INVERTEBRATE BIOLOGY

REVISTA DE Biología Tropical

https://doi.org/10.15517/rev.biol.trop..v71i1.51166

The characteristics of stingless bee nests (Apidae: Meliponini) in the Cycloop Mountain Nature Reserve, Indonesia

David Reinhard Jesajas[1]; https://orcid.org/0000-0001-8294-9612
Tri Atmowidi[2]*; https://orcid.org/0000-0002-2179-3914
Berry Juliandi[2]; https://orcid.org/0000-0003-0348-5675
Sih Kahono[3]; http://orchid.org/0000-0001-7222-3180

1. Student of Animal Bioscience Study Program, Graduate School, IPB University, Bogor 16680, Indonesia; juandaud10@gmail.com
2. Department of Biology, Faculty of Mathematics and Natural Sciences, IPB University, Bogor 16680, Indonesia; atmowidi@apps.ipb.ac.id (*Correspondence), bjuliandi@apps.ipb.ac.id
3. Research Center for Applied Zoology-BRIN, Cibinong 16912, Indonesia; sihkahono@gmail.com

Received 29-V-2022. Corrected 06-II-2023. Accepted 02-V-2023.

ABSTRACT

Introduction: Stingless bees are widespread in tropical and subtropical regions. In Indonesia, the distribution of stingless bees are grouped in three regions, namely Indo-Malayan, Wallacea, and Indo-Australian. Ten species of stingless bees have been recorded in Papua, seven of which are endemic. The Cycloop Mountains Nature Reserve (CMNR) is one of the conservation area in Papua, Indonesia, for flora and fauna. Unfortunately, the study of the diversity of stingless bees in Papua has been limited.

Objective: To measure the diversity, nesting sites, nest entrance characteristics and nest architecture of stingless bees.

Methods: Observation of the stingless bee nests in the nature reserves and in the residential areas used a road sampling method and information from local people, respectively. A total of 22 colonies were studied.

Results: Two species of stingless bee were found, namely *Tetragonula sapiens* (Cockerell, 1911) and *Heterotrigona* (*Platytrigona*) *planifrons* (Smith, 1865). The current study showed new distribution records for *T. sapiens* and *H. planifrons* in the CMNR. The nesting site of *T. sapiens* was commonly found in house foundation, while that of *H. planifrons* was in coconut palm cavities. The nest entrance of *T. sapiens* varied, i.e., elliptical, oval, rounded, irregular, horizontally or vertically elongated. Meanwhile, the nest entrance of *H. planifrons* was vertically elongated. The brood cells of *T. sapiens* varied, i.e., vertical, horizontal, or semi-clusters, while in *H. planifrons* was layered vertically.

Conclusions: Two species of stingless bees found, *T. sapiens* and *H. planifrons,* showed a new distribution records and *T. sapiens* was a dominant species in Papua. The nest entrance of the species varied in shape, color, and texture.

Key words: Cycloop Mountains Nature Reserve; diversity; nest characteristics; stingless bee.

RESUMEN

Ubicación y características de los nidos de abejas sin aguijón (Apidae: Meliponini) en la Reserva Natural Cycloop Mountain, Indonesia.

Introducción: Las abejas sin aguijón están muy extendidas en las regiones tropicales y subtropicales. En Indonesia, la distribución de las abejas sin aguijón se agrupa en tres regiones: Indo-Malayan, Wallacea e

Indo-Australian. Se han registrado diez especies de abejas sin aguijón en Papua, siete de las cuales son endémicas. La Reserva Natural de las Montañas Cycloop (CMNR) es una de las áreas para la conservación de flora y la fauna en Papua, Indonesia. Desafortunadamente, el estudio de la diversidad de abejas sin aguijón en Papua ha sido limitado.

Objetivo: Medir la diversidad, los sitios de anidación y describir la arquitectura y características de entrada al nido de las abejas sin aguijón.

Métodos: Se observaron los nidos de abejas sin aguijón en reservas naturales y áreas residenciales, mediante el método de muestreo de caminos e información de la población local, respectivamente. Se estudiaron 22 colonias.

Resultados: Se encontraron dos especies de abejas sin aguijón, *Tetragonula sapiens* (Cockerell, 1911) y *Heterotrigona* (*Platytrigona*) *planifrons* (Smith, 1865). Este estudio mostró nuevos registros de distribución de *T. sapiens* y *H. planifrons* en el CMNR. El sitio de anidación de *T. sapiens* se encontró comúnmente en los cimientos de las casas, mientras que el de *H. planifrons* estaba en las cavidades de las palmas de coco. La forma de la entrada al nido de *T. sapiens* varió: elíptica, ovalada, redondeada, irregular, alargada horizontal o verticalmente. Mientras tanto, la entrada al de *H. planifrons* se alarga verticalmente. Las celdas de cría de *T. sapiens* variaron, entre verticales, horizontales o semi-racimos, mientras que en *H. planifrons* eran verticales.

Conclusiones: Se encontraron dos especies de abejas sin aguijón, *T. sapiens* y *H. planifrons*, que mostraron nuevos registros de distribución y *T. sapiens* fue una especie dominante en Papúa. La entrada al nido de las especies varió en forma, color y textura.

Palabras clave: reserva natural montañosa Cycloop; diversidad; características de nido; abejas sin aguijón.

INTRODUCCIÓN

The stingless bees (Apidae: Meliponini) are a cosmopolitan group of bees in the tropics and subtropics. Stingless bees are distributed in tropical regions of the world across the Neotropical, Afrotropical, and Australasian realms (Michener, 2000) and are the highest diversity among bees consist of more than 600 species (Rasmussen, 2008; Rasmussen & Cameron, 2007). Indonesia, as part of the Indo-Malayan and Australasian ecoregions, has 46 recorded stingless bee species across the islands of Sumatra, Java, Borneo, Timor, Sulawesi, Ambon, Maluku, and Papua (Kahono et al., 2018). The species of this group are small to medium sized with a vestigial stinger and live in colonies (Michener, 1974). These beehives can be found under the soil surface, in tree and wood cavities, house wall cavities, or hollows of bamboo trees (Dollin et al., 1997; Engel et al., 2019; Michener, 1974; Sakagami et al., 1983). Stingless bees have a high prospect as a pollinator of agricultural crops related to its small body size, have a high foraging activity, and high adaptation to environmental stress (Kahono, 2015). Stingless bees play an important role in pollinating of various plant species (Michener, 2007), include in mustard (Atmowidi et al., 2007), *Tetragonula laeviceps* in strawberry (*Fragaria* x *annanassa*) and *Heterotrigona itama* in melon (*Cucumis melo*) in the greenhouse (Atmowidi et al., 2022). Nesting preference and nest characteristics, such as the morphology of nest entrance, nest architecture, and nest height from the ground are supporting characters that can be used to identify stingless bee species. Nest entrances vary in shape, texture, length, ornamentation, and color according to each species (Anaktototy et al., 2021; Kelly et al., 2014). For example, the nest entrance of *Heterotrigona itama* (Cockerell, 1918) is funnel-shaped and in *Geniotrigona thoracica* (Smith, 1857) is rounded (Kelly et al., 2014). The internal nest architecture consists of brood cells, honey and pollen pots (Efin et al., 2019; Franck et al., 2004; Michener, 1974; Sayusti et al., 2021).

The Cycloops Mountains Nature Reserve (CMNR) located in the Jayapura region of Papua Province, Indonesia. It is a tropical forest area with high biodiversity and ecological functions that are important for human life. Human activities in this area have occurred for a long time that impact the biodiversity, including stingless bees. Forest disturbance in CMNR

is mainly caused by community socio-economic activity (Ngutra, 2017). Limited information and knowledge are a limiting factor for the local community. People in Papua haven't cultivated yet the stingless bees for producing honey and propolis. Community knowledge is key factor affecting stingless bee conservation. Until now, poor knowledge of taxonomy and phylogeny of these bees in the studied región are based for conducting this research. Therefore, studying the diversity and nests characteristics of stingless bees in the CMNR area is needed. This study aims to determine the species richness, characteristics of the nesting sites, and nest architecture of stingless bees in the CMNR, Papua, Indoesia.

MATERIALS AND METHODS

Observation of nest characteristic of stingless bees: The observations of stingless bees in the CMNR were conducted at three locations, namely Maribu village (including Mount Batu, Dumukribun, Dawari, and Maribu Kampung), Dosay village (including Kausei and Dansari), and Kemiri village (including Kemiri-2 of Forestry Residential) (Table 1). Nest of stingless bee was documented using a Nikon D5300 camera. The nest characteristics at Mount Batu and Dawari were observed by a road sampling method (Garton et al., 2004). While in Maribu Kampung, Dosay village, and Kemiri village, sampling was based on information from local people. The nest features

TABLE 1
Study sites and the number of colonies of stingless in Maribu, Dosay, and Kemiri villages of Papua

Maribu Village	Coordinate/Altitude (mdpl)	Colony number	Species		Nesting sites
Gunung Batu (Dumukribun)	02°27'31.7" S & 140°23'35.8" E/364	1	*T. sapiens*		Mountains-coconut tree
Dawari	02°28'47.5" S & 140°21'48.9" E/142	2	*T. sapiens*		Local farm-dry wood
	02°28'54.1" S & 140°21'43.7" E/126	3			Local farm-coconut tree
	02°29'05.0" S & 140°21'37.3" E/160	4	*T. sapiens*		Local farm-dry wood
	02°28'42.1" S & 140°21'47.0" E/133	5	*T. sapiens*		Local farm-house foundation
Maribu Kampung	02°29'00.9" S & 140°22'15.8"E/118	6	*T. sapiens*		Housing-coconut tree
	02°29'06.0" S & 140°22'13.7" E/112	7	*T. sapiens*		Housing-coconut tree
	02°29'03.6" S & 140°22'16.4" E/122	8	*T. sapiens*		Housing-fern tree
	02°29'06.5" S & 140°22'12.0" E/109	9	*T. sapiens*		Housing-house foundation
	02°29'08.5" S & 140°22'09.2" E/112	10	*T. sapiens*		Housing-fern tree
	02°29'20.3" S & 140°22'05.1"E/80	11	*T. sapiens*		Housing-house wall
	02°29'11.1" S & 140°22'10.6"E/107	12	*T. sapiens*		Housing-house wall
Dosay Village					
Kausei	02°30'42.1" S & 140°24'05.8"E/127	1		*H. planifrons*	Local farm-coconut tree
	02°30'41.9" S & 140°24'07.3"E/128	2	*T. sapiens*		Housing-house foundation
	02°30'42.2" S & 140°24'07.4" E/128	3	*T. sapiens*		Housing-house foundation
	02°30'42.3" S & 140°24'07.5"E/129	4	*T. sapiens*		Housing-house foundation
	02°30'43.6" S & 140°24'07.8"E/125	5	*T. sapiens*		Housing-house foundation
Dansari	02°30'24.8" S & 140°24'29.5"E/140	6	*T. sapiens*		Housing-soil
Kemiri Village					
Kemiri-2 (Forestry Residential)	02°33'17.8" S & 140°29'06.0"E/117	1	*T. sapiens*		Housing-house wall
	02°33'10.7" S & 140°29'02.8"E/125	2	*T. sapiens*		Housing-house foundation
	02°33'11.1" S & 140°29'03.0"E/125	3	*T. sapiens*		Housing-house foundation
	02°33'11.1" S & 140°29'03.4"E/133	4	*T. sapiens*		Housing-house foundation
Total colony (%)		22	21 (95 %)	1 (5 %)	

observed were nesting site, nest entrance measurements (length, diameter, height from ground), shape, and texture (Dollin et al., 1997; Kelly et al., 2014). The coordinates of nesting sites were determined using GPS (Garmin etrex 10).

Collection, preservation, and identification of stingless bee specimens: Five individuals of worker bees from each colony were collected. The samples were then preserved using the dry preservation method (Borror et al., 1989). Samples were stored in bottles and labeled. Identification of stingless bee specimens were based on Sakagami et al. (1990), Dollin et al. (1997), Rasmussen et al. (2017), Engel et al. (2019), and Engel (2019). The identification was carried out at the Laboratory of Animal Biosystematics and Ecology, Department of Biology, IPB University, Bogor, Indonesia. Then, the specimens were verified and deposited at the Research Center for Ecology and Ethnobiology, Research and Innovation Agency (BRIN), Cibinong, West Java, Indonesia.

Data analysis: The t-test analysis was used to compare the nest entrance variation within species of *T. sapiens*, consisting of the width and height of the nest entrance, funnel length, and the height from the ground using Paleontological Statistics version 4.09 (Hammer et al. 2001).

RESULTS

Richness of stingless bee: Two species of stingless bees were found in the three villages, namely *Tetragonula sapiens* and *Heterotrigona* (*Platytrigona*) *planifrons* (Fig. 1). A total of twenty-two colonies were found, i.e., one in Maribu Village including Gunung Batu (Dumukribun), four in Dawari, seven in Maribu Kampung, five in Dosay village and Kausei, one in Dansari, and five in Kemiri Village includes the Kemiri-2 of forestry residential (Table 1). *Tetragonula sapiens* was the dominant species (21 colonies; 95 %) found in all observation sites, while, *Heterotrigona planifrons* (one colony; 5 %) was only found in Kausei village.

Nesting sites: The dominant nesting site of *T. sapiens* was in house foundations (nine colonies, 43 %), followed by coconut tree cavities (four colonies, 19 %), house walls (three colonies, 14 %), dry wood (two colonies, 10 %), fern tree (two colonies, 10 %), and in the soil (one colony, 5 %). The nest of *H. planifrons* (one colony) was found in a coconut tree cavity.

Nest entrance characteristics: The nest entrance tunnel of *T. sapiens* varied, being horizontally elongated (4 colonies), oval (6 colonies), round (2 colonies), irregular (2 colonies), ellipses (4 colonies), and vertically

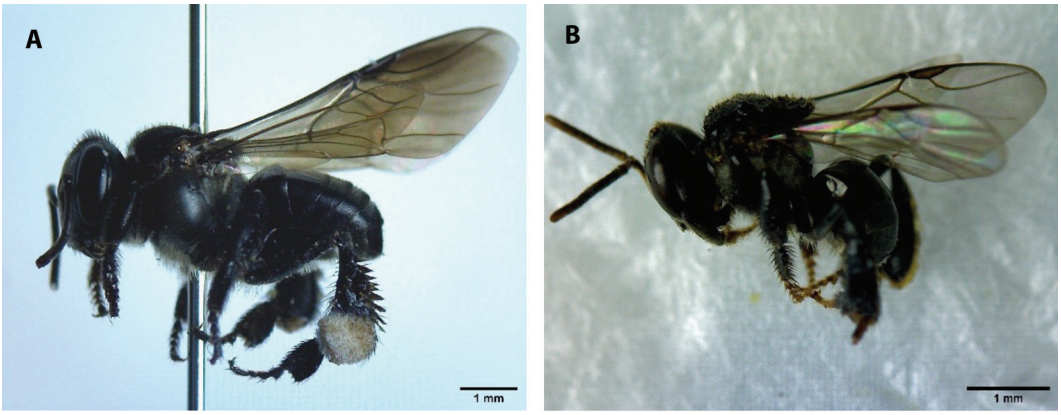

Fig. 1. Worker of two species of stingless bees found in Cycloop Mountains Nature Reserve. **A.** *Tetragonula sapiens* and **B.** *Heterotrigona planifrons.*

elongated (2 colonies), while in *H. planifrons* it was vertically elongated (1 coloni). The color of *T. sapiens* entrances was brown, dark brown, blackish, light brown with grayish on the tube-end, brownish-gray, dark brown, blackish gray with blackish on the tube-end, with hard to soft textures. In *H. planifrons,* the color of the nest entrance tunnel was light brown with a hard texture (Fig. 2). The nest entrance opening of *H. planifrons* was 5.5 cm in height and 7.5 cm in wide, while in *T. sapiens* ranged 0.6-3 cm in height and 0-3.5 cm in wide (Table 2). The differences in the diameter of the nest entrance opening in *T. sapiens* and *H. planifrons* may be due to differences in body size, colony size, and nest age. In Dosay-Kausei villages, we found the vertically elongated nest entrance of *H. planifrons* with characteristics was 2.0 cm in width and 5.5 cm in height, light brown color, 7.5 cm of funnel length, and no ornamentation (Fig. 2) with a thick and hard-texture in tube-end, respectively and the nest height from ground was 162 cm (0-325 cm) (Table 2).

Nest architecture: The brood cells of *T. sapiens* in three villages (four colonies) were a vertically cluster, horizontally cluster, and semi-cluster. The brood cell*s* were connected to other cells by lamellate pillar structures (Fig. 3, Table 3). The brood cells were oval in shape

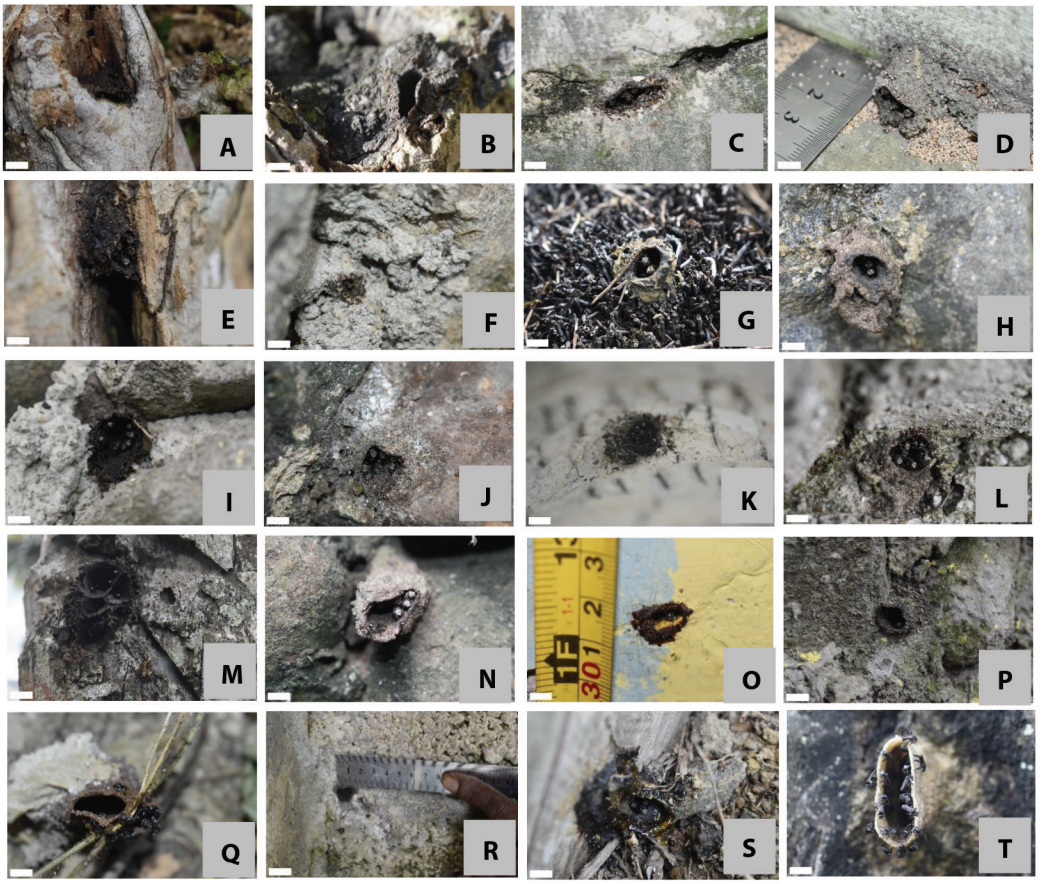

Fig. 2. Types of nesting entrance opening of *T. sapiens* in Maribu, Dosay, and Kemiri villages. **A.-D.** elongated horizontal with dark brown, blackish and slightly blackish gray on tube-end. **E.-J.** oval with brown, blackish brown, light brown on tube end, blackish gray, and brownish black. **K.-L.** round with dark brown. **M.-N.** irregular with dark brown and brownish gray. **O.-R.** ellipses with brown, dark brown, and blackish gray. **S.** Elongated vertically with dark brown. **T.** elongated vertical with light brown hard texture in *H. planifrons*. Scale = 1 cm).

TABLE 2
The average of nest entrance characteristics of stingless bees in Maribu, Dosay, and Kemiri villages of Papua.

Species, Nest locations	Nest entrance											
	Width (cm)			Height (cm)			Tube length (cm)			Height from ground surface (cm)		
	M	R	SD	M	R	SD	M	R	SD	M	R	SD
T. sapiens												
Maribu (n=11)	1.43[a]	0.6-2.4	0.54	1.54[a]	0.6-2.9	0.75	1.24[a]	0-4.7	1.54	118.6[ab]	0-325	120
Dosay (n=5)	2.14[a]	1.4-2.8	0.53	1.76[a]	1.1-3	0.74	2.02[a]	0.2-3.4	1.24	9.3[a]	1-25	10.2
Kemiri (n=4)	1.92[a]	0.8-2.9	0.86	1.27[a]	0.7-2.5	0.82	1.9[a]	0.1-3.5	1.75	27[a]	8-63	24.6
H. planifrons												
Dosay (n=1)	2	2	0	5.5	5.5	0	7.5	7.5	0	162	162	0

Note: M=Mean; R=Range; SD=Standard deviation; Different letters in the same column indicate a significant difference between the means based on the t-test.

TABLE 3
Nest architecture of *T. sapiens* and *H. planifrons* (Modification of Wille & Michener, 1973; Dollin, et al., 1997).

Atribut	*T. sapiens*				*H.* (*P.*) *planifrons*
	Maribu Village			Kemiri Village	Dosay Village
Nest characteristics	Colony 2	Colony 5	Colony 10	Colony 22	Colony 13
Entrance tunnel shape	horizontal wide	horizontal wide	vertical elongated	horizontal wide	vertical elongated
Entrance width (cm)	1.6	2	0.8	2.1	2
Entrance height (cm)	0.6	1	2.6	1	5.5
Funnel length (cm)	1	0	4.7	3.5	7.5
Funnel texture	hard	hard	hard	hard	hard
Pollen pot space length (cm)	7.5	11.9	12.3	11.2	73
Pollen pot diameter (cm)	0.6-0.8	0.6-1	0.5-0.9	0.8-1.6	5.2-6.8
Pollen pot shape	irregular*	irregular*	irregular*	irregular*	irregular*
Pollen pot color	black	dark brown	brown	dark brown	black brown
Honey pot space length (cm)	15.5	4.8	11.5	11	30
Honey pot diameter (cm)	0.6-0.9	0.7-0.9	0.7-1.1	0.6-1.2	5.1-6.9
Honey pot shape	irregular*	irregular*	irregular*	irregular*	irregular*
Honey pot color	black	dark brown	blackish brown	dark brown	black brown
Length of pollen pot space + honey pot space (cm)	18	12.3	25.9	22.2	103
Nest space length (cm)	44	18.6	50	52	143
Brood cells					
Arrangement	vertical cluster	semi-cluster	vertical cluster	horizontal cluster	layer vertical comb
Room length (cm)	26.6	13.5	23.3	32.2	40
Cell height (cm)	0.31-0.36	0.26-0.31	0.3-0.4	0.39-0.44	1.58-2.22
Cell width (cm)	0.19-0.26	0.17-0.22	0.04-0.05	0.21-0.30	0.55-0.62
Shape	oval	oval	oval	oval	oval
Color	light cream-blackish brown	light cream-blackish brown	light cream-blackish brown	light cream-blackish brown	cream-dark brown
Pillar	columnar	columnar	columnar lamellate	columnar	lamellate
Nesting habitat					
Substratum (nesting site)	dry wood	dry wood	fern stem	house foundation	coconut tree
Height from ground surface (cm)	290	70	91	15	162

* round, oval, and ellipse coincide with each other.

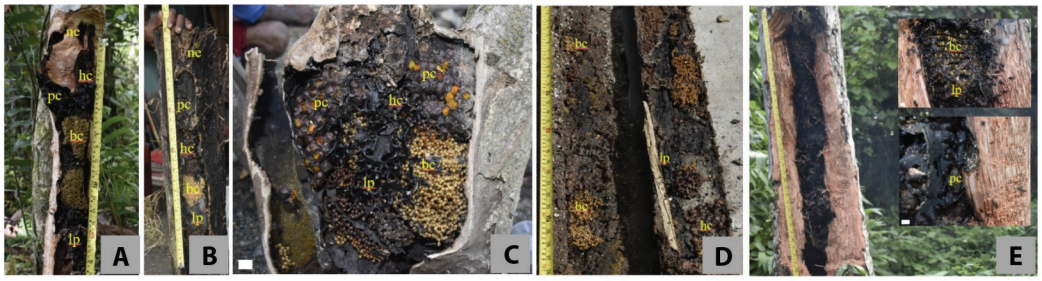

Fig. 3. The internal nest architecture of four colonies of *T. sapiens* in Maribu, Dosay, and Kemiri villages, Papau: **A.-B.** vertical cluster, **C.** semi-cluster, D. horizontal cluster, and **E.** layered vertical comb in *H. planifrons* (insert for detail). ne=nest entrance, bc=brood cells, pc=pollen cells, hc=honey cells, lp=lamellate pillars. Scale=1cm.

and light brown in color (brood cells with adult larvae) and dark brown (brood cells with young larvae). The pollen pots of *T. sapiens* were irregular (0.5-1.1 cm in width and 7.5-12.3 cm in length) with brown, dark brown, and black colors. The honey pots had an irregular shape (0.6-1.2 cm in width) and were dark brown, blackish, and black. The nest heights of *T. sapiens* from ground level ranged from 15 to 290 cm (Table 3).

In Dosay-Kausei village, the brood cells of *H. planifrons* had a vertically elongated with a layered vertical comb with a lamellate pillar structure that connect it to the tree trunk. The brood cells of the species was oval in shape, light brown (old cells) and dark brown (young cells), with height ranging from 1.58-2.22 cm and a width of 0.55-0.62 cm (Fig. 3). The pollen pots were irregular, while the honey pots were an irregular shape with blackish (Table 3).

DISCUSSION

Morphologically, stingless bees are difficult to identify (Sakagami & Inoue, 1985). The current study identified two species as *Tetragonula sapiens* (Australasian stingless bee) and *Heterotrigona* (*Platytrigona*) *planifrons* (Papuasian stingless bee). This study added a new distribution record for *T. sapiens* and *H. planifrons* in Papua, specifically in the CMNR area of Jayapura Regency. Previous studies reported *T. sapiens* was distributed in the Solomon islands and Papua New Guinea (Dollin et al., 1997), while *H. planifrons* has been reported from the Central Mamberamo District, Bovendigul District, Merauke District, Manokwari of Papua, and in the Bulolo District, Morobe, and Oro Provinces of Papua New Guinea (Engel, 2019). Previous studies in Papua reported four species of *Tetragonula*, namely *T. fuscobalteata* (Cameron, 1908), *T. sapiens* (Cockerell, 1911) (Dollin et al., 1997), *T. clypearis* (Friese, 1908), and *T. biroi* (Friese, 1898) (The Papua Insect Foundation, 2008), and four species of *Heterotrigona*, namely *H. planifrons* (Smith, 1865), *H. lamingtonia* (Cockerell, 1929), *H. flaviventris* (Friese, 1908) and *H. keyensis* (Friese, 1901) (Engel et al., 2019; Engel, 2019).

The nesting sites of stingless bee are usually in a tree cavity, soil, and hollow walls (Slaa et al., 2000). Some species, such as of the genera *Tetragonula, Tetragonisca, Partamona, Paratrigona,* and *Plebeia* build nests on tree trunks or solid substrates (Roubik, 2006). In this study, we found that the nesting site of *T. sapiens* was dominatly in house foundation (9 colonies), followed by coconut trees (4 colonies), house walls (3 colonies), dry wood (2 colonies), fern trees (2 colonies), and soil (1 colony). In contrast, the nesting site of *H. planifrons* was in a coconut tree cavities. The limited nesting sites of *H. planifron*s (1 colony found) may be a result of burning the nest due to their aggressive biting.

The nests of aggressive stingless bees are usually found individually in specific tree

trunks, such as palm trees (Roubik, 2006). Meanwhile, the nests of non-aggressive stingless bee colonies are generally close to other stingless bee species (Roubik, 1983). The current study found more colonies building nests close-together in sap-producing trees, such as Psidium or cashew (*Anacardium occidentale*: Anacardiaceae), merbau (*Intsia bijuga*: Fabaceae), mango (*Mangifera indica*: Anacardiaceae), jackfruit (*Artocarpus heterophyllus*: Moraceae), and wood milk (*Alstonia scholaris*: Apocynaceae). Resin in the nest entrance protects the colony from predators (Roubik, 2006). The texture of the nest entrance is related to the various resins collected from gummy plants. Variation in the nest entrance is influenced by nest age, genetics, predators, parasites, symbionts, rain, wind, and light (Sakagami et al., 1983; Wille & Michener, 1973). This study found a pronged and a branched nest entrance of *T. sapiens* in Maribu village. A branching nest entrance has also been found in *Lepidotrigona ventralis* (Smith, 1857) (in Thailand), *Lepidotrigona*, *Plebeia*, *Scaptotrigona*, and *Tetragona* (Roubik, 2006).

The results showed that the nest entrance of *T. sapiens* was a short funnel, whereas in *H. planifrons* it was an elongated. Unfortunatley, we only found one colony of the species and no variation of nest entrance characteristics was shown. We suppost that there are variation of the nest entrance characteristics in the species. So, more exploration in a wide areas in Papua should be done in the future. Nest entrances with a short funnel are usually found in stingless bees of the Neotropics (*T. cilipes*) and Asia (*T. collina*). Similarly, an elongated nest entrance was also found in two Asian stingless bees with aggressive behavior, namely *H. canifrons* and *H. itama* (Sakagami et al., 1983). The color and texture of the nest entrances of *T. sapiens* varied, such as brown, dark brown, blackish, cream (grayish on the tube-end), brownish, brownish-black, blackish gray (blackish on the tube-end), with a hard and soft texture. In *H. planifrons* (Smith, 1865), the color of nest entrance is light brown with a hard texture. The color variation of the nest entrance may be due to the different resin sources (Sakagami et al., 1983; Wille & Michener, 1973). Nest entrance variation in *T. sapiens* may be related to polyphenism, in which two or more phenotypes result from the same genotype (Mayr, 1963). Polyphenism is influenced by environmental conditions that cause phenotypic preferences in neurochemical and hormonal pathways related to nest-building behavior (Simpson et al., 2011).

The brood cells of *T. sapiens* are connected by a columnar lamellate pillar (Fig. 3, Table 3), oval shape and light- and dark-brown, while the pollen and honey pots were irregular, probably an adaptation to substrate types. The modification of nest architecture in stingless bees is closely related to the adaptability of a species to its environment. Species with high intraspecific and phenotypic variations are usually more adaptive to environmental changes than endemic species with low intraspecific variations and limited distribution in certain geographic area (Cohet et al., 1980; Lavergne & Molofsky, 2007). In this study, *T. sapiens* found in all sampling sites with various nest entrance characters and able to live at varying altitudes (107-364 m.a.s.l). In contrast, *H. planifrons* showed a limited distribution, at just one sampling site at an altitude of 127 m.a.s.l. The observations and interviews with local communities at West Sentani to Sentani districts showed *H. planifrons* had a limited distribution and was only found in the Dosay village.

Ethical statement: the authors declare that they all agree with this publication and made significant contributions; that there is no conflict of interest of any kind; and that we followed all pertinent ethical and legal procedures and requirements. All financial sources are fully and clearly stated in the acknowledgements section. A signed document has been filed in the journal archives.

ACKNOWLEDGMENTS

We acknowledge to PT Freeport Indonesia for funding this research and head of Cycloops

Mountains Nature Reserve for allowing the authors to conduct this research. We also thank Laboratory of Entomology, Research Canter for Ecology and Ethnobiology, National Research and Innovation Agency (BRIN) for verified stingless bee specimens.

REFERENCES

Anaktototy, Y., Priawandiputra, W., Sayusti, T., Lamerkabel, J. S. A., & Raffiudin, R. (2021). Morphology and morphometric variation of stingless bees in the Moluccas, Indonesia. *Indonesian Journal of Entomology, 18*(1), 10–22.

Atmowidi, T., Buchori, D., Suryobroto, B., & Hidayat, P. (2007). Diversity of pollinator insect in relation of seed set of mustard (*Brassica rapa* L.; Cruciferae). *Hayati Journal of Bioscience, 14*(4), 155–161. https://doi.org/10.4308/hjb.14.4.155.

Atmowidi, T., Prawasti, T. S., Rianti, P., Prasojo, F. A., & Pradipta, N. B. (2022). Stingless Bees Pollination Increases Fruit Formation of Strawberry (*Fragaria* x *annanassa* Duch) and Melon (*Cucumis melo* L.). *Tropical Life Sciences Research, 33*(1), 43–54.

Borror, D. J., Triplehorn, C. A., & Johnson, N. F. (1989). *An introduction to the study of insects* (7th Ed). Saunders College Publishing.

Cohet, Y., Vouidibio, J., & David, J. R. (1980). Thermal tolerance and geographic distribution: A comparison of cosmopolitan and tropical endemic *Drosophila* species. *Journal of Thermal Biology*, *5*(2), 69–74.

Dollin, A. E., Dollin, L. J., & Sakagami, S. F. (1997). Australian stingless bees of the genus *Trigona* (Hymenoptera: Apidae). *Invertebrate Taxonomy*, *11*(1997), 861–896.

Efin, A., Atmowidi, T., & Prawasti, S. T. (2019). Morphological characteristics and morphometric of stingless bee (Apidae: Hymenoptera) from Banten Province, Indonesia. *Biodiversitas, 20*(6), 1693–1698.

Engel, M. S. (2019). Notes on Papuasian and Malesian stingless bees, with the descriptions of new taxa (Hymenoptera: Apidae). *Journal of Melittology, 88*(2019), 1–25.

Engel, M. S., Kahono, S., & Peggie, D. (2019). A key to the genera and subgenera of stingless bees in Indonesia (Hymenoptera: Apidae). *Treubia, 45*(2019), 65–84.

Franck, P., Cameron, E. G., Rasplus, Y., & Oldroyd, B. P. (2004). Nest architecture and genetic differentiation in a species complex of Australian stingless bees. *Molecular Ecology, 13*(8), 2317–2331.

Garton, O. G., Ratti, J. T., & Giudice, J. H. (2004). Research and experimental design. In C. Braun (Ed.), *Techniques For Wildlife Investigations and Management* (pp. 1–3). The Wildlife Society, Bethesda MD. Preprint.

Hammer, O., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Palaeontological Statistic software package for education and data analysis ver 4.09. *Palaeontologia Electronica, 4*(1), 9.

Kahono, S. (2015). Pengembangan model perlebahan LIPI untuk edukasi, ekoturisme, *dan produksi yang dapat diimplementasikan kepada masyarakat*. Lembaga Ilmu Pengetahuan Indonesia.

Kahono, S., Chantawannakul, P., & Engel, M. S. (2018). Social bees and the current status of beekeeping in Indonesia. In P. Chantawannakul, G. Williams, & P. Neumann (Eds.), *Asian beekeeping in the 21st century* (pp. 287–306). Springer Verlag. https://doi.org/10.1007/978-981-10-8222-1_13.

Kelly, N., Farisya, M. S. N., Kumara, T. K., & Marcela, P. (2014). Species diversity and external nest characteristics of stingless bees in Meliponiculture. *Pertanika Journal Tropical Agricultural Science, 37*(3), 293–298.

Lavergne, S., & Molofsky, J. (2007). Increased genetic variation and evolutionary potential drive the success of an invasive grass. *Proceedings of the National Academy of Sciences*, *104*(10), 3883–3888.

Mayr, E. (1963). *Animal species and evolution*. Harvard University Press.

Michener, C. D. (1974). *The social behavior of the bees: A comparative study*. Harvard University Press.

Michener, C. D. (2000). *The bees of the world* (1st Ed). The Johns Hopkins University.

Michener, C. D. (2007). *The bees of the world, (*2nd Ed). The Johns Hopkins University Press.

Ngutra, N. R. (2017). *Model pengembangan ekonomi lokal masyarakat dalam rangka pelestarian kawasan Cagar Alam Pegunungan Cycloop Jayapura Papua* (Master's thesis). Institut Pertanian Bogor University, Bogor. Indonesia.

Rasmussen, C. (2008). Catalog of the Indo-Malayan/Australasian stingless bees (Hymenoptera: Apidae: Meliponini). *Zootaxa*, *1935*(1), 1–80. https://doi.org/10.11646/zootaxa.1935.1.1

Rasmussen, C., & Cameron, S. A. (2007). A molecular phylogeny of the Old World stingless bees (Hymenoptera: Apidae: Meliponini) and the non-monophyly of the large genus Trigona. *Systematic Entomology*, *32*(1), 26–39. https://doi.org/10.1111/j.1365-3113.2006.00362.x

Rasmussen, C., Thomas, C. J., & Engel, S. M. (2017). A new genus of eastern hemisphere stingless bees (Hymenoptera: Apidae), with a key to the supraspecific groups of Indomalayan and Australasian Meliponini. *American Museum Novitates, 3888*(3888), 1–33.

Roubik, D. W. (1983). Nest and colony characteristics of stingless bee from Panama. *Journal of the Kansas Entomological Society, 56*(3), 327–355.

Roubik, D. W. (2006). Stingless bee nesting biology. *Apidologie, 37*(2), 124–143.

Sakagami, S. F., Inoue, T., Yamane, S., & Salmah, S. (1983). Nest architecture and colony composition of the Sumatran stingless bee *Trigona* (*Tetragonula*) *laeviceps*. *Kontyû, 51*(1), 100–111.

Sakagami, S. F., & Inoue, T. (1985). Taxonomic notes on three bicolorous *Tetragonula* stingless bees in Southeast Asia. *Kontyû, 53*(1), 174–189.

Sakagami, S. F., Inoue, T., & Salmah, S. (1990). Stingless bees of central Sumatra. In S. F. Sakagami, R. Ohgushi, & D. W. Roubik (Eds.), *Natural history of social wasps and bees in Equatorial Sumatra* (pp. 125–137). Hokkaido University Press.

Sayusti, T., Raffiudin, R., & Kahono, S. (2021). Stingless bees (Hymenoptera: Apidae) in South and West Sulawesi, Indonesia: Morphology, nest structure, and molecular characteristics. *Journal of Apicultural Research, 60*(1), 143–156.

Simpson, S. J., Sword, G. A., & Lo, N. (2011). Pholypenism in insects. *Current Biology*, *21*(18), 738–749.

Slaa, E. J., Sanchez, L. A., Sandi, M., & Salazar, W. (2000). A scientific note on the use of stingless bees for commercial pollination in enclosures. *Apidologie, 31*(1), 141–142.

The Papua Insects Foundation. (2008). *Taxonomic and faunistic overviews on the insect species living in Papua and West-Papua (Indonesian New Guinea*). https://www.papua-insects.nl

Wille, A., & Michener, C. D. (1973). The nest architecture of the stingless bee with special reference to those of Costa Rica. *Revista de Biología Tropical*, *21*(1), 1–278.