	Mt. Mulu, Sarawak	MG546473
KU 17717	*Rhipidura*	*javanica*	Padas Damit, Sabah	JN546011
LSUMNS B-46972	*Rhipidura*	*javanica*	Mt. Kinabalu, Sabah	GQ145404
LSUMNS B-58663	*Rhipidura*	*javanica*	Mt. Pueh, Sarawak	MG546463
LSUMNS B-79018	*Rhipidura*	*javanica*	Meratus Mountains, South Kalimantan	MG546464
LSUMNS B-79254	*Rhipidura*	*javanica*	Limbang, Sarawak	MG546465
LSUMNS B-93595	*Rhipidura*	*javanica*	Berau, East Kalimantan	MG546466
LSUMNS B-93602	*Rhipidura*	*javanica*	Berau, East Kalimantan	MG546467
KU 13977	*Rhipidura*	*nigritorquis*	Camiguin, Philippines	JN546013

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Tissue No.*	Genus	Species	Locality	GenBank No.
KU 10230	*Rhipidura*	*albicollis*	Guangxi, China	GQ145386
LSUMNS B-36474	*Rhipidura*	*albicollis*	Mt. Trus Madi, Sabah	GQ145387
LSUMNS B-52563	*Rhipidura*	*albicollis*	Mt. Trus Madi, Sabah	MG546457
LSUMNS B-79050	*Rhipidura*	*albicollis*	Meratus Mountains, South Kalimantan	MG546458
LSUMNS B-79098	*Rhipidura*	*albicollis*	Meratus Mountains, South Kalimantan	MG546459
LSUMNS B-88121	*Rhipidura*	*albicollis*	Mt. Pueh, Sarawak	MG546460
LSUMNS B-88230	*Rhipidura*	*albicollis*	Mt. Mulu, Sarawak	MG546461
LSUMNS B-88238	*Rhipidura*	*albicollis*	Mt. Mulu, Sarawak	MG546462
LSUMNS B-38662	*Dendrocitta*	*cinerascens*	Mt. Kinabalu, Sabah	MG546364
LSUMNS B-61577	*Dendrocitta*	*cinerascens*	Meligan Range, Sabah	MG546365
LSUMNS B-78702	*Dendrocitta*	*cinerascens*	Kelabit Highlands, Sarawak	MG546366
LSUMNS B-79092	*Dendrocitta*	*cinerascens*	Meratus Mountains, South Kalimantan	MG546367
LSUMNS B-79129	*Dendrocitta*	*cinerascens*	Meratus Mountains, South Kalimantan	MG546368
LSUMNS B-88039	*Dendrocitta*	*cinerascens*	Mt. Mulu, Sarawak	MG546369
LSUMNS B-88245	*Dendrocitta*	*cinerascens*	Mt. Mulu, Sarawak	MG546370
LSUMNS B-38614	*Alophoixus*	*ochraceus*	Mt. Kinabalu, Sabah	DQ402229
LSUMNS B-61635	*Alophoixus*	*ochraceus*	Mt. Kinabalu, Sabah	KY547863
LSUMNS B-79045	*Alophoixus*	*ochraceus*	Meratus Mountains, South Kalimantan	MG546336
LSUMNS B-79068	*Alophoixus*	*ochraceus*	Meratus Mountains, South Kalimantan	MG546337
LSUMNS B-85179	*Alophoixus*	*ochraceus*	Mt. Mulu, Sarawak	KY547847
LSUMNS B-88028	*Alophoixus*	*ochraceus*	Mt. Mulu, Sarawak	KY547848
LSUMNS B-88045	*Alophoixus*	*ochraceus*	Mt. Mulu, Sarawak	KY547844
LSUMNS B-88172	*Alophoixus*	*ochraceus*	Mt. Penrissen, Sarawak	KY547868
LSUMNS B-88299	*Alophoixus*	*ochraceus*	Mt. Pueh, Sarawak	MG546338
KU 15140	*Hemixos*	*flavala*	Kyi Tan, Myanmar	GU112648
LSUMNS B-38649	*Hemixos*	*flavala*	Mt. Kinabalu, Sabah	KY547905
LSUMNS B-38659	*Hemixos*	*flavala*	Mt. Kinabalu, Sabah	DQ402224
LSUMNS B-79173	*Hemixos*	*flavala*	Meratus Mountains, South Kalimantan	MG546392
LSUMNS B-79203	*Hemixos*	*flavala*	Meratus Mountains, South Kalimantan	MG546393
LSUMNS B-88173	*Hemixos*	*flavala*	Mt. Penrissen, Sarawak	KY547908
LSUMNS B-88235	*Hemixos*	*flavala*	Mt. Mulu, Sarawak	MG546394
LSUMNS B-88254	*Hemixos*	*flavala*	Mt. Mulu, Sarawak	MG546395
LSUMNS B-88289	*Hemixos*	*flavala*	Mt. Pueh, Sarawak	MG546396
LSUMNS B-88303	*Hemixos*	*flavala*	Mt. Pueh, Sarawak	MG546397
KU 17730	*Urosphena*	*whiteheadi*	Meligan Range, Sabah	MG546498
LSUMNS B-61550	*Urosphena*	*whiteheadi*	Meligan Range, Sabah	MG546499
LSUMNS B-79133	*Urosphena*	*whiteheadi*	Meratus Mountains, South Kalimantan	MG546500
LSUMNS B-79200	*Urosphena*	*whiteheadi*	Meratus Mountains, South Kalimantan	MG546501
KU 21046	*Phyllergates*	*cucullatus*	Luzon, Philippines	JX006118
LSUMNS B-52577	*Phyllergates*	*cucullatus*	Mt. Trus Madi, Sabah	JX006119
LSUMNS B-79210	*Phyllergates*	*cucullatus*	Meratus Mountains, South Kalimantan	MG546445
LSUMNS B-52702	*Phylloscopus*	*trivirgatus*	Mt. Kinabalu, Sabah	MG546446
LSUMNS B-61581	*Phylloscopus*	*trivirgatus*	Meligan Range, Sabah	MG546447
LSUMNS B-79165	*Phylloscopus*	*trivirgatus*	Meratus Mountains, South Kalimantan	MG546448
LSUMNS B-79167	*Phylloscopus*	*trivirgatus*	Meratus Mountains, South Kalimantan	MG546449
429247	*Phylloscopus*	*trivirgatus*	Philippines	FJ173457
LSUMNS B-36278	*Seicercus*	*montis*	Mt. Kinabalu, Sabah	MG546483
LSUMNS B-52597	*Seicercus*	*montis*	Mt. Trus Madi, Sabah	KY547975
LSUMNS B-61549	*Seicercus*	*montis*	Meligan Range, Sabah	MG546484
LSUMNS B-79159	*Seicercus*	*montis*	Meratus Mountains, South Kalimantan	MG546485

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Tissue No.*	Genus	Species	Locality	GenBank No.
LSUMNS B-79216	*Seicercus*	*montis*	Meratus Mountains, South Kalimantan	MG546486
LSUMNS B-88115	*Seicercus*	*montis*	Mt. Pueh, Sarawak	KY547972
LSUMNS B-88278	*Seicercus*	*montis*	Mt. Pueh, Sarawak	MG546487
LSUMNS B-88300	*Seicercus*	*montis*	Mt. Pueh, Sarawak	MG546488
KU 17792	*Orthotomus*	*sericeus*	Crocker Range, Sabah	JN826602
LSUMNS B-36370	*Orthotomus*	*sericeus*	Crocker Range, Sabah	KJ865188
LSUMNS B-51034	*Orthotomus*	*sericeus*	Mendolong, Sabah	KJ865189
LSUMNS B-58160	*Orthotomus*	*sericeus*	Miri, Sarawak	KJ865180
LSUMNS B-58183	*Orthotomus*	*sericeus*	Miri, Sarawak	KJ865179
LSUMNS B-74736	*Orthotomus*	*sericeus*	Mt. Mulu, Sarawak	MG546425
LSUMNS B-74766	*Orthotomus*	*sericeus*	Mt. Mulu, Sarawak	MG546426
LSUMNS B-79005	*Orthotomus*	*sericeus*	Meratus Mountains, South Kalimantan	MG546427
LSUMNS B-79109	*Orthotomus*	*sericeus*	Meratus Mountains, South Kalimantan	MG546428
LSUMNS B-93551	*Orthotomus*	*sericeus*	Berau, East Kalimantan	MG546429
LSUMNS B-93604	*Orthotomus*	*sericeus*	Berau, East Kalimantan	MG546430
KU 17756	*Yuhina*	*everetti*	Meligan Range, Sabah	JN826709
LSUMNS B-36290	*Yuhina*	*everetti*	Mt. Kinabalu, Sabah	FJ460779
LSUMNS B-79163	*Yuhina*	*everetti*	Meratus Mountains, South Kalimantan	MG546507
LSUMNS B-79193	*Yuhina*	*everetti*	Meratus Mountains, South Kalimantan	MG546508
LSUMNS B-88025	*Yuhina*	*everetti*	Mt. Mulu, Sarawak	KY548027
LSUMNS B-88190	*Yuhina*	*everetti*	Mt. Penrissen, Sarawak	KY548030
LSUMNS B-88237	*Yuhina*	*everetti*	Mt. Mulu, Sarawak	MG546509
LSUMNS B-88279	*Yuhina*	*everetti*	Mt. Pueh, Sarawak	MG546510
LSUMNS B-84895	*Zosterops*	*palpebrosus*	Santubong, Sarawak	MG546511
LSUMNS B-36444	*Zosterops*	*atricapilla*	Mt. Trus Madi, Sabah	FJ460802
KU 19110	*Zosterops*	*everetti*	Mindanao, Philippines	MG546512
LSUMNS B-79166	*Zosterops*	*chloris*	Meratus Mountains, South Kalimantan	MG546513
LSUMNS B-79170	*Zosterops*	*chloris*	Meratus Mountains, South Kalimantan	MG546514
AMNH 12558	*Zosterops*	*chloris*	Sulawesi Selatan, Sulawesi	FJ460798
KU 17726	*Mixornis*	*bornensis*	Meligan Range, Sabah	JN826571
LSUMNS B-46958	*Mixornis*	*bornensis*	Mt. Kinabalu, Sabah	HQ011004
LSUMNS B-51033	*Mixornis*	*bornensis*	Mendolong, Sabah	HQ011001
LSUMNS B-52121	*Mixornis*	*bornensis*	Kuching, Sarawak	HQ011018
LSUMNS B-52135	*Mixornis*	*bornensis*	Kuching, Sarawak	HQ011017
LSUMNS B-79004	*Mixornis*	*bornensis*	Meratus Mountains, South Kalimantan	MG546404
LSUMNS B-79042	*Mixornis*	*bornensis*	Meratus Mountains, South Kalimantan	MG546405
LSUMNS B-93556	*Mixornis*	*bornensis*	Berau, East Kalimantan	MG546406
LSUMNS B-93601	*Mixornis*	*bornensis*	Berau, East Kalimantan	MG546407
KU 10167	*Stachyris*	*nigriceps*	Guangxi, China	JN826673
LSUMNS B-36288	*Stachyris*	*nigriceps*	Mt. Kinabalu, Sabah	JN826674
LSUMNS B-61636	*Stachyris*	*nigriceps*	Mt. Kinabalu, Sabah	KY547978
LSUMNS B-78993	*Stachyris*	*nigriceps*	Meratus Mountains, South Kalimantan	MG546494
LSUMNS B-79114	*Stachyris*	*nigriceps*	Meratus Mountains, South Kalimantan	MG546495
LSUMNS B-79483	*Stachyris*	*nigriceps*	Mt. Pueh, Sarawak	KY548009
LSUMNS B-79667	*Stachyris*	*nigriceps*	Mt. Penrissen, Sarawak	KY547999
LSUMNS B-88022	*Stachyris*	*nigriceps*	Mt. Mulu, Sarawak	KY547993
LSUMNS B-88041	*Stachyris*	*nigriceps*	Mt. Mulu, Sarawak	KY547996
LSUMNS B-36426	*Stachyris*	*poliocephala*	Tawau Hills Park, Sabah	HQ011178
LSUMNS B-47082	*Stachyris*	*poliocephala*	Mt. Kinabalu, Sabah	HQ011180
LSUMNS B-51066	*Stachyris*	*poliocephala*	Tawau Hills Park, Sabah	HQ011182

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Tissue No.*	Genus	Species	Locality	GenBank No.
LSUMNS B-52096	*Stachyris*	*poliocephala*	Panti Forest, West Malaysia	HQ011192
LSUMNS B-52140	*Stachyris*	*poliocephala*	Kuching, Sarawak	HQ011186
LSUMNS B-79001	*Stachyris*	*poliocephala*	Meratus Mountains, South Kalimantan	MG546496
LSUMNS B-79107	*Stachyris*	*poliocephala*	Meratus Mountains, South Kalimantan	MG546497
LSUMNS B-36337	*Stachyris*	*leucotis*	Crocker Range, Sabah	MG546489
LSUMNS B-36340	*Stachyris*	*leucotis*	Crocker Range, Sabah	JN826671
LSUMNS B-58528	*Stachyris*	*leucotis*	Mt. Pueh, Sarawak	MG546490
LSUMNS B-79135	*Stachyris*	*leucotis*	Meratus Mountains, South Kalimantan	MG546491
LSUMNS B-79217	*Stachyris*	*leucotis*	Meratus Mountains, South Kalimantan	MG546492
LSUMNS B-79625	*Stachyris*	*leucotis*	Kuching, Sarawak	MG546493
KU 12358	*Malacopteron*	*magnirostre*	Samarakan, Sarawak	JN826585
LSUMNS B-36421	*Malacopteron*	*magnirostre*	Tawau Hills Park, Sabah	FJ460778
LSUMNS B-51159	*Malacopteron*	*magnirostre*	Tawau Hills Park, Sabah	MG546414
LSUMNS B-79220	*Malacopteron*	*magnirostre*	Meratus Mountains, South Kalimantan	MG546415
LSUMNS B-79223	*Malacopteron*	*magnirostre*	Meratus Mountains, South Kalimantan	MG546416
LSUMNS B-79477	*Malacopteron*	*magnirostre*	Mt. Pueh, Sarawak	MG546417
KU 12320	*Malacopteron*	*cinereum*	Samarakan, Sarawak	JN826583
LSUMNS B-38552	*Malacopteron*	*cinereum*	Tawau Hills Park, Sabah	MG546408
LSUMNS B-51118	*Malacopteron*	*cinereum*	Tawau Hills Park, Sabah	MG546409
LSUMNS B-74719	*Malacopteron*	*cinereum*	Mt. Mulu, Sarawak	MG546410
LSUMNS B-79077	*Malacopteron*	*cinereum*	Meratus Mountains, South Kalimantan	MG546411
LSUMNS B-79492	*Malacopteron*	*cinereum*	Kuching, Sarawak	MG546412
LSUMNS B-88095	*Malacopteron*	*cinereum*	Mt. Mulu, Sarawak	MG546413
LSUMNS B-36430	*Pellorneum*	*capistratum*	Tawau Hills Park, Sabah	FJ460772
LSUMNS B-47202	*Pellorneum*	*capistratum*	Klias Forest Reserve, Sabah	HQ011068
LSUMNS B-51058	*Pellorneum*	*capistratum*	Tawau Hills Park, Sabah	HQ011069
LSUMNS B-52098	*Pellorneum*	*capistratum*	Panti Forest, West Malaysia	HQ011077
LSUMNS B-58211	*Pellorneum*	*capistratum*	Kota Samarahan, Sabah	HQ011074
LSUMNS B-79000	*Pellorneum*	*capistratum*	Meratus Mountains, South Kalimantan	MG546439
LSUMNS B-79105	*Pellorneum*	*capistratum*	Meratus Mountains, South Kalimantan	MG546440
LSUMNS B-93598	*Pellorneum*	*capistratum*	Berau, East Kalimantan	MG546441
KU 17798	*Pellorneum*	*pyrrogenys*	Mt. Kinabalu, Sabah	JN826614
LSUMNS B-36316	*Pellorneum*	*pyrrogenys*	Crocker Range, Sabah	KY547936
LSUMNS B-78985	*Pellorneum*	*pyrrogenys*	Meratus Mountains, South Kalimantan	MG546442
LSUMNS B-79106	*Pellorneum*	*pyrrogenys*	Meratus Mountains, South Kalimantan	MG546443
LSUMNS B-88033	*Pellorneum*	*pyrrogenys*	Mt. Mulu, Sarawak	KY547943
LSUMNS B-88042	*Pellorneum*	*pyrrogenys*	Mt. Mulu, Sarawak	KY547944
LSUMNS B-88132	*Pellorneum*	*pyrrogenys*	Mt. Penrissen, Sarawak	KY547937
LSUMNS B-88166	*Pellorneum*	*pyrrogenys*	Mt. Penrissen, Sarawak	KY547949
LSUMNS B-88294	*Pellorneum*	*pyrrogenys*	Mt. Pueh, Sarawak	MG546444
LSUMNS B-52557	*Napothera*	*epilepidota*	Mt. Trus Madi, Sabah	JN826601
LSUMNS B-52626	*Napothera*	*epilepidota*	Mt. Trus Madi, Sabah	MG546421
LSUMNS B-78722	*Napothera*	*epilepidota*	Kelabit Highlands, Sarawak	MG546422
LSUMNS B-79100	*Napothera*	*epilepidota*	Meratus Mountains, South Kalimantan	MG546423
LSUMNS B-79101	*Napothera*	*epilepidota*	Meratus Mountains, South Kalimantan	MG546424
KU 17766	*Alcippe*	*brunneicauda*	Crocker Range, Sabah	JN826469
LSUMNS B-36359	*Alcippe*	*brunneicauda*	Crocker Range, Sabah	FJ460770
LSUMNS B-78700	*Alcippe*	*brunneicauda*	Kelabit Highlands, Sarawak	MG546332
LSUMNS B-79053	*Alcippe*	*brunneicauda*	Meratus Mountains, South Kalimantan	MG546333
LSUMNS B-79221	*Alcippe*	*brunneicauda*	Meratus Mountains, South Kalimantan	MG546334

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Tissue No.*	Genus	Species	Locality	GenBank No.
LSUMNS B-88287	*Alcippe*	*brunneicauda*	Mt. Pueh, Sarawak	MG546335
LSUMNS B-69904	*Ianthocincla*	*mitrata*	Sumatra, Indonesia	MG546390
KU 17728	*Ianthocincla*	*treacheri*	Meligan Range, Sabah	JN826518
LSUMNS B-36460	*Ianthocincla*	*treacheri*	Mt. Trus Madi, Sabah	FJ460776
LSUMNS B-78696	*Ianthocincla*	*treacheri*	Kelabit Highlands, Sarawak	KY547901
LSUMNS B-79099	*Ianthocincla*	*treacheri*	Meratus Mountains, South Kalimantan	MG546391
LSUMNS B-85203	*Ianthocincla*	*treacheri*	Mt. Mulu, Sarawak	KY547902
LSUMNS B-88040	*Ianthocincla*	*treacheri*	Mt. Mulu, Sarawak	KY547903
LSUMNS B-36314	*Cyornis*	*banyumas*	Crocker Range, Sabah	MG546358
LSUMNS B-51153	*Cyornis*	*banyumas*	Tawau Hills Park, Sabah	MG546359
LSUMNS B-78684	*Cyornis*	*banyumas*	Kelabit Highlands, Sarawak	MG546360
LSUMNS B-78992	*Cyornis*	*banyumas*	Meratus Mountains, South Kalimantan	MG546361
LSUMNS B-79069	*Cyornis*	*banyumas*	Meratus Mountains, South Kalimantan	MG546362
LSUMNS B-88188	*Cyornis*	*banyumas*	Mt. Penrissen, Sarawak	MG546363
KU 17741	*Eumyias*	*indigo*	Meligan Range, Sabah	MG546378
LSUMNS B-79169	*Eumyias*	*indigo*	Meratus Mountains, South Kalimantan	MG546379
LSUMNS B-88243	*Eumyias*	*indigo*	Mt. Mulu, Sarawak	MG546380
LSUMNS B-36275	*Vauriella*	*gularis*	Mt. Kinabalu, Sabah	MG546502
LSUMNS B-79067	*Vauriella*	*gularis*	Meratus Mountains, South Kalimantan	MG546503
LSUMNS B-79175	*Vauriella*	*gularis*	Meratus Mountains, South Kalimantan	MG546504
LSUMNS B-88049	*Vauriella*	*gularis*	Mt. Mulu, Sarawak	MG546505
LSUMNS B-88050	*Vauriella*	*gularis*	Mt. Mulu, Sarawak	MG546506
FMNH 357529	*Ficedula*	*westermanni*	Mindanao, Philippines	DQ674452
LSUMNS B-79089	*Ficedula*	*westermanni*	Meratus Mountains, South Kalimantan	MG546386
LSUMNS B-79196	*Ficedula*	*westermanni*	Meratus Mountains, South Kalimantan	MG546387
LSUMNS B-88117	*Ficedula*	*westermanni*	Mt. Pueh, Sarawak	MG546388
LSUMNS B-88226	*Ficedula*	*westermanni*	Mt. Mulu, Sarawak	MG546389
ANSP 1133	*Ficedula*	*dumetoria*	Kg. Makanitan, Sabah	DQ674458
LSUMNS B-36298	*Ficedula*	*dumetoria*	Crocker Range, Sabah	MG546381
LSUMNS B-58559	*Ficedula*	*dumetoria*	Mt. Pueh, Sarawak	MG546382
LSUMNS B-79076	*Ficedula*	*dumetoria*	Meratus Mountains, South Kalimantan	MG546383
LSUMNS B-88199	*Ficedula*	*dumetoria*	Mt. Penrissen, Sarawak	MG546384
LSUMNS B-88276	*Ficedula*	*dumetoria*	Mt. Mulu, Sarawak	MG546385
LSUMNS B-51149	*Chloropsis*	*kinabaluensis*	Tawau Hills Park, Sabah	MG546354
LSUMNS B-52618	*Chloropsis*	*kinabaluensis*	Mt. Trus Madi, Sabah	MG546355
LSUMNS B-79071	*Chloropsis*	*kinabaluensis*	Meratus Mountains, South Kalimantan	MG546356
LSUMNS B-79195	*Chloropsis*	*kinabaluensis*	Meratus Mountains, South Kalimantan	MG546357
KU 12405	*Prionochilus*	*maculatus*	Samarakan, Sarawak	GQ145275
LSUMNS B-51073	*Prionochilus*	*maculatus*	Tawau Hills Park, Sabah	HQ011104
LSUMNS B-52072	*Prionochilus*	*maculatus*	Sedenak Forest Reserve, West Malaysia	HQ011115
LSUMNS B-57415	*Prionochilus*	*maculatus*	Ulu Tungud Forest Reserve, Sabah	HQ011112
LSUMNS B-78999	*Prionochilus*	*maculatus*	Meratus Mountains, South Kalimantan	MG546450
LSUMNS B-88078	*Prionochilus*	*maculatus*	Mt. Mulu, Sarawak	MG546451
LSUMNS B-93571	*Prionochilus*	*maculatus*	Berau, East Kalimantan	MG546452
LSUMNS B-93577	*Prionochilus*	*maculatus*	Berau, East Kalimantan	MG546453
UWBM 82050	*Prionochilus*	*maculatus*	Sarawak	HQ011114
LSUMNS B-36306	*Arachnothera*	*longirostra*	Crocker Range, Sabah	JN126640
LSUMNS B-38546	*Arachnothera*	*longirostra*	Tawau Hills Park, Sabah	JN126643
LSUMNS B-46985	*Arachnothera*	*longirostra*	Mt. Kinabalu, Sabah	MG546343
LSUMNS B-52237	*Arachnothera*	*longirostra*	Miri, Sarawak	JN126685

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Tissue No.*	Genus	Species	Locality	GenBank No.
LSUMNS B-57069	*Arachnothera*	*longirostra*	Bintulu, Sarawak	JN126684
LSUMNS B-74742	*Arachnothera*	*longirostra*	Mt. Mulu, Sarawak	MG546344
LSUMNS B-78987	*Arachnothera*	*longirostra*	Meratus Mountains, South Kalimantan	MG546345
LSUMNS B-79043	*Arachnothera*	*longirostra*	Meratus Mountains, South Kalimantan	MG546346
LSUMNS B-93535	*Arachnothera*	*longirostra*	Berau, East Kalimantan	MG546347
LSUMNS B-93538	*Arachnothera*	*longirostra*	Berau, East Kalimantan	MG546348
LSUMNS B-38549	*Arachnothera*	*hypogrammicum*	Tawau Hills Park, Sabah	JF956935
LSUMNS B-47081	*Arachnothera*	*hypogrammicum*	Mt. Kinabalu, Sabah	HQ010965
LSUMNS B-51127	*Arachnothera*	*hypogrammicum*	Tawau Hills Park, Sabah	HQ010972
LSUMNS B-52085	*Arachnothera*	*hypogrammicum*	Bukit Hanta Forest Reserve, West Malaysia	HQ010989
LSUMNS B-74741	*Arachnothera*	*hypogrammicum*	Mt. Mulu, Sarawak	MG546398
LSUMNS B-78991	*Arachnothera*	*hypogrammicum*	Meratus Mountains, South Kalimantan	MG546399
LSUMNS B-79046	*Arachnothera*	*hypogrammicum*	Meratus Mountains, South Kalimantan	MG546400
LSUMNS B-88102	*Arachnothera*	*hypogrammicum*	Mt. Mulu, Sarawak	MG546401
LSUMNS B-93541	*Arachnothera*	*hypogrammicum*	Berau, East Kalimantan	MG546402
LSUMNS B-93547	*Arachnothera*	*hypogrammicum*	Berau, East Kalimantan	MG546403
UWBM 81984	*Arachnothera*	*hypogrammicum*	Kubah National Park, Sarawak	HQ010983
AMNH 648559	*Arachnothera*	*everetti*	Sarawak	JF956980
LSUMNS B-36309	*Arachnothera*	*everetti*	Crocker Range, Sabah	JF956951
LSUMNS B-36402	*Arachnothera*	*everetti*	Tawau Hills Park, Sabah	JF956974
LSUMNS B-78752	*Arachnothera*	*everetti*	Kelabit Highlands, Sarawak	MG546339
LSUMNS B-79021	*Arachnothera*	*everetti*	Meratus Mountains, South Kalimantan	MG546340
LSUMNS B-79213	*Arachnothera*	*everetti*	Meratus Mountains, South Kalimantan	MG546341
LSUMNS B-88259	*Arachnothera*	*everetti*	Mt. Mulu, Sarawak	MG546342
KU 17801	*Arachnothera*	*everetti*	Mt. Kinabalu, Sabah	JF956920

* AMNH = American Museum of Natural History, New York; FMNH = Field Museum of Natural History, Chicago; KU = University of Kansas Museum of Natural History, Lawrence; LSUMNS = Louisiana State University Museum of Natural Science, Baton Rouge; and UWBM = University of Washington Burke Museum, Seattle.

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