

# Habitat Characteristics of Maleo (*Macrocephalon maleo*) Nesting Sites in Bukit Jaya Village, Banggai Regency, Indonesia

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## Abstract

The Maleo (*Macrocephalon maleo*) is an endemic bird species found in Central Sulawesi, Indonesia. This species belongs to the order Galliformes and is distinguished by a prominent black, hard casque on its head, an orange beak, predominantly black plumage, and yellowish facial skin. The Maleo exhibits a unique reproductive strategy, as it does not incubate its eggs directly. Instead, it buries them in loose sandy soil that is naturally heated by geothermal activity. According to the 2021 assessment by the International Union for Conservation of Nature (IUCN), the Maleo is classified as Critically Endangered under criteria A2cd+4cd (Version 3.1) of the IUCN Red List. This study aimed to describe the characteristics of Maleo nesting habitats in Bukit Jaya Village, Banggai Regency, in order to support the conservation of suitable in situ breeding and nesting environments. The study employed a descriptive qualitative approach, focusing on direct field observations and literature review. Sampling stations were determined using an exploratory survey method, in which sites were purposively selected based on habitat characteristics to observe Maleo nesting conditions and the surrounding vegetation. Data collected included nesting-hole depth and width, temperatures inside and outside the nesting holes, sand surface temperature, and humidity. Measurements were conducted three times daily at 08:00, 13:00, and 17:00. The results showed that: (1) nesting-hole depth ranged from 43 to 46 cm, with an average of 44.4 cm; (2) nesting-hole width ranged from 47 to 53 cm, with an average of 50 cm; (3) between 08:00 and 17:00, the average temperature inside the nesting holes was 31°C, the average temperature outside the holes was 35.74°C, the average sand surface temperature was 36.2°C, and the average relative humidity was 72.62%; and (4) the nesting habitat in Bukit Jaya Village was characterized by diverse vegetation growth forms, including trees, shrubs, herbs, and climbing plants (lianas). A total of 16 plant species belonging to 12 families were identified within the nesting habitat. The protection of nesting habitats should be continuously strengthened to help prevent the extinction of this valuable and iconic bird species.

**Keywords:** Maleo (*Macrocephalon maleo*); nesting habitat; habitat characteristics; conservation; Banggai Regency.

## INTRODUCTION

Maleo (*Macrocephalon maleo*) is an endemic bird species found exclusively on Sulawesi Island, Indonesia. This species belongs to the order Galliformes (fowl). Due to its habit of digging holes or burrows in the ground to deposit its eggs, the Maleo is classified as a mound-nesting or burrow-nesting species (Abrar et al., 2019). One of its most distinctive characteristics is the prominent black, hard casque on top of its head, which is believed to function in detecting and measuring the temperature of nesting sites where eggs are laid (Santrio et al., 2022). The Maleo has predominantly black plumage, yellowish facial skin, and a medium-sized body with an average length of approximately 55 cm (Wantogia et al., 2024). Its gray legs and orange beak are used for digging nesting holes and searching for food. The species primarily feeds on seeds, including candlenuts and coconut fragments (Gonibala et al., 2021).

The Maleo inhabits a variety of environments, including forests, sandy hills covered with shrubs or specific vegetation, and forested areas near coasts and rivers. As one of Sulawesi's endemic species, the Maleo is currently threatened with extinction and requires specific habitat conditions for survival (Putra et al., 2023). The species exhibits a unique reproductive strategy in which eggs are not incubated by the parents. Instead, they are buried in loose sandy soil naturally heated by geothermal activity. Vegetation with strong root systems plays an important role in stabilizing surface sand, thereby providing suitable conditions for nest excavation. Maleo habitats range from open landscapes to montane forests and are characterized by diverse tree species that provide shelter and resting sites for the birds (Wantogia et al., 2024).

The Maleo population has continued to decline due to egg poaching and habitat degradation, resulting in its classification as a threatened species. In Indonesia, the species is legally protected under Government

Regulation No. 7 of 1999 concerning the Preservation of Plant and Animal Species. Internationally, the Maleo is listed in Appendix I of the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES), which prohibits international commercial trade of the species. Furthermore, according to the 2021 assessment of the *International Union for Conservation of Nature* (IUCN), the Maleo is categorized as Critically Endangered under criteria A2cd+4cd (Version 3.1) (Aldiansyah & Wahid, 2024).

Bukit Jaya Village in Banggai Regency is one of the remaining areas where Maleos continue to nest naturally in geothermal sandy sites and warm open-ground habitats that are essential for their reproductive success. However, one of the major threats faced by the species in this area is the lack of adequate protection and monitoring of nesting grounds. Therefore, research on the characteristics of Maleo nesting habitats in Bukit Jaya Village is essential to support conservation efforts and ensure that these in situ habitats remain suitable for nesting and breeding activities. This study aims to describe the characteristics of Maleo nesting habitats in

Bukit Jaya Village, Banggai Regency, thereby providing baseline information for the conservation and management of this critically endangered endemic species.

## MATERIALS AND METHODS

### Study Area

The study was conducted in March 2026 in Bukit Jaya Village, Toli Jaya District, Banggai Regency, Central Sulawesi, Indonesia (Figure 1). The study area is characterized by environmental conditions predominantly consisting of gently sloping hilly landscapes and plantation areas. It has a tropical climate with warm temperatures and high humidity. The vegetation is relatively diverse, ranging from moderately dense to open cover in several locations. These environmental conditions provide suitable nesting habitats for the endemic Maleo bird. The sample used in this study consisted of the habitat characteristics of Maleo nesting sites.

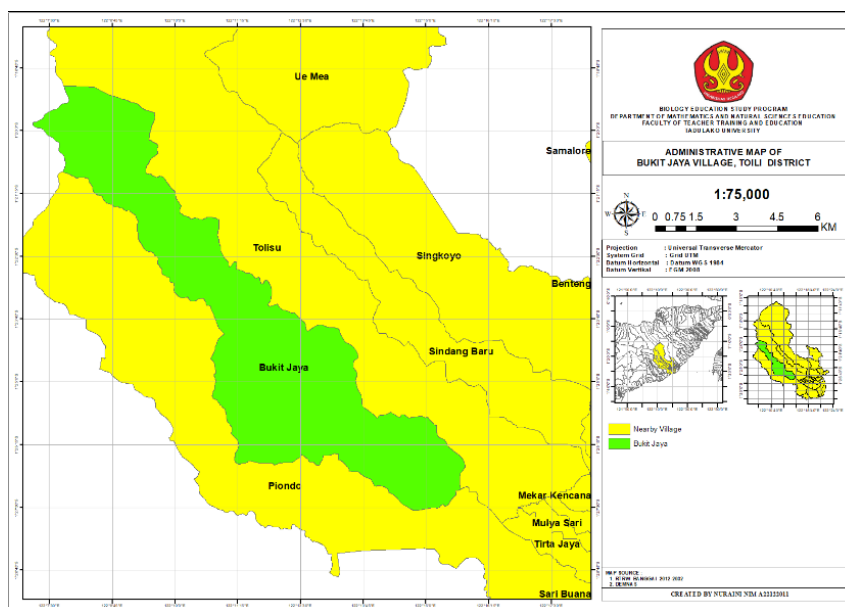


Figure 1. Map of the research location in Bukit Jaya Village, Toli Jaya District, Banggai Regency, Central Sulawesi, Indonesia.

## Procedures

### Abiotic Data

The initial stage of the study involved a comprehensive literature review. The collection of abiotic components constituting the physical environment began with the determination of sampling stations based on secondary information obtained from local communities. The selection of sampling stations within the study area was conducted through direct field observations, supported by interviews with relevant stakeholders and literature studies, which served to complement and validate the information gathered. The research was carried out

during the Maleo nesting season to ensure that habitat conditions accurately reflected the environmental characteristics associated with active nesting sites.

Sampling stations were established using an exploratory survey method, in which samples were purposively selected based on specific habitat characteristics. The selected sites were active Maleo nesting locations identified by the presence of footprints or excavated nesting holes, warmer soil or sand temperatures indicating potential geothermal activity, and surrounding vegetation commonly associated with Maleo habitats. In addition, the sites exhibited minimal

direct disturbance from human activities. These criteria were used to ensure that the sampled locations represented suitable and actively utilized nesting habitats for the endemic Maleo bird.

### *Biotic Data*

Biotic data collection in this study began with the identification of the central observation point, namely an active nesting hole that had been previously identified within the study area. Subsequently, the researchers surveyed the surrounding area within a radius of approximately 10 m from the nesting site, which served as the sampling boundary for vegetation assessment. All vegetation encountered within this area was recorded directly in the field and subsequently classified according to its scientific name. During the observation process, the researchers documented all plant species present around the nesting sites, including various growth forms such as trees, shrubs, herbs, and climbing plants (lianas). Each plant species encountered was carefully identified using relevant taxonomic references to determine its scientific name accurately. This approach was employed to provide reliable information on the composition and diversity of vegetation associated with Maleo nesting habitats and to support a comprehensive characterization of the biotic components within the study area.

### **Data Analysis**

Data obtained from the identification of the nesting habitat characteristics of the Maleo bird (*Macrocephalon maleo*) in Bukit Jaya Village, Banggai Regency, were analyzed using a descriptive qualitative approach. This method involved the systematic description and interpretation of general patterns observed during direct field observations, reflecting the actual environmental conditions of the study area. The analysis aimed to provide a comprehensive overview of the physical and biological characteristics associated with Maleo nesting habitats.

The collected data were presented in the form of percentages, tables, and narrative descriptions. Observed abiotic parameters included nest-hole depth and width, temperature inside and outside the nest hole, sand surface temperature, and relative humidity. Measurements were conducted directly at the nesting sites three times per day: in the morning (08:00 WITA), afternoon (13:00 WITA), and evening (17:00 WITA). These repeated measurements were performed to capture daily variations in environmental conditions that may influence nesting-site suitability.

Vegetation data collected from the areas surrounding the Maleo nesting sites were analyzed descriptively by summarizing the species composition and growth forms recorded during the survey. Each observed parameter was described in detail and supplemented with tables to facilitate interpretation of the habitat characteristics. This descriptive analysis was used to characterize the

vegetation structure and plant diversity associated with Maleo nesting habitats and to provide ecological insights into the environmental conditions supporting nesting activities.

## **RESULTS AND DISCUSSION**

### **Nesting Hole Dimensions**

A total of five active Maleo nesting sites were identified within the study area, distributed along the Bukit Jaya river corridor. Measurements were conducted at all nesting sites to assess the physical (abiotic) characteristics of the nesting microhabitats, as presented in Table 1. The results revealed variations among nests for each measured parameter. The depth of the nesting holes ranged from 43 to 46 cm, with an average depth of 44.4 cm, while the width ranged from 47 to 53 cm, with an average width of 50 cm (Table 1). The depth of Maleo nesting holes is largely influenced by the intensity of available heat sources, including geothermal heat and solar radiation. When the influence of these heat sources is strong, nesting holes generally range from 30 to 50 cm in depth. In contrast, under conditions of weaker geothermal influence, Maleos tend to excavate deeper nesting holes, reaching depths of approximately 80–100 cm (Muhi et al., 2021). The nesting sites observed in this study were located approximately 50 m from the river, where monitor lizards were frequently encountered. Nest dimensions were measured using a measuring tape to determine both depth and width. The nesting holes at the study site were generally circular in shape and gradually narrowed toward the bottom.

### **Internal and External Nest Temperatures**

Measurements of nest temperature, ambient temperature outside the nest, and sand surface temperature were conducted three times daily at 08:00, 13:00, and 17:00 WITA. The results indicated that internal nest temperatures ranged from 27–31°C in the morning, with an average of 29.6°C; 31–33°C at midday, with an average of 32.6°C; and 28–32°C in the afternoon, with an average of 31.0°C. External temperatures around the nests ranged from 33.2–35.1°C in the morning, averaging 34.36°C; 38.0–42.5°C at midday, averaging 40.48°C; and 31.8–33.1°C in the afternoon, averaging 32.38°C (Table 1). The observations showed no substantial fluctuations in the average temperature within the nesting holes throughout the day. These temperature values remain within the thermal range considered suitable for Maleo egg incubation (Muhi et al., 2021). The relatively stable temperatures recorded inside the nests are likely attributable to the thermal properties of sand, which can effectively absorb and retain heat. Such thermal stability is an important factor influencing the success of natural egg incubation, as it provides a consistent environment for embryonic development (Kesaulya et al., 2023).

### Sand Surface Temperature

The results demonstrated that sand surface temperature was strongly influenced by solar radiation. In the morning (08:00 WITA), surface temperatures ranged from 29–32°C, with an average of 30.6°C. As solar intensity increased throughout the day, sand surface temperatures also increased, reaching their highest values at midday (13:00 WITA), when temperatures ranged from 43–50°C and averaged 45.6°C. By the afternoon (17:00 WITA), temperatures had declined but remained relatively high, ranging from 32–33°C with an average of 32.4°C (Table 1). The elevated sand surface temperatures observed at the study site can be attributed to the absence of substantial vegetation cover, which allowed direct exposure of the substrate to solar radiation (Afandi et al., 2022). Open nesting grounds enable greater heat absorption by the sand, thereby creating favorable thermal conditions for egg incubation. Such conditions are particularly important for Maleo birds, which rely on environmental heat sources rather than parental incubation to facilitate embryo development and successful hatching.

### Relative Humidity

Relative humidity measurements were recorded three times daily at the nesting sites. In the morning (08:00 WITA), humidity ranged from 75.2–77.6%, with an average of 76.5%. At midday (13:00 WITA), values

ranged from 67.0–70.9%, averaging 69.12%, while in the afternoon (17:00 WITA), humidity ranged from 70.8–73.4%, with an average of 72.25% (Table 1). These humidity levels are generally within or close to the optimal range reported for Maleo egg incubation. Previous studies have indicated that incubation humidity levels between 60% and 74% can support hatching success rates of up to 100% (Rimu et al., 2022). The success of egg incubation is strongly influenced by the stability of the nest microclimate, including humidity conditions that remain relatively constant and avoid extreme fluctuations (Summers et al., 2023). Stable humidity levels help maintain appropriate moisture conditions for embryonic development and reduce the risk of desiccation or excessive water absorption by the eggs. The humidity values recorded in the present study differed considerably from those reported for nesting habitats in the Rawa Aopa Watumohai National Park (TNRAW), Indonesia, where humidity levels ranged from 94.44% to 95.37%, with an average of 94.75% (Nafiu et al., 2015). Such differences in humidity conditions may be associated with variations in elevation above sea level and vegetation density surrounding the nesting areas. Sites located at different elevations and with varying degrees of vegetation cover can exhibit distinct microclimatic conditions, including differences in air moisture and temperature regulation (Rosalia et al., 2025).

**Table 1.** Characteristics of maleo nesting sites.

Location Characteristics	Location	
	Range (cm)	Average (cm)
Hole size		
Hole depth	43–46	44.4
Hole width	47–53	50
Temperature (°C)		
08.00 WITA	27–31	29.6
13.00 WITA	31–33	32.6
17.00 WITA	28–32	31
Temperature (°C)		
08.00 WITA	33.2–35.1	34.36
13.00 WITA	38–42.5	40.48
17.00 WITA	31.8–33.1	32.38
Temperature (°C)		
08.00 WITA	29–32	30.6
13.00 WITA	43–50	45.6
17.00 WITA	32–33	32.4
Humidity (%)		
08.00 WITA	75.2–77.6	76.5
13.00 WITA	67–70.9	69.12
17.00 WITA	70.8–73.4	72.25

### Vegetation Composition

The vegetation identified within the Maleo nesting habitat is presented in Table 2. Based on field observations conducted around the nesting habitat of the Maleo (*Macrocephalon maleo*) in Bukit Jaya Village, Banggai Regency, a total of 16 plant species belonging to

12 families were recorded. These species included *Glochidion zeylanicum*, *Nephrolepis brownii*, *Praxelis clematidea*, *Stachytarpheta jamaicensis* L., *Macaranga grandifolia*, *Casuarina equisetifolia*, *Imperata cylindrica*, *Neolamarckia cadamba*, *Passiflora foetida* L., *Hibiscus tiliaceus* L., *Blumea balsamifera*, *Lantana*

*camara*, *Psidium guajava* L., *Waltheria indica* L., *Calamus* sp., and *Arenga pinnata*. The nesting grounds were predominantly covered by *Imperata cylindrica* and *Nephrolepis brownii*, except for the immediate nesting areas where vegetation was absent. The open conditions surrounding the nesting holes are likely advantageous for nesting activities, as they facilitate excavation and maximize exposure of the substrate to solar radiation, an important heat source for egg incubation.

The presence of relatively tall vegetation surrounding the nesting sites provides several ecological benefits for Maleo birds. In addition to serving as a source of food, particularly seeds, these plants were observed to be directly utilized by Maleos, which were seen feeding on grass seeds within the study area. Vegetation around the

nesting grounds also functions as protective cover, reducing the vulnerability of nesting birds to predators during the egg-laying process. Furthermore, Maleos tend to select nesting locations where the distance between trees remains within their flight capability. This preference is associated with their relatively limited flying ability, requiring vegetation structures that facilitate safe movement and provide shelter while traveling between feeding and nesting areas. The diversity and arrangement of vegetation surrounding nesting sites therefore play an important role in supporting the ecological requirements of maleo populations, contributing not only to food availability but also to habitat security and overall nesting success (Karim et al., 2022).

**Table 2.** Vegetation of maleo habitat plants.

No.	Family	Local Name	Species
1	Phyllanthaceae	Rawasan	<i>Glochidion zeylanicum</i>
2	Nephrolepidaceae	Paku Pedang	<i>Nephrolepis brownii</i>
3	Asteraceae	Praxelis	<i>Praxelis clematidea</i>
4	Verbenaceae	Pecut Kuda	<i>Stachytarpheta jamaicensis</i> L.
5	Euphorbiaceae	Pohon Daun Payung	<i>Macaranga grandifolia</i>
6	Casuarinaceae	Pohon Cemara Laut	<i>Casuarina equisetifolia</i>
7	Poaceae	Alang-Alang	<i>Imperata cylindrica</i>
8	Rubiaceae	Pohon Jabon Putih	<i>Neolamarckia cadamba</i>
9	Passifloraceae	Rambusa	<i>Passiflora foetida</i> L.
10	Malvaceae	Waru	<i>Hibiscus tiliaceus</i> L.
11	Asteraceae	Sembung	<i>Blumea balsamifera</i>
12	Verbenaceae	Tembelekan	<i>Lantana camara</i>
13	Myrtaceae	Pohon Jambu Biji	<i>Psidium guajava</i> L.
14	Malvaceae	Uhaloa	<i>Waltheria indica</i> L.
15	Arecaceae	Rotan	<i>Calamus</i> sp.
16	Arecaceae	Pohon Aren	<i>Arenga pinnata</i>

## Discussion

Sulawesi is well known for its rich endemic fauna, exemplified by the presence of the maleo, a bird species found exclusively on the island. The Maleo is classified as a burrow-nesting bird, constructing nesting holes in the ground for egg incubation (Manalu et al., 2023). Unlike most bird species, Maleos do not incubate their eggs directly. Instead, they rely on environmental heat sources, particularly geothermal energy and solar radiation, to facilitate embryonic development within buried eggs (Muhi et al., 2021). This unique reproductive strategy requires highly specific habitat conditions, making the species particularly vulnerable to environmental disturbances. Habitat degradation, coupled with intensive nest exploitation through continuous egg collection, has contributed significantly to the decline of Maleo populations and has increased their risk of extinction (IUCN Standards and Petitions Committee, 2021). Consequently, the conservation of Maleo populations plays an essential role in maintaining ecological balance and biodiversity within Sulawesi's ecosystems (Karim et al., 2020).

Field observations revealed that the nesting habitat in Bukit Jaya Village is characterized by lowland areas situated within a hilly landscape and influenced by nearby river systems. The terrain is generally gentle to moderately sloping, creating favorable conditions for nest establishment. The nesting substrate consisted predominantly of sandy and gravelly soils, which are considered highly suitable for Maleo nesting activities because they facilitate excavation and provide appropriate thermal conditions for incubation. Sandy and gravelly substrates possess good heat-conducting properties and are less susceptible to waterlogging, thereby helping maintain stable incubation conditions within the nesting chamber (Rosalia et al., 2024). In addition, gently sloping habitats generally exhibit effective drainage systems, reducing the likelihood of nest flooding during periods of heavy rainfall. Maleos typically avoid steep slopes because of the risk of soil erosion and instability, while completely flat areas may retain excessive water, potentially threatening egg survival (Rosalia et al., 2024). At the study site, nesting holes were located in open, unvegetated areas composed primarily of exposed sand receiving continuous sunlight

throughout the day. Such conditions promote increased sand temperatures and provide suitable thermal environments for egg incubation, thereby supporting successful nesting activities (Diko et al., 2026).

Five active nesting sites were recorded within the study area. The relatively limited number of active nests appears to be influenced by both ecological and anthropogenic factors. According to information provided by the Jaya Lestari community conservation group, the local Maleo population consists of approximately eight breeding pairs. Consequently, the reproductive capacity of the population and the likelihood of nest establishment remain naturally limited. Furthermore, Maleos exhibit a high degree of habitat selectivity, particularly regarding microhabitat characteristics such as sand temperature, humidity, and soil stability, all of which are critical for successful natural incubation (Froese & Mustari, 2019). The nesting-hole dimensions observed in this study differed from those reported by Poli et al. (2016), who documented an average nesting-hole depth of  $41.8 \pm 14.28$  cm in Muara Pusia, located within the Bogani Nani Wartabone National Park. Variations in nesting-hole depth are primarily associated with the availability and intensity of environmental heat sources. Where geothermal influence is strong, suitable incubation temperatures can be achieved at relatively shallow depths, with soil temperatures reaching approximately  $34^{\circ}\text{C}$  at around 20 cm below the surface. Under such conditions, Maleos generally excavate nesting holes approximately 20–30 cm deep. In contrast, when geothermal heat originates from deeper underground sources and its influence on surface soils is weaker, birds compensate by excavating deeper holes, commonly ranging from 40–70 cm or more, to reach suitable incubation temperatures. Nest-hole width is also influenced by depth and soil texture. As nesting holes become deeper, wider excavations are required to facilitate soil removal during digging and to reduce the risk of soil collapse into the nesting chamber (Lase et al., 2024). These findings highlight the adaptive nesting behavior of Maleos in response to local environmental conditions and emphasize the importance of specific substrate and microclimatic characteristics in determining nesting-site suitability.

The temperatures recorded at the Maleo nesting sites in Bukit Jaya Village were within the thermal range considered suitable for Maleo reproduction and embryo development (Rimu et al., 2022). Temperature is one of the most important environmental factors influencing egg incubation, as it directly affects embryonic growth and hatching rates. Variations in nest temperature can alter the duration of incubation, with higher temperatures generally accelerating embryonic development, whereas lower temperatures may prolong the incubation period or reduce hatching success. Measurements of sand surface temperature indicated a strong influence of solar

radiation. Surface temperatures increased progressively throughout the day as solar intensity became greater, reaching their highest values during midday. In the afternoon, sand temperatures remained relatively high but showed a decline compared with midday measurements. These findings differ from those reported by Karim et al. (2019) for Maleo nesting grounds in Taima Village, where sand surface temperatures were recorded at  $30^{\circ}\text{C}$  at 06:00,  $43^{\circ}\text{C}$  at 09:00,  $48^{\circ}\text{C}$  at 12:00,  $45^{\circ}\text{C}$  at 15:00, and  $34^{\circ}\text{C}$  at 18:00. The differences between the two studies are likely attributable to variations in nesting-site characteristics. The nesting grounds investigated by Karim et al. (2019) were located in coastal areas adjacent to the shoreline, whereas the present study was conducted in an inland river-associated habitat. Coastal environments are typically characterized by higher surface temperatures due to prolonged exposure to sunlight and the thermal properties of beach sand. Sandy coastal substrates possess relatively high thermal conductivity, allowing them to absorb, store, and transfer heat rapidly. Consequently, solar heat can penetrate deeper soil layers more efficiently, resulting in extremely high substrate temperatures during the hottest periods of the day (Baussa et al., 2025).

Relative humidity is another critical factor influencing the incubation success of Maleo eggs (Rimu et al., 2022). Appropriate humidity levels are essential for maintaining water balance within the eggs and supporting normal embryonic development. Nesting holes with shallower depths generally exhibit higher humidity levels, whereas deeper nesting chambers tend to have lower humidity. This pattern is closely related to temperature conditions within the nest. As nest depth increases, soil temperatures may become higher due to closer proximity to geothermal heat sources beneath the surface. Elevated temperatures enhance water evaporation within the nesting chamber, thereby reducing relative humidity levels. Consequently, the interaction between temperature and humidity plays an important role in determining the suitability of nesting sites for successful incubation (Rizka et al., 2022).

Vegetation surveys conducted around the Maleo nesting habitat revealed a diverse assemblage of plant growth forms, including trees, shrubs, herbs, and climbing plants (lianas). The species identified included *Glochidion zeylanicum*, *Nephrolepis brownii*, *Praxelis clematidea*, *Stachytarpheta jamaicensis*, *Macaranga grandifolia*, *Casuarina equisetifolia*, *Imperata cylindrica*, *Neolamarckia cadamba*, *Passiflora foetida*, *Hibiscus tiliaceus*, *Blumea balsamifera*, *Lantana camara*, *Psidium guajava*, *Waltheria indica*, *Calamus* sp., and *Arenga pinnata*. The most represented plant families were Asteraceae, Verbenaceae, Malvaceae, and Arecaceae. The presence of these taxa indicates that the nesting habitat possesses a relatively complex and heterogeneous vegetation structure, which contributes to maintaining environmental stability around the nesting

grounds (Kumaji et al., 2024). The vegetation surrounding the nesting sites exhibited a multilayered structure, consisting of herbaceous plants in the lower stratum, shrubs and small woody plants in the intermediate layer, and trees together with climbing plants forming the upper canopy. Such structural complexity provides ecological functions that may influence the nesting environment, including regulation of temperature, maintenance of soil moisture, and protection from predators. These findings are consistent with those reported by Dhafir et al. (2022), who observed that Maleo habitats were similarly dominated by a mixture of grasses, shrubs, trees, and lianas. Species recorded in their study included *Imperata cylindrica*, *Saccharum officinarum*, *Bambusa* sp., *Pandanus* sp., *Eucalyptus deglupta*, and *Pometia pinnata*. Differences in vegetation composition and structure among nesting habitats are likely to influence microhabitat conditions, particularly soil temperature and humidity, which are key factors affecting the suitability of nesting sites and the reproductive success of maleo populations (Manalu et al., 2023).

Several maleo nesting sites in Bukit Jaya Village characterized by grass (*Imperata cylindrica*), fern, and shrub vegetation are generally located in abandoned agricultural lands that are no longer actively managed. Over time, these areas have undergone natural succession and developed into secondary vegetation communities. Nesting sites situated along riverbanks are exposed to additional environmental risks associated with fluctuations in river water levels. During periods of high water discharge or flooding, river overflow may reach the nesting grounds, potentially inundating nests and disrupting the thermal conditions required for successful incubation. Such disturbances may alter the stability of heat supplied by geothermal sources, which is essential for embryonic development in Maleo eggs (Kumaji et al., 2024). In these riverine nesting areas, many nesting holes were found beneath vegetation cover and on sloping terrain characterized by dense and complex root systems. The selection of sloped nesting sites may represent an adaptive strategy to minimize the risk of water accumulation, particularly during the rainy season. Effective drainage on inclined surfaces reduces the likelihood of nest flooding, thereby protecting eggs from prolonged exposure to excess moisture. In addition, stable root networks contribute to soil cohesion, helping maintain nest integrity and preserving the microenvironment necessary for successful incubation. These habitat characteristics enable nesting sites to maintain relatively stable temperature and humidity conditions despite seasonal environmental fluctuations (Manalu et al., 2023).

Vegetation surrounding Maleo habitats plays a crucial role in supporting various aspects of the species' ecology. Primary and secondary forests, in particular, provide essential shelter and protection from predators.

Areas with dense and diverse vegetation offer suitable locations for resting, roosting, and concealment, thereby enhancing the survival prospects of adult birds (Maarif & Andriwibowo, 2023). Beyond its protective function, vegetation also serves as a movement corridor connecting forest habitats with nesting grounds. Although Maleos spend much of their lives in forested environments, they regularly travel to open areas such as riverbanks, coastal beaches, and geothermal sites to lay their eggs. This behavior is closely related to their morphological characteristics; Maleos possess relatively short wings compared with their body size, resulting in limited flight capability and a greater reliance on terrestrial movement. Previous studies have shown that breeding pairs travel from forest habitats to nesting grounds, excavate nesting holes, deposit their eggs, and subsequently return to the forest to avoid predators and continue their daily activities (Rosalia et al., 2025). The presence of vegetation around nesting sites also contributes significantly to the maintenance of favorable microclimatic conditions. Vegetation acts as a natural buffer that moderates environmental fluctuations by reducing direct solar radiation reaching the soil surface. This shading effect helps regulate temperature and moisture levels within and around nesting areas, creating conditions that are more suitable for egg incubation. Furthermore, vegetation contributes to soil stabilization through root systems that bind soil particles together and reduce erosion, thereby preserving the structural integrity of nesting substrates (Silayar et al., 2018).

## CONCLUSIONS

The nesting habitat of the Maleo (*Macrocephalon maleo*) in Bukit Jaya Village, Banggai Regency, is characterized by the presence of trees, shrubs, and bushes, with 16 plant species from 12 families identified around the nesting sites. Environmental measurements showed average temperatures of 31.0°C inside the nesting holes, 35.74°C outside the holes, and 36.2°C on the sand surface, with an average relative humidity of 72.62%. Nesting-hole depth ranged from 43–46 cm (mean 44.4 cm), while nest width ranged from 47–53 cm. Overall, these habitat characteristics indicate favorable environmental conditions for Maleo nesting and egg incubation.

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