

Habitat preferences and site fidelity of *Tarsius supriatnai* in agricultural area and secondary forest of Popayato-Paguat Landscape (Gorontalo, Indonesia)

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Abstract. Zakaria Z, Abinawanto, Angio MH, Supriatna J. 2022. Habitat preferences and site fidelity of *Tarsius supriatnai* in agricultural area and secondary forest of Popayato-Paguat Landscape (Gorontalo, Indonesia). *Biodiversitas* 23: 3844-3851. *Tarsius supriatnai* is a new species experiencing a declining population trend due to deforestation. This study aims to determine the microhabitat preferences and site fidelity of *T. supriatnai* in the agricultural areas and secondary forests of the Popayato-Paguat landscape, Gorontalo, Indonesia. Measuring important value index (IVI) conducted by vegetation analysis of the nest tree location found in the two habitats was carried out using a quadrat method in seedling, sapling, pole, and tree forms. In addition, temperature and light intensity around the nest tree was also measured. The results showed that in the habitat of agricultural areas, the plant with the highest IVI was not the nest tree. Meanwhile, in the secondary forest habitat, the plant with the highest IVI at the tree form (*Ficus virens*) was the nest tree used by *T. supriatnai*. The diversity value of the H' and E index showed that the two habitats were in the high to moderate. There was no significant difference in temperature and light intensity between the two habitat types. The results also showed that *T. supriatnai* mostly used the nest tree of *Bambusa vulgaris* (26.32%) in the agriculture area and *Schizostachyum lima* and *Calamus zollingeri* (28.57%) in the secondary forest. A survey was conducted to evaluate site fidelity to several nest trees found in 2018. The result revealed that *T. supriatnai* still uses 42.9% of nest trees.

Keywords: Habitat, important value index, preferences, site fidelity, *Tarsius supriatnai*

INTRODUCTION

The Tarsier is a living fossil whose taxonomy is not yet stable (Supriatna 2022). The Tarsier is derived from its elongated tarsal bone (Gursky 2016). Groves and Shekelle (2010) classify the family Tarsiidae into three separate genera: *Cephalopagus*, *Carlito*, and *Tarsius*. The distribution of the genus *Cephalopagus* is in Borneo and Sumatera, genus *Carlito* in the Philippines, and genus *Tarsius* in Sulawesi. The taxonomy of *Tarsius* is continually evolving. Twelve species have been successfully described from the 16 areas of the Tarsier endemism that have been proposed by Shekelle and Leksono (2004). The genus includes *T. tarsier* Erxleben 1777, *T. fuscus* Fischer 1804, *T. sangirensis* Meyer 1897, *T. dentatus* Miller and Hollister 1921, *T. pumilus* Miller and Hollister 1921, *T. pelengensis* Sody 1949, *T. larian* Merker and Groves 2006, *T. tumpara* Shekelle et al. 2008, *T. wallacei* Merker et al. 2010, *T. spectrumgurskyae* Shekelle et al. 2017, *T. supriatnai* Shekelle et al. 2017, and *T. niemitzi* Shekelle et al. 2019 (Niemitz et al. 1991;

Merker and Groves 2006; Shekelle et al. 2008; Groves et al. 2008; Merker et al. 2010; Groves 2012; Shekelle et al. 2017 Shekelle et al. 2019). Based molecular data using autosomal phylogenetic and the SRY gene showed that the Tarsier came to Proto-Sulawesi during the initial Miocene tectonic uplift (Driller et al. 2015), with *T. pumilus* being the basal Tarsier in Sulawesi (Hagemann et al. 2022). The conservation status of the Tarsier, especially 12 species of Tarsier in Sulawesi, is categorized as data-deficient to critically endangered (Supriatna 2022).

Jatna's Tarsier (*Tarsius supriatnai*), a species of Tarsier in Sulawesi that has been described since 2017 (Shekelle et al. 2017), is experiencing a trend of declining population. The distribution of *T. supriatnai* is ranged from isthmus in Gorontalo to Oгатemuku areas in Central Sulawesi (Shekelle et al. 2017). Bienkowski et al. (2021) stated that the potential area of occupancy of *T. supriatnai* is less than 5000 km, with the extent of occurrence around 11,000 km², making it continue to face the threat of habitat change. More than 30% of its habitat has been converted in the last 20 years. This species is currently classified as vulnerable,

according to IUCN (Shekelle 2020). Furthermore, based on Supriatna et al. (2020), *T. supriatnai* had lost 12% of its habitat in non-conservation areas and 3% in conservation areas between 2000-2017. According to Merker and Yustian (2008), forest conversion into commercial plantation areas (agricultural) seems almost unstoppable. Thus, an assessment of how the Tarsier adapts to agricultural habitat is essential to predict the survival of Tarsier in the future. Studies on the primate's adaptation in the agroecosystem have been quite extensive. Estrada et al. (2012) analyzed 57 primate taxa from four regions, Mesoamerica, South America, Sub-Sahara Africa (including Madagascar), and Southeast Asia, finding primates used 38 types of agroecosystems as their temporary or permanent habitats.

As a result of forest conversion, the agroecosystem forces the Tarsier to adapt to the occurring changes, previous research has confirmed that the Tarsier can still be found in secondary forests to plantation areas (Merker et al. 2005; Merker and Yustian 2008; Saroyo et al. 2017). Merker et al. (2005) stated that *T. dentatus* could inhabit mixed plants of cacao and gliricidia (*Gliricidia sepium*), which are interspersed with dense shrubs. Besides, *T. dentatus* also inhabit other trees such as bamboo (*Bambusa* spp.), reeds (*Imperata cylindrica*), and corn outside the natural forests. According to Saroyo et al. (2017), the biggest threat to the Tarsier in secondary forest and agricultural areas is using chemical herbicides and applying anthropogenic activities such as land clearance by burning in plantation areas. Meanwhile, Clough et al. (2011) proved that in a properly designed small-scale cacao agroecosystem, the production capacity can still increase without reducing the diversity of animals. In this paper, we aim to study the microhabitat preferences of *T. supriatnai* nest tree as a form of adaptation to the agricultural areas and to study the site fidelity during the last five years in the agricultural areas and secondary forests in the Popayato-Paguat landscape.

MATERIALS AND METHODS

Study site

Popayato-Paguat Landscape is a forest area of 72,256 Ha designated as a Key Biodiversity Area (KBA) by Burung Indonesia (Burung Indonesia 2014). According to Riggs et al. (2021), the entire landscape reached 84,726 Ha, including the area of production forest, protected forest, and small-scale plantation. Meanwhile, Pusparini et al. (2022) stated that the total area of this landscape could reach 1.29 million Ha and form a corridor that connects two nearby protected forest areas and two KBAs. Pusparini et al. (2022) found that this landscape is consistently identified as one of the highest prioritized areas for protection in various scenarios in the model that has been made. This research was conducted in Mekarti Jaya Village in Puhowato District, Gorontalo Province, Indonesia directly adjacent to this landscape. The research area was divided into two types: agricultural area and secondary forest. Data collection of this research was done in March-

May 2022 with permission from the government of Puhowato District, Gorontalo Province, through the letter numbered 203/KBP/23/III/2022.

Data collection

The observation began with identifying the location of trees where the Tarsier was sleeping. It was done by following the direction of the Tarsier duet call during 05.00-06.00 in the morning and detecting the smell of Tarsier urine, which is a part of their territory marking. The nest trees identified in the morning went under observation again around 18.00-19.00 to ensure that the Tarsier was leaving from the same nest trees. The locations of the nest trees were marked by GPS and documented by a camera. The characteristics of the recorded nest trees include the type of the trees, light intensity, and temperature around them.

Vegetation data around the nest trees were retrieved with the quadrat method by using a 20x20m plot in each tree found. This main plot was used to measure the vegetation data of the tree. Then, this main plot was divided into several sub-plots of 10x10m, 5x5m, and 2x2m used to measure the vegetation data of pole, sapling, and seedling, respectively. The vegetation clustering used in this research was adopted from Mueller-Dumbois and Ellenberg (2016), who characterized diameter at breast height (DBH) of tree >20 cm, DBH of pole 19.9-10 cm, DBH of sapling <10 cm with a height of more than 1.5 m and seedling for vegetation with a height of less than 1.5 m. The data of trees and poles consists of the name of the species, the number of individuals, and DBH. Meanwhile, the data of saplings and seedlings consist of the name and the number of individuals. Identification of vegetation found in all the plots was carried out using multiple reference guides (Culmsee et al. 2011; Cappers and Bekker 2013; POWO 2022). Validation of the identification of several nest trees was carried out by Botanical Characterization Laboratories through E-Layanan Sains National Research and Innovation Agency. The data of site fidelity used seven out of nine nest trees in 2018, identified by Ismail (2018) and Sulkifli (2019). All seven trees were resurveyed in this research to observe the use of the same nest trees in the last five years (2018-2022).

Data analysis

The data of the nest trees obtained were then plotted onto the Sentinel-2 RGB composite image acquired on 2018-04-02, which was overlaid with the Sentinel-2 image acquired on 2022-03-15 to see the areas that have experienced changes in canopy cover as well as to determine the distribution of *T. supriatnai* in the last five years. Image data processing was done using ArcGIS 10.4. The vegetation structure data around the nest trees were analyzed using Google Sheet to obtain relative density, relative frequency, relative dominance, and Important Value Index (IVI) (Mueller-Dumbois and Ellenberg 2016). The data of plant vegetation was analyzed to calculate Shannon Wiener's diversity index (H') and Pielou's evenness index (E). The interpretation of the value of the diversity index and evenness index is based on Magurran

(1988). The data of environmental parameters were analyzed using Mann-Whitney test to assess the differences in the physical condition of the environment around the nest trees in the two habitats. Shannon-Wiener's diversity index and Pielou's evenness index were carried out using Paleontological Statistical (PAST) version 4.

RESULTS AND DISCUSSION

Description of the habitat of *Tarsius supriatnai*

The survey found 115 species from 64 families with 1117 individuals in all the growth forms (tree, pole, sapling, and seedling) in the two habitats. Based on the IVI value (Table 1), it can be seen that in the agricultural area, *Theobroma cacao* dominated in tree and pole form. In contrast, *Macaranga grandifolia* and *Palaquium obtusifolium* dominated in sapling and seedling forms. Meanwhile, *Ficus virens* and *M. grandifolia* dominated in tree and pole form in the secondary forest. In contrast, *Mallotus mollissimus* and *Arenga pinnata* dominated sapling and seedling forms.

In Table 2, it can be seen that the value of the Shannon-Wiener index (H') indicates that vegetation diversity around *T. supriatnai* nest trees in agricultural areas is in the moderate category (tree and pole form) to high category (sapling and seedling form). Meanwhile, vegetation diversity in the secondary forest is in the high category (tree, pole, sapling, and seedling form). The calculations using the Pielou's evenness index E also show the evenness of vegetation in agricultural habitats in the moderate (trees) to high (poles, saplings, and seedlings) categories. While in

secondary forest habitat, the evenness of vegetation in all categories is relatively high, so the tendency of the number of individuals for each taxon is relatively the same, and there is no dominance.

Tarsius supriatnai nest tree and physical parameter

The survey found 19 nest trees in the agricultural areas and 14 nest trees in secondary forests. The distribution of each nest tree in the two habitats is shown in Figure 3. Direct encounters with *T. supriatnai* happened nine times in the agricultural areas and seven times in the secondary forests. The survey results also showed the groups of *T. supriatnai* observed in the agricultural areas would always return to the same nest trees every morning. However, some groups observed in secondary forests tended to use alternative nest trees when there was a disturbance and would return to their original nest trees a few days later after the disturbance was gone.

Based on Figure 1, it can be seen that the type of plant most frequently used as a nest tree in an agricultural area is *Bambusa vulgaris* (26.32%) and in the secondary forest is *Schizostachyum lima* and *Calamus zollingeri* (28.57%). According to Table 3, the distribution of nest trees by the family was dominated by the family Poaceae (35.71%), Arecaceae (21.43%), and Moraceae (7.14%) in the agricultural area and family Poaceae (14.29%), Arecaceae (14.29%) and Moraceae (7.14%) in secondary forest. In Table 3, we can see that in the two habitats, trees from the Moraceae family were used by only one group of *T. supriatnai*, while trees from the Poaceae family were the most widely used as nest trees in both habitats.

Table 1. Dominant types of vegetation around *Tarsius supriatnai* nest trees in the habitats of agricultural areas and secondary forests in Mekarti Jaya Village, Puhowato District, Gorontalo Province, Indonesia

Habitat type	Growth form	Family	Species		RDE (%)	RF (%)	RDO (%)	IVI (%)
			Binomial name	Local name				
Agricultural area (n: 19)	Tree	Malvaceae	<i>Theobroma cacao</i>	Kakao	43.83	4.76	26.19	74.78
	Pole	Malvaceae	<i>Theobroma cacao</i>	Kakao	25.00	13.73	21.53	60.26
	Sapling	Euphorbiaceae	<i>Macaranga grandifolia</i>	Owoti	13.95	10.20	-	24.16
	Seedling	Sapotaceae	<i>Palaquium obtusifolium</i>	Tahi	14.49	13.43	-	27.93
Secondary forest (n: 14)	Tree	Moraceae	<i>Ficus virens</i>	Luluo	0.90	1.32	67.16	69.73
	Pole	Euphorbiaceae	<i>Macaranga grandifolia</i>	Owoti	9.17	5.71	10.38	25.27
	Sapling	Euphorbiaceae	<i>Mallotus mollissimus</i>	Mata putih	8.38	5.60	-	13.98
	Seedling	Arecaceae	<i>Arenga pinnata</i>	Aren	12.25	9.17	-	21.42

Note: RDE: Relative Density; RF: Relative Frequency; RDO: Relative Dominance; IVI: Important Value Index

Table 2. The value of Shannon-Wiener diversity (H') index and Pielou's evenness (E) index of vegetation around *Tarsius supriatnai* nest trees in the habitat of agricultural area and secondary forest in Mekarti Jaya Village, Puhowato District, Gorontalo Province, Indonesia

Habitat type	Growth form	Number of species	Shannon-Wiener's diversity (H')		Pielou's evenness (E)	
			Value	Interpretation	Value	Interpretation
Agricultural area (n: 19)	Tree	31	2.39	Moderate	0.69	Moderate
	Pole	29	2.90	Moderate	0.86	High
	Sapling	26	3.13	High	0.96	High
	Seedling	33	3.02	High	0.86	High
Secondary forest (n: 14)	Tree	34	3.25	High	0.92	High
	Pole	45	3.63	High	0.95	High
	Sapling	47	3.50	High	0.90	High
	Seedling	46	3.23	High	0.84	High

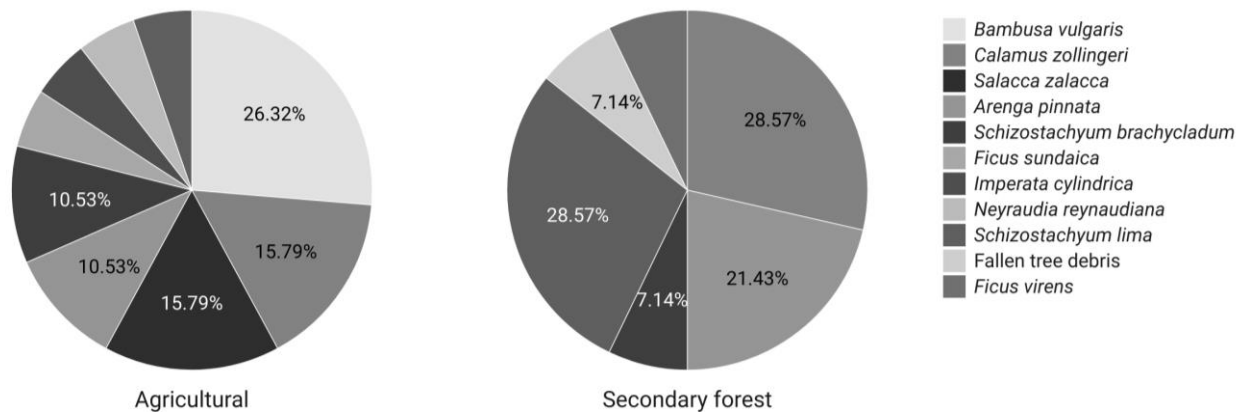


Figure 1. The percentage of types of *Tarsius supriatnai* nest tree in the habitat of agricultural areas (n: 19) and secondary forest (n: 14) in Mekarti Jaya Village, Puhowato District, Gorontalo Province, Indonesia

The result of the physical parameter test (Figure 2) using Mann-Whitney test showed that the temperature parameter around the nest in the two habitats was significantly different (p : <0.01; U : 32.5). Meanwhile, the light intensity parameter around the nest in the agricultural area and the secondary forest did not significantly differ (p : 0.347; U : 182).

Site fidelity

A small-scale habitat observation (Ismail, 2018) and behavioral study of *T. supriatnai* were carried out in 2018 (Sulkifli, 2019). These studies resulted in the finding of nine nest trees distributed in the agricultural area and secondary forest. From the nine nest trees found, seven trees were resurveyed in 2022 (Figure 3). The survey result showed that 42.9% of the trees continue to be used until 2022. The missing nest tree is *S. lima* and *B. vulgaris*, cleared by burning for agricultural expansion. Local farmers often perform trunk removal of *S. lima* to use it as a plant supporting stake for several crops such as tomatoes,

melons, and some legumes. Based on the land use map in Figure 3, several habitats found in 2018 have experienced changes in land cover due to the expansion of the new agricultural area.

Discussion

Habitat is essential for the survival of the Tarsier as it plays a role in providing food and protecting from predators and the weather (MacKinnon and MacKinnon 1980). The survey showed that the Tarsier can still be found in agricultural habitats by occupying vegetation patches among cacao plantations or mixed farming areas. Besides, the Tarsier also used Salak trees (15.79%) to adapt nest preferences in agricultural land near the settlement. In this village, Salak trees were used as a natural border to divide the land ownership status of cacao plantation areas. The survey results also showed that some farmers who owned lands around the riverbank preserved bamboo and the surrounding vegetation, anticipating river erosion from affecting their lands.

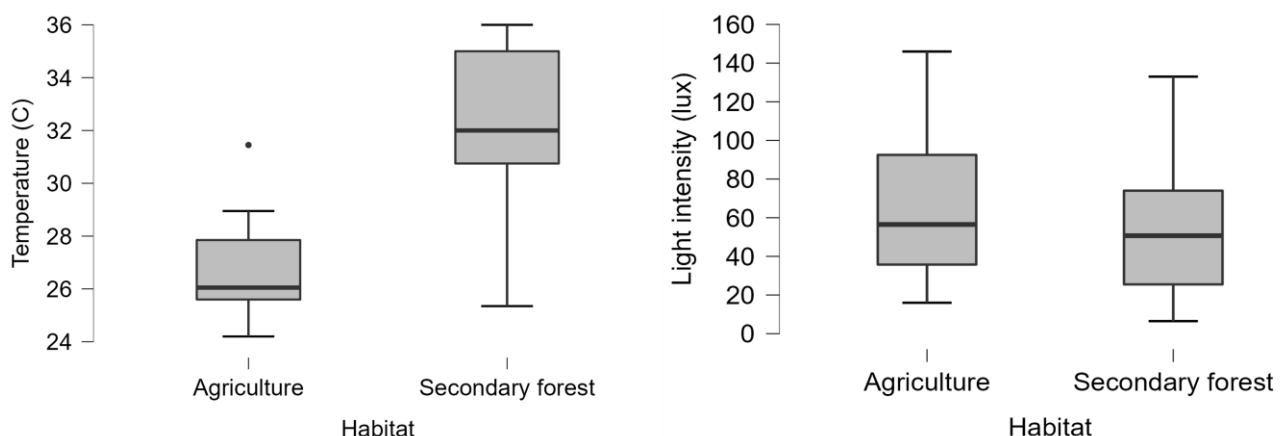


Figure 2. The result of temperature and light intensity parameter around *Tarsius supriatnai* nest tree in the two habitats in Mekarti Jaya Village, Puhowato District, Gorontalo Province, Indonesia

Vegetation analysis of the habitat of the agricultural areas showed that all plants in all growth forms with the highest Important Value Index (IVI) were not the nest trees used by the Tarsier groups. On the contrary, in the secondary forest habitat, the plants with the highest IVI (*F. virens*) in the tree form were used by the Tarsier groups as a nest. However, as shown in Table 1, *F. virens* had a moderately low density and relative frequency. Although the plants with the highest IVI in agricultural habitats were not used by *T. supriatnai* as nest trees, these plants were presumed to provide locomotion support for the Tarsiers' movement and food hunting around the nest. MacKinnon and MacKinnon (1980) stated that Tarsiers explore branches with small diameters of <4 cm and at least 3 m height from the ground for hunting, while branches with medium (4-8 cm) and large (>8) diameters are mostly for resting and marking. In addition, according to Mustari et al. (2013), fruiting plants such as cacao are generally a gathering place for insects which are the leading food of the Tarsier. The preference to use clumping trees from the Poaceae and Arecaceae families for nests is also made by other Tarsiers like *T. fuscus* (Mustari et al. 2013), *T. spectrumgurskyae* (Saroyo et al. 2017), and *T. dianae* (Merker and Yustian 2008). This condition might be possible because both plant families provide low light intensity and a suitable substrate for gripping during sleep. MacKinnon and MacKinnon (1980) mentioned some particular characteristics of the Tarsiers' nest trees preferences, such as low light intensity, availability of the surface for gripping during sleep, protection from rain and wind, and accessibility to avoid predators. Wirdateti and Dahrudin (2008) stated that *T. fuscus* prefers bamboo clumps 2-4 m in circular shape with dense and tall grooves.

The vegetation analysis in the secondary forest showed that the type of nest trees used was the plant with the highest IVI in the tree form (*F. virens*). Although the IVI value of *F. virens* was the highest, this plant's density and relative frequency were relatively low. Most of the researchers (Mustari et al. 2013; Saroyo et al. 2014; Gursky

2016; Arrijani and Rizki 2019; Andriyani et al. 2021) found that *Ficus* is a tree species that is widely used as nest trees in secondary forests. Furthermore, Gursky (2016) stated that *F. caulocarpa* is the most commonly used tree for *T. spectrumgurskyae* nest, with 30-700 cm circumference. However, only one *Ficus* tree per hectare is enough to accommodate one group of the Tarsiers. This limited sampling area is one factor that the research result only showed one group of Tarsiers using *Ficus* tree as their nest. Moreover, the result showed that *S. lima* and *C. zollingeri* is the most widely used vegetation as nesting tree because it shares the same characteristics as most nesting trees in protecting from predators, alternative escape route, and availability of the surface for gripping during sleep (MacKinnon and MacKinnon 1980).

Several studies have demonstrated that the Tarsiers can tolerate moderate to severe human activity (Merker et al. 2005; Merker 2006; Yustian et al. 2008). According to Grow et al. (2013), *T. pumilus* had a clumped distribution along the anthropogenic borders, which was associated with higher levels of insect abundance and biomass. Tarsiers are able to adapt to conditions of intensive anthropogenic activity by increasing the size of their home ranges and the length of the nighttime paths they use to find food (Merker 2006). Although the Tarsiers can still be found in agricultural areas, the Tarsier population density is lower than in primary and secondary forest habitats (Merker et al 2005; Yustian et al. 2008). Our results show that *T. supriatnai* can still survive by using clumped vegetation such as bamboo, rattan, and reeds around riverbanks. Fascinatingly, several small groups of the Tarsiers discovered outside of riverbanks chose Salak clumps as nesting sites in the near vicinity of human habitations. In areas with a high level of anthropogenic activity, the selection of Salak clumps as land ownership boundaries creates a habitat that is conducive to the survival of the Tarsiers. The characteristics of the clumps and spines of the Salak tree provide adequate protection and microhabitat for *T. supriatnai*.

Table 3. Important value index of each nest tree of *Tarsius supriatnai* in the two types of habitats in Mekarti Jaya Village, Puhowato District, Gorontalo Province, Indonesia

Habitat type	Growth form	Family	Species		IVI (%)	Number of sleeping site
			Binomial name	Local name		
Agriculture	Tree	Arecaceae	<i>Salacca zalacca</i>	Salak	11.64	3
			<i>Arenga pinnata</i>	Aren	17.17	2
		Moraceae	<i>Ficus sundaica</i>	Luluo	8.59	1
	Pole	Poaceae	<i>Bambusa vulgaris</i>	Talilo	31.60	5
			<i>Schizostachyum brachycladum</i>	Wawohu	3.82	2
	Sapling	Arecaceae	<i>Calamus zollingeri</i>	Rotan	11.94	3
			<i>Schizostachyum lima</i>	Hulapa	4.37	1
		Poaceae	<i>Neyraudia reynaudiana</i>	Tebu air	5.53	1
	Seedling	Poaceae	<i>Imperata cylindrica</i>	Alang-alang	5.78	1
Secondary forest	Tree	Moraceae	<i>Ficus virens</i>	Luluo	69.37	1
		Arecaceae	<i>Arenga pinnata</i>	Aren	16.87	3
	Pole	Poaceae	<i>Schizostachyum brachycladum</i>	Wawohu	2.96	1
	Sapling	Poaceae	<i>Schizostachyum lima</i>	Hulapa	10.07	4
			<i>Calamus zollingeri</i>	Rotan	8.95	4
	NA	NA	Fallen tree debris (unknown species)	NA	NA	1

Note: IVI: Important Value Index; NA: Not Available

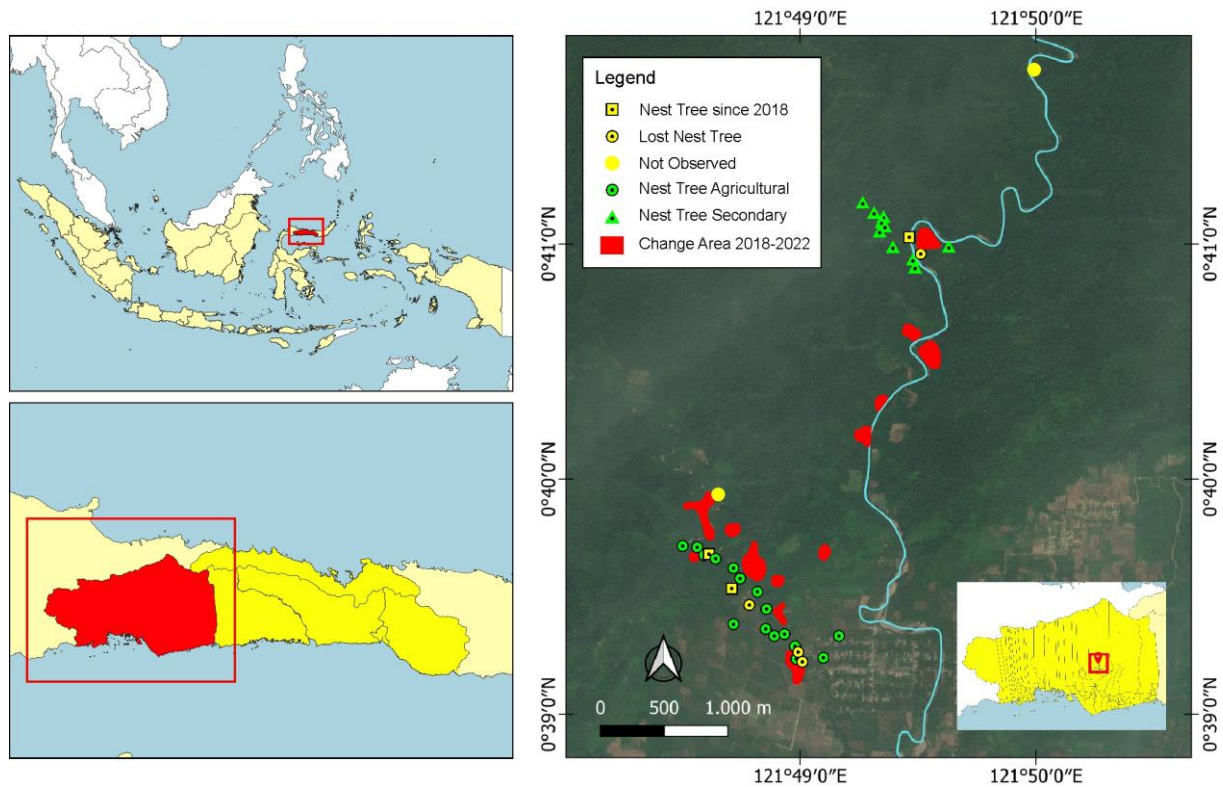


Figure 3. The change in land use in Mekarti Jaya Village, Puhowato District, Gorontalo Province, Indonesia and the site location of three (42.9%) nest trees continued to be used from 2018 to 2022. LPF (limited production forest), PF (protected forest), and OUA (other use areas). Map source: Sentinel-2 RGB composite image acquired on 2018-04-20 and 2022-03-15 (European Space Agency); Map of the forest area of Gorontalo Province: Decree of Ministry of Forestry (SK Menhut No. 325/Menhut-II dated 25th May 2010)



Figure 4. *Tarsius supriatnai* in several types of the nest tree, such as (A) *Bambusa vulgaris*, (B) *Schizostachyum lima*, and (C) *Calamus zollingeri* (camera trap provided by Burung Indonesia). Picture (D) shows a pair of *Tarsius supriatnai* with a predator near their nest tree

In general, the Tarsiers tend to have moderate site fidelity. The research result showed that 42.9% of *T. supriatnai* groups used the same nest tree from 2018 to 2022. In Figure 3, it can be seen that in secondary forests, there has been a change in land cover in the last five years (2018-2022) due to logging activity. Several nest trees discovered in 2018 were lost due to logging activities conducted at the research site. Our ground-truthing results show that the vegetation changes shown in Figure 3 are largely the result of forest conversion to new corn fields in an effort to increase production capacity. The site fidelity of *T. supriatnai* is similar to of *T. spectrumgurskyae* in Tangkoko National Park. Gursky (2016) showed that 50% of the Tarsiers group observed since 1994 continued to use the same nest trees after five years (1999) and 60% of the Tarsier groups followed since 1999 also continued to use the same tree after five years (2004). Several disturbances caused by tourist activities in these locations were considered the cause of the migration of some the Tarsier groups into other nest trees. Although the sample size of this research was considerably small, the finding can be used as baseline data for future site fidelity research on the Tarsiers. The finding also showed that the community education project through Tarsier ecotourism in the area conducted by Burung Indonesia is proven to preserve the Tarsier nest trees in the observation sites. However, as agricultural areas are not part of the observation sites, the nest trees of the Tarsiers have been lost due to land expansion.

The research result showed that *T. supriatnai* mostly used bamboo as their nest tree in the two habitat types: in the agricultural area, using *B. vulgaris* (26.32%), and in the secondary forest, using *S. lima* and *C. zollingeri* (28.57%). Several types of nest tree are presented in Figure 4. In the agricultural area, the plant with the highest IVI was not used by *T. supriatnai* as a nest tree. In contrast, in the secondary forest, *T. supriatnai* nest tree was the vegetation with the highest IVI in tree form (*F. virens*). The result also showed that *T. supriatnai* site fidelity is moderate, where 42.9% of the Tarsier groups still used the same nest tree from 2018 to 2022.

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REFERENCES

- Andriyani AA, Nugraha R, Marlina SN. 2021. Distribution and characteristics of the Makassar tarsius *Tarsius fuscus* fischer, 1804 sleeping nest in the tropical primary and secondary forests of South Sulawesi. IOP Conf Ser Earth Environ Sci 948: 012034. DOI: 10.1088/1755-1315/948/1/012034.
- Arrijani, Rizki M. 2019. Vegetation analysis and population of tarsier (*Tarsius spectrumgurskyae*) at Batuputih Nature Tourism Park, North Sulawesi, Indonesia. Biodiversitas 20 (2): 530-537. DOI: 10.13057/biodiv/d210214.
- Bienkowski LS, Stephan RS, Kirschev T, Sayanthi R. 2021. Population density of *Tarsius supriatnai* along a forest degradation gradient in Popayato-Paguat landscape (Gorontalo Province, Sulawesi). In: Telnov D, Barclay MVL, Pauwels OSG (eds). Biodiversity, Biogeography and Nature Conservation in Wallacea and New Guinea. Volume IV. The Entomological Society of Latvia, Rīga.
- Burung Indonesia. 2014. Critical Ecosystem Partnership Fund CEPF Ecosystem Profile Wallacea Biodiversity Hotspot. https://www.cepf.net/sites/default/files/ecosystemprofile_wallacea.pdf.
- Cappers RTJ, Bekker RM. 2013. A Manual for the Identification of Plant Seeds and Fruits. Barkhuis, Netherlands.
- Clough Y, Barkmann J, Jührbandt J, Kessler M, Wanger TC, Anshary A, Buchori D, Cicuzza D, Darras K, Dwi Putra D, Erasmis S, Pitopang R, Schmidt C, Schulze CH, Seidel D, Steffan-Dewenter I, Stenchly K, Vidal S, Weist M, Wielgoss AC, Tschamtker T. 2011. Combining high biodiversity with high yields in tropical agroforests. Proc Natl Acad Sci U S A 108: 8311-8316. DOI: 10.1073/pnas.1016799108.
- Culmsee H, Pitopang R, Mangopo H, Sabir S. 2011. Tree diversity and phytogeographical patterns of tropical high mountain rain forests in Central Sulawesi, Indonesia. Biodivers Conserv 20: 1103-1123. DOI: 10.1007/s10531-011-0019-y.
- Driller C, Merker S, Perwitasari-Farajallah D, Sinaga W, Anggraeni N, Zischler H. 2015. Stop and go - Waves of tarsier dispersal mirror the genesis of Sulawesi island. Plos One 10 (11): e0141212. DOI: 10.1371/journal.pone.0141212.
- Estrada A, Raboy BE, Oliveira LC. 2012. Agroecosystems and primate conservation in the tropics: A review. Am J Primatol 74: 696-711. DOI: 10.1002/ajp.22033.
- Groves C, Shekelle M, Brandon-Jones D. 2008. Taxonomic History of the Tarsiers, Evidence for the Origins of Buffon's Tarsier, and the Fate of *Tarsius spectrum* Pallas, 1778. LIPI Press, Jakarta.
- Groves C, Shekelle M. 2010. The genera and species of Tarsiidae. Intl J Primatol 31: 1071-1082. DOI: 10.1007/s10764-010-9443-1.
- Groves C. 2012. Encyclopedia of Anthropology: Primate Taxonomy. Smithsonian Institution Press, United States.
- Grow N, Gursky S, Duma Y. 2013. Altitude and forest edges influence the density and distribution of pygmy tarsiers (*Tarsius pumilus*). Am J Primatol 75 (5): 464-477. DOI: 10.1002/ajp.22123.
- Gursky S. 2016. The Spectral Tarsiers. Routledge, New York.
- Hagemann L, Grow N, Bohr YEM, Perwitasari-Farajallah D, Duma Y, Gursky SL, Merker S. 2022. Small, odd and old: The mysterious *Tarsius pumilus* is the most basal Sulawesi tarsier. Biol Lett 18 (3): 20210642. DOI: 10.1098/rsbl.2021.0642.
- Ismail W. 2018. Analisis Vegetasi Habitat Tarsius (*Tarsius* sp) Di Kawasan Hutan Popayato-Paguat Kabupaten Pohuwato. [Undergraduate thesis]. Universitas Negeri Gorontalo, Gorontalo. [Indonesia]
- MacKinnon J, MacKinnon K. 1980. The behavior of wild spectral tarsiers. Intl J Primatol 1: 361-379. DOI: 10.1007/BF02692280.
- Magurran AE. 1988. Ecological Diversity and Its Measurement. Cambridge University Press, London, UK.
- Merker S. 2006. Habitat-specific ranging patterns of Dian's tarsiers (*Tarsius dianae*) as revealed by radiotracking. Am J Primatol 68 (2): 111-112. DOI: 10.1002/ajp.20210.
- Merker S, Yustian I, Mühlenberg M. 2005. Responding to forest degradation: Altered habitat use by Dian's tarsier *Tarsius dianae* in Sulawesi, Indonesia. Oryx 39: 189-195. DOI: 10.1017/S0030605305000438.
- Merker S, Groves CP. 2006. *Tarsius lariat*: A new primate species from Western Central Sulawesi. Intl J Primatol 27 (2): 465-485. DOI: 10.1007/s10764-006-9038-z.
- Merker S, Yustian I. 2008. Habitat use analysis of Dian's tarsier (*Tarsius dianae*) in a mixed-species plantation in Sulawesi, Indonesia. Primates 49: 161-164. DOI: 10.1007/s10329-007-0072-z.

- Merker S, Driller C, Dahrudin H, Wirdateti, Sinaga W, Perwitasari-Farajallah D, Shekelle M. 2010. *Tarsius wallacei*: A new tarsier species from Central Sulawesi occupies a discontinuous range. *Intl J Primatol* 31 (6): 1107-1122. DOI: 10.1007/s10764-010-9452-0.
- Mustari AH, Mansyur FI, Rinaldi D. 2013. Karakteristik habitat dan populasi tarsius (*Tarsius fuscus* Fischer 1804) di Resort Balocci, Taman Nasional Bantimurung Bulusaraung, Sulawesi Selatan. *Media Konservasi* 18: 47-53. DOI: 10.29244/medkon.18.1. [Indonesia]
- Mueller-Dumbois D, Ellenberg H. 2016. *Ekologi Vegetasi: Tujuan dan Metode*. Translated by K. Kartawinata and R. Abdulhadi. LIPI Press and Pustaka Obor, Jakarta. [Indonesia]
- Niemitz C, Niestch A, Warter S, Rumpel Y. 1991. *Tarsius diana*: A new primate species from Central Sulawesi (Indonesia). *Folia Primatologica* 56: 105-116. DOI: 10.1159/000156534.
- POWO. 2022. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. <http://www.plantsoftheworldonline.org>.
- Pusparini W, Cahyana A, Grantham H, Maxwell S, Soto-Navarro C, Andayani N, Macdonald D, Linkie M. 2022. A bolder conservation future for Indonesia: Conserving biodiversity, carbon and unique ecosystem in Sulawesi. *Res Sq* 1-23. DOI: 10.21203/rs.3.rs-1219965/v1.
- Riggs RA, Achdiawan R, Adiwinata A, Boedhihartono AK, Kastanya A, Langston JD, Priyadi H, Ruiz-Pérez M, Sayer J, Tjiu A. 2021. Governing the landscape: Potential and challenges of integrated approaches to landscape sustainability in Indonesia. *Landsc Ecol* 36: 2409-2426. DOI: 10.1007/s10980-021-01255-1.
- Saroyo, Tallei TE, Koneri R. 2017. Density of spectral tarsier (*Tarsius spectrum*) in agricultural land, mangrove, and bush habitats in North Sulawesi, Indonesia. *Biosci Res* 14: 310-314.
- Saroyo S, Koneri R, Siahaan R, Tallei TE, Kiroh HJ, Repi T. 2014. Density of Tangkasi (*Tarsius spectrum*) population and development of population estimation method based on duet call at Tangkoko-Batuangus Nature Reserve, North Sulawesi. *Curr Res J Biol Sci* 6: 42-45. DOI: 10.19026/crjbs.6.5496.
- Shekelle M. 2020. 8235 *Tarsius supriatnai*. The IUCN Red List of Threatened Species 2020.
- Shekelle M, Leksono SM. 2004. Strategi konservasi di Pulau Sulawesi dengan menggunakan Tarsius sebagai flagship species. *Biota* 9 (1): 1-10. [Indonesia]
- Shekelle M, Groves C, Merker S, Supriatna J. 2008. *Tarsius tumpara*: A new tarsier species from Siau Island, North Sulawesi. *Primate Conserv* 23 (1): 55-64. DOI: 10.1896/052.023.0106.
- Shekelle M, Groves CP, Maryanto I, Mittermeier RA. 2017. Two new tarsier species (Tarsiidae, Primates) and the biogeography of Sulawesi, Indonesia. *Primate Conserv* 31: 61-70.
- Shekelle M, Groves CP, Maryanto I, Mittermeier RA, Salim A, Springer MS. 2019. A new tarsier species from the Togeian Islands of Central Sulawesi, Indonesia, with references to Wallacea and conservation on Sulawesi. *Primate Conserv* 33 (33): 65-73.
- Sulkifli. 2019. Deskripsi Perilaku Tarsius di Sekitar Sarang di Blok Hutan Popayato-Paguat. [Undergraduate Thesis]. Universitas Negeri Gorontalo, Gorontalo. [Indonesia]
- Supriatna J. 2022. *Field Guide to the Primates of Indonesia*. Springer, Switzerland.
- Supriatna J, Shekelle M, Fuad HAH, Winarni NL, Dwyahreni AA, Farid M, Mariati S, Margules C, Prakoso B, Zakaria Z. 2020. Deforestation on the Indonesian island of Sulawesi and the loss of primate habitat. *Glob Ecol Conserv* 24: e01205. DOI: 10.1016/j.gecco.2020.e01205.
- Wirdateti W, Dahrudin H. 2008. An exploration on the habitat, feeds and distribution of *Tarsius tarsier* (tarsier) in Selayar Island and Patunung Nature Reserve, South Sulawesi. *Biodiversitas* 9 (2): 152-155. DOI: 10.13057/biodiv/d090215.
- Yustian I, Merker S, Supriatna J, Andayani N. 2008. Relative population density of *Tarsius diana* in man-influenced habitats of Lore Lindu National Park, Central Sulawesi, Indonesia. *Asian Primates J* 1 (1): 10-16.