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RESEARCH ARTICLE

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Nesting Site Preference of *Tarsius fuscus* in Bantimurung Bulusaraung National Park, South Sulawesi

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ABSTRACT

Tarsius fuscus is one of the smallest primates in the world. Endemic to South Sulawesi, *T. fuscus* as a wildlife tend to choose nests in places with certain criteria. Nests are an essential factor in wildlife habitat. It is related to anti-predator, sleeping site, and reproductive functions. Therefore, research on *T. fuscus* nesting preferences is important to analyze because it will give information about the factors influencing them. This research was conducted at the Mallawa Resort, Bantimurung Bulusaraung National Park, South Sulawesi from July to August 2021. The method used was direct observation of *T. fuscus* nesting points. Biotic and abiotic data are recorded at each point by direct measurement or with GIS as a component of advanced analysis. *T. fuscus* nesting preference was determined by PCA calculation and Neu Index. In this research we found that *T. fuscus* have specific nesting preferences based on seven parameters such as land cover, nest substrate, the height of the nest from ground level, distance from settlements, slope, elevation, and distance from rivers. Information about *T. fuscus* nesting preferences are crucial for *T. fuscus* conservation efforts.

Introduction

Makassar tarsiers (*Tarsius fuscus* Fischer 1804) are the smallest primates in the world, and are endemic to South Sulawesi. This animal belongs to the Tarsiidae Family and is classified as vulnerable according to the IUCN Red List due to the downward trend in its population from time to time. The population of *T. fuscus* has decreased by 30% in the last 22.5 (three generations) [1]. This condition is caused by various factors, including reduced habitat suitability, habitat conversion and degradation, hunting and wildlife trade, and predation by wild dogs and cats [1].

Bantimurung Bulusaraung National Park (Babul National Park) is a protected area for *T. fuscus* and has made it as a conservation priority species. The population of tarsiers in Babul National Park is threatened by poaching and habitat loss [2], and the population of *T. fuscus* in Babul National Park, especially in the Balocci Resort, has been recorded as having a density of 151 individuals/km^2 in secondary forests, 36 individuals/km^2 in plantation areas, and 23 individuals/km^2 in vegetation close to community settlements [3]. Protecting the habitat of *T. fuscus* can help maintain its population to conserve this endemic species.

The nest is an important element in the habitat of *T. fuscus*. Selecting a nest site based on the animals' preference is an important factor for their survival in wildlife [4]. Wildlife animals use their nests as shelter to hide and avoid predators [5]. A previous study by Mustari et al. [6] on the preferential habitat characteristics of *T. fuscus* in Babul National Park indicated that tarsiers were closely related to altitude and slope. In addition, recent research related to the distribution and characteristics of *T. fuscus* nest nests has been conducted [2]. Nesting behavior in wildlife is generally influenced by disturbances, one of which is caused by humans [7].

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T. fuscus is considered to have specific nesting preferences. To protect *T. fuscus* populations, it is important to conduct research on *T. fuscus* nesting preferences to identify and preserve habitats that are suitable for T. *fuscus* needs. The objective of this study was to analyze *T. fuscus* nesting preferences and the factors that influence them, which are crucial data for *T. fuscus* conservation. This study will be used as a reference to conserve *T. fuscus* habitats and populations, especially in Babul National Park.

Materials and Methods

Study Area

This research was conducted from July to August 2021 in the forests around Bentenge Village, Samaenre Village, Resort Mallawa, and Bantimurung Bulusaraung National Park (Figure 1). Bantimurung Bulusaraung (Babul) National Park authorized as a national park on 18 October 2004 by Minister of Forestry Decree Number SK. 398/ Menhut-II/2004. Babul National Park located in South Sulawesi Island, and become on of the habitat for endemic and rare animals, esspecially for *T. Fuscus* [8]. As a part of the Maros-Pangkep karst forest, Babul has an vital role for bological diversity due to its potential area.

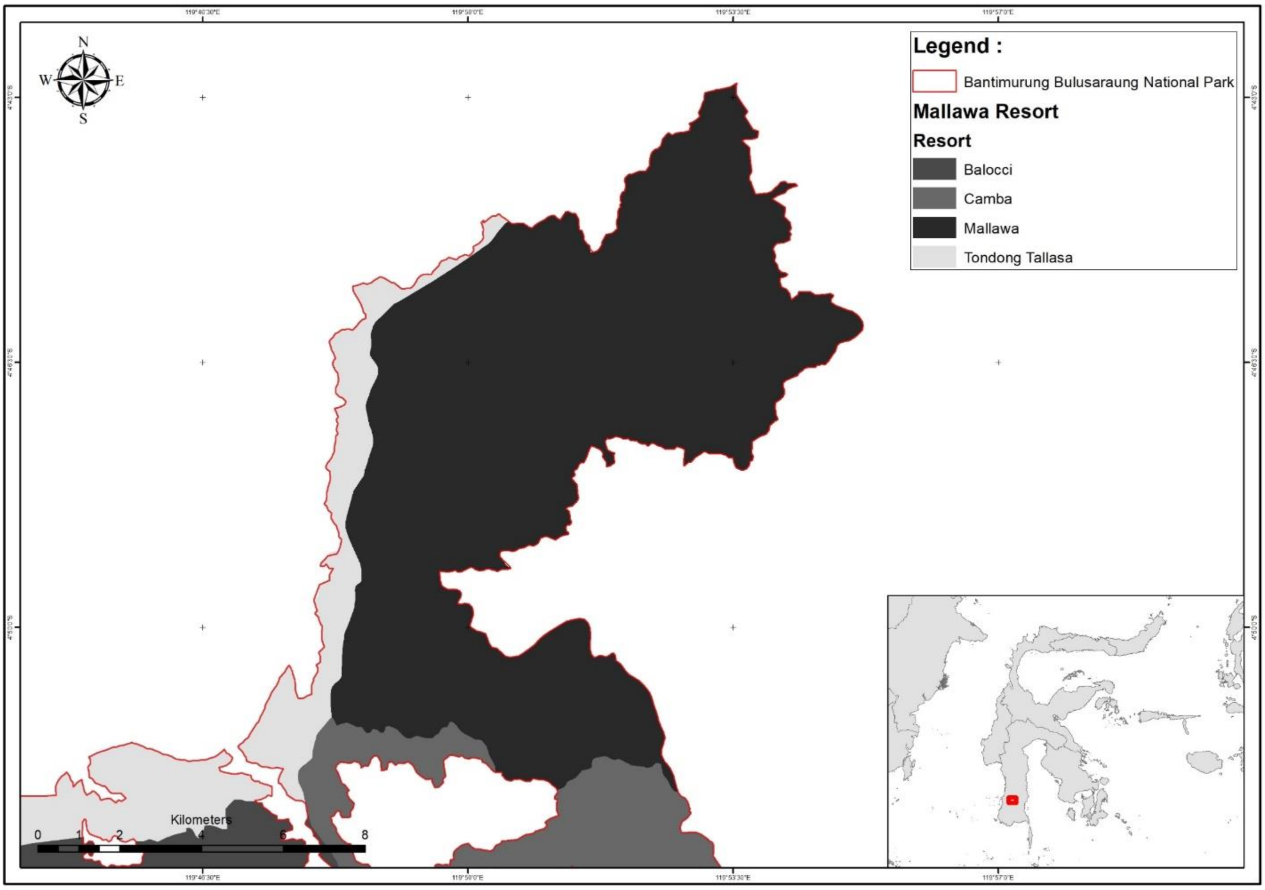

Figure 1. Research site map.

Research Method

Data collection was initiated by looking for active *T. fuscus* nests. The presence of *T. fuscus* groups can be indicated by their loud sounds at approximately 04.00 AM to 05.00 AM *waktu Indonesia tengah* (WITA). Tarsiers usually make vocalization sounds when they leave and return to their nests [9]. Tarsiers in every activity always vocalize to provide signs for their group [10]. Similar research conducted by Yustian et al. [11] also stated that tarsiers always vocalize in their activities starting around 05.00 PM to 07.00 AM. Another method is to smell the urine of *T. fuscus*, which is a sign that the location is the nest's location. Tarsiers usually mark their nests or home ranges with urine in the morning [12]. This behavior was used to determine the specific location of the tersier nest.

Another study by Wojciechowski et al. [13] stated that tarsiers tend to follow other tarsiers' urine when retrieved. Therefore, this can be used as a determining parameter to verify the observation area on the following day. Abiotic and biotic data were collected for the analysis of *T. fuscus* nesting preferences. To ensure the nesting site of *T. fuscus*, observations were made until *T. fuscus* was seen entering its nest which was usually a hole or aperture in trees and rocks. Detailed data collected on *T. fuscus* nesting sites are listed in Table 1.

Table 1. Types of data used to analyze tersier-nesting preferences using data collection methods and data processing sources.

No.	Data collected	Data sources / measurement tools	Data collecting method
1	Nest coordinates	GPS	Direct measurement
2	Nest height (m)	Roll meters	
3	Nest substrate	-	
4	Number of individual tarsiers	-	
5	Distance from forest edge (km)	LANDSAT OLI 8	Indirect measurement (GIS)
6	Distance from settlements (km)	LANDSAT OLI 8	
7	Distance from the river (km)	RBI Map	
8	Distance from the road (km)	RBI Map	
9	Elevation (meter above sea level/m asl)	DEMNAS - ASTER GDEM	
10	Land cover	2019 KLHK Delineation	
11	Slope (%)	DEMNAS - ASTER GDEM	
12	Air temperature (°C)	LANDSAT OLI 8	GIS and direct measurement

Data Analysis

The processing of *T. fuscus* nesting location preference data included three stages: parameter reduction, determination of classes and intervals, and calculation of the Neu Index.

Parameter Reduction

Parameter reduction was performed using principal component analysis (PCA) to select parameters that influenced the selection of *T. fuscus*. This method is a multivariate analysis [14] that simultaneously analyzes the results of various ecological measurements of each individual or object being observed [15]. The resulting new variables are independent of one another [14]. PCA was performed with the help of the softwar*e* PAST 4.06. The parameters processed by PCA are numerical parameters.

Categorical parameters (land cover and nest substrate) were directly processed using preference analysis. The number of PCA was determined by reviewing the PCA output as an eigenvalue in the scree plot. Principal component (PC) selection can also be performed by selecting the PCA with the highest eigenvalue [16]. The PC selected was the PC before the inflection point [15]. For each PC, there were parameters with their respective correlation coefficient values. The parameters selected for the preference analysis had a correlation coefficient value ≥ 0.5 [14].

Determination of Class and Interval

The parameters considered in the preference analysis correlated with the selection of *T. fuscus* nesting sites based on the PCA results. Each parameter is divided into classes with the number of types adjusted to the needs, because there are parameters in the form of categorical data (land cover and nesting sites) and numerical data (height of nest from ground level, slope, air temperature, elevation, distance from the road, distance from the river, distance from settlements, and distance from the edge of the forest). The interval length in each class was determined by considering the convenience or suitability of the calculation [17]. This reduces the risk of missing information or data by classifying and determining intervals [18]. Rules regarding the same class intervals are challenging to apply to the distribution of data that are not normal (uneven). The data are spread over a wide range, but are highly concentrated in a small part of its range, with relatively small amounts in other parts. The determination of the number of classes and their intervals is carried out after obtaining data from the research location because it depends on the number of nests found and the values of each parameter.

Neu Index Calculation

Data regarding tarsiers nesting preferences were processed to produce the Neu Index. The Neu method can be utilized to detect and calculate habitat preferences based on specific parameters [19,20]. Parameters that are calculated in the Neu Index are those that have been determined by class and interval. In the calculations, the data that will be collected include the area of the site on certain parameters (Ai), proportion of the area where active tarsier nests are found (pi), frequency of meetings of tarsiers and their nests in a location (ni), proportion of tarsier encounters and their nests (Ui), preference index (wi), and standardized preference index (bi). For class data in parameters where the area could not be found, p is the proportion of the number of nests observed. The nesting preference index was analyzed using the equation:

$$wi = \frac{Ui}{pi} \tag{1}$$

The nest is preferred if the value is (wi > 1). If the value is (wi < 1), then the nest is not preferred [21].

Results and Discussion

Result

The observation revealed 13 nesting sites of *T. fuscus* around Mallawa Resort. A distribution map of the nesting sites is shown in Figure 2. Several nest locations were identified based on the findings at the research site. Each nesting site was used by different groups of *T. fuscus*. Ten nesting sites were found in the secondary dryland forest (SDF), and the rest were found in the scrubland. Several parameters were used to determine the habitat preference of *T. fuscus*.

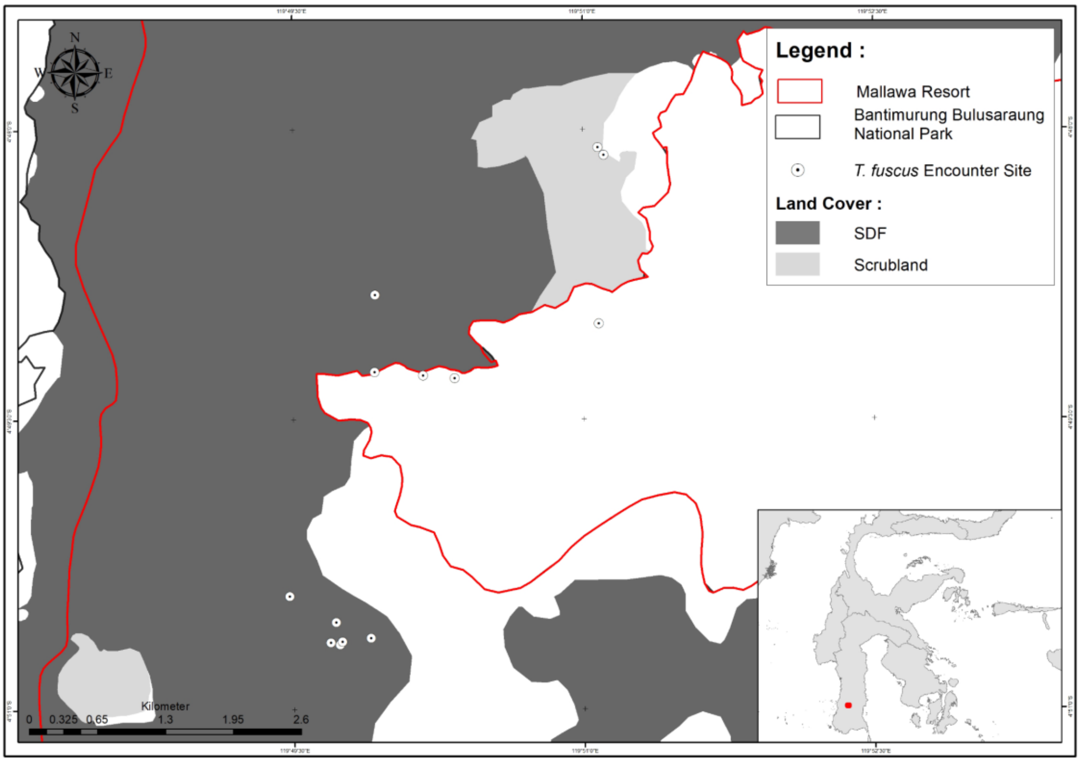

Figure 2. Distribution map of *T. fuscus* nesting site.

As a result of data processing with PCA, three PCs were obtained: PC 1, PC 2, and PC 3. A Screen plot visualization based on eigenvalues is presented in Figure 3. The distance parameter from settlements obtained a correlation coefficient of ≥ 0.5 on PC 1. The height parameter nests and elevation obtained a correlation coefficient of ≥ 0.5 on PC 2. The slope and distance from the river obtained a correlation coefficient of ≥ 0.5 on PC 3. Five parameters based on PCA numeric calculation have correlation coefficients more than ≥ 0.5. The five parameters based on PCA numerical analysis were distance from settlements, nest height, elevation, slope, and distance from the river. In addition, two non-numerical parameters can be used to analyze the tarsier-nesting preferences. As a result, seven parameters were used to analyze *T. fuscus* nesting preferences. The eigenvalues of each component are shown in Figure 3. After parameter reduction using PCA, several parameters were found to influence *nest selection by T. fuscus*.

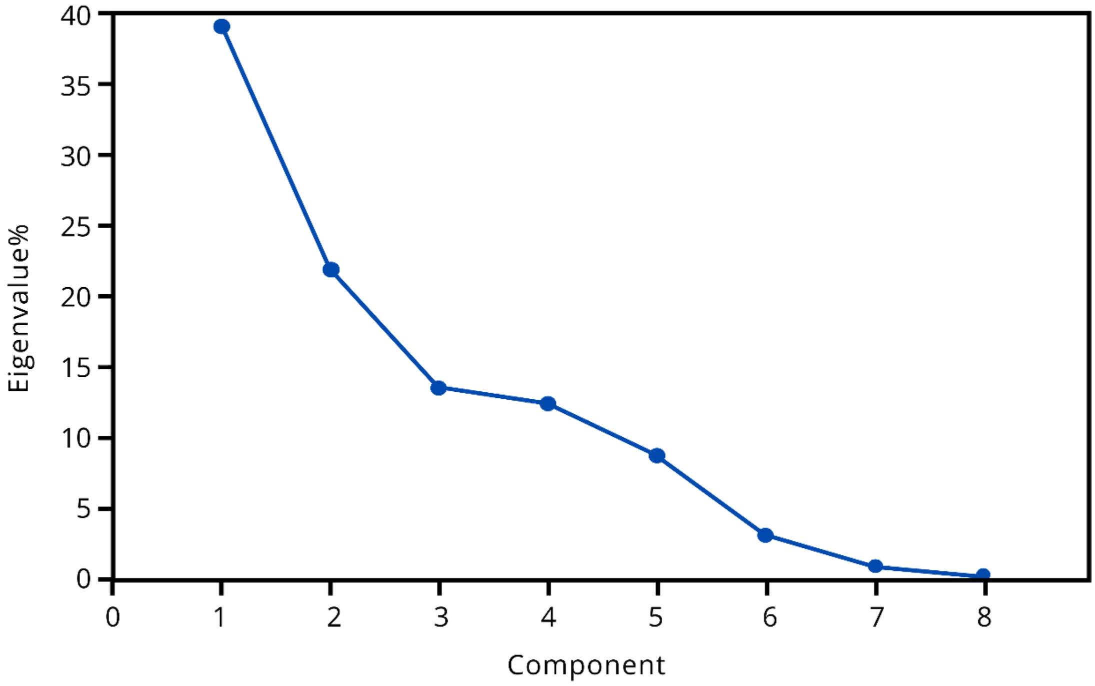

Figure 3. Eigenvalue visualization in PCA screen plot.

T. fuscus was found at the study site in two land covers: SDF and scrubland. The calculation results showed that scrubland is the preferred land cover for nesting by *T. fuscus*, with a selection index of 1.117. Table 2 shows the results of the calculation of the *T. fuscus* habitat selection index based on land cover.

Table 2. *T. fuscus* nest preference index based on land cover (LC).

LC	Ai	Pi	Ni	Ui	Wi	Bi
SDF	318.86	0.728	39	0.813	1.117	0.618
Scrubland	119.25	0.272	9	0.188	0.689	0.381
Total	438.11	1	48	1	1.806	1

Based on research, *T. fuscus* nests were found on several types of substrates, including holes and crevices in trees, shrubs, and rocks. Seven types of substrates are used by *T. fuscus* for nesting. Table 3 presents the results of calculating the selection index for *T. fuscus* nests based on the substrate category. Settlement has a significant influence on the existence of tarsiers, especially when choosing their nests. Field observations revealed that tarsiers selected nests at a distance of 0.924–1.124 km from the settlements. The nest selection preference index is presented in Table 4.

Table 3. *T. fuscus* nest preference index based on nest substrate (NS).

SS	Ai	Pi	Ni	Ui	Wi	Bi
Pala-pala tree	1	0.077	3	0.063	0.813	0.109
Rock hole	1	0.077	5	0.104	1.354	0.182
Mana-mana tree	4	0.308	16	0.333	1.083	0.145
Kajuara karisak batang tree	2	0.154	8	0.167	1.083	0.145
Scrub	2	0.154	6	0.125	0.813	0.109
Kajuara langa langa tree	1	0.077	3	0.063	0.813	0.109
Kajuara lompo tree	2	0.154	7	0.146	0.948	0.127
Total	13	1	48	1	6.906	0.927

Table 4. *T. fuscus* nesting site preference based on distance from settlements (DS).

DS	Ai	Pi	Ni	ui	Wi	Bi
0.524–0.724	2	0.154	6	0.125	0.813	0.161
0.724–0.924	5	0.385	17	0.354	0.921	0.182
0.924–1.124	4	0.308	17	0.354	1.151	0.228
1.124–1.324	1	0.077	4	0.083	1.083	0.214
1.324–1.524	1	0.077	4	0.083	1.083	0.214
Total	13	1	48	1	5.051	1

T. fuscus in the study site was found nesting at several heights from the ground. Nest height from ground level is divided into four classes as shown in Table 5. *T. fuscus* nests at the study site can be found at various elevations. Tarsiers select nesting sites in the altitude range of 510–910 meters above sea level, which related to the selection of nesting categories. Stone pits under the roots of the kajuara ballusu tree (*Ficus sundaica*) and other trees are favorite places for tarsiers at an altitude of 0.0–4.0 m. Table 6 shows five elevation classes of *T. fuscus* nesting sites in this study.

Table 5. *T. fuscus* nesting sites preference based on nest height (NH).

NH	Ai	Pi	Ni	Ui	Wi	Bi
0.0–4.0	11	0.846	42	0.875	1.034	0.389
4.0–8.0	1	0.077	3	0.063	0.813	0.306
8.0–12.0	0	0.000	0	0.000	0,000	0.000
12.0–16.0	1	0.077	3	0.063	0.813	0.306
Total	13	1	48	1	2.659	1

Table 6. *T. fuscus* nesting sites preference based on elevation.

Elevation	Ai	Pi	Ni	Ui	Wi	Bi
510–610	104.390	0.238	14	0.292	1.224	0.320
610–710	89.462	0.204	4	0.083	0.408	0.107
710–810	116.837	0.267	6	0.125	0.469	0.123
810–910	127.399	0.291	24	0.500	1.719	0.450
Total	438.087	1	48	1	3.820	1

T. fuscus nests at the study site can be found on several slopes. According to Taufik et al. [22], there are five classes of slopes, flat, sloping, slightly steep, steep, and very steep. The slopes where *T. fuscus* nested in this study were only found on four slope classes, namely flat to steep. The slope class of *T. fuscus* nesting sites can be seen in Table 7. Tarsiers at the study site were found at a distance of 0.006–0.241 km from the river. Mansyur et al. [12] revealed that the distance between *T. fuscus* nests varied between 50–412 m. The distance from the river in the nest preference analysis based on this study was grouped into 5 classes as shown in Table 8.

Table 7. *T. fuscus* nesting sites preference based on the slope.

Slope	Ai	Pi	Ni	Ui	Wi	Bi
< 8% (flat)	56.64	0.130	17	0.354	2.724	0.459
–15% (sloping)	73.73	0.169	10	0.208	1.231	0.207
15–25% (rather steep)	109.43	0.251	11	0.229	0.912	0.154
25–45% (steep)	154.7	0.355	7	0.146	0.411	0.069
> 45% (very steep)	41.12	0.094	3	0.063	0.662	0.111
Total	435.62	1	48	1	5.940	1

Table 8. *T. fuscus* nesting sites preference based on distance from the river (DR).

DR	Ai	Pi	Ni	Ui	Wi	Bi
0.006–0.056	5	0.385	17	0.354	0.921	0.182
0.056–0.106	4	0.308	17	0.354	1.151	0.228
0.106–0.156	2	0.154	7	0.146	0.948	0.188
0.156–0.206	1	0.077	3	0.063	0.813	0.161
0.206–0.256	1	0.077	4	0.083	1.083	0.214
Total	13	1	48	1	4.916	0.973

Discussion

Seven parameters are further calculated in the preference analysis due to their strongest correlation with the other parameters. Two of these are land cover and nesting sites, which are non-numerical parameters. Based on the order of the correlation coefficient values, the other five parameters, including the distance from settlements, nest height, elevation, slope, and distance from rivers, are the largest PCA results.

The diversity of vegetation levels influences the number of tarsier encounters because it will also affect the diversity of insects that are a source of tarsier food [23]. The analysis using the Neu Index showed some 1.117, meaning that tarsiers tend to roost in secondary dryland forest land cover rather than scrubland. In addition, according to Novotny and Miller [24], the abundance of insect species can represent the abundance of vegetation types in a location. The highest population of tarsiers was mostly found in the secondary forest [25]. Rosyid et al. [26] research on *Tarsius lariang* in Lore Lindu National Park stated almost the same thing, namely that tarsiers tend to choose habitat in SDF compared to primary dryland forest (PDF), presumably due to the greater number of insects as tarsiers feed in SDF.

The nest selection index showed that rock holes tend to be preferred by *T. fuscus* for nesting. Mansyur et al. [12] suspects that *T. fuscus* tends to nest in rock holes or karst crevices because of its location far (high) from the ground surface and difficult to access by humans. Hence, they feel safer owing to disturbances caused by human activity. The condition of the rock holes found at the study site is under the kajuara ballusu tree (*Ficus sundaica*) with a fairly steep location on a cliff or ravine below which there is a river with a fairly swift flow. Several small plants and forest pandanus cover the nest (*Pandanus* sp.).

The research results of Mansyur et al. [12] stated that apart from being found in many *Ficus* spp. trees and tarsiers on Buton Island were also found nesting in rock crevices. Based on the Neu Index, a value of ≥ 1 was also obtained for mana-mana tree (*Blumeodendron kurzii*) and the kajuara karisak batang tree (*Ficus sumatrana*). Tarsiers use places that are not so large with a diameter range of 1–10 cm to facilitate their activities in finding [27]. Tarsiers usually used tree trunks smaller than 5 cm in diameter for their activity [28]. The existence of these statements fits perfectly with the characteristics of any tree, which has many small, dense branches growing from the lower sides of the main trunk. Tarsiers prefer these three places because these tree species are fruitful trees that are food for tarsier insects [3].

The nest selection index based on the table above shows that *T. fuscus* prefers nests at a distance of 0.924–1.124 km from settlements. Mustari et al. [6] stated that *T. fuscus* in the Pattunuang Resort, Babul National Park was found in habitats 351 to 513 m from settlements. The presence of tarsiers at this distance risks disturbance caused by activities, such as clearing roads, agricultural land, and plantations, and harvesting forest resources, such as bamboo which is one of the places used as tarsier nests [6].

Based on this, the tarsiers at Resort Mallawa tend to choose locations farther from settlements so that it can be assumed they tend to be safer from human activities that have the potential to become a nuisance. The presence of settlements near forests, agricultural land, and other human-related activities is likely to threaten this species in the future, possibly exacerbating habitat loss [29]. Another thing is the reason for selecting nests at that distance. Research by Andriyani et al. [2] found that more *T. fuscus* nests were found at a distance of 1,000 to 2,000 m from settlements. This study stated that tarsiers' nests were increasingly rare at a distance that was increasingly far from settlements. Until now, research on tarsiers' response to the presence of human activity still needs to be done. However, research on tarsiers response to disturbance was conducted by Andriyani et al. [2] on *Tarsius fuscus* in Bantimurung Bulusaraung National Park. The results show that tarsiers can live very close to humans despite differences in population density and home range compared to tarsiers which are far from disturbance. Tarsiers that are closer to disturbances tend to have higher population densities and narrower home ranges.

The nest selection index is based on Table 8, which shows that *T. fuscus* tends to prefer to nest at an altitude of 0.0–4.0 m from the ground. Any tree is a sympodial tree, that is, it has branches at a height below 1.3 m, which means it is still in the range of 0.0–4.0 m. These branches are small and dense so that *T. fuscus* can easily grasp them to support their mobility while protecting the *T. fuscus* nest from the risk of predators and wind attacks. Thickets of rattan (*Calamus* sp.) are often found around the tarsiers nests at the study site at an altitude of 0.0–4.0 m. Rattan has a thorny stem that can prevent tarsier nests from being attacked by predators, such as weasels and snakes. This is also thought to be one of the reasons for selecting nests at that altitude. Tarsiers requires a small tree or branch diameter for its locomotion, so based on research [30] tarsiers predominantly using nest trees from family poaceae. Andriyani et al. [2] further stated that tarsiers usually nest in tree holes with a height of 2 to 7 m above ground level.

Based on observations, 14 calculation results showed that *T. fuscus* tended to prefer nesting sites at an altitude of 810–10 m asl. Research conducted by Mustari et al. [6] showed differences in nest preferences based on the height where *T. fuscus* prefers to occupy nests at 75–360 m asl. The research by Andriyani et al. [2] showed that *Tarsius fuscus* can live at 68–947 m asl. This is different for *T. pumilus*, which prefer to nest at an altitude of 2,000–3,000 m asl [31]. Differences in the range of elevations in research can affect the results of calculations so further research with a wider range of elevations is needed.

The nest selection index showed that *T. fuscus* tended to choose nest sites in the sloping slope class with a flat slope (< 8%). One factor influencing habitat selection in sloping areas is the lack of predators due to massive human activity [32]. Research conducted by Mustari et al. [6] showed that *T. fuscus* was found at a slope of 0–25%.

The nest selection index based on the table above shows that *T. fuscus* prefers nests at 0.056–0.106 km from settlements. The reason for choosing tarsier nests at these distance intervals can also be said to be related to the choice of tarsiers nesting sites. In the previous sub-chapter, regarding the preferences of tarsiers nesting sites, it has been found that tarsiers prefer nesting sites in rock holes or crevices. The tarsiers's nest in that place was about 0.103 km from the river, which means it was still within the distance they preferred.

Conclusions

T. fuscus has specific nesting preferences based on seven parameters: land cover, nest substrate, the height of the nest from ground level, distance from settlements, slope, elevation, and distance from rivers. The nesting substrate that tends to be chosen by *T. fuscus* is in the secondary dryland forest, with the form of holes in rocks under tree roots or cliffs at a height of 0.0–4.0 m from the ground. *T. fuscus* tends to choose a flat location for nesting with a slope ≤ 8% with elevations around 810–910 m asl. The site that *T. fuscus* chooses for nesting usually has a distance between 0.924–1.124 km from settlements and 0.056–0.106 km from the river.

Author Contributions

LEM, SAM, AHM: Conception and Design of The Study; **RR, SAM**: Acquisition of Data; **RR, SAM, LEM**: Analysis and Interpretation of Data; **SAM, LEM**: Drafting; **TAL**: Draft Formatting; **AHM**: Critical Review; **MKG, RGM, SNMA, MRA**: Others.

Conflicts of interest

There are no conflicts to declare.

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