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Nest And Species Assemblage of Stingless Bees (Apidae: Meliponini) in Riparian Forests of Royal Belum State Park, Perak, Malaysia

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ABSTRACT

This study investigated the nest and species assemblage of stingless bees in riparian forests of Royal Belum State Park (RBSP), Perak, Malaysia. Sampling was conducted during dry and wet seasons. A total of five stingless bee species were recorded and the assemblage was strongly dominated by *Lepidotrigona doipaensis*, which contributed the highest proportion of individuals across both seasons. Diversity analyses revealed higher Shannon–Wiener diversity, Simpson's diversity and Pielou's evenness during the wet season, indicating a more balanced community structure compared to the dry season. Individual-based rarefaction curves showed more rapid species accumulation and complete species representation during the wet season and Principal Coordinates Analysis (PCoA) based on Bray–Curtis dissimilarity indicated moderate seasonal turnover in assemblage structure driven primarily by changes in relative abundance. These findings highlight the ecological importance of protected riparian forests in supporting stingless bee diversity and provide baseline data for long-term monitoring and conservation in tropical forest ecosystems.

1. Introduction

Stingless bees (Apidae: Meliponini) are key pollinators in tropical and subtropical ecosystems, contributing significantly to the reproduction of wild plants and agricultural crops. In Southeast Asia, stingless bees exhibit high diversity and occupy a wide range of forest habitats, including lowland dipterocarp forests, mangroves, and riverine ecosystems [10,13]. Although stingless bees play a vital ecological role, studies focusing on their assemblage structure and abundance within protected riparian forests remain scarce, particularly in Malaysia.

Riparian forests function as ecological corridors that provide floral resources, nesting substrates and stable microclimatic conditions for insects [11]. Forest rivers within protected areas such as Royal Belum State Park (RBSP) are relatively undisturbed, making them ideal systems for studying natural stingless bee assemblages. Understanding species assemblage and abundance patterns in such habitats is crucial for pollinator conservation and ecosystem management [17]. Specifically, the study

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addresses the following objectives which is to document the species of stingless bees occurring in riparian forests of Royal Belum State Park.

2. Literature Review

2.1 Stingless Bee Diversity in Southeast Asia

Southeast Asia is recognised as a hotspot for stingless bee diversity, with numerous species belonging to the genera Lepidotrigona, Tetragonula and Tetragonilla [13]. Stingless bees form highly diverse, socially complex assemblages that dominate many tropical pollinator communities. Across the Neotropics they comprise several hundred cryptic species, often indistinguishable without detailed morphological or molecular work, which makes accurate species inventories difficult. Malaysia hosts a rich assemblage of stingless bees, many of which exhibit habitat-specific nesting preferences [10].

In Southeast Asia, stingless bee diversity is shaped by complex biogeographic history, forest structure, and climatic conditions. Species distributions are often influenced by forest type and degree of habitat disturbance, with some species showing strong preferences for primary or mature secondary forests. Such habitat specificity can result in distinct assemblage patterns even within relatively small geographic areas, underscoring the importance of site-based surveys in protected forest landscapes [15].

2.2 Ecological Role of Stingless Bees

Stingless bees play a crucial role as pollinators of both forest plants and crops, enhancing plant reproductive success and maintaining ecosystem stability [3,17]. Their foraging activity supports plant diversity, particularly in tropical forests. Meliponini occupy a broad latitudinal range (≈ 35 °S to 23.5 °N) and exploit a variety of nesting substrates, from abandoned beetle burrows to termite nests, building wax-resin structures that may be concealed or exposed. Brood cells are typically mass-provisioned and arranged in horizontal combs, though some species retain ancestral clustered cell patterns. Morphologically, they are distinguished by simple female claws, absent hind tibial spurs, reduced wing venation, and greatly reduced sting apparatus.

Beyond their role as pollinators, stingless bees contribute to broader ecosystem functioning through their interactions with plant communities and other insects. Their year-round foraging activity ensures continuous pollination services, particularly in tropical forests where flowering phenology may be asynchronous. Differences in foraging range, body size, and recruitment behaviour among species further influence plant–pollinator networks and may affect plant reproductive success at local scales [6,12].

2.3 Riparian Forests as Pollinator Habitats

Riparian forests provide continuous floral resources and nesting substrates, supporting diverse insect communities [8,11]. These habitats are especially important for bees due to their proximity to water and stable microclimates. Natural vegetation plays an important role in sustaining pollinator populations and enhancing pollination services [17]. Studies have shown that agricultural systems located near forested habitats experience increased crop yields, highlighting the value of natural ecosystems as reservoirs for pollinators [6,14]. Other than that, riparian forest also functions as ecological corridors that facilitate movement of pollinators across fragmented landscapes. Their linear structure and high plant diversity can support both resident and transient bee populations, enhancing landscape-level connectivity. In protected areas such as Royal Belum State Park, intact riparian zones may therefore serve as important refugia for pollinators, particularly in regions where surrounding habitats are increasingly modified [8,11].

2.4 Nest Characteristics and Abundance

The nest entrance structure, nest height and substrate type have been shown to influence colony strength and forager activity in stingless bees [2,5]. Abundance estimates based on forager captures are commonly used as proxies for colony activity [4]. Stingless bees exhibit species-specific nesting requirements and foraging preferences that influence colony establishment and local abundance. Natural colony reproduction occurs infrequently, limiting population expansion and making nest-site availability an important factor determining stingless bee distribution in natural habitats [17].

Although forager capture rates are commonly used to estimate stingless bee abundance, such measures are influenced by environmental conditions, time of sampling, and nest accessibility. Species that nest underground or within dense substrates may exhibit lower observable foraging activity at nest entrances, potentially leading to underrepresentation in abundance assessments. Consequently, abundance estimates should be interpreted as relative indicators of activity rather than direct measures of colony size [2,4].

2.5 Knowledge Gaps in Protected Areas

Despite increasing research on stingless bees, studies focusing on species assemblage and abundance in protected riparian forests remain limited, particularly in Malaysia. Baseline data from undisturbed forest systems are essential for understanding natural assemblage structure, monitoring population trends, and informing long-term conservation planning [1,10]. In Malaysia, most stingless bee studies have focused on meliponiculture or agricultural systems, while ecological data from protected forests remain limited. This imbalance restricts understanding of natural assemblage structure and baseline population dynamics. Studies conducted within protected areas are therefore critical for distinguishing natural variation from human-induced change and for informing long-term conservation strategies for tropical pollinators [1,12].

3. Methodology

3.1 Study Area

The study was conducted in Royal Belum State Park (RBSP), Perak, Malaysia, a protected tropical rainforest characterised by extensive river networks. The study therefore focused on direct assessment of confirmed nest sites at Sungai Ko’oi, Sungai Bandak, Sungai Tiang, Sungai Kenarong and Sungai Papan, all located within the RBSP boundary.

3.2 Nest Survey and Species Identification

Fig. 1. Map showing the location of stingless bee sampling sites within Royal Belum State Park (RBSP), Perak, Malaysia

Stingless bee nests were located through systematic searches along riparian forest areas with the assistance of local Orang Asli guides who possess extensive traditional knowledge of forest landscapes and stingless bee nesting habits. Their guidance was particularly valuable for locating concealed, elevated and underground nests that were difficult to detect through visual surveys alone. The capture-based approach near nest entrances was applied in this study. This approach for stingless bee studies was meant to estimate relative abundance. Previous studies have demonstrated that the number of foragers captured near nest entrances reflects colony strength and foraging intensity, providing a reliable basis for comparing abundance among species and sites [2,4,5]. Species identification was conducted using a combination of nest entrance characteristics and external worker bee morphology, following published taxonomic keys and descriptions for stingless bees in Peninsular Malaysia [10,13].

4. Result

4.1 Abundance of Stingless Bee Nests

A total of ten stingless bee nests were recorded across the riparian forest sites in Royal Belum State Park. *Lepidotrigona doipaensis* accounted for the highest number of nests, followed by *Tetragonula laeviceps* and *Tetragonilla collina* with two nests each. *Lepidotrigona terminata* and *Homotrigona apicalis* were each represented by a single nest. The uneven distribution of nests among species reflects pronounced dominance patterns and species-specific nesting success within the riparian forest environment. Although some species were represented by few nests, their presence contributes to overall assemblage composition and highlights the importance of riparian forests as nesting habitats for multiple stingless bee taxa.

Table 1
Number of stingless bee nests recorded for each species in riparian forest sites of Royal Belum State Park, Perak

Species	Number of nests
Lepidotrigona doipaensis	4
Tetragonula laeviceps	2
Tetragonilla collina	2
Lepidotrigona terminata	1
Homotrigona apicalis	1
Total	10

4.2 Species Composition

A total of five stingless bee species were recorded across both dry and wet seasons in the riparian forests of Royal Belum State Park. Among these, *Lepidotrigona doipaensis* was the most dominant species, contributing the highest proportion of individuals across seasons. This was followed by *Tetragonula laeviceps* and *Tetragonilla collina*, which formed intermediate components of the assemblage in terms of abundance.

In contrast, *Homotrigona apicalis* and *Lepidotrigona terminata* occurred at much lower abundances and showed strong seasonal restriction. These species contributed minimally to the overall assemblage, resulting in an uneven distribution of individuals among species. Consequently, the stingless bee assemblage was characterised by pronounced dominance of a single species, with the remaining species contributing unevenly to total abundance.

Table 2
Relative abundance (%) of stingless bee species recorded in riparian forests of Royal Belum State Park based on combined dry and wet season sampling

Species	Relative abundance (%)
Lepidotrigona doipaensis	61
Tetragonula laeviceps	15
Lepidotrigona terminata	13
Tetragonilla collina	9
Homotrigona apicalis	1

Fig. 2. Lepidotrigona doipaensis recorded in riparian forests of Royal Belum State Park

Fig. 3. *Tetragonula laeviceps* recorded in riparian forests of Royal Belum State Park

Fig. 4. Lepidotrigona terminata recorded in riparian forests of Royal Belum State Park

Fig. 5. Tetragonilla collina recorded in riparian forests of Royal Belum State Park

Fig. 6. Homotrigona apicalis recorded in riparian forests of Royal Belum State Park

Individual-based rarefaction curves indicated clear seasonal differences in species accumulation patterns. The wet season curve reached an asymptote at five species, reflecting complete representation of the recorded assemblage, whereas the dry season curve plateaued at four species due to the absence of *Lepidotrigona terminata*. Species accumulation occurred more rapidly during the wet season, indicating higher effective diversity and a more even distribution of individuals among species. In contrast, the slower rise and lower asymptote of the dry season curve reflected strong dominance by *Lepidotrigona doipaensis*. The clear plateauing of both curves suggests that sampling effort was sufficient to characterise the stingless bee assemblages in both seasons.

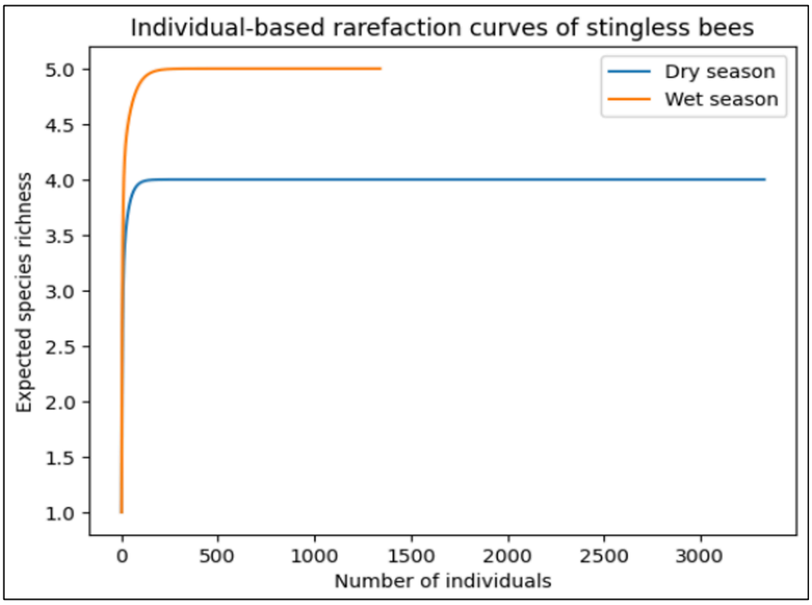

Fig. 7. Individual-based rarefaction curves for stingless bee assemblages during dry and wet seasons in riparian forests of Royal Belum State Park, Perak

The wet season exhibited higher Shannon–Wiener diversity and Simpson's diversity compared to the dry season, indicating a more even distribution of individuals among species. In contrast, the dry season assemblage showed lower diversity values, reflecting strong dominance by *Lepidotrigona doipaensis*. Pielou's evenness index further supported this pattern, with greater evenness observed during the wet season. Differences in diversity indices between seasons were influenced by seasonal variation in species occurrence and the accessibility of nesting sites [2,15]. *Lepidotrigona terminata* was absent during the dry season resulting in zero recorded individuals. Species with zero abundance were excluded from diversity calculations to avoid overestimation of richness and bias in evenness metrics, following standard ecological practice [9].

In the wet season, the higher diversity and evenness observed can be attributed to the increased availability of floral resources, which supports a more balanced distribution of stingless bee species. The abundant resources in the wet season reduce competition for food, allowing multiple species to thrive and maintain similar population sizes [6]. This is reflected in the higher Shannon-Wiener index, which indicates greater diversity and the Simpson's and Pielou's evenness indices, which show that no single species dominated the community. These findings contrast with the dry season, where limited resources led to greater competition, allowing species like *Lepidotrigona doipaensis* to dominate, resulting in lower diversity and more uneven distribution among the species [10,17].

Next, Principal Coordinates Analysis (PCoA) based on Bray–Curtis dissimilarity revealed a clear separation between dry and wet season stingless bee assemblages in Royal Belum State Park (Bray–Curtis = 0.63). Bray–Curtis dissimilarity between dry and wet season assemblages was 0.63, indicating a moderate to high level of compositional difference driven primarily by changes in species relative abundance rather than complete species turnover. Since only two assemblages were examined, the ordination revealed a single axis that explained 100% of the variance, which is expected when analysing distance matrices with two samples [7]. This result indicates a moderate level of seasonal turnover in assemblage structure, driven by changes in species presence and relative abundance between seasons.

5. Discussion

In this study, the stingless bee assemblage in the riparian forests of Royal Belum State Park was characterised by low species richness but pronounced dominance patterns, with *Lepidotrigona doipaensis* emerging as the numerically dominant species across seasons. Such dominance is consistent with previous studies in Southeast Asian forests, where *Lepidotrigona* species frequently exhibit high abundance due to their flexible nesting behaviour and broad foraging range [2,13]. The higher number of nests recorded for *L. doipaensis* further supports the interpretation that colony availability and nesting success play an important role in shaping assemblage composition, rather than abundance patterns being driven solely by short-term foraging activity.

Then, seasonal differences in species diversity and evenness suggest that environmental conditions strongly influence stingless bee community structure in riparian forests. Higher Shannon–Wiener diversity, Simpson's diversity and Pielou's evenness during the wet season indicate a more balanced assemblage, likely supported by increased floral resource availability and more favourable microclimatic conditions. Similar seasonal shifts in bee diversity have been reported in tropical systems, where wetter periods promote flowering continuity and reduce interspecific competition, allowing subordinate species to persist alongside dominant taxa [6,17]. In contrast, the lower diversity and evenness observed during the dry season reflect intensified dominance by *L. doipaensis*, suggesting that resource limitation may disproportionately favour competitively superior or more generalist species.

The absence of *Lepidotrigona terminata* during the dry season contributed to reduced effective richness and lower diversity values. Seasonal absence of certain stingless bee species has been attributed to changes in nest accessibility, reduced foraging activity, or temporary colony inactivity during unfavourable conditions [15]. Excluding species with zero abundance from diversity calculations is consistent with standard ecological practice and avoids artificial inflation of richness or bias in evenness metrics [9]. These findings highlight the importance of considering seasonal detectability and sampling context when interpreting diversity indices in tropical bee assemblages.

The Principal Coordinates Analysis based on Bray–Curtis dissimilarity further supports the presence of seasonal turnover in assemblage structure. The Bray–Curtis value of 0.63 indicates a moderate to high degree of compositional dissimilarity between dry and wet season assemblages, driven primarily by changes in species relative abundance rather than complete species replacement. Because only two assemblages were compared, ordination collapsed onto a single axis explaining all observed variance, which is an expected outcome in distance-based ordination with two samples [7]. This pattern suggests that seasonal shifts in dominance and evenness, rather than species loss alone, are key drivers of community differentiation.

Other than that, individual-based rarefaction analysis revealed clear seasonal differences in species accumulation patterns, with the wet season reaching a higher asymptotic species richness than the dry season. This indicates that seasonal changes influence not only total abundance but also the detectability and effective richness of stingless bee assemblages. Similar seasonal turnover patterns have been documented in tropical agricultural landscapes, where changes in floral resource availability and climatic conditions lead to shifts in bee species composition and relative dominance across seasons [16]. In such systems, rarefaction curves often plateau rapidly due to strong dominance by a small number of species, while seasonal presence or absence of less common species contributes to observed differences in richness between sampling periods. The congruence between rarefaction patterns and diversity indices in this study supports the interpretation that wet season assemblages in riparian forests are more balanced and species-rich, whereas dry season assemblages are characterised by stronger dominance and reduced effective diversity.

Overall, the results demonstrate that protected riparian forests in Royal Belum State Park support functionally important stingless bee assemblages whose structure varies seasonally in response to environmental conditions. The combination of nest abundance data, diversity indices, rarefaction analysis and ordination provide a robust baseline for understanding stingless bee community dynamics in undisturbed tropical forests. Such baseline information is essential for long-term monitoring, particularly in the context of climate variability and habitat change and reinforces the role of riparian forests as critical refugia for native pollinators [1,10].

6. Conclusion

For conclusion, five species were recorded, with *Lepidotrigona doipaensis* consistently dominating the assemblage, reflecting its strong ecological adaptability to riparian forest conditions. Diversity analyses demonstrated clear seasonal differences, with higher diversity and evenness observed during the wet season, while the dry season was characterised by stronger dominance patterns. Rarefaction analysis confirmed adequate sampling effort and highlighted more complete species representation during the wet season and PCoA results indicated moderate seasonal shifts in assemblage structure driven by changes in species relative abundance rather than complete species replacement. These findings underscore the role of riparian forests as important habitats for sustaining stingless bee communities in protected landscapes.

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