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Traditional Knowledge of Plants for *Sunggau* Rafters on Three Forest Types for Conservation of *Apis dorsata* in Indonesia

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Abstract: The traditional knowledge of *sunggau* rafters for *Apis dorsata* nesting is essential for livelihood and forest conservation. We determine the plant species needed to support the conservation of *A. dorsata* in Belitung Islands, Indonesia, by investigating the distribution of the *sunggau* in the three types of forests, the traditional knowledge regarding the plant species used for *sunggau*, and the vegetation structure of forests in which the *sunggau* is installed. Distribution of *sunggau* were explored on heath, swamp heath, and mangrove forests. We conducted a vegetation survey in those forests and an ethnobotanical survey by interviewing bee farmers regarding the plants used for *sunggau* and other uses. We found 95 *sunggau* distributed in the heath, swamp heath, and mangrove forest. Based on interviews, we recorded 65 plant species for *sunggau* and six other uses, including bee forages. *Calophyllum* sp., *Cryptocarya* sp., *Melaleuca cajuputi*, and *Syzygium urceolatum* are the most important plants according to bee farmers. The last two species dominate all forests, except mangroves, which are dominated by *Lumnitzera littorea*, according to vegetation surveys. However, the availability of several plants for *sunggau* is declining. Therefore, the conservation of *A. dorsata* needs the sustainability of *sunggau* and bee forage plants.

Keywords: bee ecotourism; conservation; forest honey bee; heath forest; local wisdom; *Lumnitzera littorea*; *Melaleuca cajuputi*; *Syzygium urceolatum*

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1. Introduction

Deforestation has become a major worldwide problem [1] that affects the sustainability of forest resources [2] and climate [3,4]. The rapid rate of deforestation in South-east Asia reached one percent per year between 2000 and 2010 due to the industrial plantations and agriculture [5]. In accordance, deforestation of over five percent annually occurs in Indonesia, particularly in the eastern lowlands of Sumatra and the peatlands of Kalimantan [5]. The conversion of forests into oil palm plantations in tropical South America and Asia threatens forest ecosystems and biodiversity [6,7]. In Indonesia, mining activities, especially in Belitung, also decrease the forest area, in addition to oil plantations [8,9].

Belitung Islands lie between Sumatra and Borneo in Indonesia and are part of the savanna corridor in Sundaland [10]. The ecosystem in Belitung Islands comprises mainly the heath forest, which stands almost entirely on Belitung Island [11] with small areas of lowland rainforests [12]. As an archipelago, the Belitung Islands also have an extensive mangrove forest ecosystem, which is a species-rich community [13]. The heath forest, also known as Sundaland heath forest or *kerangas* forest (local name), is a typical tropical moist forest found only on Borneo, Belitung, and Bangka Islands. Permanently or temporarily waterlogged heath forests are known as swamp heath forests [14]. However, these various types of forests in Belitung are currently threatened by mining activities and the expansion of oil palm plantations [8,9].

In Belitung Islands, the conversion of forests into tin mining sites and oil palm plantations has raised concerns about the ecological consequences of these activities, which might lead to fragmentation of the forests [15], affect biodiversity loss, and drain water sources [9]. In fact, the people in Belitung have rich traditional knowledge and local wisdom regarding the utilization and conservation of land as well as biodiversity. They have a culture of preserving plant species, especially fruit plants, medicinal plants, or other valuable plants, in an area called *kelekak* [16].

Traditional knowledge (TK) is knowledge, know-how, skills, and practices developed, sustained, and passed on from generation to generation within a community, often forming part of its cultural or spiritual identity [17]. The traditional knowledge involves practices that preserve and promote the conservation of forests and associated biodiversity, as well as the resilience of local communities [18,19]. People in Belitung have local wisdom in conserving the forest, such as by constructing a rafter (called *sunggau* by local people) for the honey bee *Apis dorsata* in the forest. *Apis dorsata* naturally builds nests in the bee trees, known as *sambit* by local people in Belitung [20,21]. However, when the bee farmer installs *sunggau*, the bees prefer to construct the nest on the *sunggau* rather than the bee trees [22,23]. In general, there are two categories of *sunggau*: ground (*tunggak muke*, *ungad*, *tanger*) and climbing (*bantayan*, *bersilang*) that are constructed in heath forest, swamp heath forest, mangroves [20,22,23], and riparian areas [20].

The existence of *A. dorsata* in the Belitung Islands plays a fundamental role in community life. The bees contribute as important pollinators for natural plant communities and crops [24,25] and provide bee products such as honey and beebread [15]. The giant *A. dorsata* migrates annually to the blooming flowers across the continent [26,27]. Belitung Islands serve as a bridge between Kalimantan and Sumatra Island in *A. dorsata*'s migration path [20,28].

The bee farmers in Belitung have traditional knowledge regarding the requirements for constructing *sunggau*, i.e., the time of the flowering season, the *rendap* (composition of the vegetation surrounding the *sunggau*), and the *renak* (the path of sun rays entering the *sunggau*), as well as the plant species suitable for the *sunggau* [20,22]. Therefore, the bee farmers protect the forests with their local wisdom to maintain *sunggau* practice. However, this traditional knowledge has yet to be documented scientifically because it has been transmitted through generations. Thus, this knowledge is prone to become extinct. Previous studies reported that several species are used for *sunggau* [22]. Our study expands the knowledge of the diversity of plants used for *sunggau* and strengthens the importance of plants for *sunggau* by exploring the other uses of these plants. Our studies aimed to investigate the traditional knowledge of bee farmers relating to *sunggau*, i.e., (1) the type and distribution of the *sunggau* in heath, swamp heath, and mangrove forests; (2) the importance of plant species used to construct *sunggau*, defined by number of used (NU), cultural important index (CI), and relative frequent citation (RFC); and (3) composition, diversity pattern, and vegetation structure of forest types which serve *sunggau*.

2. Methods

2.1. Study Areas

Our study was conducted in the Sub Regency of Membalong, Belitung Regency, Belitung Islands, Indonesia (Figure 1). Data were collected in three villages: Perpat (Per), Kembiri (Kem), and Tanjung Rusa (TR). Data in TR were collected in two islands: Belitung Island (TR-Bel) and Kampak Island (TR-Kam) (Figure 1). These villages were chosen due to the fact that many skilled bee farmers practice *sunggau*, according to the Regional Planning and Development Agency (or BAPPEDA) of Belitung Regency. The total area of Sub Regency Membalong is 910.37 km^2.

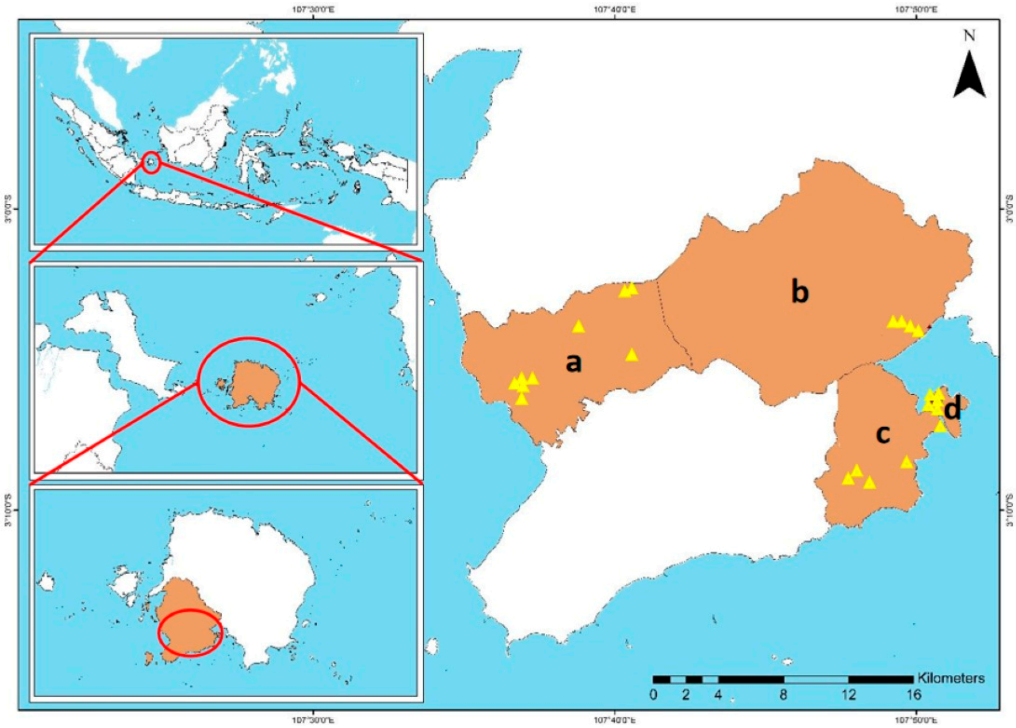


Figure 1. Map shows the locations of *sunggau* (▲) in three villages in the Sub Regency of Membalong, Belitung, Indonesia: a = Perpat (Per), b = Kembiri (Kem), c = Tanjung Rusa in Belitung Island (TR-Bel), and d = Tanjung Rusa in Kampak Island (TR-Kam).

The people of Membalong are mostly from the Belitung-Malay ethnic group [29], whose primary income is from forestry, fishing, and mining activities [30]. Membalong has rainy and dry seasons; the highest annual rainfall was 3026 mm [30], with two peaks of rainfall during October–January and March–May; the dry season ranges from June to September [31]; and the annual average temperature is 28.1 °C [30].

2.2. Ethnobotanical Survey

Respondents were selected based on the following criteria: (1) has a traditional ecological knowledge of *sunggau*; (2) has the ability to construct *sunggau* and harvest honey of *A. dorsata*; (3) a minimum of one year experience in *sunggau* construction; (4) willing to share their knowledge; and (5) effective communicators [32]. The respondents are the residents of the three villages who are 18 years or older (Table S1), due to this age group being able to describe their opinions independently [33]. All respondents were informed about the purpose of the research prior to the interview [32] and signed the informed consent. Data on *sunggau* were collected from respondents through in-depth interviews [32,34] using a questionnaire. We asked the respondents: (1) the type of *sunggau*, (2) the type of forest where the *sunggau* was built, (3) plants used for the construction of *sunggau* and other uses, and (4) the availability of the plants in nature.

2.3. Field Survey for Exploring Sunggau Type and Measurement

We explored the distribution of five types of *sunggau*, i.e., *tunggak muke*, *ungad*, *tanger*, *bantayan*, and *bersilang*, that are constructed in heath forest, swamp heath forest, and mangrove forest [20,22,23]. We measured the structure of the *tunggak muke*, which has the highest distribution in the three types of forests. The measurement consists of (1) the height of the front poles (HFP), (2) the back poles (HBP), (3) the length of the plank (LP), (4) the diameter (DP), and (5) the incline (IP) of the plank. The measurement of the incline of *sunggau* used clinometer apps for Android.

2.4. Vegetation Survey

The vegetation survey covered three types of forest in which *sunggau* was constructed: heath forest, swamp heath forest, and mangrove forest. The heath forest is characterized by nutrient-poor soil [35], low soil pH [35,36], and is dominated by white sand with a thin organic layer [35,36]. Therefore, heath forest has a low diversity and canopy, dominated by tolerant and semi-tolerant species with poor nutrients [14]; the plants have small stem and thick and small leaves [14,36]. The swamp heath forest is a type of heath forest that floods during the rainy season and has a water level below ground level throughout the dry season [37]. The mangrove forest is characterized by being periodically flooded with seawater [38] and usually consists of plants from the Rhizophoraceae family such as *Bruguiera* and *Rhizophora* [13,39].

The current study explored floristic composition, vegetation structure, and diversity pattern of the forest type in which *sunggau* were constructed (Table S2). Our data were combined with the data of the previous studies (Table S2). Vegetation survey in each forest was conducted using four quadrants (20 × 20 m) placed along a transect. The transect was established based on the location of *sunggau* and following the flight direction of *A. dorsata*. We assessed the floristic composition and vegetation structure using a nested quadrat sampling technique; that is, 20 × 20 m quadrats for the tree stage (the diameter at breast height (DBH) $\geq$ 20 cm), 10 × 10 m quadrats for the pole stage (DBH 10–20 cm), 5 × 5 m quadrats for sapling stage (DBH < 10 cm; height $\geq$ 1.5 m) and shrubs, and 2 × 2 m for seedling stage (height < 1.5 m) and herbs [14,40,41].

We documented the local name and individual number of plant species in each quadrat and the diameter at DBH of trees, poles, and saplings. All plant species observed in the field were collected as herbarium specimens for identification.

2.5. Data Analysis

The measurement data of the *tunggak muke sunggau* structure were compared among three villages and three types of forests using Kruskal–Wallis and Mann–Whitney pairwise analysis. The analysis was performed using R [42]. The data gathered from the respondents in the ethnobotanical survey were analyzed based on ethnobotanical indices in Table 1 [34] using the ethnobotanyR package of R (v0.1.9) [43]. We carried out cluster analysis to group the forest type (1) based on plant species used for *sunggau* using a present–absent data set from the interview and (2) floral composition from vegetation analysis. A dendrogram was generated using binary distance methods and hierarchical clustering with single agglomeration methods using R [42].

Table 1. The ethnobotanical basic values and indices analyzed using ethnobotanyR package in R [34,43].

No	Basic Value/Indices	Criteria
1	Number of Uses (NU)	The total of all categories (i.e., *sunggau* and other used) for which a species is considered useful
2	Use Report (UR)	The sum of all the times that individual informants named the species for a specific use category and the sum of all those categories
3	Cultural Importance index (CI)	The overall proportion of informants who mentioned the use of each species by considering the distribution of use (number of informants) of each species, and the range of its uses. The CI is given by the formula CI = UR/N, where UR (use reports) is the use recorded for each species and N is the total number of informants.
4	Frequency of Citation (FC)	The total of informants that cite the use for a species used for *sunggau* and other uses categories
5	Relative Frequency Citation (RFC)	The RFC determines the importance of each species depending on the number of informants reporting a species compared to the total number of informants. The RFC is given by the formula RFC = FC/N, where FC is the total number of informants that referred to the species, and N is the total number of informants.

Data gathered in the vegetation survey were tabulated and analyzed to characterize floral composition within the forest types (heath forest, swamp heath forest, and mangrove forest). The relative density, relative dominance, and relative frequency values for each species were determined to obtain the Importance Value Index (IVI), which gives the idea of the relative importance of each species in the community. The IVI indicates the species dominance and ecological success with a single value [40,44]. We also analyzed the importance of tree species with high IVI values for *A. dorsata* (i.e., sources of pollen, nectar, or both) in each forest type. Patterns of the forest types were analyzed based on the Shannon–Wiener index (H') [45].

3. Results

3.1. The Distribution of Sunggau Types

A total of 95 *sunggau* were found in this study, including 57, 19, 10 and 9 at Perpat, Kembiri, Tanjung Rusa-Belitung Island, and Tanjung Rusa-Kampak Island, respectively (Figure 2, Table S3). We found ground *sunggau*: *tunggak muke*, *ungad*, and *tanger*; while *bantayan* and *bersilang* were found for climbing *sunggau* (Table 2). *Tunggak muke* is the most common and widespread *sunggau* found in all villages and all forest types (Figure 2). *Ungad* were found in all villages except in the swamp heath forests of Perpat and Tanjung Rusa-Kampak Island. *Bantayan* are commonly found in the heath forests with tree height of five to ten meters (personal observation). *Bantayan* are also found in swamp heath forests and mangroves (Figure 2).

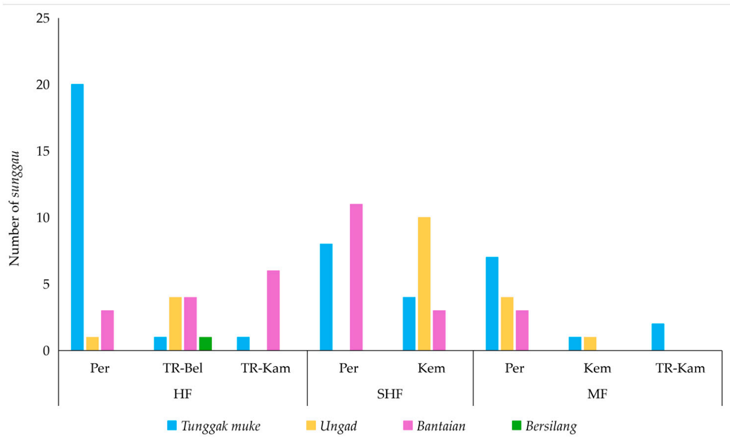


Figure 2. Types of *sunggau* are constructed in heath forest, swamp heath forest, and mangrove forest. The coordinate of the *sunggau* is shown in Table S3. HF = Heath forest; SHF = Swamp heath forest; and MF = Mangrove forest; Per = Perpat; Kem = Kembiri; TR-Bel = Tanjung Rusa in Belitung Island; TR-Kam = Tanjung Rusa in Kampak Island.

Table 2. Category and descriptions of *sunggau* types found in this study. = front poles; = back poles; = plank, = *A. dorsata* comb.

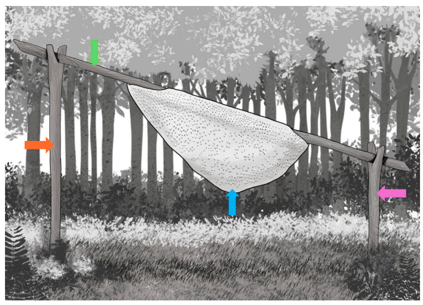
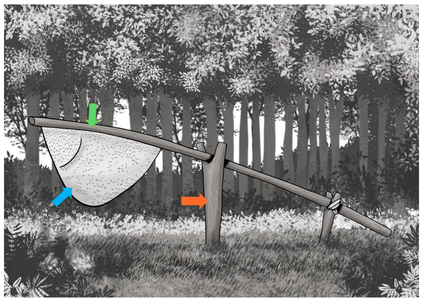
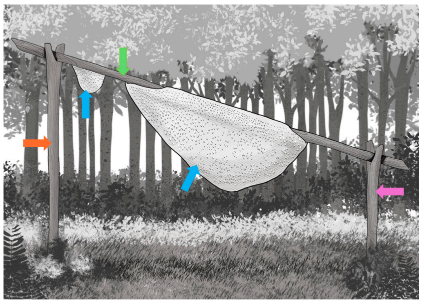
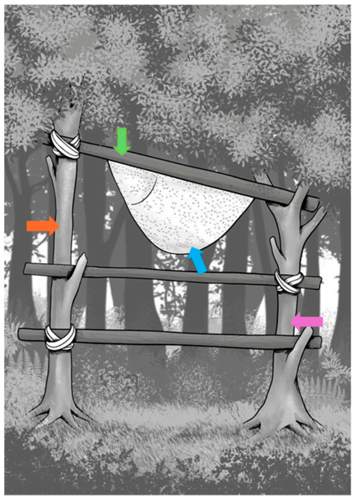
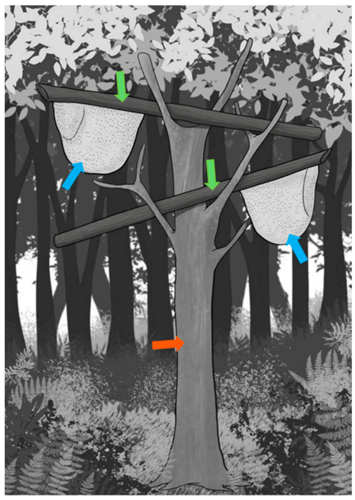
Category and Type of *Sunggau*	Description	Figures
Ground *Sunggau*: constructed close to the ground, consisting of three types, i.e., *tunggak muke*, *ungad*, and *tanger.*		
a. *Tunggak muke*	Constructed by three parts of a small log: front pole, back poles, and plank. The front or/and back poles can be substituted with tree trunks.	

Table 2. *Cont.*

Category and Type of *Sunggau*	Description	Figures
b. *Ungad*	Built with only one pole in the middle of the plank, the back end of the plank touches the ground or sometimes is tied to branches.	
c. *Tanger*	A variant of *tunggak muke*, with two nests found on the same plank.	
Climbing *Sunggau:* constructed high above the ground, consisting of two types, i.e., *bantayan* and *bersilang*		
d. *Bantayan*	Constructed on two living trees as the poles with one plank and equipped with a horizontal log as the ladder to reach the plank.	
e. *Bersilang*	Variant of *bantayan*, constructed by two planks cross each other on the same living tree as the pole.	

Tunggak muke was measured in different villages and different forest types for comparison (Table 3). Based on pairwise analysis, *tunggak muke* was similar in all category measurements in both villages and forest types ($p > 0.05$), except the diameter of plank for *tunggak muke* in different villages (Table 3, $p = 0.08$). In Kembiri, the plank diameter of *tunggak muke* (0.39 ± 0.04) was significantly higher than those in Perpat.

Table 3. Measurement of parts of *tunggak muke sunggau* in three villages and three forest types.

Parts of *sunggau*	Villages			Forest Types			Mean
	Perpat	Kembiri	Tanjung Rusa	Heath Forest	Swamp Heath Forest	Mangrove	
HFP (m)	1.96 ± 0.38 ^{a}	2.03 ± 0.15 ^{a}	2.07 ± 0.40 ^{a}	2.03 ± 0.46 ^{a}	2.20 ± 0.42 ^{a}	1.85 ± 0.21 ^{a}	1.98 ± 0.37
HBP (m)	1.26 ± 0.31 ^{a}	1.30 ± 0.35 ^{a}	1.30 ± 0.26 ^{a}	1.34 ± 0.32 ^{a}	1.45 ± 0.07 ^{a}	1.11 ± 0.26 ^{a}	1.27 ± 0.30
LP (m)	3.20 ± 0.41 ^{a}	3.30 ± 0.36 ^{a}	2.87 ± 0.64 ^{a}	3.16 ± 0.44 ^{a}	3.40 ± 0.28 ^{a}	3.04 ± 0.52 ^{a}	3.14 ± 0.45
DP (m)	0.31 ± 0.04 ^{b}	0.39 ± 0.04 ^{a}	0.32 ± 0.04 ^{ab}	0.31 ± 0.04 ^{a}	0.36 ± 0.00 ^{a}	0.34 ± 0.05 ^{a}	0.33 ± 0.04
IP (degree)	21.64 ± 5.90 ^{a}	17.33 ± 3.05 ^{a}	21.33 ± 3.21 ^{a}	22.74 ± 5.08 ^{a}	16.50 ± 3.53 ^{a}	21.57 ± 6.13 ^{a}	21.59 ± 5.47

HFP = Height of front pole; HBP = Height of back pole; LP = Length of plank; DP = Diameter of plank; IP = Incline of plank; The different letter in the same raw showed the significant difference.

3.2. Traditional Knowledge of Plant Species Used for Sunggau

Bee farmers used 65 plant species from 36 families for *sunggau* constructions (Figure 3, Table S4). The list of plant species for *sunggau* (Figure 3, Table S4) shows that Myrtaceae is the highest family with 15 species, followed by Callophylaceae, Lauraceae, and Malvaceae, respectively, with five, four, and three species. Combretaceae, Dipterocarpaceae, Euphorbiaceae, Fabaceae, Fagaceae, and Theaceae contributed two plant species for *sunggau*, while the remaining 26 families were represented by only one taxa used for *sunggau*.

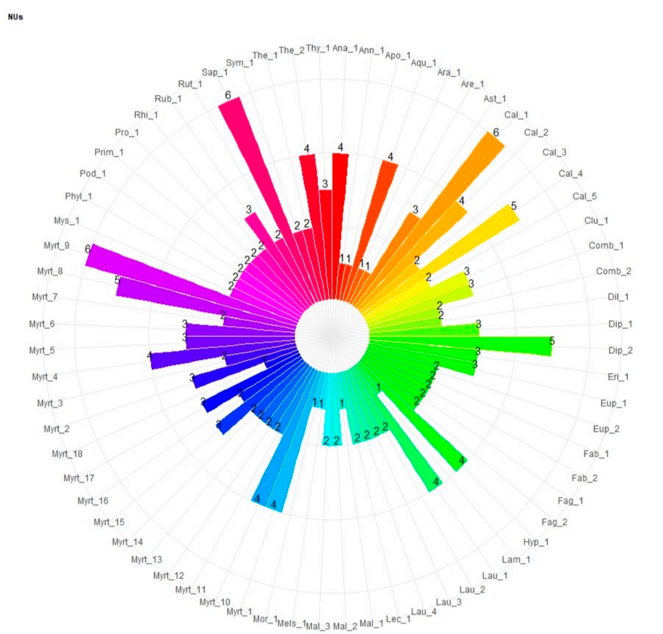


Figure 3. The radial bar chart shows the Number of Uses (NU) of 65 plant species used in the *sunggau* construction. Each plant species is displayed in the form of a circular segment with a radius proportional to the number of uses; code species names are presented in Table S4.

Most of the plant species used for *sunggau* have other uses; at least one of these uses are (1) bee colony smokers, (2) source for pollen and nectar, (3) building and furniture material, (4) traditional medicine, (5) firewood material, and (6) additional food (Figures 3 and 4). The species that have the most various uses are *Syzygium urceolatum*, *Calophyllum* sp., and

Guioa diplopetala; they have a value of 6 for Uns. Other species have UNs ranging from 1–5, meaning they have one to five categories of uses (Figures 3 and 4).

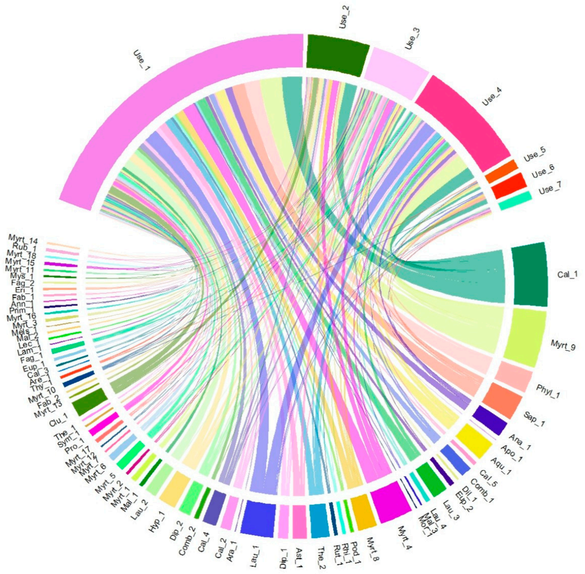


Figure 4. Chord diagram depicting the distribution of 608 use reports (UR) for 65 plant species used for *sunggau* and other use categories among 38 bee farmer informants. The diagram shows the plant species (in the bottom half of the circle; code species names are presented in Table S4 and relate to seven use categories (in the top half circle; use_1 = *sunggau* construction; use_2 = bee colony smokers; use_3 = source for pollen and nectar; use_4 = building and furniture material; use_5 = traditional medicine; use_6 = firewood material; use_7 = additional food).

The distribution of ethnobotanical knowledge on plants for *sunggau* among the bee farmers is shown in Figure 5. Bee farmers informed ranges of 1–36 plant species for *sunggau* and 1–6 categories of uses other than *sunggau* (Figure 5). The bee farmer's knowledge of plants for building and furniture material is in second place after *sunggau*, whereas bee forage and bee smoker plants are both in third place.

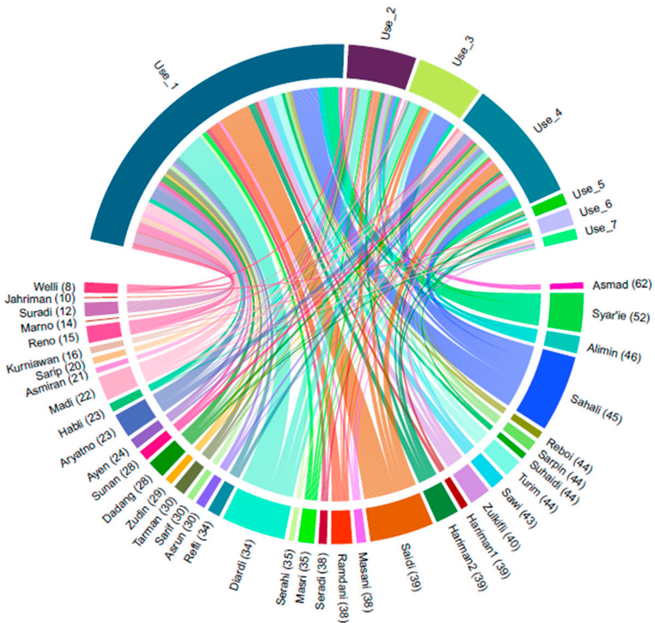


Figure 5. The chord diagram depicts the distribution of 38 bee farmer respondents related to their knowledge of plant species used for *sunggau* and other uses. Numbers in brackets following the name

of bee farmers indicate the length (in years) of their experience in installing *sunggau* constructions. The thickness of each bar (in the bottom of half circle) indicates the respondent's knowledge of plant species used for *sunggau* construction and other use categories (shows in the top of half circle; use_1 = *sunggau*; use_2 = bee colony smokers; use_3 = source for pollen and nectar; use_4 = building and furniture material; use_5 = traditional medicine; use_6 = firewood material; use_7 = additional food).

The experience of bee farmers in installing *sunggau* construction ranges from 8 to 62 years, mostly obtain from their fathers (Table S1). More than half of bee farmers (63%) had 25–50 years of experience in constructing *sunggau*, and 32% had less than 25 years of experience. We also found that about 5% of bee farmers have more than 50 years of experience (Figure 5). Based on the interviews, we found that several bee farmers with long experience installing *sunggau* do not always provide much information (Figure 5).

The important value of *sunggau* plants is determined based on ethnobotanical indices. Among the 65 species of *sunggau* plants, we obtained the top four species with the highest number of use reports (UR) and cultural importance index (CI), namely *Callophylum* sp. (UR 68; CI 1.789), *Syzygium urceolatum* (UR 60; CI 1.579), *Cryptocarya* sp. and *Melaleuca cajuputi* (UR 35; CI 0.921) (Figure 6, Table S4). The three highest RFC values of plant species were *Syzygium urceolatum* (RFC 0.737), *Calophyllum* sp. (RFC 0.684), and *Aporosa frutescens* (RFC 0.5) (Figure 7, Table S4).

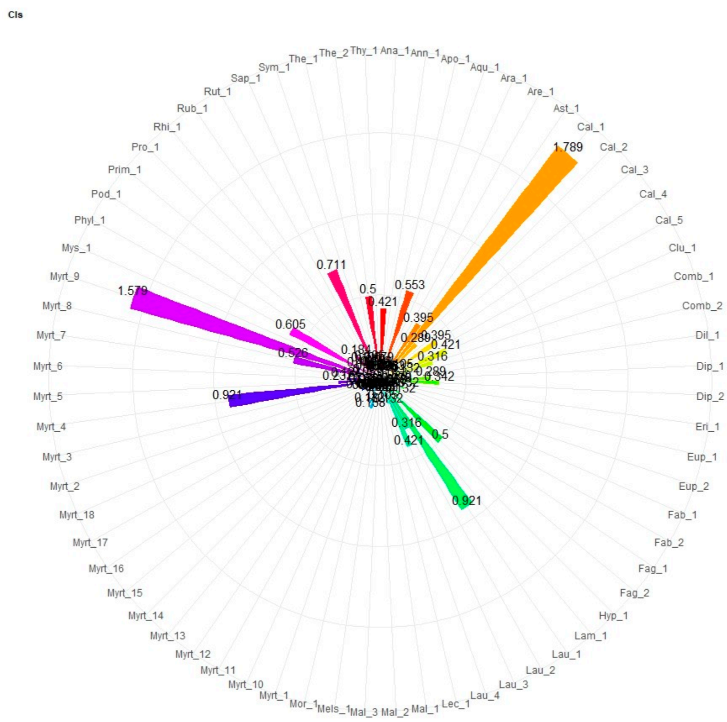


Figure 6. The radial bar chart shows the Cultural Importance (CI) index of 65 species used in the *sunggau* construction. Each species is displayed in the form of a circular segment with a radius proportional to the CI values; code species names are presented in Table S4.

We conducted a cluster analysis of forest type groups based on the diversity of plant species used for *sunggau* obtained from the interview (Figure 8, Table S5a). The dendogram shows that similar forest types (SHF and MF) in different villages are clustered, except the SHF in Kemiri, which clustered with HF in Perpat and Tanjung Rusa (Belitung). However, the HF in Tanjung Rusa (Kampak Island) is clustered with SHF and MF.

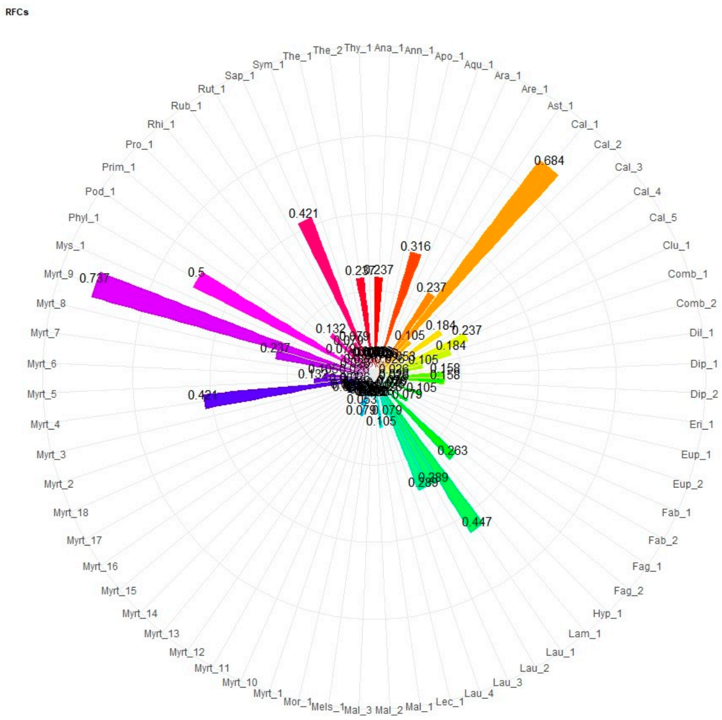


Figure 7. The radial bar chart shows the Relative Frequency of Citation (RFC) index of 65 species used in the *sunggau* construction; each species is displayed in the form of a circular segment with a radius proportional to the RFC values; code species names are presented in Table S5.

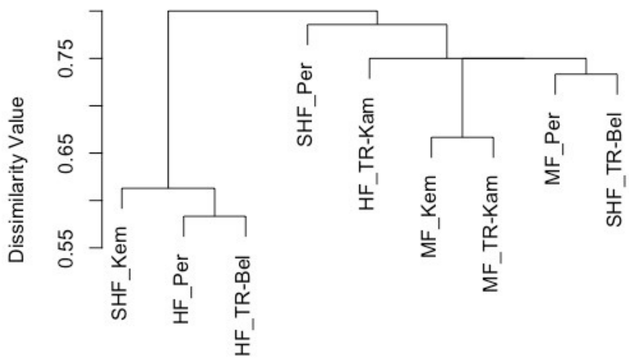


Figure 8. Forest type groups based on the diversity of plant species used for *sunggau* were obtained from the interview. HF = Heath forest; SHF = Swamp heath forest; and MF = Mangrove forest; Per = Perpat; Kem = Kembiri; TR-Bel = Tanjung Rusa in Belitung Island; TR-Kam = Tanjung Rusa in Kampak Island.

The respondents informed on the decline of several plant species for *sunggau* in three villages, such as *Syzygium urceolatum*, *Tristaniopsis obovate*, and *Guioa diplopetala* in Tanjung Rusa-Belitung Island; *Lithocarpus* sp. in Perpat; and *Litsea accedens*, *Shorea balangeran* in Kemiri (Table S6)

3.3. Vegetation Structure of the Forest Types

A total of 158 species were found in the three forest types. Heath forest in all villages showed a high number of species (32–74 species). The swamp heath forest in Kembiri also has 70 species, while approximately half of that was found in Perpat. The species richness in mangrove forests was the lowest (9–16 species) (Table S5b).

The dendrogram shows that the floristic composition of swamp heath forest is clustered with heath forest. However, the swamp heat forest in Tanjung Rusa village in Kampak

Island (TR-Kam) has quite a different floristic composition compared to the swamp heath forests and heath forests in other villages (Figure 9, Table S5b). We confirm that the floral composition in mangrove forests is clustered and split from the branches of heath and swamp heath forests.

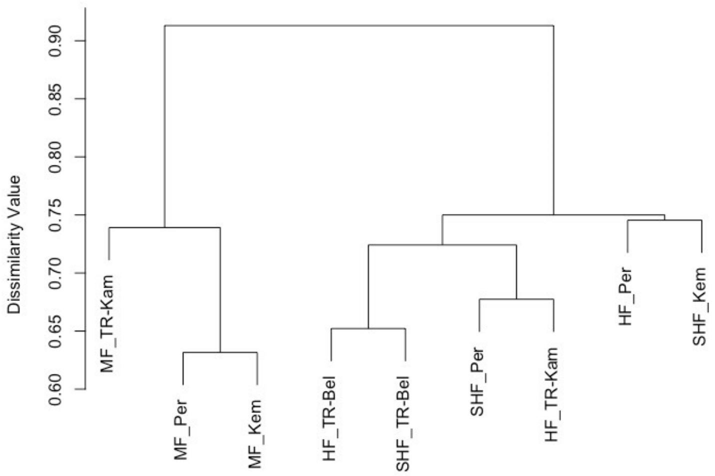


Figure 9. Forest type groups based on the floral composition. HF = Heath forest; SHF = Swamp heath forest; and MF = Mangrove forest; Per = Perpat; Kem = Kembiri; TR-Bel = Tanjung Rusa in Belitung Island; TR-Kam = Tanjung Rusa in Kampak Island.

Across the three forest types, the plant diversity index value (H′) using the criteria of the Shannon–Wiener index is categorized as medium (1 < H′ < 3) (Figure 10). At each growth stage, we found that the H′ of heath forest in Perpat is higher than that of the heath forests in other villages. The swamp heath forest in Tanjung Rusa village in Belitung Island (TR-Bel) has a lower H′ than those in other villages. We found that the H′ of mangrove forests in all villages is mostly lower than that of other forest types. We note that the seedling phase of the mangrove forest in the village of Perpat has the lowest H′ (Figure 10).

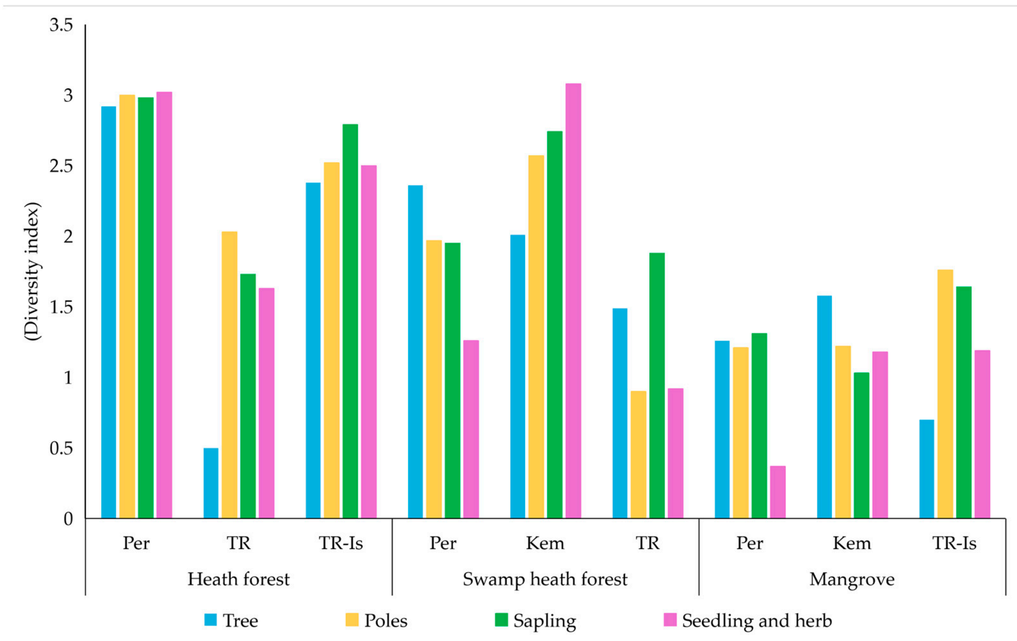


Figure 10. Diversity index (H′) of heath forest, swamp heath forest, and mangrove forest at Perpat (Per), Kembiri (Kem), Tanjung Rusa in Belitung Island (TR-Bel) and Kampak Island (TR-Kam).

Based on vegetation surveys, we found that the heath forest in Perpat village has dominant tree species that differ from those in Tanjung Rusa village in Belitung Island and Kampak Island (Table 4 and Table S7). *Schima wallichii*, *Syzygium urceolatum*, and *Syzygium muelleri* (Myrtaceae) are the three top trees with the highest IVI in the heath forest of Perpat village. *Melaleuca cajuputi* (Myrtaceae) and *Salacia grandifolia* (Celastraceae) are the dominant species in the Tanjung Rusa heath forest on Belitung Island and Kampak Island, respectively. *Melaleuca cajuputi* is also found to be dominant in the swamp heath forest of Kembiri and Perpat villages. *Antidesma cuspidatum* (Phyllanthaceae) had the highest IVI in the swamp heath forest of Tanjung Rusa village (Belitung Island). Mangrove forests are dominated (the highest IVI) by *Lumnitzera littorea* (Combretaceae) in Perpat and Tanjung Rusa (TR-Kam) and *Excoecaria agallocha* (Euphorbiaceae) in Kembiri.

Table 4. Top 5 trees with the highest Importance Value Index (IVI) and its role as a food source for *A. dorsata* (P = pollen source, N = nectar source) in three forest types in Perpat, Kembiri, Tanjung Rusa (Belitung Island and Kampak Island). (cs) = current study; * = bee farmers information.

Village/Type of Forest	Total Species	Species	IVI (%)	Food Source	Citation of Food Source
Perpat Heath forest [41]	27	*Schima wallichii*	53.45	P	[46]
		Syzygium urceolatum	38.15	P, N *	[47]
		Syzygium muelleri	33.71	P, N	[48]
		Calophyllum pulcherrimum	31.81	P *	[47]
		Shorea balangeran	19.49	P	[49]
Swamp heath forest (cs)	22	*Malaleuca cajuputi*	71.73	P, N	[50]
		Syzygium urceolatum	23.69	P	[47]
		Schima wallichii	23.60	P	[46]
		Syzygium cf. *calophyllifolium*	22.81	N	[47]
		Cratoxylum glaucum	21.58	P *, N *	
Mangrove forest (cs)	6	*Lumnitzera littorea*	83.21	P	[51]
		Bruguiera gymnorhiza	45.69	P	[39]
		Bruguiera sexangula	25.50	na	
		Malaleuca cajuputi	19.17	P, N	[50]
		Podocarpus nerrfoliius	10.50	na	
Kembiri					
Swamp heath forest [41]	12	*Malaleuca cajuputi*	143.46	P, N	[50]
		Schima wallichii	33.85	P	[46]
		Syzygium urceolatum	28.79	P, N *	[47]
		Cratoxylum glaucum	23.25	P *, N *	
		Decaspermum parviflorum	15.75	P, N	[41,52]
Mangrove forest (cs)	10	*Excoecaria agallocha*	70.04	na	
		Bruguiera gymnorhiza	65.11	P	[39]
		Lumnitzera littorea	53.54	P	[51]
		Bruguiera sexangula	50.39	na	
		Xylocarpus granatum	38.28	na	
Tanjung Rusa-Belitung Island					
Heath forest [39]	9	*Acacia mangium*	64.44	na	
		Schima wallichii	42.69	P	[46]
		Hevea braciliensis	41.31	P, N	[53]
		Salacia grandifolia	37.78	na	
		Lepisanthes amoena	34.35	na	
Swamp heath forest [39]	5	*Antidesma cuspidatum*	144.62	na	
		Malaleuca cajuputi	40.46	P, N	[50]
		Salacia grandifolia	20.20	na	
		Lepisanthes amoena	19.67	na	
		Vitex pinata	18.45	na	
Tanjung Rusa-Kampak Island					
Heath forest [39]	16	*M. cajuputi*	165.43	P, N	[50]
		Syzygium urceolatum	36.65	P, N *	[47]
		Syzygium cf. *calophyllifolium*	25.23	N	[47]
		Adinandra dumosa	22.32	na	
		Baccaurea deflexa	16.08	na	
Mangrove forest [39]	3	*L. littorea*	214.58	P	[51]
		R. mucronata	65.91	P	[39]
		Pandanus tectorius	19.65	na	

Most of the dominant trees in each forest type are sources of nectar and pollen for *A. dorsata* (Table 4). Plants that provide both pollen and nectar include *Syzygium urceolatum*, *Syzygium muelleri*, and *M. cajuputi.* The last plant species is often found abundantly in swamp heath forests. Pollen source plants that do not provide nectar include *S. walliciana* (dominant in heath forests) and *L. littorea* (dominant in mangrove forests).

4. Discussion

Our study is the first report on the ethnobotany of plant species used for *sunggau.* We recorded the diversity of plant species used for *sunggau* through field observation and interviews (Figures 3–7). Three plant species, i.e., *medang* (*Litsea* sp.), *bettor* (*Callophyllum pulcherricum*), and *samak* (*Eugenia garcinaefolia*), are used for *sunggau* [22]. Our current study added to the knowledge of more than 62 plant species for *sunggau:* the six most mentioned by bee farmers (high RFC) are *samak* (*Syzygium urceolatum*, Myrtaceae), *bettor* (*Calophyllum* sp., Callophylaceae), *pelangas* (*Aporosa frutescens*, Phyllantaceae), *medang* (*Cryptocarya* sp., Lauraceae), *gelam* (*Melaleuca cajuputi*, Myrtaceae), and *pulas* (*Guioa diplopetala*, Sapindaceae) (Figure 7, Table S4).

The bee farmers use the plants for *sunggau* for other purposes, such as for house material, furniture, the pole for pepper cultivation, and traditional medicine. The most relevant and useful plant species for bee farmers based on the use report (UR) and cultural importance (CI) value are *Callophylum* sp. (Callophylaceae), *Syzygium urceolatum* (Myrtaceae), *Melaleuca cajuputi* (Myrtaceae), and *Cryptocarya* sp. (Lauraceae) (Figure 4, Table S4). These species are dominant in the heath forest and the swamp heath forest, except *Cryptocarya* sp. Our study emphasized the importance of heath and swamp heath forests since both not only provide habitat and plants used for *sunggau* such as *A. dorsata* nesting, but also support the livelihood of the community in the villages. Previous research reported that many plant species in the Belitung heath forest have potential as medicinal plants [54].

The heath and swamp heath forest also provide sources of nectar and pollen for *A. dorsata*, such as *Schima wallichii*, *Syzygium urceolatum*, *Salacia grandifolia*, and *Melaleuca cajuputi,* which are dominant in this forest (Table 4), as confirmed by a previous study [14]. Thus, efforts should be taken to conserve these two types of forests for bee farmers who construct the *sunggau* as the nesting site of giant honey bees since they are important sources of income for bee farmers (Figure 2). However, the bee farmers are concerned about the decline of several species of trees for *sunggau* in the three villages, such as *Syzy-gium urceolatum* in Tanjung Rusa-Belitung Island (Table S6). *Syzygium urceolatum* is a favored species for *sunggau* and important for many uses; therefore, it has a high CI index. Other declining species are *Lithocarpus sundaicus* and *Shorea balangeran* due to the high demand for construction materials or poles in pepper cultivation (Figure 4, Table S6).

The conservation of mangrove forests Is also important for *sunggau* and the foraging site of *A. dorsata*. We found that plant species for *sunggau* in mangrove forest are highly similar to those in swamp heath forest (Figure 8). This similarity is due to the bee farmers taking the logs for *sunggau* construction in the mangrove forest from the swamp heath forest. We compare the knowledge of plants for *sunggau* from bee farmers with the vegetation survey (Figures 8 and 9). The floral compositions in mangrove forests in the three villages are highly similar and differ from those in heath and swamp heath forests. Despite the low diversity index of plants in mangrove forests, this type of forest has high potential for *sunggau*, since many species serve as pollen sources, i.e., *Lumnitzera littorea*, *Bruguiera gymnorhiza*, and *Melaleuca cajuputi*, the latest also as a nectar source (Table 4). The fact that the giant bees also migrate to the *sunggau* in mangrove forests (Figure 2) [20] means that the canopy of mangrove forests also provides *rendap*. Therefore, sunrays (*renak*) penetration through the *rendap* guides the bees to find the *sunggau*.

Despite the decline of several important trees for *sunggau*, bee farmers in Belitung have local wisdom in maintaining the forest. This wisdom is to determine the forest for *sunggau* as a customary forest protected by customary law (*hukum adat*) in Kembiri or village regulation in Perpat. One type of customary forest known as *riding* is located at the border of two villages. The *riding* area ranges from 50–500 m; housing and agricultural activities are prohibited in this area. However, the community can collect firewood, logs for *sunggau*, and medicinal herbs and hunt wild animals within the area.

The practice of customary laws plays a crucial role in community-based conservation initiatives in Indonesia [55]. Bee farmers in Perpat, Kembiri, and Tanjung Rusa villages also have local wisdom related to *sunggau* management for conserving the forest and *A. dorsata*, such as prohibiting cutting down trees excessively. In addition to the local wisdom in protecting the forests for *sunggau*, the government of Belitung Regency has regulations prohibiting mangrove conversion for other purposes and limiting excessive use of forest products, such as in mangrove forest in Selat Nasik village, Mendanau Island, Belitung Regency [38]. The conservation of *A. dorsata* and their habitat should be comprehensively carried out in all migration destinations in Belitung Island and surrounding islands. We suggest that customary forest use for *sunggau* as the strategy for its conservation.

Bee farmers face other challenges, such as the development of monoculture plantations in Belitung, particularly at Kembiri. Several customary heads agreed to convert the customary forest to oil palm plantation because of the high income. This issue should be a concern of the government and the customary head for the sustainability of forests in Belitung. Forest conversion to monoculture plantations impacts habitat fragmentations in South-East Asia [1], including Indonesia [56], and also the loss of pollen and nectar plant sources [57].

The second issue also arises from the human resources needed to construct *sunggau*, as mostly the age of bee farmers is above 35 years. We found that 78% of the skilled bee farmers are in their thirties, and the youngest is 31 years old. There were no farmers in their twenties that were interested in learning *sunggau* construction. Based on the interviews, the experience in constructing *sunggau* ranges from 8–62 years, and it was learned from their fathers. To overcome this problem, the government and resource persons can socialize the importance of *sunggau*. Management concerning the sustainability of *sunggau* practice was established by LPHD (Village Forest Management Committees) under the Head of Villages in Perpat Village. The other management was organized by '*Satgas Pelindung Hutan*' (Team for Forest Protection) in Tanjung Rusa.

We found good practice in management for sustainability of *sunggau* for ecotourism in Kembiri; although there is no formal organization to protect the habitat and *sunggau*, farmers work personally to introduce *sunggau*. One of the skilled bee farmers in Kembiri village, Ki Syar'ie, performs ecotourism activities for tourists who want to experience *A. dorsata* honey harvesting. Thus, we found another promising use of *sunggau* that has the potential as ecotourism. All of the above efforts aim to sustain the *sunggau* traditional knowledge, *A. dorsata*, and the forests. The ecotourism of *A. dorsata* nesting in natural bee trees has been practiced in Buloh Seuma, South Aceh Regency, Sumatra [58], and Batudulang Village, Sumbawa Regency in Sumbawa Island [59]. However, the sustainability of ecotourism activity needs support from government policy makers and other stakeholders.

In the Belitung Islands, protected mangrove forests have the potential as an ecotourism destination, such as the mangrove in Selat Nasik village, Mendanau Island [38]. Our research found *sunggau* in the mangrove forest in Perpat, Kembir,i and Tanjung Rusa villages (Figure 2). Enlightened with the ecotourism in Selat Nasik, mangrove forests in our study areas are also potential *A. dorsata* ecotourism destinations. The characteristic of ecotourism in this area is the *A. dorsata* nesting on *sunggau* which differs from those in Aceh [58] and Sumbawa [59]. According to this study, mangrove forests provide adequate nectar and pollen sources such as *Lumnitzera littorea* (pollen source) and *Melaleuca kajuputi* (nectar source), which have the highest importance value index in Perpat and Kampak Island (Table 4). However, the local communities need to prepare infrastructure in the mangrove forest [38], such as bridges to connect *sunggau* areas and observation spots. They also have to provide information of calendar visits based on *A. dorsata* migration to the mangrove.

The uniqueness of the Belitung Islands is its encirclement by many pristine satellite islands, such as the Kampak islands, that have the potential for ecotourism. A previous study reported the distribution of *sunggau* on mainland Belitung Island [20,22,23]. Our research expands the knowledge of *sunggau* distribution to Kampak Island (Figure 2) as the destination of *A. dorsata* during migration. These giant honey bees migrate to Kampak Island due to the flowering *L. littorea* and *R. mucronate* in mangrove forests as the nectar and pollen source for the bees (Table 4). The forests in Kampak Island also provide nectar and pollen sources for *A. dorsata* such as *M. cajuputi*, *Syzygium urceolatum*, and *Syzygium* cf. *calophyllifolium* in heath forest (Table 4).

The proposed ecotourism of *A. dorsata* nesting on *sunggau* in Belitung has several advantages, i.e., the low height of the nest (2–3 m), the diversity of *sunggau* types, and the traditional knowledge of *sunggau*. Two categories of *sunggau* based on construction are ground and climbing *sunggau* (Table 2). The ground *sunggau* consist of *tunggak muke*, *ungad*, and *tanger* (Table 2), and climbing *sunggau* have two variations: *bantayan* and *bersilang* (Table 2). *Tunggak muke* is the most common and widely distributed *sunggau* in Belitung (Figure 2). It is characterized by two short poles that are close to the ground. Therefore, the visitors can easily observe the bees and honey harvest. The climbing *sunggau* is inspired by the nest of *A. dorsata* in nature. *Apis dorsata* naturally constructs the nest on the branches of trees, which is locally named *sambit* [21]. Myrtaceae, Anacardiaceae, Combretaceae, and Moraceae are the common family trees for *sambit* [21].

Based on traditional knowledge, the log used for the plank should be straight with rugged bark, lack strong odor, and have a diameter about the same diameter as an adult man's upper arm. The diameter measurement of the plank is important since it supports the weight of the *A. dorsata* nest. The bee farmer uses either the same or different tree species for plank and poles. This traditional knowledge is crucial for the sustainability of *sunggau*. By preserving their knowledge, they conserve the sustainability of forest structure, plant biodiversity, *A. dorsata*, and the sources of income from honey as a non-timber forest product.

Visitors can also learn the traditional knowledge to construct the *sunggau.* Based on this study, we found that the measurement of the poles and planks from all villages and types forest is transmitted through generations. Our measurements of parts of *sunggau* are the first data in the knowledge of *sunggau*. The measurements of *tunggak muke* in all villages and forest types apparently showed no difference (Table 3) despite the diversity of tree species used for *sunggau* (Table S4), thus showing that most villagers practice similar knowledge of *tunggak muke* in all forest types. This similarity suggests that the traditional knowledge of *sunggau* measurement has been taught through generations and among bee farmers in different villages.

The culture of constructing *tunggak muke sunggau* is similar to that for rafters in other Asian countries, such as Vietnam [60] and Thailand [61]. The rafter is called *bang kad* in Thailand and *gac keo* in Vietnam. Bee farmers in Tung Bang Nok Ohk forest in Thailand used *Acacia auriculiformis*, *Peltophorum pterocarpum*, *Litsea grandis*, and *Ficus religiosa* for the main structure of *bang kad* rafter [60]. Our study also found *Litsea* used for the *sunggau* rafter, especially *Litsea accedens*. Tung Bang Nok Ohk is an important resource area in Thailand dominated by *Melaleuca* forest. However, bee farmers do not use *Melaleuca* for *bang kad* because the bees usually do not build their nests on it, because it has a soft bark and is often overgrown by endophytic fungus. Although the *Melaleuca* are not used for constructing *bang kad*, *Melaleuca* serve as the nectar source for the bees [60].

The structure of *bang kad* is similar to *tunggak muke sunggau*; they have two poles to support the plank which is laid across the top. The high of *bang kad* is approximately two to three meters [60], while *tunggak muke* is an average 1.98 ± 0.37 m for the front poles and 1.27 ± 0.30 m for the back poles. Bee farmers in Khuan So (Thailand) also use other materials such as concrete beams for the plank of *bang kad* to make it more durable and reduce the use of natural wood [60]. In Belitung, we also found that bee farmers use bamboo for the plank, which is easy to find and can grow rapidly to reduce the use of logs by cutting trees in the forest.

The bee farmers in Khuan So face problems in the sustainability of the *Melaleuca* forest due to forest fires [60]. Similar to the problem faced by bee farmers in Belitung, particularly in Kembiri, bee farmers in Thailand also face the melaleuca forest transformation to oil palm and rubber plantations [60]. The strategies of the Khuan So community to conserve the knowledge of *bang kad* is to transfer the knowledge to the younger generation. They also work in teams to develop a honey market and gain support from various organizations [60].

The bee farmers in Vietnam build the rafter *gac keo* in U Minh Ha National Park; they use trees such as *Melaleuca leucadendron* and *Areca catechu* for the plank and poles [62]. U Minh Ha National Park consists of swamp forest and mangrove forest. *Apis dorsata* migrate and construct the nests between mangrove and swamp forests [62]. The swamp forest vegetation is dominated by *M. lecandendron* and *M. cajuputi* [63]. This swamp forest is similar to the swamp heath forest we found in Belitung. The mangrove serves plant species as nectar and pollen sources for *A. dorsata*, such as *Sonneratia alba*; *Avicennia officinalis* and *A. alba*; *Ceriops tagal*, *C. decandra*, *Bruguiera gymnorhiza*, *Rhizophora mucronatam*, and *Excoecaria agallocha* [62]. Land clearance of forest to agriculture found in Indonesia and Thailand is also faced by Vietnamese bee farmers. The other problem in Vietnam is overusing of both *M. lecadendron* and *M. cajuputi* for timber and firewood [62]. In addition, the *Melaleuca* swamp forest in Vietnam is also at risk of forest fires in the dry season due to climate change. Forest fires in Thailand also impact the loss of many herbaceous plants that are important as sources of pollen and nectar [63].

Across South-east Asia, the existence of rafters face the same challenge of forest conservation as the nesting habitat and foraging sites for *A. dorsata*. However, several promising uses of rafters arise from ecotourism. Therefore, the variations and traditional knowledge of rafters and their composition, diversity patterns, and vegetation structure of forest types that serve rafters in each country need to be protected by all stakeholders in the penta helix, i.e., government, investors, communities, scientists, and media, along with dissemination not only to bee farmers but also to scientists and governments. The knowledge of important plant diversities and traditional knowledge of *sunggau* in Belitung Islands can be used as the model for the conservation of forest and *A. dorsata* within the migration regions of this giant honey bee.

5. Conclusions

Sunggau rafter construction is a practice of the bee farmers in Belitung, Indonesia, to attract the forest honey bee *A. dorsata* for nesting by using traditional knowledge that has been passed through generations. Our study found *sunggau* distributed in the three types of forest in Belitung, i.e., heath forest, swamp heath forest, and mangrove forest. The bee farmers use local wisdom to choose the plants for constructing *sunggau*. By combining traditional knowledge and vegetation analysis, our study revealed the important plants for the *sunggau*. Based on traditional knowledge, plant species with the highest uses, either for *sunggau* or the other six uses, are *Syzygium urceolatum*, *Calophyllum* sp., and *Guioa diplopetala*. Based on vegetation surveys, the most important species in the heath forest are *Schima wallichii*, *Acacia mangium*, and *Melaleuca cajuputi*. The latest species and *Antidesma cuspidatum* dominated in the swamp heath forest, whereas *Lumnitzera littorea* and *Excoecaria agallocha* are dominant in mangrove forests. These plants are important for the sustainability of *sunggau* and bee forage; thus, efforts should be made to conserve them. Therefore, the traditional knowledge of *sunggau* by local people implies the conservation of *A. dorsata* as well. Moreover, management concerning the sustainability of *sunggau* has been established in village institutions such as LPHD (Village Forest Management Committees) and *Satgas Pelindung Hutan'* (Team for Forest Protection) that support the sustainability of *sunggau* practice.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/f15040657/s1, Table S1: Profile of the bee farmers respondent; Table S2: Data source for the vegetation analysis in three types of forests in Perpat, Kembiri, Tanjung Rusa in Belitung Island and Kampak Island; Table S3: Distribution of *sunggau* types (village, coordinate) and plant species used for *sunggau* in three types of forest. SG = *sunggau*, Per = Perpat, Kem = Kembiri, TR-Bel = Tanjung Rusa-Belitung Island, TR-Kam = Tanjung Rusa-Kampak Island, HF = heath forest, SHF = swamp heath forest, MF = mangrove forest; Table S4: Ethnobotanical indices of plant species use for *sunggau*: Number of Uses (NU), Use Report (UR), Cultural Index (CI), Frequency of Citation (FC), Relative Frequency of Citation (RFC); Table S5: (a) The species use for *sunggau* (based on interview and field observation) and (b) species composition (based on vegetation analysis) at the three forest types (HF = Heath forest, SHF = Swamp heath forest, MF = Mangrove forest) in Perpat, Kembiri, and Tanjung Rusa Villages, (a: 1 = citated used for *sunggau*, 0 = not citated used for *sunggau*; b: 1 = present, 0 = absent); Table S6: Plant species for *sunggau* that is decreasing based on the information from bee farmers; Table S7: The analysis vegetation in three forest types. HF = Heath forest, SHF = Swamp heath forest, MF = Mangrove forest; Informed consent of bee farmer respondents; Questionnaire used for interviewing respondents;

Author Contributions: S.D.H. collected and analyzed the data. S.D.H. prepared the original draft of the manuscript. I.Q. supervised the research and revised the manuscript. R.R. conceived and designed the research, and prepared the original draft and developed the manuscript. N.S.A. (the corresponding manuscript author) contributed to data analysis of the ethnobotanical and vegetation survey, prepared the original draft, and developed the manuscript. W.P. contributed to data analysis of the ethnobotanical and vegetation survey and review of the manuscript. M.M. contributed to the review of the manuscript. All authors contributed to writing and revising the draft of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: Data is contained within the article or Supplementary Materials.

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