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Stingless Beehive Entrance Shape and Size in the Imbo Putui Customary Forest, Kampar Regency

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Abstract. Imbo Putui Customary Forest supports high biodiversity, including stingless bees; however, data regarding the specific morphology of their nest entrances in this region remain limited. This study aimed to characterize the entrance funnel length, diameter, nest height, color, shape, and nesting habitat conditions of stingless bees in Imbo Putui Forest. The study employed a survey method with purposive sampling across three zones: roadside (Zone I), forest interior (Zone II), and riparian/oil palm plantation areas (Zone III). Eight stingless bee species were identified: Heterotrigona itama, Tetragonula laeviceps (black and yellow), Tetragonilla collina, Tetragonula drescheri, Tetragonula testaceitarsis, Tetragonula iridipennis, and Homotrigona fimbriata. Nest measurements indicated funnel lengths of 1–27 cm, entrance diameters of 5–20 mm, and nest heights ranging from 1 cm to 1000 cm. Morphologically, the nest entrances were predominantly round or oval in shape, with colors consistently ranging from brownish black to grayish brown.

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1. Introduction

Indonesia is known as a megabiodiversity country because it has a high diversity of flora and fauna. As a tropical country, Indonesia is blessed with a high wealth of bee species, one of which is the stingless bee (Nuraini et al., 2020). The existence of a stingless bee nest is characterized by the entrance and exit of the bee colony in the nest. Stingless bee species have different lengths and colors of nest entrances, to distinguish between one species and another. Distinctiveness in the size and architecture of the nest

makes this bee has a high diversity (Fadhilah et al., 2022). Differences in stingless bee nest entrances help in understanding diversity within species groups. Generally, a large entrance can increase the range and make a strong defense when attacked (Segers et al., 2022).

Several researchers have conducted research to determine the entrance of stingless bees in Indonesia, including Febrianti et al. (2020), in their research in the Surya Perdana Mandiri Mangrove Forest Area, Setapuk Besar Village, North Singkawang found differences. *Heterotrigona itama* has a long slender funnel shape and a large short funnel. While *Tetragonula laeviceps* does not have a funnel, it only makes a hole as a place to enter and exit the nest. In addition, Rivaldy et al. (2023), in their research in the Balaban Resort Conservation Area, Bukit Raya National Park, West Kalimantan, found that *Hemotrgona fimbriata*, *Tetragonilla collina*, and *Tetragonula melanocephala* are characterized by two forms of entrance cavity openings, namely circles and ellipses. *Tetragonilla melina* is the species with the longest funnel found. *Tetragonula apicalis* was the only species that built the highest nest entrance compared to the other species.

Imbo Putui Customary Forest is a customary forest in Petapahan Village, Tapung District, Kampar Regency, Riau Province, which has abundant flora and fauna diversity. Imbo Putui Customary Forest has an ecosystem that is still preserved so that many types of stingless bees are found. Imbo Putui Customary Forest is currently one of the forests that the Petapahan community is very proud of, especially now that it has become an ecotourism sector, which is an opportunity to increase income for the Petapahan community. This change of function results in an increase in the number of visitors so that it can cause damage or changes to the environment and disturbance to the habitat of stingless bee nests in the forest.

Based on the explanation from the forest manager, so far there is no accurate information related to the number of stingless bees and the shape, size of the entrance to the stingless bee nest in the Imbo Putui Customary Forest. Therefore, researchers are interested in conducting research on the shape and size of stingless bees in the Imbo Putui Customary Forest. The novelty obtained from this research is knowing the shape and size of the stingless bee entrance found in the Imbo Putui Customary Forest.

2. The Methods

2.1 Population and sample

The population in this study was all stingless bee nests along the observation path in three regions. While the samples observed in this study were the length of the entrance funnel, the diameter of the entrance funnel, the color of the nest, the height of the nest, the shape of the entrance funnel of stingless bees.

2.2 Time and location of research

The research was conducted from May to August 2024. Located in the Imbo Putui Customary Forest. Determination of the research location was carried out with an initial survey to obtain an overview of the research location. Placement of the research area using purposive sampling technique. Based on the condition of the forest environment, it is divided into 3 areas, namely Region I is on the edge of the road, Region II is in the middle of the forest and Region III is around the river and oil palm plantations. The placement of the area can be seen in Figure 1.

2.3. Research instruments

The tools used were digital camera, GPS, thermohygrometer, meter, ruler and stationery. The object observed was a stingless beehive.

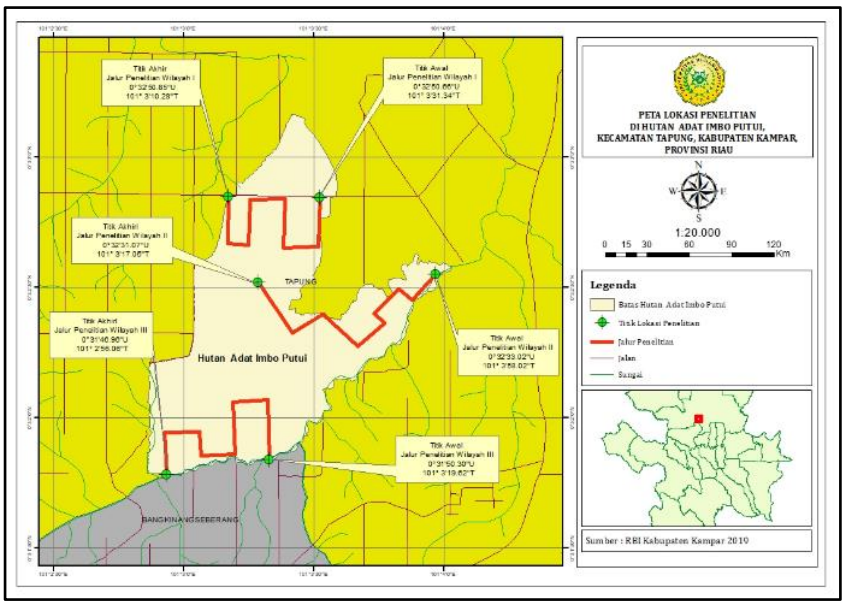

Figure 1. Research location map.

2.4. Sampling technique

Sampling was carried out using purposive sampling technique, which was determined in three different areas with 2000 meters of exploration. Data collection was carried out by measuring nest height, nest diameter, nest length using a ruler. Observations of nest color and shape were made by photographing bee nests without stings. As well as measuring environmental parameters such as temperature and humidity using a thermohygrometer.

2.5. Data snalysis technique

Observation data were tabulated and then analyzed descriptively quantitatively and compared with previous studies.

3. Result and Discussion

3.1. Number of stingless bee hives

Based on the results of research conducted in the three regions, 38 nests were found, which can be seen in Table 1 below:

Table 1. Number of Stingless Bee Hives in Each Region

No.	Species	Region			Total
		I	II	III	
1	*Tetragonilla collina*	15	3	8	26
2	*Tetragonula laeviceps* yellow	1	0	1	2
3	*Tetragonula laeviceps* black	1	1	0	2
4	*Tetragonula iridipennis*	0	1	0	1
5	*Tetragonula drescheri*	0	1	1	2
6	*Tetragonula testaceitarsis*	0	1	0	1
7	*Heterotrigona itama*	0	3	0	3
8	*Homotrigona fimbriata*	0	1	0	1
	Total	17	11	10	38

Based on the results of the research conducted, 38 nests with 8 species of stingless bees were found in the Imbo Putui Customary Forest. The region where the most stingless bee nests were found was in

Region I with 17 nests of 3 species. This shows that the diversity of a species in an area is determined by environmental conditions and the condition of the vegetation around the nest. Region I has various types of plants, so stingless bees tend to make nests on land that has a supply of flowers to produce honey and sap or resin to make nests. The presence of stingless bees can also be detected by observing plants that flower and have sap. Bees take nectar to produce honey and take resin or sap to make their nests. If you have found the nest, you can be sure that around a radius of 50 to 500 m from that location there is a nest or bee colony.

Region I has various plant species that produce flowers and resins such as gerunggang (*Cratoxylum arborescens*), red kelat (*Syzygium palembanicum*), wild cempedak (*Artocarpu integer*), mendarahan (*Myristica lowiana*), petatal (*Ochanostachys amentaceae*), kulim (*Scorodocarpus borneensis*) and lalan (*Santiria laevigata*). The temperature obtained in Region I is 28.3˚ C with humidity reaching 88%. This condition is very suitable for stingless bees. Stingless bees need a stable temperature to develop well. According to Kerisna et al. (2019), the minimum temperature of stingless bees is 28˚ C and the maximum temperature is 33˚ C, while the minimum humidity of stingless bees is 60% and the maximum humidity is 82%. Pujirahayu et al. (2022), added that stingless bee nests are generally found in forest vegetation that is not dense and has a fairly high light intensity. Another factor that can affect the life and development of stingless bee colonies is the availability of food.

The fewest stingless bee nests were found in Region III, namely 10 nests of 3 species, with a temperature of 29˚ C and humidity of 80%. Region III is located around oil palm plantations with a lot of activity, resulting in environmental conditions being damaged and disrupting the lives of stingless bees. Land clearing for oil palm plantations often results in the loss of natural habitats such as forests, which are the main residence of stingless bees. The loss of hollow trees and sources of resin or sap makes it difficult for bees to build nests. In addition, forests surrounded by oil palm plantations no longer provide a suitable environment for stingless bees to breed and find adequate food sources, and the use of pesticides or herbicides in plantations can also negatively impact bee and other insect populations. Exposure to these chemicals can harm the health of stingless bees, reduce the ability of stingless bees to reproduce, and even cause colony death. Research conducted by Rachmawati et al. (2022), stated that the existence of stingless bee nests is influenced by environmental factors around the nest.

The variation in numbers between species was not very large, but differences were seen in *T. collina* which was much more numerous than other species with a total of 26 nests spread throughout the study area. This finding suggests that the forest environment provides optimal conditions that support stingless bees. The dominance of this species indicates that the Imbo Putui Customary Forest is very suitable for the life of *T. collina*, both in terms of nesting needs, such as underground located around the base of large trees, as well as supporting ecological factors, such as the availability of abundant food sources, the presence of trees or natural cavities suitable for nesting, and relatively low levels of disturbance from predators and human activities. This is supported by the statement of Rivaldy et al. (2022), stating that *T. collina* has a very wide distribution pattern, so its presence can be found easily in various locations. This wide distribution shows that *T. collina* species are able to adapt to various conditions that support their distribution to occur effectively.

The least common stingless bee species were *T. testaceitarsis*, *T. iridipennis* and *H. fimbriata*, each of which was only found in very small numbers, namely one nest in Region II. Similar research results were also reported by Izfa & Imran (2019), who noted that the stingless bee species H. fimbriata and *T. testaceitarsis* were each only found in one nest. This suggests that the presence of both species in nature is very limited, with small populations and difficult to find. Another study conducted by Rivaldy et al. (2022) reinforced these findings, with *T. iridipennis* also found in only one nest. These findings provide a consistent picture that these species are difficult to live in very limited habitats. This condition is

strongly suspected to be caused by various factors, such as damage to the environmental ecosystem and low adaptability.

Research on the presence and number of stingless bee nests has been conducted in various regions by several researchers. Iqbal et al. (2016), reported the results of their research in the Rumbio Village Customary Prohibition Forest area, found as many as 19 nests consisting of 3 stingless bee species. This research shows that the area has a fairly high diversity of stingless bee species, which is supported by suitable environmental conditions. In addition, similar research was conducted by Rivaldy et al. (2022), in the Belaban Resort Conservation Area of Bukit Baka Bukit Raya National Park, West Kalimantan, 32 nests were found consisting of 7 species of stingless bees, this shows that the conservation area has a fairly high diversity of stingless bee species, which is supported by natural environmental conditions that are still maintained. Another study was conducted by Febrianti et al. (2022), which examined the number of stingless bee nests in the Green Open Space area of Tanjungpura University Pontianak, found 22 nests with 4 species. This finding shows that green open spaces also play an important role as habitat for stingless bees, especially in central urban areas that may lack natural ecosystems.

Based on the research results in Regions I, II and III have vegetation that is not dense. Stingless bees like not dense vegetation to make nests. Vegetation that is not too dense tends to be better for the life of stingless bees because these conditions provide easier access for bees to fly. With more open space, bees can move from flower to flower in search of food, and return to the hive unhindered, which is especially important for stingless bees with limited flying ability. Vegetation that is not dense stingless bees will also get a stable temperature and humidity and get enough light intensity, while in dense vegetation bees will find it difficult to get sunlight. According to Pujirahayu et al. (2020), the area around the stingless bee nest has vegetation that is not dense so that the stingless bees will get enough light and moisture. Syafrizal et al. (2014), added that stingless bee nests are mostly found in open areas, exposed to sunlight. In addition, open areas tend to have high temperatures, so stingless bees do not require too much energy to reach food sources.

3.2 Shape, size and color of stingless bee hive entrance

It was found that the shape, size and color of the stingless beehive entrance varied, as shown in Table 2. It shows that stingless bees have very unique and diverse variations, especially in terms of the shape, size, and color of their nest entrance funnel. This variation reflects the adaptability of stingless bees to various environmental conditions and materials available in their habitat. The shape of the entrance funnel can vary from round to oval, while the size also varies depending on the species and colony size. In addition, the color of the nest entrance funnel is usually influenced by the material from which the nest is made. The architecture of the nest entrance is one of the characters specific to each species.

The same results were also stated by Sriwahyuni et al. (2023), mentioning the architecture of stingless bee nests, varying greatly in shape, arrangement, size and composition of each part which is influenced by the vegetation around the nest, but also influenced by the age of the colony and the space it occupies. Soh et al. (2022), added that the architecture of nest inlets built by stingless bees is diverse, and can distinguish species levels and be useful for identification.

The most common stingless bee species found in the Imbo Putui Customary Forest is *T. collina* with the longest nest entrance among other species. *T. collina* has a nest length of 3 - 27 cm, round in shape and has a whitish brown color that blends in with the surrounding natural environment. Most are found building underground nests with the entrance tube often protruding from the base of the tree (see Figure 2.). *T. collina* nests were found in gerunggang (*C. arborescens*), red kelat (*S. palembanicum*), forest cempedak (*A. integer*), mendarahan (*M. lowiana*), petatal (*O. amentacea*), kulim (*S. borneensis*) and lalan (*S. laevigata*) trees.

Table 2. Characteristics of stingless bee nest entrances in imbo putui customary forest (shape, color, and dimensions).

No.	Species	Entrance shape	Entrance color	Funnel length (cm)	Nest height (cm)	Entrance diameter (mm)
1	*Tetragonilla collina*	Round	Whitish brown	3–27	1–150	5–10
2	*Tetragonula laeviceps* (yellow)	Round and Oval	Black to dark brown	1–4	80–200	10
3	*T. laeviceps* (black)	Oval	Black to dark brown	6–11	35–90	10–15
4	*T. iridipennis*	Oval	Blackish brown	1	200	10
5	*T. drescheri*	Oval	Greenish yellow	3	10–50	5–10
6	*T. testaceitarsis*	Round	Yellowish brown	1	1	10
7	*Heterotrigona itama*	Round and Oval	Light brown	5–10	700–1000	10–15
8	*Homotrigona fimbriata*	Round	Grayish brown	8	2	20

Figure 2. *T. collina* nest

The same nest shape was also found by Izfa & Imran (2019), which states that the majority of *T. collina* have round nests with long tubes as a defense mechanism. Li et al. (2021), added that *T. collina* is the only species described as having underground nests, which often coexist with ant and termite colonies. They also nest at the base of live or dead trees, as well as the base of bamboo.

Stingless bees with the shortest entrance funnel were found in the species *T. laeviceps*, *T. iridipennis* and *T. testaceitarsis* with a nest length of only 1 cm. The nests of *T. laeviceps* and *T. testaceitarsis* were found to have a round shape and yellowish brown color. *T. iridipennis* was found with blackish brown nests and oval-shaped nests found in hollow trees (shown in Figure 3.).

This characteristic is also stated by Choudhary et al. (2020), stating that *T. iridipennis* nests in stone or rock wall structures, living trees and has no clear or very short inlet. Prasetyo et al. (2022), added that not all entrances of the *T. laeviceps* species have funnels as a sign of a nest, but some are in the form of holes as entrances.

(a) (b) (c)

Figure 3. Nest shape (a) *T. iridipennis*; (b) *T. testaceitarsis*; (c) *T. laeviceps*

(a) (b)

Figure 4. *T. laeviceps* nest shape (a) oval; (b) rounded

The most striking distinctiveness of the entrance characters in this study was found in the species *T. laeviceps* and *H. itama* because both species have two forms of entrance cavities, namely round and oval with entrance openings having varying colors, ranging from brownish black to yellowish brown which serves to camouflage their presence from predators or to adapt to the natural environment in which they live. The entrance shapes of *T. laeviceps* and *H. itama* found in the Imbo Putui Customary Forest can be seen in Figures 4 and 5.

In line with the results of research conducted by Rachmawati et al. (2020), found that *T. laeviceps* nests have irregularly shaped entrances, round, pupa-like, or flat to oval with black color, besides that the entrance of *T. laeviceps* tends to be wet and sticky. *H. itama* has a nest with a cylindrical shape like a tube and has a light brown entrance color, has a very soft and fragile entrance. The stingless bee nest structure can be adapted to the dimensions of the space, creating different nest shape patterns.

(a) (b)

Figure 5. *H. itama* nest shape (a) oval; (b) rounded

The oval-shaped nest entrance with a slightly downward sloping funnel is the most common form found in the Imbo Putui Indigenous Forest which functions as a natural protection from predators,

protects from rain and strong winds, and facilitates activities in and out of the nest found in the species *T. drescheri, T. laeviceps*, *T. iridipennis* and *H. itama* (seen in Figure 6.).

(a) (b)

Figure 6. Oval nest entrances with a downward-sloping funnel structure in (a) *T. iridipennis* and (b) *T. laeviceps*, serving as protection against predators and extreme weather.

The same results were also obtained by Couvillon et al. (2008), the elliptical shape is the most dominant stingless bee hive entrance shape in Brazil. The elliptical shape is a strategic design for most species because it is wider and larger to facilitate the exit and entry activities of stingless bee workers and support the life of stingless bee colonies, besides that it can also maintain temperature and humidity in the hive. Furthermore, Alves et al. (2018), stated that the cylindrical funnel functions to prevent rainwater from entering the hive and usually with sticky propolis to prevent predators from entering. Pujirahayu et al. (2022), added that the long and downward sloping direction of the funnel helps to avoid raindrops entering the nest to keep it dry and safe, because the nest is not protected by dense foliage.

Based on observations of entrance diameter, the species with the widest opening is *H. fimbriata* which has a diameter of up to 20 mm, making it the largest compared to other species. The large diameter allows easier access for transporting pollen and resin. Nests were found to be gray in color, blending in with the surrounding environment to reduce the risk of predator attack. *H. fimbriata* nests found can be seen in Figure 7

Figure 7. Nest of *H. fimbriata* with a large entrance diameter (up to 20 mm) and a grey structure that blends with the surrounding environment.

The same results were also obtained by Syafrizal et al. (2020), mentioning *H. fimbriata* is a stingless bee species that has the largest body size. Streinzer et al. (2016), stated that body size affects the flight distance and foraging activities of stingless bees, with larger body sizes allowing longer flight distances

and wider areas for good food sources. Shackleton et al. (2019), added that larger hive entrances allow greater forager traffic but require more guards to defend themselves.

The smallest entrance diameter was found in the species *T. collina* and *T. drescheri* with a large entrance opening diameter of up to 5 mm, this is because environmental factors such as wind, sunlight and rain and foraging activities affect the diameter of the nest opening. *T. collina* and *T. drescheri* nests are found in areas where there is not much vegetation, so stingless bees make nests with a small diameter to avoid the entry of rainwater. Sunlight in unshaded forests will make light reach the ground surface quickly, affecting the ambient temperature. In addition, wind can also affect the airflow around the hive and make stingless bees adjust the size of the entrance to prevent air from entering the hive. Li et al. (2021), stated that variations in entrance size between colonies are also related to the number of worker bee colonies, attacks from predators and environmental factors such as rain, wind and sunlight. In addition, observations on the same colony at different phases, tubes tend to have narrow entrance mouths when the colony population is small or foraging activity is reduced, while tubes tend to have larger entrance mouths when foraging activity is active and colonies are numerous.

The difference in nest height from ground level shows that stingless bees have a certain height to build nests, especially in the Imbo Putui Indigenous Forest. *H. itama* is the species with the highest nest height found, reaching 700 - 1000 cm. This is because higher nests are difficult to reach by predators and a certain height can provide a stable temperature for colony development and provide better access to food sources. The vegetation in the Imbo Putui Customary Forest has different characteristics, as well as different tree diameters and tree heights, which causes stingless bees to adjust the height of the nest to the availability of food available. Food source plants around the *H. itama* nest are gerunggang (*C. arborescan*), rengas (*G. renghas*), ubar (*S. cerina*), banyan (*F. benjamina*) and lalan (*S. laevigata*) these plants have tall trees and produce flowers that attract stingless bees as nectar and pollen producers. According to Pujirahayu et al. (2020), the average nest height of 3.4 m is the ideal distance to maintain humidity and light intensity due to not too dense vegetation. The higher location of the nest is due to the area around the nest has rather dense vegetation so that the bees place the nest at a distance that is quite ideal for obtaining light and moisture.

The stingless bee species with the lowest nest found was *T. testaceitarsis* with a height of only 1 cm. Lower nests can be protected from strong winds and low places have temperatures suitable for colonies. The temperature around the *T. testaceitarsis* nest is 32˚ C with humidity reaching 63%, which is a suitable temperature and humidity for stingless bees. Pujirahayu et al. (2022), stated that a good temperature for the development of stingless bee colonies ranges from 26˚ C - 32˚ C. The humidity required by stingless bees is between 60% - 80%, low humidity will make the nest dry. Syafrizal et al. (2014), adding that stingless bees are classified as cold-blooded animals, their lives are strongly influenced by the surrounding air temperature. Furthermore, Pujirahayu et al. (2020), nests found in habitat conditions that are below have more stable temperature and humidity and high and low stingless bee nests are caused by changes in nesting substrates and climatic conditions.

Variation in nest entrance morphology and coloration serves as a key characteristic for distinguishing stingless bee species. In *Tetragonula testaceitarsis*, the nest entrance was observed to be yellowish-brown with a unique shape resembling the sun (a radiating funnel structure). This observation aligns with Sanjaya et al. (2019), who noted that *T. testaceitarsis* displays a striking reddish-yellow coloration. Due to this distinct entrance morphology, the species is frequently referred to as the 'sun bee.' In contrast, *T. drescheri* entrances were observed to be yellowish-green, while *Homotrigona fimbriata* entrances were grayish. These findings are consistent with Izfa and Imran (2019), who reported that *T. drescheri* typically constructs elliptical, greenish-black entrances, whereas *H. fimbriata* entrances are grayish-brown.

Choudhary et al. (2020), mentioned that the newly built entrance is soft in color, but retains its shape in various seasons. The color of the entrance tube becomes darker and becomes rigid as time passes. Furthermore, Saaivignesh et al. (2023), the color of the entrance to the stingless bee hive blends with the color of the substrate or the basic color of the hive it is in. Rachmawati et al. (2022), added that stingless bees have varied entrance colors. This is thought to be due to differences in resin sources around the nest. Resin obtained by bees and the influence of other external factors such as hive age, light, rainfall, and predation.

Resin source plants found at the research site are gerunggang (*Cratoxylun arborescens*), wild cempedak (*Artocarpus integer*), white kelat (*Syzygium abulugense*), ubar (*Syzygium cerina*), banyan (*Ficus benjamina*) and lalan (*Santiria laevigata*) produce white to slightly yellowish resin and become yellowish brown after drying. Red kelat (*Syzygium palembanicum*), mendarahan (*Myristica lowiana*), kulim (*Scorodocarpus borneensis*) produce reddish brown resin and will darken to dark brown to black when dry. Rengas (*Gluta renghas*) and petatal (*Ochanostachys amentacea*) produce yellowish resin that gradually darkens upon drying.

Stingless bee nesting sites are generally influenced by species, environment and food availability. The dominant stingless bee nesting vegetation found in the Imbo Putui Customary Forest is the red kelat tree (*S. palembanicum*). This plant has a large and tall tree diameter that can produce resin as a nest-making material and produce pollen as a food source for stingless bees. Iqbal et al. (2016), stated that stingless bees nest in large red kelat trees with a diameter of more than 80 cm as a nesting site. Stingless bees prefer to occupy large trees because they have larger crowns so that the surrounding air is more stable.

Research conducted by Kerisna et al. (2019), stated that the stingless bee nesting sites found were dominated by living trees with a diameter of 60 cm and above and nested in tree trunk cavities whose cavities were naturally formed making it easier for stingless bees to make nests. Cavities in trees provide protection from extreme weather and predators, and have stable temperature and humidity. In addition, some stingless bee species choose to nest in soil crevices, building cracks and wooden poles. Suhri et al. (2023), added that most stingless bee species found in Southeast Asia nest in large canopied trees that provide microenvironments suitable for stingless bee life and build their main entrances into available tree cavities.

4. Conclusion

There were 38 stingless bee nests found in the Imbo Putui Customary Forest. The shape of the nest entrance found in the Imbo Putui Customary Forest is round and oval. The size of the nest varies, with length between 1 - 27 cm, diameter ranging from 5 - 20 mm and the height of the nest found reaching 1 – 1000 cm. The color of stingless bee nests found varies greatly, namely brownish black, yellowish brown, greenish yellow to grayish brown

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